The functional analysis of shoe wear patterns : theory and application.

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REFERENCE

THE FUNCTIONAL ANALYSIS OF SHOE WEAR PATTERNS: THEORY AND APPLICATION

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ABSTRACT

Shoe wear patterns have potential value in clinical diagnosis and forensic identification, although they lack rigorous study. Podiatrists have claimed understanding of shoe wear patterns, associating foot pathologies with characteristic patterns and implying a "one-condition, one wear pattern" hypothesis. This project was commenced to understand and clarify this relationship. Round one of an initial Delphi exercise to seek agreements over such wear pattern associations however indicated that, many different patterns could be associated with single named foot pathologies with round three agreements appearing to relate to the most common pattern associations. Analysis of the patterns in the Delphi exercise produced an instrument to describe and compare shoe wear patterns using focal points – points from which areas of shoe wear would spread.

A following survey questionnaire suggested that podiatrists were most familiar with wear patterns associated with four foot pathologies – pronation, hallux rigidus, pes cavus and rearfoot varus. Patterns associated with these pathologies were collected from U.K. podiatrists in a single round questionnaire. Inductive analysis of these patterns from a hermeneutic phenomenological perspective using the focal point concept suggested that if the pathological context is known, wear patterns could be classified on the basis of causative function. A theoretical model was proposed of factors important in wear pattern production, suggesting that primary walking intention (the intended walking function of the foot) was more influential than foot pathologies in wear pattern formation and that "external" factors could also influence shoe wear.

Validation and grounding of the focal point concept and model of shoe wear influence was planned, involving paired podiatry observers, to determine whether focal points could clarify, differentiate and show similarities between shoe wear patterns in reality and whether the model of wear influence was justified. To reduce the potential for observer error, two prior exercises were undertaken. A Delphi exercise focused participants on the required task and produced statements for the recognition of variables, which may influence shoe wear patterns. Inter-observer reliability tests demonstrated that clinical observation agreement levels were acceptable for the validation. In the validation, three subjects exhibiting pathologies, including hallux rigidus, and their owned footwear (22 items) were studied. The presence, level and effect of variables potentially influencing the wear patterns present, were determined by paired observations of foot pathologies, shoe fit and function, video analysis of foot function and subject interview for the footwear history. The focal point concept showed similarities and differences between shoe wear patterns, although wear pattern clarity limitations occurred. Within the pathological context the patterns predicted the related functions. The model of wear influence was supported with external influences needing to be major to override primary walking intention and foot pathology effects.

A method to describe and compare shoe wear patterns and a model to explain the link between function and wear, showing the relationship of factors important in wear pattern production have been produced. This model provides an alternative perspective on foot function to that of biomechanical theory and could represent the basis of a new taxonomy for podiatry. This greater understanding of shoe wear patterns should improve their potential value in forensic identification and in clinical diagnosis.

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1. INTRODUCTION

1.1 THE BACKGROUND, HISTORY, AND POTENTIAL OF SHOE WEAR PATTERNS

Accumulative summary

Footprints are universally present and shoe outsole wear patterns may be observed in footprint impressions. Outsole wear patterns have potential value in podiatry and forensic investigation, although they have not been fully understood through lack of rigorous study. Podiatrists have believed that wear patterns relate directly to foot pathologies, therefore wear patterns may assist with clinical diagnosis. Forensic podiatry is a new discipline in crime investigation and there is increasing interest in the value of footwear in identification. Improved wear pattern understanding would therefore be timely and potentially valuable, although there are current doubts over their meaning and usefulness. These have been epitomised by past problems in attempted forensic identification using shoe wear patterns. If wear patterns can be measured, interpreted or explained, or a link between function and wear can be shown, this new knowledge would assist with podiatry practice and forensic identification.

1.1: THE BACKGROUND, HISTORY AND POTENTIAL OF SHOE WEAR PATTERNS

1.11 Introduction to shoe wear patterns

> "Nor in this wilderness of peat should one whoop for joy upon coming across footprints, which too often don't indicate a track, but merely the erratic wanderings of some unhappy wretch as hopelessly lost as yourself" (Wainwright, 1968: 163)

Footprints are something which we all leave behind, whoever we are, wherever we go. Although footprints are common to all, they can have significant importance depending on the circumstances in which they occur. Defoe (1719) classically used a footprint to produce a powerful literary impact in Robinson Crusoe and many detective writers including Conan Doyle and P. D. James have used footprints to provide clues pointing to the perpetrators of fictional crimes. Various disciplines have used prints and impressions of many types to classify and identify animals, vehicles, foot types and shoe types. In western society, footwear is usually worn, with the term "shoe-prints" relating to this practice.

Materials of the outsole of footwear are gradually destroyed during use and the examination of patterns created by this wear was first recorded 85 years ago (Schuster, 1914; 1915). Although Schuster did not suggest patterns which characterised foot pathologies, five years later, Ware (1920) did relate some pattern variations to named foot conditions. Interest in diagnosis through shoe wear patterns peaked in the 1940's and 1950's, with several authors including Hanby and Walker (1949), Napier (1957) and Gibbard (1958, a; b) advocating wear pattern interpretation. Minimal reference to wear patterns in podiatric literature during the next 30 years suggests that clinical interest had ceased. Anthropological interest began, however, when Robbins, an American forensic anthropologist published personal footprint and wear pattern theories (Robbins 1978; 1984; 1985; 1986) and began to present shoe wear evidence as forensic evidence in criminal cases (Valmassey, 1982). Robbins' work was however informally, but publicly discredited as idiosyncratic. Later, Bodziak, a forensic footwear examiner, provided definitions of wear patterns although he was sceptical about their value:

> "Wear on shoe outsoles may be defined as the erosion of the outsole due to frictional and abrasive forces that occur between the outsole and the ground."
>
> "The wear pattern or position of wear can be defined as an arrangement or pattern of wear characteristics that stands out against areas of relatively less or greater wear. The wear pattern is largely influenced by the shape, size, bone structure and biomechanics of the wearers feet." (Bodziak, 1990: 305 - 306)

Following Robbins' errors and Bodziaks' scepticism, forensic interest in shoe wear patterns rapidly declined. In England, however, Facey, a respected forensic scientist continued to believe that wear patterns would eventually prove to have forensic value, but was unable to demonstrate this personally (Facey, Hannah and Rosen, 1992a; b; 1993). Podiatrists still examine and claim understanding of outsole wear patterns (Gorman, 1997; Anderson and Black, 1998; Hinter) but there is no evidence to justify their claims, despite the increasing application of biomechanical principles in podiatry.

While shoe wear patterns may have several uses in podiatry and forensic identification, through lack of rigorous study they are not yet understood either clinically or forensically. Bodziak has described shoes as "fascinating items of clothing" (Bodziak, 1990: xv) and outsole wear patterns are one of the most fascinating aspects of shoes. This thesis therefore concerns the interpretation and meaning of the patterns of wear called shoe wear patterns that can be transferred onto supporting surfaces by functional use of the foot.

1.12 The potential value of shoe wear patterns in clinical podiatry

DiMaggio (1995) described a podiatrist as "a specialist who studies foot pathology from a structural and functional standpoint and who treats medical problems dealing with the foot". The term is formally described as being synonymous with "chiropodist" (Sinclair, 1995). The term "chiropodist" has long since been deleted in the U.S.A. to prevent confusion and this term is expected to soon become obsolete in the U.K., where "podiatrist" is used by those wishing to extend chiropody practice (Tollafield and Dagnall, 1997).

During the course of everyday practice, clinical podiatrists treat soft tissue lesions of the feet which may have arisen from functional aberrations, structural deformities or footwear inadequacies. Diagnosis of the underlying cause of these soft tissue lesions is an integral part of modern podiatry practice which now involves problem solving diagnostic skills in addition to the traditional palliative approach once adopted (Borthwick, 1999). In podiatry, shoe wear patterns may be used to confirm diagnoses apparent through patient examination or to suggest diagnoses not easily arrived at where time is restricted in busy working clinics. Although clinicians use shoe wear in diagnosis, this knowledge has been informal, without research and of uncertain value. Podiatry has now developed the speciality of biomechanics as the "scientific basis" on which the modern day profession is founded.

> "The study of biomechanics allows today's practitioner to understand how and why the mechanical function of the lower extremity can lead to a wide variety of pathologic conditions. Once today's practitioners understand the normal and pathologic function of the lower extremities, they may then successfully implement a variety of treatment regimens specifically directed towards improving their patients' lower extremity mechanical function" (Valmassey, 1995: xv)

The speciality of biomechanics is however complex and requires in-depth diagnostic assessment of the foot from a functional aspect in order to determine the biomechanical abnormalities requiring treatment. This is time consuming and specialist diagnostic equipment has been developed to assist with this process. If shoe wear patterns are "records" of the repetitive function of the foot, they may have the potential to offer functional information to the practitioner which enables greater understanding and improved treatment without recourse to such expensive equipment.

In podiatry teaching, wear pattern knowledge could improve students' understanding of foot function and the development of pattern interpretation devices may accelerate the recognition and understanding of pathologies. Podiatry (chiropody), being a comparatively new and underdeveloped profession (Larkin, 1983), lacks a sound research basis. Although knowledge of foot function is fundamental to podiatry, research has focused on normal function. If shoe wear is influenced by amended function, study of wear may promote greater understanding of pathological function with the potential for improved approaches to treatment.

1.13 The potential value of shoe wear patterns in forensic identification

Footwear evidence

> "It is necessary in almost every criminal investigation to determine and prove through forensic science that a particular person or persons may or may not have been present at the scene of a crime....... Since criminals must enter and exit crime scene areas, it should be reasonably assumed that they would leave traces of their footwear" (Hilderbrand, 1999: 3-4)

Personal identity is formed from infinite combinations of physical and mental features. As identikit apparatus and genetic fingerprinting show, while no feature is unique to an individual, combinations of features constitute a unique identity. Forensic science seeks to establish the identification of an individual either directly or indirectly with a particular scene of crime. Forensic investigations involve the finding of evidence, the evaluation of that evidence and the comparison of this unknown item with a known item (belonging to a suspect) with the objective of proving either a match or a mismatch. This demonstrates the presence or absence of the conclusive link sought. When a physical match is made, this can be at two different levels – class and identifying characteristic levels. A **class** characteristic is a characteristic which all similar items have in common (Bodziak, 1990). They are obvious features which distinguish an object, but which don't on their own constitute uniqueness. An **identifying** characteristic is one which represents uniqueness (Bodziak, 1990). The presence of such characteristics can allow an identification to be made with absolute certainty. In terms of footwear evidence, the forensic footwear examiner may be required to analyze and compare footprints, shoeprints or shoes of unknown origin with those of known origin to seek the required match.

Class characteristics of footwear evidence relate to the dimensions, type, patterns and make of shoes. Shoe outsole wear patterns are currently viewed as class characteristics. In a footwear context, identifying characteristics are the points of minor damage to be found on the outsoles of worn shoes. The probability of two shoes of the same type receiving identical damage of this type is so low as to suggest absolute uniqueness. This uniqueness is expressed in the position, shape, size and orientation of the cuts, nicks, splits and tears which have formed on the outsole. When the various class and identifying characteristics have been defined on the unknown shoe or print, they can be compared with a known shoe or print. In this, all relevant aspects of footwear belonging to a suspect would be directly compared point by point with the unknown shoe, or print and a conclusion arrived at as to whether these were identical or compatible.

The use of footwear in criminal investigations has become a specialty in its own right, however great reliance is placed on the comparison of accidental damage present on the shoe outsole. As the characteristics that need to be directly compared may be changed or obliterated as the outsole wears, identification depends on finding the footwear item leaving a print as soon as possible after a criminal event. Unlike clinical situations, the forensic investigator may not have access to the wearer and it would be advantageous if conclusions could be drawn from shoes or prints in the absence of those shoes or the wearer. Reliable shoe wear pattern interpretation would not just provide evidence of relationship with a wearer even in his or her absence but, by comparing footwear items for wear compatibility, a suspect might also be connected with a crime scene through his or her other footwear even if the item producing the print had been destroyed. Conversely, a suspect might be cleared of involvement. Any such shoe wear pattern interpretations must be error-free. If they are not dependable, unsound expert opinion should not be heard in criminal court proceedings.

Forensic podiatry

The potential of an alliance between chiropody problem-solving and footwear evidence in forensic investigation was recognised thirty years ago when Lucock (1967) demonstrated an approach to comparing footwear to establish common ownership. However, over two decades passed before Nirenburg (1989) suggested that forensic podiatry should be developed as a specialty and still longer before techniques in forensic podiatry appeared in the literature. In 1991, Gunn (1991a; b) reported methods of analysing three-dimensional footprints and in 1994, Vernon reported the results of a preliminary study of the use of podiatry records in forensic investigation. His technique of retrospective analysis of records was subsequently refined by introduction of an 'identification strength scale' (Sanger and Vernon, 1997). Since 1994, podiatrists have presented papers at all annual conferences of the International Association for Identification (I.A.I.) (Appendix 1[1]) and a podiatrist wrote a guest editorial (DiMaggio, 1995) for the journal of the I.A.I. in 1995. Kippen (1996) has presented a podiatrist's view of forensic podiatry as a developing specialty across the globe and Gorman (1997) wrote a promotional article for *Podiatry Today* explaining the potential benefits of podiatrists' involvement in forensic investigation. In response to increasing interest, Vernon and McCourt (1999) recently summarised and defined forensic podiatry in the *British Journal of Podiatry*.

Footwear evidence is being seen as having increasing importance in forensic investigations. The four textbooks devoted to this subject area (Abbott, 1964; Cassidy, 1987; Bodziak, 1990; Hilderbrand, 1999) with an updated edition of Bodziaks' comprehensive text being anticipated in the near future, are testament to the increasing importance of footwear evidence in forensic investigations. A course of study and certification programme in footwear examination has recently been developed by the I.A.I. to educate investigators in the techniques and maintain high standards of forensic investigation. Footwear evidence was central in the high profile O.J. Simpson trial, with both defence and prosecution presenting evidence to support their cases (Bodziak, 1996). Footwear evidence is therefore highly topical in forensic identification and it is anticipated that such evidence will become widely used through increasing understanding and awareness of its potential. Techniques of identification utilising shoe wear patterns underpinned by podiatric understanding would therefore be both timely and valuable.

1.14 Limitations in shoe wear pattern understanding in podiatry

> "While the potential worth of this adjunct to clinical diagnosis is usually admitted, the fact remains that the study of shoe-wear patterns lies somewhere in the limbo between the realms of charlatanism on the one hand and folklore on the other" (Napier, 1957: 145)

Whether foot/gait function can be interpreted through shoe wear is not known although there is a belief that this must be possible. Although some wear patterns have been described and linked to foot pathologies in chiropody literature, the basis of these

[1] For ease of reading, all diagrams, tables, graphs and appendices have been placed in Volume 2

suggested relationships is unknown. There is no previous research into wear pattern significance and attempted forensic interpretation has been discredited (Valmassey, 1982). Despite this, podiatrists have believed that wear patterns can be interpreted. Shoe examination is a routine aspect of podiatry diagnosis (Neale, 1981) with unsubstantiated faith that wear patterns are diagnostic indicators. Wear pattern knowledge is therefore currently informal and acquired through personal experience.

The development of shoe wear pattern use in podiatry

The first records of the use of shoe wear in podiatry literature are provided by Schuster (1914; 1915). In his first paper, Schuster reports the excessive wearing of an outer border of a shoe due to Mortons' neuralgia, and in his second paper he recommends the examination of shoes for wear as part of the routine diagnosis of foot conditions. While advocating the examination of footwear for wear variation, he does not suggest any characteristic pattern association with named pathologies. In 1920, Ware elaborated further and associated a limited number of wear variations with named categories of foot condition. He believed that "improper" walking, shoe neglect, ankle rotation and improperly fitting shoes were the most important factors in causing abnormal outsole wear. No other wear references can be found until 1938, when increased confidence in wear pattern interpretation is expressed by Stamm, an orthopaedic surgeon, who stated that:

> "People whose toes are paralysed or deformed do not wear out the sole of their shoes further forward than the line of the metatarsal heads, whereas if the toes are normal, the sole wears out almost evenly all over" (Stamm, 1938: 171-172)

This represented a definite shift towards believing that specific relationships exist between wear patterns and foot conditions. A series of other publications referring to wear patterns followed, with signs of increasing confidence in the relationship of foot pathologies to specific characteristic shoe wear patterns. Gottlieb believed that:

> "a mere glance of the sole showing much wear on the lateral surface suffices for diagnosis of hallux rigidus" (Gottlieb, 1939: 319)

'This indicates a belief that examination of shoes permits diagnosis in isolation from the feet that usually wear them. Gottlieb's view may, however, have been overoptimistic as well as arrogantly expressed. He was writing in a publication for chiropodists in an era when the scope of allied health professions was defined by medicine and their knowledge bases were not deemed to be separate or unique in any way (Parry, 2000). As a medical doctor, he possessed the intuitive knowledge and schemata that Elstein, Shulman and co-authors (1979) suggested were the foundation for diagnostic problem solving in medicine. However, not only did he not have the personal constructs and theories of experienced chiropodists but Vernon and co-authors (1998) have shown that assumptions about the dependability of intuitive knowledge may itself be dangerous.

A year after Gottlieb's article, Gordon (1940-1941) described the outer heel and area below the first metatarsal head as the most common places for shoe wear to occur. This suggests that shoes were being examined regularly for wear associations with increasing recognition. Indeed, the use of shoe wear in clinical diagnosis may have had its heyday during the 1940's and 1950's with more frequent references to the value of wear and its perceived associations than at any other period. These included the advocation of shoe examination for wear during clinical assessment (Smith, 1942-3; Pickering, 1942-3; Lake, 1943; Le Rossignol, 1949), reports of wear in case study examples (Nield, 1952) and reference to unusual wear in childrens' shoes leading to advice being sought by concerned parents (Thomas, 1952). Podiatrists began to publish written descriptions (Scholl, 1942) and sketched depictions (Hanby and Walker, 1949; Turchin, 1955; Napier, 1957Gibbard, 1958, a; b;) of specific shoe wear patterns which they linked categorically to named foot pathologies of the normal foot (Diagram 1). This outpouring implied belief in the hypothesis that "one condition will create one specific shoe wear pattern". The supposition must be treated sceptically, however. None of these authors' sketched depictions of wear pattern associations included evidence of supporting research to underpin the claims made. When these sketches are placed together, variations that emerge imply that more than one pattern form may be associated with any single foot pathology (Diagram 1). By the end of the 1940s, the possibility of a non-pathological influence over shoe wear had also begun to be considered, with Korn (1949) describing the wear effects of shoes fitted too short or too narrow and Gibbard (1958a) describing wear associated with bad shoe fitting.

The work of Barnett

In 1956, Barnett and co-researchers undertook an experimental study of shoe wear in order to determine whether the assumption that shoes are a reliable means of estimating the effects of locomotor disorder of gait was supported by critical analysis. They concluded that shoe wear could provide reliable information on abnormal gait if all available evidence from the shoe in its entirety is taken into account. Their paper reported observations on 10 case studies involving patients with sciatic nerve lesions. The subjects were examined clinically to determine their lower limb status and their stance phase of gait was assessed with a plastic pedograph. The plastic pedograph consisted of packed vertical perspex rods on a rubber base which were depressed when vertical force was applied. When walked upon, the depressed rods were filmed and each frame converted to a record showing an outline of the shoe sole along with an index of the overlying pressure at that point in time. For each case study, pedograph records and shoe wear were presented diagrammatically along with descriptions of the pressure involved. It allowed sciatic nerve lesions to be described along with detail of shoe appliances used, the frequency of shoe repairs, descriptions of shoe distortions and the presence of major foot pathologies. Although the researchers claimed that the wear patterns correlated well with vertical pressures underfoot, some unexpected wear patterns were seen and possible reasons were suggested for them. While representing the only attempt to study shoe wear patterns to date, Barnett and his co-researchers were hampered by limitations in their knowledge of function and foot pathology as well as the relatively unsophisticated equipment.

The plastic pedograph is now obsolete and Barnett and co-researchers acknowledged the restrictions impeding their investigations of the functional implications of wear. The equipment was only capable of measuring the length of each phase of gait (stance and swing), the duration of weight bearing in stance phase and the intensity of vertical forces during weight bearing. The pedograph did not measure friction or shear or torsion forces under foot, all of which may have affected wear of the outsole. It is not surprising therefore that Barnett and co-researchers (1956) referred to several discrepancies between pedograph readings of high pressure areas and wear of the associated shoe outsole, indicating that other factors may have been present of which they remained unaware. In their reported case two, they directly explained a wear area discrepancy as relating to frictional and shearing forces not revealed by the pedograph. In reported case 5, they suggested that poor correlation between pressure and wear may have been due to an out-turned foot indicating again that factors other than vertical force may have been present. They also observed areas of high pressure where excessive wear did not occur in addition to wear occurring where there was minimal pressure – again an indication that pressure may not be the main factor of wear production influence.

Other inadequacies of the pedograph related to poor sensitivity with the team noting that it failed to provide evidence of either scuffing or light pressure ground contact on occasion. It also appeared to be insensitive to the sites of pressure focus during stance, recording heavily outlined areas of pressure which may have obscured accuracy. Consequently, some claimed correlations are dubious because "blanket" vertical pressure patterns may hide the true nature of the forces involved. In this respect, Barnett and co-researchers (1956) noted that scrutiny of the shoe outsole was a more sensitive observation of foot/ground contact than the pedograph.

Despite the discrepancies which occurred between the wear patterns and the pedograph vertical pressure records, Barnett and co-researchers (1956) stated that shoe wear patterns arise from the pressure effect of standing, walking and running. In the absence of more sensitive instrumentation, this statement is not valid. Discrepancies are not explained by the vertical pressure-effect proposal and the non-measured forces (i.e. friction, shear and torsion) may have been present in addition to the vertical pressure noted. The project therefore lacked construct validity in the absence of more sensitive instrumentation or additional evidence (e.g. visual function analysis). The appropriateness of the instrumentation is further brought into question in their discussion, where they noted that the gait evaluation systems used were more suitable for research than general clinical use. If gait abnormalities have clinical significance, then factors causing that significance may be more important to study than those without value to the clinician. It is doubtful however, whether more appropriate instrumentation would have been available in 1956, although filmed observations may have been a useful supplement.

Barnett and co-researchers (1956) may have also been limited through a lack of podiatric knowledge. In reported case two, they suggested that a slight passive movement of a stiff hallux may have been responsible for an observed wear pattern. Experience suggests that podiatrists may have given a stiff hallux greater importance and may have interpreted the situation with greater confidence and suggested more positive conclusions. In the same case, a podiatrist may have related the wear pattern of the right shoe to excessive pronation (flattening of the foot) in light of the pedograph patterns recorded. The presence of a valgus insole with the shoe would support a previous diagnosis of "valgus foot" – a condition now viewed as representing a state of excessive pronation. While Barnett and co-researchers (1956) stated that all available evidence had been taken into account, details of foot pathologies with the exception of those of a more obvious nature were not stated. All of this incomplete and negative information mitigates against critical examination. In stating that uppers would also need to be considered, this again may indicate that further information was needed in order to critically evaluate the wear patterns, possibly information relating to foot pathologies which would have been understood by podiatrists.

Barnett and co-researchers (1956) made a commendable attempt to demonstrate shoe wear pattern links with abnormal function, but had focused on the vertical pressure aspects of function only. They were restricted by inadequate equipment, lack of podiatric knowledge and the restricted knowledge of function available at the time. Their claimed "striking agreements" between pedograph records and wear were not always justified implying that other factors than vertical pressure may have influenced the wear patterns seen, particularly aspects of function which may have created friction, shear or torsional stress on the outsole. The study was experimental and attempted to show that wear may be useful in diagnosis. The findings, while demonstrating that this may be possible, required further work in order to produce useful conclusions including theories of wear formation. The work also did not clarify whether characteristic wear patterns would be created by specific foot pathologies. Despite this initial research, the work was not followed up by either Barnett and co-researchers, or by podiatrists, who continued to accept the "one condition, one pattern" theory with the suggested non-researched wear pattern associations remaining.

Other professions interests in shoe wear patterns

Members of associated medical specialties also believed that shoe wear patterns had diagnostic value. In addition to Stamms' paper (1938), another orthopaedic surgeon, Du Vries, advised that, during diagnosis, shoes should be examined for wear (Inman, 1973) and Cailliet (1968), a specialist in physical medicine, also referred to the diagnostic value of shoe wear. The value of shoe wear pattern information to physicians was also referred to by Cavanagh (1980), who outlined major areas of outsole wear in running shoes. Again, none of these other authors offered research data to support the claims made, although Cavanagh had collected numerous running shoes from university students to examine areas of wear and tear throughout the shoes.

Sources of confusion

Despite the claims made for the value of shoe wear patterns in clinical diagnosis, there is considerable doubt about their meaning and usefulness, with disagreements between wear pattern diagrams which have never been resolved. Without evidence or reference to research, podiatrists claimed wear pattern knowledge is without foundation or validity. Far from clarifying the situation for podiatry students, podiatry teaching has added to this confusion. A 1978, student information sheet depicted wear patterns which could be used diagnostically (Appendix 2). This was un-referenced and contained several errors:

- While stating that normal wear affects the posterio-lateral border of the heel, an accompanying diagram showed contradictory posterio-medial heel wear.
- Heel wear diagrams showed central posterior heel wear as normal and posterior-lateral heel wear associated with foot strain.
- Another diagram associated posterior heel wear with foot rigidity.
- The depicted foot strain pattern was described as similar to the hallux rigidus pattern, which deviated from patterns previously published.

During the author's studentship, staff and students did not query these errors; rather acceptance indicated failure to understand fundamental aspects of wear patterns.

Further complications arise from enhancements of understanding of foot function. Changes in perception have led to deletion of past terminologies describing conditions no longer recognised. Some wear patterns have been associated with such conditions. Turchin (1955) described wear related to laterally, medially and biplanar unbalanced feet. Similarly, Ware (1920) referred to arch and ankle weakness as did Scholl (1942) while Hanby and Walker (1949) and Charlesworth (1961) described the weak long arch, all with associated wear patterns. These obsolete terms probably represented a wide spectrum of currently recognised, but differently named pathologies.

Previous shoe wear "experts" had fundamental implied beliefs which remain unchallenged. The first of these is the hypothesis that one specific condition will create one specific wear pattern (p.11). Diagram 1 patterns imply that this is incorrect. Further doubt is suggested by recent functional considerations of hallux rigidus. Root and co-authors (1977) suggested only one functioning mechanism for hallux rigidus requiring the distal phalanx of the hallux to hyperextend to compensate for limited 1st toe dorsiflexion. Neale (1981) supported this view, while also noting that the foot may supinate to partially compensate. Dananberg (1986; 1993) and Rzonka and co-authors (1984) however suggested that hallux rigidus may present with other compensatory functioning. Through a correspondence column, Sherman (1993) stated that his experience supported this notion. If these suggestions are correct, then the "one condition, one pattern" belief may not be. Between them, Dananberg , Sherman and Rzonka and co-authors suggested eight alternative methods of functioning with hallux rigidus (Appendix 3). If shoe wear can be affected by gait function as suggested by Barnett and co-authors (1956), then at least eight different forms of wear pattern would be anticipated in association with hallux rigidus assuming that shoe fitting variables were not having additional effects.

Summary

Shoe wear patterns may have diagnostic use, but while ultimately this may be possible, the discrepancies, errors, possible unappreciated compensations of named pathologies and lack of research indicate that such diagnoses cannot yet be made reliably. These concerns must be addressed before diagnostic claims can be justified. There is also a long standing belief that wear pattern interpretation cannot be used in isolation (Ware, 1920), contradicting other claims made or implied by published pattern depiction. Again, lack of clear understanding may be responsible for this contradiction and research into shoe wear patterns may make isolated pattern interpretation possible.

Over the past 30 years, podiatry interest in shoe wear patterns has diminished. With the exception of forensic podiatry articles and wear references in Neales' text, shoe wear patterns have not been referred to in podiatry literature during this time. Interest in shoe wear patterns in forensic science however began in the 1980's.

1.15 Past problems with the attempted forensic use of shoe wear patterns

Early forensic considerations of shoe wear patterns

Major problems have occurred with attempted forensic shoe wear interpretation. Forensic use of wear patterns was first mentioned in 1920 by Gerard, who considered possibilities for utilising the foot in criminal investigation. This included wear assessment, deductions from shoe type and repair and psychological interpretations (e.g. determination, curiosity, cynicism and sarcasm) from gait patterns. No supportive research was offered however.

Until the 1980's shoe wear patterns had minimal use as forensic evidence. Only one example can be found where shoe wear patterns provided evidence in a burglary trial (Smith, 1959). The whole shoe was available as evidence however with gross foot pathologies identifiable (i.e. leg length discrepancy, "withered foot" and overlying 4th toe). The wear pattern interpretation in this case may have been incorrect. It was assumed that heavier right sole wear showed that most bodyweight was borne by that leg. Heavier wear, however, may have had other causes, (i.e. pathologies which increase wear through shearing stress and not simply from greater weight bearing on that side). Lucocks' approach (1967) to comparing footwear for signs of common ownership included the presentation of depictions of "classic" wear pattern associations said to be a feature helpful in this type of comparison. There is no indication however that Lucock had ever undertaken actual case work using these techniques and no evidence of underpinning research to support his paper.

The Robbins' controversy

In the 1980's, forensic anthropologist, Dr. Louise Robbins began to present shoe wear as evidence in U.S.A. courts. Robbins had an interest in footprints and had studied ancient footprints anthropologically, developing measurement systems for bare feet. Robbins published papers (1978; 1984; 1986) and a textbook (1985) on footprints which included wear pattern interpretation. This work, which is the only recorded attempt to explain shoe wear pattern formation, however, was flawed, causing serious problems in forensic investigations (Bodziak, 1994). In 1981, Robbins perceptions were successfully challenged in court by two podiatrists (Valmassey, 1982). A logical and informed argument based on knowledge of foot function refuted Robbins work and highlighted errors in Robbins' testimony which demonstrated basic misunderstandings in knowledge of the foot. Later, other evidence provided by Robbins was re-examined and found to reflect the same misconceptions.

To understand Robbins' mistakes, it is necessary to refer to her book *Footprints: their collection, analysis and interpretation* (1985) which states her beliefs and philosophies with regard to shoes and prints. As an anthropologist, Robbins understood anatomy and structure but not foot function and dynamics. This is reflected in Robbins' bibliography. By 1985 there had been many examples of observational and instrument based research into foot function, several being recent (Murray et. al., 1970; Viladot, 1973; Klenerman, 1976; Stokes et. al., 1979; Gibbs and Boxer, 1982). Of 60 publications in Robbins' bibliography, none of these fundamental papers were recorded. This was a serious omission. Only eight bibliographic items related to foot function/gait and all but one were out-dated. Robbins' work therefore did not reflect current theories which were supported by new technologies. A bibliography relating to work on wear patterns would require an emphasis on functional texts and this is not the case. Failure to consider function indicates failure to understand the nature of shoe wear patterns. Robbins' bibliography mostly contains anatomical and anthropological references, seeming to imply a belief that wear patterns are purely morphological and anatomical reflections of the foot.

Of equal concern is the absence of a reference section in the book, with a bibliography only being published. The information contained is not referenced and had not been researched. The information therefore can only be viewed as unsubstantiated opinion. Robbins alludes to shoe wear impressions being produced by downward force or pressure, stating that wear patterns correspond to specific downward pressure sites. Although Barnett and co-authors (1956) also believed in a connection between vertical pressure and wear, they did not always take this literally and justified non-correlations in terms of the laws of physics and the suspected presence of other forces. Force plate findings have repeatedly shown that in normal walking, maximum load of downward pressure occurs at 15% of the walking cycle when it exceeds body weight by 10-20% and at 45% of the walking cycle when it exceeds body weight by 25% (Root et. al., 1977; Klenerman, 1976; Lord et. al., 1986). These points occur just before mid stance and at toe off (Neale, 1981). If Robbins' assertions were correct, the heaviest wear areas of a normally functioning foot would relate to these peaks of pressure. Observations of worn shoes have not supported this notion. Davis and DeHaan (1977) examined 650 pairs of used footwear and found that the "outside rear corner of the heel edge" was the most frequently worn section of the shoe. Lucock (1967) suggested that a "normal" wear pattern shows marked wear at the posterior-lateral heel edge and under the "big and little toe" joints. This contradicts Robbins' theory which would place the heaviest wear at the front of the heel unit and across the area corresponding to all toes for the toe-off component of the stance phase. Robbins however notes that severe wear is to be found at the heel area corresponding with initial heel strike. Following her argument that the amount of downward pressure controls the amount of wear, this implies a belief that maximum loading occurs at heel strike - a belief contrary to research findings (Klenerman, 1976; Betts et. al., 1980; Lord et. al., 1986).

Robbins does not consider the effects of acceleration, deceleration, shear, inversion, eversion and torsional movements of the foot as wear influences. The triplanar movements of the foot are therefore replaced by a two dimensional view of foot function with unavoidable incorrect assumptions on wear. This lack of understanding is reflected in Robbins' terminology. There are differing views on biomechanical terminology of the foot which lacks universally accepted systems of nomenclature and has misinterpretation potential (Wall et. al., 1987). Robbins however ignored all such terminologies in favour of her own. In abandoning these terms there has been failure to appreciate their meaning. Pronation is described as " a dropping of the inner side of the foot" - a simplistic and inaccurate description of a complex foot pathology. Anatomical location terms of anterior, posterior, medial and lateral are deleted and the terms front, rear, inner and outer substituted, again reflecting insufficient understanding.

Robbins also stated that footwear will not influence foot function. This contradicts Viladots' kinematic, cinemaradiographic and radiographic evidence (1992). Failure to appreciate variable effects of footwear could lead to incorrect interpretations being placed on foot function when attempting to match shod and unshod feet forensically.

Robbins' attempt to understand, interpret and explain shoe wear patterns is flawed with a number of major errors made. Like Gottlieb (1939), Robbins lacked the professional background to understand foot function and this inadequacy was not addressed by research and supportive reading, which undoubtedly caused her downfall in the American courts.

1.16 Continued forensic attempts to understand shoe wear patterns

There has since been a general mistrust of forensic wear pattern interpretation. This is reflected by Bodziak in stating that while few studies have been carried out on wear patterns:

> "It should be emphasised that, just as in a direct comparison of wear characteristics with the shoes believed to have made those impressions, wear characteristics do not alone constitute a basis for positive identification. To attempt to reach an opinion using this kind of comparison is extremely dangerous and can easily result in mistaken identification or mistaken nonidentification." (Bodziak, 1991: 330)

Bodziak considered that wear patterns have too many variable influences to provide firm conclusions from wear alone, supporting Ware's earlier comments (1920). Forensic interpretation of shoe wear patterns has remained elusive to date.

Other forensic scientists have attempted to understand wear patterns. Davis and DeHaan's survey (1977) noted that wear patterns differed widely, but in using footwear donated to charity, could not examine the shoe owners for comparison. In surveying 97 shoes, Cassidy (1987) noted that wear varied, but restricted examination to the heel only. In a second survey of 60 shoes, only two similar wear patterns were found. Cassidy also advised that footwear observation should not be based on general wear alone. As with Davis and DeHaan, there was no attempt to compare wear with the shoe owners foot/gait status.

Subsequent attempts to understand shoe wear patterns have been restricted to the U.K.

> "It has long been thought that the information about an individual is contained in the shape and position of the general shoe-wear apparent on the shoe sole" (Facey et. al., 1992a: 16).

While acknowledging the above statement, Facey and co-researchers used a dynamic pedobarograph to compare foot to ground pressure with general shoe wear. Along with two follow-up studies (1992b; 1993), Facey and co-researchers attempted to produce a quantitative method of wear pattern analysis and comparison. While noting that subjects could be differentiated using pedobarograph imagery, an analysis and comparison method was not found. The need for such a system remains.

1.17 Summary - The value of wear pattern description, understanding and interpretation

The reporting of personal wear pattern experiences in podiatry literature is not adequate to justify the forensic usage of shoe wear patterns in identification. Discrepancies noted preclude their use until they are fully understood or resolved. Research demonstrating the interpretation and meaning of wear patterns or proving that variables confound interpretative meaning would benefit both clinicians and forensic scientists. The production of descriptive and comparison systems would help forensic scientists who could then use wear patterns in routine shoe and shoeprint examinations instead of ignoring them through lack of knowledge. Although podiatrists have claimed wear pattern understanding, discrepancies exist indicating that such understanding is not justified. Podiatry has no research base of wear pattern interpretation and forensic science investigations have not yet produced understanding of wear patterns and their interpretation. Forensic anthropology claims on wear pattern interpretation have been discredited.

If a method of describing and interpreting or explaining wear patterns can be produced or if the link between functioning and wear can be explained, this new and original knowledge will benefit both podiatry practice and forensic identification.

1.2 METHODOLOGIES: THE NATURAL HISTORY AND EVOLUTION OF THE PROJECT RESEARCH STRATEGIES.

Accumulative summary

An introduction is given to the philosophy, methodologies and methods adopted in the project. From setting out to elucidate an implied "one condition, one pathology" theory, an initial Delphi study unexpectedly disproved this position,. A hermeneutic phenomenological position was adopted to understand a situation where multiple patterns apparently existed with single pathological conditions. A descriptive instrument was produced using qualitative analysis and a following focused survey captured a wide range of patterns for analysis within the context of associated pathology. This analysis produced a basic model to explain wear pattern influence. Case study methodology involving paired clinical observers and semi-structured interviews validated and grounded the theories represented by the model and descriptive instrument. This followed observer development and testing using a further Delphi technique and inter-observer reliability studies respectively.

1.2 METHODOLOGIES: THE NATURAL HISTORY AND EVOLUTION OF THE PROJECT RESEARCH STRATEGIES

1.21 The project overview

The broad sequence of progression involved three distinct phases of research (Diagram 2). These were:

Phase one. This phase sought agreement about associations between characteristic shoe wear patterns and foot pathologies. Importantly and unexpectedly, wide ranges of associated patterns were revealed rather than the single characteristic pattern forms anticipated with single foot pathologies. At the same time, a useful instrumental means of comparing these patterns emerged.

Phase two. The second phase sought to understand and explain the reasons for such variations. In the process, a basic theoretical model of wear pattern influence was developed.

Phase three. The final phase validated the pattern comparison instrument and model of influence, which facilitated expansion of the theory and empirical grounding of the study. The overall research strategy was qualitative with a variety of methods and techniques chosen and used from a hermeneutic phenomenological perspective.

1.22 The qualitative approach to the research

The original aim of the project was to elucidate wear patterns and confirm the "one condition, one wear pattern" hypothesis. It was envisaged that the process would create and evaluate an instrument to describe and interpret shoe wear patterns. An experimental approach that required deliberate manipulation of foot function in order to determine the effects of wear was considered and rejected. According to Bevans (1992), during normal gait the foot is slightly supinated (inverted) at the end of the swing phase of gait, pronates (everts) as the heel makes contact with the ground and then supinates again. That is, when viewed from the rear, the foot rotates anti-clockwise about its long axis from the heel to the second toe as the heel strikes then rotates clockwise as weight is transferred from the heel to the toes with complex movements of the small joints of the foot throughout. On consideration, it was judged that altering foot function artificially would not replicate the structural and functional states of the complex joint relationships caused by foot pathologies and other physical attributes. Therefore, experimental observations would not reflect "real" wear patterns. Additionally, despite the "one condition, one wear pattern"' hypothesis, review of the literature showed that published associations between pathologies and patterns were both limited and unsubstantiated and that there was no firm theoretical framework for hypothesis formulation. Morse and Field (1996) stated that a qualitative approach is appropriate when little is known about a phenomenon. This was adopted and hypotheses and theories were inductively derived as the study progressed.

1.23 Phase 1: Description

Consensus methodology: an attempt to elucidate and confirm the "one condition, one wear pattern" theory of shoe wear

Although formal wear pattern knowledge is limited, podiatrists are taught to use shoe wear patterns in clinical diagnosis (Anderson and Black, 1998) and some knowledge is codified in handouts. (Appendix 2). It can be assumed that this knowledge is extended and changed by experience. In particular, 'knowing how' is non-propositional knowledge acquired by practitioners through practice and experience (Ryle, 1949). It constantly evolves through experiential learning but does not require the knower to articulate underlying personal theories. Polyani (1967) invented the term "tacit knowledge" to describe that which people know but cannot tell; and Eraut (1994; p. 15) asserts that "people do not know what they know". He also discusses (p.49) the intuitive capacity of professionals to digest, distil and select from previous experience. According to Parry and Stone (1991), this intuitive knowledge is a combination of logic and heuristics, tricks of the trade, rules of thumb, and the ability to reason from partial knowledge and to make reasonable guesses. Higgs and Titchen (1995) refer to health practitioners' *theories- in-use* which allow them to interpret incomplete and ambiguous data and identify implications that are not directly deducible from explicit data. There is therefore evidence that podiatrists are taught to use wear patterns. Furthermore, theories of professional knowledge development suggest that this basic knowledge may be refined and developed with experience although difficulties may arise in conveying this knowledge to others. This may explain why such knowledge has remained informal. In the absence of formal wear pattern knowledge, an approach which utilised this potential informal knowledge resource was appropriate. At the same time, published inconsistencies relating to wear patterns needed to be resolved. Such an approach was expected to elucidate and confirm the "one condition, one wear pattern" hypothesis of shoe wear and in doing so, lead to a database of characteristic wear pattern associations with named foot pathologies.

> "The focus of consensus methods lies where unanimity of opinion does not exist owing to lack of scientific evidence or where there is contradictory evidence on an issue. The methods attempt to assess the extent of agreement (consensus measurement) and to resolve disagreement (consensus development)" (Jones and Hunter, 1995)

This description of consensual methodology suggested that such methods would address the research requirements stated above. Consensus methods have become widely used in health and medicine (Fink et. al., 1984). They use the insights of appropriate experts (Jones and Hunter, 1995) and follow a structured process to collect and analyse information provided by participants in order to produce immediate solutions to problems (Fink et. al., 1984). Consensus methods include the Delphi technique, the nominal group technique, the consensus development conference, National Institute of Health (NIH) consensus development and Glasers' state-of-the-Art approach, all of which were considered as the method to be utilised. All these consensus techniques involve a structured approach to communication between a group of experts.

The Delphi technique involves several rounds of questionnaire distributed to a group of selected experts. It is widely used in health and enables widely distributed participants to be involved cheaply and anonymously, therefore allowing uninhibited response. The nominal group technique is a facilitated, structured meeting of experts with two rounds of rating and discussion of considered items (Jones and Hunter, 1995). While the technique is similar to Delphi, it does not offer any advantages, while involving much greater expense and the logistical problems of arranging a meeting of geographically dispersed experts. The face to face group nature of this technique may also be potentially inhibiting to some participants. Glasers state-of-the-Art approach, a variation on the nominal group technique, is idiosyncratic to Glaser and its' applicability to fields outside his own specialty of chronic obstructive pulmonary disease has not been evaluated (Fink et. al., 1984). The NIH consensus development is an in-house technique used to evaluate new health techniques (Fink et. al., 1984). It has been developed for a specific purpose requiring the resources of the NIH and is therefore not available or appropriate externally. Similarly, the consensus development conference is usually operated within defined programmes and requires resources prohibitory to researchers (Jones and Hunter, 1995). The method selected was therefore the Delphi technique which could potentially address the research requirement, while allowing practical, cost-effective access to busy practitioners and respecting their anonymity.

The Delphi technique

The Delphi technique was first devised by Dalkey and associates of the RAND Corporation in the early 1950's, but had been previously suggested as a method by both Whitehead and Churchman (Grant and Kinney, 1992). RAND developed the technique to obtain the most reliable consensus of a group of experts for nuclear strike prediction purposes (Everett, 1993). The technique has since been adopted by other disciplines and has been used in nursing since 1975. While many health professionals now use the Delphi technique, there have only been two previously reported uses of Delphi in podiatry (Ashford, 1991; Wood and Wayne, 1981). Linstone and Turoff define the technique as:

> "a method for structuring a groups' communication process so that the process is effective in allowing a group of individuals as a whole, to deal with a complex problem" (Linstone and Turoff, 1975: 3)

Several rounds of questionnaire are involved, all being completed by the same group of experts. Delphi characteristics include anonymity, feedback, statistical group response (Dalkey, 1967), use of informed respondents (Miles-Tapping et. al., 1990) and group consensus (Grant and Kinney, 1992). As podiatry shoe wear pattern knowledge may have been limited even in an expert group, anonymity and the expert group focus were seen to be valuable characteristics for this project. Williams and Webb (1994) attribute a wide range of additional strengths to the techniques including equal weighting of responses, wide access to experts, time efficiency, inexpensive to perform, early production of overview and flexibility. The Delphi technique was appropriate to obtaining a consensus of opinion about characteristic wear patterns associated with foot pathologies that would have been difficult to obtain by alternative means due to the practicalities of arranging a clinical expert group meeting. Linstone and Turoff (1975) also stressed that Delphi disagreements may be important and should not be overlooked in favour of achieving consensus. Although unexpected, divergent viewpoints encountered in this study were the most valuable Delphi product. During implementation, Delphi was also found to be a useful learning and focusing tool and it was used again for these purposes prior to the validation stage of the research to prepare podiatrists for optimal participation.

1.24 Phase 2: Interpretation

Hermeneutic Phenomenology: a strategy to understand the cryptic message of diverse wear pattern associations

The wide range of patterns produced for single named pathologies in round 1 of the Delphi exercise was a startling phenomenonon that challenged podiatrists' claim that they understood shoe wear patterns. This in turn discredited the "one pathology, one wear pattern" hypothesis and demanded a new approach. Initially, Glaser and Strauss's grounded theorising appeared to offer the most appropriate strategy for achieving a conceptually dense theory of shoe wear patterns in the presence of such diverse pattern forms, but it lacked the contextual elements required to achieve understanding of the phenomenon through interpretation. While phenomenology is concerned with description (Jasper, 1994; Koch, 1995), hermeneutics relates to the principles of interpretation and explanation (Palmer, 1969). The approach adopted here was analagous to the classic meaning of phenomenology and hermeneutics. Two different stages in achieving understanding are reflected here – description followed by explanation. The descriptive instrument successfully described shoe wear patterns and allowed them to be compared, but could not explain what produced the pattern. Understanding the findings required the more interpretive approach akin to hermeneutic phenomenology.

Hermeneutics is a form of inductive analysis which derives from the Greek verb *hermenuein*, "to interpret" and Hermeios referred to the priest or oracle at Delphi, whose cryptic messages required interpretation (Palmer, 1969). The multiple wear pattern associations with single foot pathologies were viewed as cryptic messages. While hermeneutics has no prescribed methodology, interpretation is founded on the structure and context of meaning (Palmer, 1969). In order to understand the influences on wear patterns and their effects and relationships, wear pattern formation was considered in the context of known variables. To achieve hermeneutic understanding, separate components of understanding are considered in unity within context. This unification forms a hermeneutic circle which characterises the interpretation of meaning (Patton, 1990), allowing a "leap of understanding" into this circle. Therefore, separate elements of understanding (e.g. pathologies, pattern form description, and pattern variability) could be related to produce unified hermeneutic understanding. Hermeneutic theory also implies that interpretation is grounded in reality (Palmer, 1969). This dictated a final requirement to ground the research empirically, which would test and further develop the induced theories. A hermeneutic phenomenological approach was, therefore, the sequel to the unexpected pattern variations occurring in Delphi round 1. It provided the strategic framework for the overall project, namely:

Phase one – description
Phase two – interpretation
Phase three – grounding

Initial inductive analysis of the pattern range produced "phenomenological" description. Patterns were initially categorised and ordered on the basis of components of wear and, subsequently, from the points from which each wear component was spreading. This analysis produced a descriptive instrument (Diagram 3) which could describe and compare wear patterns. In comparison, pattern recognition methodology which had only limited previous success (Facey, Hannah and Rosen, 1992b), would have been extremely time-consuming and appeared to have no advantage over inductive analysis.

Survey methodology: sampling for interpretation

For the interpretation requirement, a wider, more specific sample of wear patterns than that obtained in the Delphi round one was required to provide more focus for a rich analysis. Survey and case study methodologies were initially considered in this phase. Like the Delphi phase, survey methodology again provided access to a wide range of podiatrists' experiences of specific wear pattern associations and could use a similar format to that used in the Delphi questionnaire. Case study analysis would not allow access to such a wide range of wear pattern experiences and wear pattern understanding was not well enough developed at this stage of the project for case study methodology to be adopted. The technique of questionnaire survey adapting the Delphi round one format was selected as the most appropriate form of survey to provide the data required.

Questionnaire survey

Questionnaire surveys have many different uses, and are seen as simple information gathering techniques (Kane, 1990). Survey data can be used in descriptive studies, to explore, seek explanations and provide data for testing hypotheses (Robson, 1993). Questionnaires can also be used to provide preliminary information in order to limit research (Kane, 1990). After the Delphi, two separate questionnaires were needed:

1. To provide data to limit and focus the research after the Delphi study.
2. To "collect" a wide range of podiatrists' experiences of shoe wear pattern associations.

In both cases, cost-effectiveness, efficiency and ability to capture wide ranges of experience quickly (Bork and Francis, 1985), promoted questionnaires as the method of choice. Despite the advantages, Courtenay (1987) has identified potential problems relating to appropriateness of design, which should match the study aims and nature of the respondents, be unambiguous, engage co-operation and seek truthful answers. Care was taken in preparation of the questionnaire, with reference to the recommendations of Bork and Francis (1985) and Courtenay (1987). Lessons learned from the Delphi questionnaires resulted in an amended format to allow respondents to show multiple patterns for each named pathology.

An alternative direct patient survey technique was also considered. While having the advantage of providing real-life pattern examples, this method was again unlikely to produce the variety of focused experiences which could be captured by the questionnaire format.

1.25 Phase 3: Grounding

Grounding: theories of wear pattern description and influence validated

The hermeneutic phenomenological approach required grounding of the theories built during the project. For this, subjects were required to be studied in real life situations to test and validate the theories and determine the conditions under which they would apply. For this, case study methodologies were appropriate. In the previous phase, the requirement had been to study a wide selection of very specific variables i.e. wear patterns within a restricted context. The requirement in this subsequent phase was to consider the effect of a wide range of potentially confounding variables on a smaller sample of wear patterns, therefore grounding the theories within reality from a podiatry perspective. An alternative approach to validation was that of presenting the theories to peer podiatrists for confirmation. The project findings however had suggested that podiatry knowledge in this area had not developed to a point where this approach would be reliable. A more empirical grounding was also preferred due to the highly theoretical approach adopted prior to this phase.

Case study methodology

Case studies have been described as:

> "a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its' real-life context using multiple sources of evidence" (Robson, 1993: 146).

The requirements of the grounding and validation phase of the study were to examine the project theories within real life situations to determine whether the theories applied in reality, their limitations, and to provide further elaboration of these theories. Such studies are especially useful where great depth of understanding is required and where the aim is to capture individual differences. This was the situation required in validation of the work where variables acting on footwear needed to be studied in great depth to confirm and expand the theories being validated.

Structured observation method

Several techniques were considered in the case study methodology, including technological equipment analysis, structured observation and subject interview. Technological equipment analysis and structured observation were alternative means of assessing clinical aspects of each subject for the grounding. Structured observation by paired observers was chosen. Due to the potential for reliability and validity to be impaired when introducing other participants into a study:

> "It is highly desirable to have more than one observer in any study involving structured observation" (Robson, 1993: 221)

This allowed the assessment of a much broader range of variables than the technological approach, was more achievable through improved accessibility, and allowed grounding in podiatry as opposed to bioengineering practice.

The paired observer approach to the case studies however, presented several potential problem areas to be addressed before implementation, including the potential for observer error (Keenan and Bach, 1996; Curran and Jagger 1997), lack of standardised terminology (Neale, 1981), and absence of several variable definitions. All of these threatened validity and needed to be addressed before embarking on the final data gathering phase.

Semi-structured interview

In addition to the clinical observation aspects of the grounding and validation phase, footwear history variables also required consideration. In this area, only questionnaire and interview methods could produce the required information. The semi-structured interview was an ideal technique for this purpose, allowing a structure which ensured that all potential variables had been addressed while maintaining flexibility to investigate any declared variables in greater depth. The questionnaire approach was dismissed as too inflexible.

Delphi as a learning and focusing tool

The value of Delphi studies as a learning and focusing technique was demonstrated in phase one and had been previously reported (Linstone and Turoff, 1975; Schneider, 1972; Ludlow, 1975; Anderson, 1986). An intensive Delphi exercise to attempt to produce agreed statements of recognition for podiatric variables was essential preliminary preparation for the validation phase observers. It had two potential benefits – learning, and improved standardisation of the clinical assessments to follow. No other realistic alternatives were found to provide these desired benefits. Curran and Jagger (1997) had tested an expert system to improve podiatrists' clinical diagnosis agreements, but this was an undeveloped prototype instrument which was not yet available. Following this Delphi exercise, verification that the podiatrists involved could produce acceptable agreements was required prior to the final validation.

Inter-observer reliability tests

Following calibration through use of the Delphi technique, the podiatrists participating in the grounding and validation phase of the study required testing to verify whether they could achieve acceptable diagnostic agreements. Past work had demonstrated only poor levels of clinical agreement between podiatrists without assistance (Curran and Jagger, 1997; Keenan and Bach, 1996), therefore tests of agreement after focusing the participant group were seen as essential. Inter-reliability tests of observer agreements have been developed which use statistical measures to correct for chance agreements. Although Robson (1993) suggested that inter-observer agreements can be unnecessary, they were seen as essential to this study in view of the past poor podiatry performance in this area. Increased familiarity with the processes required before validation was a valuable by-product. The tests showed agreements at an acceptable level suggesting that the use of experienced podiatrists along with the Delphi exercise for development and focus had been beneficial.

1.26 Validity enhancement

Patton (1990) described a number of techniques and methods to enhance the quality of qualitative analysis, some of which were built into the research strategy.

Testing rival explanations

Previous rival explanations of shoe wear pattern formation were restricted to Robbins' theories of shoe wear pattern formation (Robbins, 1985) and the "one pathology, one wear pattern" hypothesis implied by past podiatry authors (e.g. Lucock, 1967; Gibbard, 1958b; Hanby and Walker, 1949). Robbins' explanations failed on a number of counts:

- Robbins' theories (1985) of shoe wear which were unsupported by references or research contradicted accepted research on the functioning foot (p. 18-20).
- When presenting evidence in American courts, Robbins was unable to substantiate her theories of shoe wear and demonstrated misunderstandings of foot anatomy and function, thereby losing credibility as an expert in this field (Valmassey, 1982, Nirenberg, 1989).
- Subsequent concern amongst forensic footwear examiners led to the scientific basis of Robbins' case evidence being re-examined. The finding that her theories could not be proven, that her claimed data appeared to be non-existent and that her evidence was unsound lead to ignominious failure of her work, with the scandal being reported on American television (Bodziak, 1994).
- Robbins' main assertions that shoe wear patterns represent foot morphology were unsupported by the Delphi, the main questionnaire and validation phases of this study.

Robbins' theories were therefore not subjected to additional testing as they were unsubstantiated, unsound, and did not provide an explanation for the findings of this research study. The "one pathology, one wear pattern" hypothesis failed at the early stages of the research, in the initial Delphi round one and main survey questionnaire, where multiple pattern forms were shown for single pathologies. In the validation phase, different pattern forms were again observed in reality for single conditions across the subjects involved.

Triangulation

Triangulation involves the combining of

> "multiple observers, theories, methods and data sources" to "overcome the intrinsic bias that comes from single-methods, single-observer and single-theory studies" (Patton, 1990: 464)

Source triangulation was used in the study to enhance further, the credibility of the work. Source triangulation requires comparison at different times and by different means within qualitative methods. Four different methods allowing comparison were involved in the study, namely the Delphi study, the pattern-collecting questionnaire survey, the clinical validation to ground the theories and examination of presentations of wear patterns in podiatry literature. Comparison of wear patterns from each section allowed the instrument for wear pattern comparison to be compared across all sections, the multiple wear pattern existence with single pathologies to be confirmed and the hierarchical model of wear pattern influence to be checked against each section for compatibility. Source triangulation was also undertaken in the final validation phase, using wear patterns within a pathological context, paired podiatrist observers and video-records to suggest functions involved in wear pattern production.

2. PART TWO: PRELIMINARY EXPLORATION

2.1 DELPHI ROUND ONE: PRELIMINARY FINDINGS OF NON-CONSENSUS

Accumulative summary

The value of shoe wear patterns as footwear evidence has long been treated with scepticism although podiatrists are known to interpret the meaning of such marks in clinical diagnosis. A first round Delphi questionnaire was devised to collate experienced podiatrists' knowledge of characteristic wear pattern associations with known foot pathologies. The results did not appear to demonstrate the level of consensus expected. Closer examination however indicated that there may be agreement about the relationship of specific areas of wear to the pathologies within the overall wear pattern shown. Reasons for the lack of overall consensus are suggested and the need for caution in the use of shoe wear patterns is reinforced pending further investigation.

2.1 DELPHI ROUND ONE: PRELIMINARY FINDINGS OF NON-CONSENSUS[2]

2.11 Introduction

While forensic scientists have been aware of shoe wear patterns for a long time, there is doubt as to whether these marks can be of value as forensic evidence (Bodziak, 1990). Consequently, although it is thought that these marks represent important information about the owner of a worn shoe (Facey et. al., 1992a), they are of limited use in forensic investigations. Experienced podiatrists use shoe wear patterns to aid clinical diagnosis and early chiropody and similar texts contain reference to wear pattern interpretation, including diagrammatic representations of wear patterns stated to be characteristically caused by named pathological conditions (Hanby and Walker, 1949; Napier, 1957; Gibbard, 1958, a,b). In 1967, Lucock, an English chiropodist, published a paper on identification from footwear illustrated with wear patterns related to given pathologies (Lucock, 1967). These published references, however, were based on clinical observation combined with experience and it is assumed that podiatrists' clinical use of wear patterns is founded on a knowledge base derived from personal experience. In common with other health professions, the knowledge base of podiatry is growing rapidly. Parry and Stone (1991) pointed out that the characteristics of knowledge underpinning physiotherapy practice are unclear and the process whereby the knowledge of a practitioner is developed from the theoretical frameworks provided by scientific disciplines and from experience is not understood. Rules of thumb, reasoned guesses, insight, informed opinion and identification of exceptions to the rule all contribute to clinical expertise. Knowledge is hidden in many ways and there is a need to retrieve informal knowledge about podiatry so that it can be transferred to students. Elicitations of knowledge about shoe wear patterns will either confirm or deny that they can be used with a degree of certainty in clinical diagnoses and forensic investigations and should be taught to students. On this basis, a Delphi study was planned to collect podiatrists'

2 This section was published in amended form as Vernon W., Parry A., Potter M., "Preliminary findings in a Delphi study of shoe wear marks", Journal of Forensic Identification, Vol. 48, No. 1, Jan./Feb. 1998, p. 22-38.

expert knowledge of characteristic shoe wear pattern associations. It was originally intended that this study would be a pilot for a larger Delphi survey to follow.

2.12 The Delphi technique

Of the many benefits derived from the use of the Delphi technique, the method was chosen for this study because:

- Experiences stated by those questioned have not been influenced by others.
- The technique allows access to experts distributed across widespread locations.
- Group consensus is possible.
- The technique is time efficient.
- All responses carry equal weighting.
- Overview is achieved after round one.
- Key issues are produced.
- The technique is simple to use.
- Participants abilities are fully used.
- The technique usually produces good response rates.

The stages of the Delphi technique include devising the research question, choosing enough suitable participants to ensure study feasibility, noting and matching subsequent responses and final presentation, explanation and analysis of results.

2.13 Aim

The aim of the Delphi rounds was to collect wear patterns, based on expert knowledge which had been gained through interpreting shoe wear patterns, and to seek consensus over this information. This knowledge would be that relating to characteristic shoe wear pattern associations with named structural or functional disorders of the foot, lower limb, or type of gait and would be presented in the form of a wide range of wear pattern depictions together with their stated cause. At this stage of the work, a wide range of disorders and their wear pattern associations were to be studied. This Delphi survey was initially planned as a pilot study with the intention of undertaking a larger Delphi survey on completion.

2.14 Method

A Delphi survey was the planned means of capturing the information sought, commencing with a first round questionnaire and concluding via feedback rounds when consensus or stability of feedback responses had been achieved.
Ten National Health Service Trusts volunteered to assist with the Delphi with each professional head of service nominating their most experienced podiatrist to take part in the study. There are no prescribed numbers for expert participation in a Delphi exercise. It has been previously reported that the range of panel size varies arbitrarily according to the researcher (Williams and Webb, 1994). Delphi studies can be found which commenced with expert panels from five (Stheeman et. al., 1994), to 2,006 participants (Butterworth and Bishop, 1995). Although reliability is believed to improve with larger panel sizes (Couper, 1984; Fink et. al., 1984), it has been suggested that when using a group with a homogenous (educational or professional) background, 10 to fifteen people should suffice for the expert panel (Duffield 1988). As this Delphi study was initially intended to be a pilot exercise, an invited panel of 10 respondents was believed to be sufficient. The questionnaire itself asked respondents to mark on blank outsole outlines (Diagram 4), a maximum of 10 characteristic patterns with which they were familiar through experience and to name the condition associated with that pattern. The questionnaire was distributed to the participating Trusts together with several items of supportive information including a covering letter, explanatory notes, an example sheet and a comprehensive "prompt" list of possible pathologies. A feedback sheet and return envelope were also included (Appendix 4). The returned wear patterns were initially collated and stored under pathology headings. Patterns given under each heading were scrutinised for similarities, and agreements and common patterns under each heading were recorded diagrammatically and prepared for return to participants in order to seek a future consensus agreement.

The level of consensus sought in Delphi studies has not been previously defined. In some Delphi studies, the level of consensus sought is not pre-set, allowing the data to determine when consensus has been achieved, as seen for example in Miles-Tapping and co-authors' study (1990), and Grubers' study (1993). Other Delphi studies have pre-set the levels of consensus sought, varying from 55% to 100% (Williams and Webb, 1994). While Grant and Kinney (1990; 1992) twice recommended that a 70% level of consensus should be sought, their justification was not given. Williams and Webb (1994) considered the issue of consensus closely, noting that it is more reliable to pre-state the level of consensus sought and that when using standard deviation (SD) as a measure of consensus, +/- 1SD contains 68% of all scores (i.e. approximately 70%). A pre-set level of consensus of 70% was therefore used in this study, being previously recommended, justified statistically in previous studies and not representing an extreme value when compared to other past Delphi studies.

2.15 Results and analysis

There was a 70% response rate achieved in round one of the study. The returned information however yielded unexpected results. The given patterns related to a total of twenty-nine different pathological states (Table 1). Wear patterns for thirteen of these pathologies were identified by more than one respondent and could therefore be examined for consensus. (Appendix 5). Initially it appeared that the majority of patterns stated under each pathology heading had no consensus whatsoever. Close scrutiny however indicated that there could indeed be a number of common wear areas suggested by respondents under each heading (Diagram 5). These commonalties related to single aspects of the entire pattern shown. This is to say that although there was no consensus suggested with regard to the entire pattern, a consensus view existed over certain single aspects of the pattern. These common features are recorded in Table 2.

The results themselves indicated six possible interpretations. As stated, while there was minimal agreement over the totality of patterns which was initially of concern, when scrutinised closely, it could be seen that consensus existed over specific areas of wear under stated headings. The six possible conclusions were:

1. The task was too difficult. That is, while podiatrists recognise patterns, they are unable to draw good likenesses of these patterns.

2. There was no consensus over patterns because the respondents did not possess the knowledge required.

3. There was no consensus over patterns because wear patterns have no relationship to underlying states.

4. There was no consensus over patterns because even though wear patterns could have a relationship to underlying states, there are too many variables present to be able to place a meaningful interpretation on these wear patterns. Examples of such variables are shoe type, occupational activity and shoe sole material.

5. There was no consensus over patterns because there are regional variations to be seen in wear patterns as related to defined states - i.e. the characteristic wear pattern will vary according to where an individual resides due to geographical, industrial, or socio-economic factors.

6. There is potential for consensus shown in the results but this is related to specific areas of the pattern as opposed to the entire patterns. For example although only three of the 12 patterns shown for calcaneo valgus appeared to be the same, eight respondents agreed that there would be wear along the entire medial sole area. This implies that some of the specific wear areas may relate to general function, secondary pathologies or other factors. **That is, in a total wear pattern some of the wear could be caused by the normal walking process, some could be characteristic of the pathological state of the foot and some could be due to secondary complications of that pathology or other factors.** If this is the case, respondents could have misinterpreted the overall pattern while still identifying the specific wear area relating to a particular condition. This may also be related to hemispheric asymmetries in cognitive style. That is, the right cerebral hemisphere of the brain is more holistic and recognises form and shape, whereas the left cerebral hemisphere is more sequentially analytical. Thus the right hemisphere recognises a whole pattern and the left attends to the separate parts.

2.16 Discussion

It was felt that lack of knowledge was <u>not</u> the reason for the wear pattern differences observed, because different patterns were presented even for very common, easily diagnosed conditions (e.g. hallux rigidus, hallux valgus). If further investigation still leaves this suggestion as a possibility, then a testing of knowledge may be required, possibly covering the currently known surviving "experts" in this field.

With regard to the idea that wear patterns have no relationship to underlying states, this is a highly unlikely conclusion. Studies using force plate technology have shown that characteristic motions and pressure patterns arise during gait cycles relating to specific states (Plank, 1995). If characteristic force and pressure pathways exist, it must necessarily follow that any interface (shoe sole) between the pressure source (foot) and the ground must be affected in a similar way on each occasion that this interface is subjected to a characteristic pressure pattern. Wear patterns are the product of usual, not variant footsteps. Extraneous variables can have an effect on shoe wear patterns however. Shoe soles can be manufactured from different materials which can wear at different rates and it is also conceivable that if the material is hard enough, foot function may be corrupted. The style of shoe may also have a role to play in altering function. A well designed trainer that allows full foot function may in turn allow a different characteristic representation of wear patterns than a shoe which through different heel height, slip on nature and forefoot and toe restriction may influence the foot function to an extent that the wear pattern alters. If a shoe is too small or too large, then this may also affect foot function. Different last types exist upon which shoes are manufactured such as straight last and curved lasts. It is therefore feasible that shoes manufactured on different lasts may exert control over foot function in different ways, therefore also affecting wear patterns. However, as shoes are "worn in", the usual footstep will begin to produce the characteristic patterns for that foot/shoe relationship.

The possibility of these variables affecting foot function and shoe wear patterns, may not account for the lack of consensus observed. Information given was based on clinical experience. Despite the presence of possible confounding factors, experience would be based on repeated observations over several years. If the observations are repeated, they have been observed on many occasions irrespective of these factors, which may not be known by the observers. Later investigation into variable effects may however have been required although at this stage, the project was only attempting to determine whether there was broad pattern agreement.

Regional factors may certainly have a part to play in confounding consensus. This is a novel suggestion, which may account for some of the disagreements currently in existence regarding biomechanical theory. This does not however take into account the fact that respondents may have worked and studied in several different areas and schools of podiatry and subjects alike may have exhibited varying degrees of mobility around the U.K. throughout life. If lack of consensus were to have continued in later Delphi rounds, this would be an area requiring further investigation, possibly by collecting data from defined areas by direct observation and recording methods.

The round one Delphi results raised a number of questions regarding the issue of wear patterns. The limited number of consensual replies received was inevitable in a test where free expression is given yet limited to a maximum of ten suggestions. The amount of commonality shown however has been adequate for the purpose of this round which aimed to investigate a limited number of areas for consensus and this objective has been achieved. An interesting point with regard to replies received is that two respondents showed patterns for Severs disease, one respondent showed a pattern for Freibergs' infraction and one respondent showed a pattern for Charcot-Marie-Tooth disease. None of these conditions are common and would not have been expected in a list based on familiarity by experience. An influencing factor could have occurred however in that when an unusual feature is encountered clinically, the clinician may then retain far more detail about that condition than usual through greater interest being generated by such an interesting case. This influence has been helpful in pulling-in data otherwise overlooked. The minimal pattern consensus was not expected, but as stated when the data is scrutinised in detail, consensus about specific areas in overall patterns can be seen. This possibility now required further investigation.

2.17 Conclusions

A number of conclusions can be drawn from Delphi round one. Round one collected the information sought successfully, but the information was not that which had been expected in that there initially appeared to be widespread lack of consensus. This needed to be investigated. The Delphi showed some sensitivity to capturing data on obscure conditions, which was useful.

The lack of apparent consensus appeared to warrant investigation but it appeared to be sensible first to investigate the possibility that consensus may exist relating to specific wear areas. If there still proved to be lack of consensus, then experts must be tested to see if any expertise existed in this field at all. If so, other influencing factors required investigation. At some stage, investigation into variable effects of footwear styles, materials and occupational factors may have been required. Although preliminary, the results reinforced the view that care should be taken in using outsole wear patterns in forensic investigations until more information became known through sound research.

It was therefore concluded that as a follow up to this Delphi round one, which was initially planned as a pilot study, a Delphi round two should be commenced. This round aimed to determine consensus (if possible) over specific wear areas as opposed to seeking consensus over the broad patterns shown initially under each structural/functional heading. This round would therefore only involve states for which more than one pattern had been given in round one. If consensus was not ultimately found, then the suggested reasons for this were to be investigated.

2.2 DELPHI ROUND TWO: PRODUCTION OF AN INSTRUMENT TO DESCRIBE AND COMPARE SHOE WEAR PATTERNS

Accumulative summary

In the first round Delphi study of podiatrists' experiences of shoe wear patterns, considerable lack of agreement occurred amongst participating podiatrists. A second Delphi round was carried out. This showed a moderate shift towards consensus among participating podiatrists in the context of overall wear interpretation. When chosen wear patterns were examined closer however, hidden agreements were found over specific areas of wear - the focal points from which the wear was spreading. These focal points can be diagrammatically represented on a drawing of a shoe outsole with identifying numbers ascribed to each such point. When this analytical instrument was used on wear pattern depictions chosen by second round respondents, specific combinations of focal codes were found to be strongly related to the associated, named pathologies. This preliminary instrument may form the basis of the first device capable of describing and comparing shoe wear patterns.

2.2 DELPHI ROUND TWO: PRODUCTION OF AN INSTRUMENT TO DESCRIBE AND COMPARE SHOE WEAR PATTERNS.[3]

2.21 Introduction

In a Delphi study of podiatrists' experiences of shoe wear patterns, unexpected lack of agreement occurred in the first round (Vernon, Parry and Potter, 1998). The data provided by participating podiatrists had been based on their many clinical observations over a number of years and supported the current belief that wear patterns are of doubtful value to forensic investigators due to the many variables acting on the shoe outsole. When the data in round one was examined in greater depth however, the possibility of a hidden consensus was noted. Where participating podiatrists disagreed over the overall pattern relating to specific foot/gait pathologies, there had appeared to be some agreement over specific components of wear relating to each condition. In round one, podiatrists had also shown that specific patterns could be caused by several different foot pathologies. To explore this further and seek a basis for consensus, a follow up Delphi round was planned. This would test participant's strength of belief over which conditions could be associated with specific wear patterns where multiple causes had been suggested. It would also test levels of agreement over specific areas of wear within an overall pattern which may relate to specific conditions.

2.22 Method

Information received in round one was presented to participants as a Delphi round two questionnaire. In this, the podiatrists were asked to associate wear patterns and wear pattern components with named pathologies which had arisen in round one. In doing this, consensual agreement was sought over two specific aspects of the round one data

[3] This section was published in amended form as Vernon W., Parry A., Potter M., "Moving towards consensus: The first draft of an evaluative instrumental grid to interpret shoe wear patterns", Journal of Forensic Identification, Vol. 49, No. 2, Jan./Feb. 1999, p. 142-173.

for which two questionnaire sections were planned:

Section 1

In this section, patterns which had been shown as having several possible causes in round one were presented again and respondents asked which of the pathologies named could lead to that pattern (Appendix 6). The patterns involved were reproduced on the questionnaire sheet along with the conditions named by respondents in round one as being related to these patterns. Participants were asked to indicate which of the possible pathologies they believed would cause the wear patterns shown and were advised that they were not restricted to a single response for each pattern. The need for the response to be based on knowledge and experience was emphasised to ensure that this was based empirically on repeated observations and not personal theory.

Section 2

In round one, three pathologies (calcaneo valgus/pronation, hallux rigidus and rearfoot varus) had been shown by respondents as having several possible related wear patterns. In section two, the patterns depicted for these pathologies were broken down and presented as wear pattern components (Diagram 6). Of the three named pathologies, fifteen possible components were shown for calcaneo valgus/pronation, six for hallux rigidus and four for rearfoot varus. Stated alongside each pattern component was the percentage of round one respondents who had associated that component with the named condition (Appendix 6). Participants were invited to indicate which of these components they would now associate with each pathology in light of the consensual levels shown.

The questionnaires were sent directly to all eight round one respondents who were asked to reply within three weeks of receipt.

2.23 Results and analysis

There was 100% response in round two.

Section 1

In 7/10 patterns presented to participants in section one, there was over 70% agreement that the pattern could have been caused by one of the conditions listed (Graph 1). Overall, only one possible causative condition was rejected - that of forefoot valgus being associated with pattern 4. For some patterns, several respondents had suggested additional causative conditions which had not been named in round one (Table 3). In section one, respondents differed in their opinions as to which conditions caused each pattern and indicated that they believed that some conditions could lead to more than one characteristic pattern (Graph 1).

Section 2

There was 100% agreement that two of the separate pattern components shown for calcaneo valgus/pronation and rearfoot varus were related to the associated condition and four of the depicted pattern components were not acknowledged by any of the participants (Graph 2). Ten of the pattern components had increased recognition from round one, seven remained the same and eight had decreased.

An instrument for the description and comparison of shoe wear patterns

Although it had been noted in round one that while different, the wear patterns offered by participants covered a number of common areas of the shoe outsole, the consensual levels achieved in round two section two showing separate wear components were only moderate. When the replies were studied in greater depth however, agreements emerged. The wear components offered were of diverse shape, but very specific outsole locations were common to several of these components (Diagram 7). These location points could be described verbally by relating them to the overlying foot anatomy (e.g. tip of 1st toe, 1st metatarso phalangeal joint etc.) and reflected the areas from which wear would be spreading. A list of these points was drawn up and extended by drawing on clinical experience to include other possible outsole locations which could act as such focal points of wear and an identifying code number was allocated to each point (Table 4). An analytical instrument was drafted on the basis of these focal points (Diagram 3). The less precise focal point for the 2nd/3rd metatarso-phalangeal joint area represented the difficulty in distinguishing between these anatomical points from the outsole. When this instrument was applied to patterns and pattern components depicted in round two, those patterns could be represented by a code summarising the focal points from which each area of pattern wear would be spreading. For example, in Pattern 7, wear radiated from the 2nd/3rd metatarso phalangeal joint area (represented by code 15) and from the tips of the 2nd, 3rd and 4th toes (represented by code 21). Pattern 7 would therefore be represented by a code of 15/21 (Diagram 8). Codes for all section one patterns and section two pattern components were stated (Table 5; Table 6). When this draft analytical instrument was used to evaluate the depicted wear pattern components shown in section 2, the deeper hidden consensus relating to these specific focal points became apparent.

Focal point consensus, Section 1

In using the instrument to verify the level of hidden agreement in section one, allowance was made for the pathologies which respondents had shown to be responsible for causing several of the patterns shown as seen in Graph 1. As some focal points were repeated in these patterns, the focal points covered by single respondents were only counted once to avoid a bias favouring respondents who had given such multiple opinions (i.e. in effect, they were stating the same case several times). After taking account of this, a consensus of 70% was seen to have been achieved for several focal points (Graph 3).

Focal point consensus, Section 2

Section 2 had been devised to pursue hidden consensus relating to specific components of wear, but the true level of agreement only became apparent when the instrument was applied to these components. As in section 1 the same allowance was made for multiple code responses for single respondents and again, hidden levels of agreement showed a strong consensual basis (Graph 4 a,b,c).

For calcaneo valgus/pronation, the pattern components selected by respondents covered thirteen focal points in total (points 1,2,3,4,9,13,14,15,16,17,18,19,20). Of these, 100% consensus was achieved for three focal points (points 16,17,20). One focal point (point 1) achieved >60% consensus and five focal points (points 9,13,14,18,19) had very low levels of agreement at <15%.

For hallux rigidus, the pattern components selected by respondents covered seven of the focal points (points 1,13,14,15,17,19,20). Of these seven focal points, >85% consensus had been achieved for four points (points 1,13,14,20), two focal points (points 15,17) had achieved >60% consensus and one focal point (point 19) had very low levels of agreement at <15%.

For rearfoot varus, the pattern components selected covered six of the focal points (points 1,6,13,16,17,18). Of these six points, >85% consensus was achieved on one point (point 6) and two points (points 13 and 18) achieved >60% agreement.

Comparison of focal point consensus in section 1 with section 2

The three conditions being examined in section 2 (calcaneo valgus/pronation, hallux rigidus and calcaneo varus) were also chosen by respondents in section 1 as being associated with some of the wear patterns shown. The hidden consensus in section 1 was compared with that also observed in section 2 for these conditions. Although the same respondents were involved in both sections, the context differed, so such a comparison would give an indication of the reliability of the responses. The consensual levels for the defined conditions in both sections compare closely. Graph 5 showed that the same levels of strong and weak agreements occurred for most focal points in both sections 1 and 2 and that these points differed between the three pathologies. Only one focal point in section 2 (Point 17) had strong agreement yet had not been selected in section 1.

2.24 Discussion

The effect of recall and recognition memory

The 70% level of consensual agreement sought had been achieved in the recognition and interpretation of 7/10 section 1 patterns and 3/25 section 2 pattern components. This was a major shift from round one where minimal consensus existed. The higher level of consensus achieved in section 1 over round one of the Delphi study seemed to demonstrate that when shown a characteristic pattern, podiatrists are capable of recognising this and reaching high levels of agreement over interpretation. This is supported by the additional fact that nine alternative pathologies not stated in round one had been suggested by respondents for the same patterns presented again in round two. This situation differed markedly from round one, where many different wear patterns had been suggested as being characteristic for a common condition. It appeared that when asked to reproduce a characteristic wear pattern from memory alone, podiatrists have difficulty, yet when shown a pattern for interpretation, this is an easier task, especially when the range of possible associations is limited. Recall from memory has proved difficult, yet when faced with an image, memory recognition occurs. Similarly, most people have no difficulty in facial recognition, yet have considerable difficulty in reproducing the face by drawing from memory. This phenomenon is well known and understood by psychologists and is explained by the difference between recall and recognition memories in a visual memory context (Baddeley, 1986). The consensual failure observed in round one (Vernon, Parry and Potter, 1998) may therefore suggest memory failure involvement. If, however, such memory failure had led to participants using direct observation and not experience for their presented patterns, this would suggest that a wide range of pattern variations with single pathologies existed in reality.

The value of focal points

Although a swing towards consensus occurred with regard to overall patterns, there were still areas of disagreement between participants. Subsequent Delphi rounds were expected to either confirm or remove these opinion differences when respondents would be asked to explain their position. Delphi round two moved towards consensus at two levels. The gross picture (i.e. that of fully depicted wear) moved towards agreement but importantly, opinion differences were still present. The instrument using focal points for comparison however demonstrated a hidden basis for agreement and in section 2, the apparently low levels of consensus dramatically increased when the instrument was applied. The focal points represented areas of the outsole which related to foot functioning during ground contact and from which wear areas spread. This is a potentially useful and novel manner of considering wear patterns. Concern has been expressed by forensic scientists over the number of variables involved in outsole wear. Both variability in wear patterns of shoes belonging to the same individual and similarity of wear in shoes belonging to different individuals has been noted, thus limiting the value of outsole wear in identification (Bodziak, 1990). It has also been stated that the number of factors influencing wear characteristics are small (Bodziak, 1990). Using focal points of wear as the basis of a measurement grid would address these concerns. Some shoe variable effects (e.g. shoe age, sole material, shoe style etc.), could be eliminated by focal point assessment - the focal point remaining the same irrespective of the amount of wear and peripheral pattern shape. Focal points would only record the fundamental effects of causative foot/gait conditions which would remain, irrespective of the spread and peripheral variability of wear. They may therefore be giving information about the condition present which led to the wear and not about the individual specifically. If however the individual had an unusual related pathology, the probability of a link with that individual would be increased. The availability of 21 grid points also increases the number of wear characteristic factors available for consideration and the high number of possible selections of grid points may in some cases provide the powerful individuality required in forensic identification. Common conditions would exhibit a bias towards a greater frequency of occurrence therefore limiting the value, but conversely, more unusual foot functions may reflect high levels of individuality. Round two analysis of focal point consensus showed that focal point code combinations for each pathology appeared to differ. The method of recording shoe wear by focal point code as represented by the instrument may therefore be useful in identification after further investigation through subsequent Delphi rounds and validation at all levels.

2.25 Conclusions

This second Delphi round moved towards a consensual basis at two levels. At an obvious level, there was a moderate consensus reflecting the difference between the recall memory utilised in round one and the recognition memory required in round two. When examined on a focal point basis a stronger hidden consensus was observed relating specific combinations of points to named pathologies. Although involving the same participants, section 1 and section 2 results correlated closely indicating that repeatability should be expected. This focal point basis is a potentially useful method of looking at wear patterns and could form the basis of a method for the description and comparison of shoe wear patterns. Using focal points of wear, variables relating to materials, style and age of footwear would be eliminated as focal points would remain the same, irrespective of wear amount. A follow up Delphi round three was then required for all patterns/pattern components that had not achieved consensus. In this following round, respondents would indicate which pattern associations they strongly disagreed with, mark focal points of wear on the depicted patterns and would be required to justify maintained minority viewpoints. If the higher levels of consensus were then achieved, then the focal point concept would be strengthened and testing and validation of the principle would later follow.

2.3 DELPHI ROUND THREE: CONSENSUS OBTAINED

Accumulative summary

A third Delphi round was prepared. This round contained two sections as in the previous round; section one again asked respondents to name the pathology which they would associate with an attached pattern and section 2 asked respondents to show which of a range of pattern components they would associate with a named pathology. Respondents were also asked to show which associations they would disagree with in addition to those which they supported. They were also asked to mark the centres from which they believed wear components were spreading. Responses, which were fewer than in previous rounds, showed that pattern relationships had been accepted, rejected, or had reached a static level of agreement which had not changed significantly from the previous round. This suggested that the Delphi had reached a natural conclusion. In marking centres of wear, respondents did not appear to appreciate the focal point concept, however their apparent attempts to mark force pathways often correlated with the focal points suggested. A final subsequent questionnaire was planned to formally conclude the Delphi and validate the theories arising which included the focal point concept, rejection of the past implied "one condition, one wear pattern" theory and replacement with a theory of functional wear pattern influence.

2.3 DELPHI ROUND THREE: CONSENSUS OBTAINED

2.31 Introduction and method

The Delphi round three was planned to pursue the consensual basis noted in round two further and to take the focal points noted in round two into account. The questionnaire again contained two separate sections.

Section 1

This section repeated the format of section 1 in the previous round i.e. patterns shown as having several possible causes in round one were presented again to participants who would select the named pathology (or pathologies) which they believed could lead to each pattern. The proportion of round two responses supporting each pathology/wear pattern association was again presented to participants as in round two for information. In order to explore the focal point basis for consensus further, participants were also asked to mark the points from which they believed the wear would spread from.

Section 2

In this section, round two, section 2 pattern components were re-presented to participants along with the proportion of respondents supporting each named pathology/component association in round two. Where round two had produced 0% or 100% agreement for a component, complete consensual agreement had been achieved and participants were advised that no further response was required. As in section 1, participants were again asked to mark the points from which wear components would spread.

It had been noted in round two that some participants adhered to minority viewpoints. In Delphi round three, participants were asked to justify their responses to accelerate the achievement of consensus – either through acceptance or rejection. Such justification would eliminate unjustified minority responses and show the rationale behind such opinions still adhered to. In previous rounds, consensus had only been sought where participants agreed that a pattern or pattern component did exist with a named pathology. In round three, respondents were also allowed to express strong disagreement with an association. This would usefully allow consensus to be achieved in several ways:

1. By high % support (70% or more) without disagreement being indicated (i.e. while participants may not have personal experience of associations between patterns/pattern components and pathologies, they would not dispute such possibilities.
2. By high % disagreement (70% or more) without opposing viewpoints.
3. By 0% agreement resulting in a "no support" consensus.
4. By a justified supportive viewpoint without disagreement giving an undisputed though minority association.

This would allow respondents to support an association which they believed to be correct even if this may be beyond their personal experience.

The Delphi round three questionnaire package included the following:

1. Covering letter to heads of service asking that the questionnaire package be forwarded to participants.
2. Explanatory letter
3. Questionnaire section 1
4. Questionnaire section 2
5. Comments sheet
6. Stamped, addressed envelope

(Appendix 7)

2.32 Results and analysis

Response rates

5/8 responses were received (62.5%), unlike the previous two rounds which produced 100% response rates. This may have related to the more difficult task required by requesting minority opinion justification. Drop-out rate is anticipated in Delphi projects (Fink et. al., 1984; Grant, Kinney and Guzzetta, 1990). Studies can be found where final round panel response rates vary from 100% of the original panel (Cronin and Owsley, 1993), to only 21.2% (Farrell and Scherer, 1983). This round three response rate of 62.5% compares to those of Butterworth and Bishop (1995), with 61% and Hitch and Murgatroyd (1983), with 60%. The remaining five respondents were slightly higher than the four final respondents reported in Stheeman and co-authors' study (1995). The responses were studied to determine levels of consensus at face level (entire pattern/pattern component agreements) and focal point level (focal point relationships with pathologies). Agreements were compared with those of the previous round and respondent comments considered.

Section 1 face level consensus

There was agreement that 8/10 patterns were associated with single named pathologies and that 11 further pathologies were not associated with their suggested patterns. There was no agreement for 13 other possible associations (Graph 6). When compared to the previous section 1 results (Graph 7), it was seen that strong agreements were further strengthened and weak agreements remained weak or were rejected. Most other associations which had been moderate in the previous round remained stable, although one exception to this showed a consensual increase.

The consensual increases seen and rejection of minority opinions appeared to show that respondents were unwilling to retain minority opinions when asked to provide justification. This may have been reinforced by participants undergoing a Delphi-catalyzed learning experience, possibly because knowledge inadequacies had been highlighted. If a learning experience had occurred, participants may have become aware of a common association – the majority opinion. However, as round one patterns had been based on experiences, although rejected later, they had been observed with associated pathologies at some point. This implied that ranges of patterns may occur with single named pathologies, with some patterns (those achieving consensus) occurring more frequently than others. If patterns are functionally caused, this implies that different functions can occur in association with individual pathologies.

Non-achievement of consensus may have related to uncommon patterns falling outside the experience of some participants who could not theoretically explain such associations. Some participants may have also incorrectly associated some patterns and pathologies through misdiagnosis.

Section 1 focal point consensus

The focal point level reflected the face consensus agreements shown. (Graph 8). The format of section 1 differed from that of section 2, in asking participants to match pathologies with given patterns (in section 2, the task was to match pattern components with named pathologies). With the primary variables therefore being named pathologies and not patterns or pattern components, further focal point analysis was not required.

Section 2 face consensus

Section 2 consensual levels are shown in Graph 9. 2/15 pattern component relationships were accepted and 4/15 rejected with no agreement being achieved for the remaining nine components. When section 2 results were compared with those of the previous round (Graph 10), similar trends were observed to that seen in section 1 (i.e. previously high agreements remained high and low agreements remained low). Moderate agreements again tended to remain moderate showing lack of agreement and uncertainty.

As in section 1, respondents were again unwilling to adhere to minority view points when asked to justify their position, and showed strong tendencies to support pattern components with previously high agreements. This may again reflect improved subject area knowledge if predominant patterns had been observed regularly since round one. In turn, this suggests less previous knowledge amongst podiatrists than assumed with possible increased participant experience as the rounds progressed. Again however, round one results suggested that all patterns had been observed empirically with named pathologies at some time. Agreements would again therefore relate to the more common pattern components with others remaining possible. The suggestion that one pathology would create one specific wear pattern therefore still appeared to be incorrect.

Section 2 focal point consensus

At focal point level 4/13 calcaneo valgus/pronation, 4/6 hallux rigidus and 3/6 rearfoot varus pattern components achieved consensual acceptance. 7/25 components overall showed moderate acceptance and 7/13 calcaneo valgus/pronation pattern components minimal acceptance (Graph 11). When focal point agreements for pattern/pathology associations were compared with those of the previous round, most focal point agreements had remained high, moderate or low (Graph 12). No pattern component rejection occurred. The association of focal point 4 with pronation and points 13 and 18 with rearfoot varus however increased slightly. As responses here were again based on experience, agreements may reflect the more commonly occurring components from a wide range of possible associations. Participants were unaware of the focal point concept in pattern comparisons and were therefore unbiased where agreements were reached. Focal point assessment is therefore supported as a method of elucidation and comparison. Peripheral wear pattern differences were however present, implying that other factors may cause such secondary wear pattern influences.

Following the arguments presented earlier (Chapter 2.1, p. 42-43), agreement levels of 70% had been sought in this Delphi exercise. Opinion stability is also seen as a cut off point for Delphi (Linstone and Turoff, 1975). This suggests the cessation of a Delphi on the grounds that on the basis of trends noted, continuing rounds would be unlikely to show further changes in agreement. In this Delphi study, at the conclusion of round three, agreements in excess of 70% had either occurred, or opinion stability reached, thereby justifying termination of the Delphi phase of the research.

General comments, sections 1 and 2

Some respondents provided written comments relating to patterns and pattern components. These were subjected to content analysis, following the approach advocated by Robson (1993), to determine what respondents were attempting to convey and what beliefs they were expressing in their comments (Appendix 8), which had been invited to justify (minority) opinions expressed in Delphi round three. The analysis isolated and categorised themes based on word meanings, with the aid of thesaurus and podiatry literature, with the objective of seeking explanations for the variations in wear to which the comments referred. All comments could be seen as attempting to justify respondents positions through:

- Describing mechanisms behind wear pattern production.
- Expressing wider knowledge of the effects of pathology on footwear.
- Suggesting that the same wear pattern could have different pathological causes.
- Suggesting alterations required in the pattern depictions for accurate portrayal of a pattern association.
- Expressing variable levels of certainty in responses.

The content analysis produced inferences from identified categories and themes, which related to perceived wear pattern influences and relationships (Appendix 8). Although respondents who provided comments believed that foot pathology could influence shoe wear, they also indicated that the strength of relationship between pathology and wear could vary and that different pathologies could be associated with the same wear pattern. Respondents also demonstrated opinions that wear patterns could be influenced by the severity of the pathology present and by functional variations in the force pathway which may not be described in pathological terms. Respondents also believed that local factors could have a direct local effect on wear within an overall pattern, suggesting that wide variations in wear and not single characteristic patterns may be anticipated with named foot pathologies.

These comments supported the theory that wide ranges of patterns may be anticipated with named foot pathologies. Local variables and the severity of named pathologies may contribute to these deviations. This suggested that the pathology itself may be just one factor and not the major cause of wear pattern production. A partial effect of foot pathology on an overall wear pattern would indicate that factors with a more widespread effect over a pattern should have a greater influence over the pattern form than the pathology. Comments relating to force pathway variations suggested that foot pathology may only be one contributory factor to a complete wear pattern form, with foot function being more influential in the total wear pattern production than the pathology itself.

Such foot function may be independent of foot pathology, although foot pathologies may have a local effect on pattern formation. The suggestion that wear can vary with foot pathology severity however may imply a stronger role for pathology in wear pattern formation, although this could indicate that some pathologies have strong functional influences. The overall suggestion is that a wide range of pattern associations can be expected with named pathologies, with function having a stronger influence over wear patterns formation than foot pathology, which may have a more local effect.

Marking the centres from which wear was spreading (focal points)

In both sections, respondents had been asked to mark the centres from which they believed the wear to be spreading to show whether their perceptions agreed with the focal point concept. 4/5 respondents complied with this request although none did this for all patterns/pattern components. Some markings given did not comply with the focal point concept with being positioned where there was no wear and some were placed in series, possibly reflecting respondent perceptions of force pathways relating to associated functions (Appendix 9). While much of the data were incomplete and ambiguous, consensual agreements could be noted with several focal points (Table 7). Respondents therefore either did not understand the instructions given or did not appreciate the focal point means of wear description – both possibilities demonstrating that the focal point concept is novel. The marking of "centres of wear" suggested that possible force pathways had been considered but without relating these to the anatomical points of ground contact.

2.33 Discussion

The Delphi concluded

The round three analysis suggested that the Delphi exercise had concluded and would serve no useful purpose by continuing. Response levels in both sections either produced consensus or had stabilised without agreement but without change from the previous round. When the Delphi commenced it was believed that a body of experience existed which suggested that specific recognisable wear patterns could be associated with specific foot pathologies – the "one condition, one wear pattern theory". The Delphi had been devised to produce agreements over such characteristic patterns. This exercise suggested that this perspective is incorrect – even at focal point level, further justifying the Delphi conclusion.

Delphi as a learning experience

Although consensual agreements occurred, the initial wide range of patterns presented were based on experience and were therefore possible. Agreements may therefore relate to common pattern associations. Two of the agreed pattern associations in section 1 (Patterns 8 and 9 – hallux rigidus) related closely to the hallux rigidus pattern previously depicted by Lucock (1980)(Appendix 10). This suggested that either respondents had revised the subject area since round one, or that past depictions showed commonly occurring patterns in the mistaken belief that these were unique to the associated pathology. Whether the additional knowledge came from theoretical reading, clinical observations, or a combination of both, this suggested that the Delphi exercise was a learning experience for respondents involved.

Functional influence over wear patterns

Lack of round three agreement may have arisen through uncommon pattern associations being beyond some respondents' experience. There was also a potential for respondent misdiagnosis of the pathologies associated with given patterns to contribute to lack of consensus. A complex position emerged with multiple patterns associating with individual pathologies. Many reasons may exist for pattern variations occurring. Respondent comments implied that there may be strong overall functional influence over wear patterns. If patterns are functionally caused, as suggested by respondent comments, multiple functions may be indicated with each pathology, with the pathology possibly contributing to, and not being responsible for, the overall wear pattern. Excluding compensation and non-compensation, such functional variations had not been considered previously. There may also be other non-pathological causes of wear variations requiring further investigation and some pathologies may exert greater influence over wear patterns than others when not present in isolation.

Focal points

The focal point concept which emerged and which related to anatomic parts of the foot achieving ground contact was useful when comparing wear patterns for similarities. While initially it was thought that this may provide a basis for consensus over characteristic wear pattern associations, this did not occur, despite some focal point combinations having strong associations with named pathologies. While respondents did not appear to appreciate this concept when asked to sketch centres of wear, the limited consensus reached in this task indicated that clinical intuition may support the suggestion as a basis for understanding and acceptability. While focal points agreed however, peripheral wear variations were still present suggesting the presence of other possible wear pattern influences.

Limitations in wear pattern understanding

The use of shoe wear patterns in forensic identification may therefore be problematical; if characteristic wear patterns do not exist, then wear patterns may not be interpretable in isolation. Conversely, if wide wear pattern variations exist, some wear pattern associations may suggest stronger individuality, thereby enhancing their identification value. If patterns relate to a functional cause then the clinical value of a wear pattern may be enhanced through the potential to indicate foot function, which may otherwise require investigation with expensive diagnostic equipment.

Wear patterns were not understood as well as previously assumed. The "one condition, one wear pattern" perspective suggested by past publications appeared incorrect and round one respondent comments suggested that direct outsole observations were undertaken in order to complete the questionnaire through lack of understanding. This notion may have been reinforced by the round three drop out rate, which coincided with the request that minority viewpoints be explained – suggesting that this task may have been too difficult.

2.34 Conclusions

The Delphi had concluded at this stage, with the "one condition, one wear pattern" hypothesis being challenged by the initial wide range of patterns observed in round one. Agreements reached in round three may relate to the more common wear pattern associations and respondent comments suggested that there is a strong functional influence over shoe wear patterns, with foot pathology having a secondary influence only. The focal point concept proved useful in the pattern comparison and analysis. While wear pattern causes are not fully understood, their use in forensic identification can not be recommended without further investigation.

To confirm the conclusions and validate the findings, a summary of consensual levels achieved along with statements relating to other conclusions drawn from the exercise would be distributed to all participants who would indicate agreement or disagreement with each conclusion made. Following this, a study of wider ranges of patterns with a view to identifying influencing trends and associations amongst pattern variations was proposed.

2.4 DELPHI ROUND FOUR: PARTICIPANT VALIDATION

Accumulative summary

Following the Delphi round three, which suggested that the Delphi rounds had reached a natural conclusion, these results were again presented to participants along with statements summarising resulting theories for ratification. Respondents accepted this re-iteration along with all derived theoretical statements. Further investigation was required as a follow up with the involvement of a wider range of wear patterns. Accepted theoretical statements suggested that while several factors could influence shoe wear, that wear is a fundamental product of foot function, with multiple functions and therefore wear patterns occurring with individual foot pathologies. Wear patterns can be compared using the focal point principle, although the forensic use of patterns could not be recommended until greater understanding had been achieved. Respondents also concurred that participation had been a learning experience with regard to wear pattern understanding.

2.4 DELPHI ROUND FOUR: PARTICIPANT VALIDATION

2.41 Introduction

Prior to the preparation of this questionnaire three previous Delphi rounds had taken place. In the first round, participants had provided sketched depictions of shoe wear patterns which they could characteristically associate with specific foot pathologies which they also named. A basis for consensus had been anticipated in that foot pathologies were thought to create specific wear patterns, however, this did not occur, with multiple patterns being associated with single pathologies. While the subsequent two rounds produced consensus, round one patterns had been based on experience and therefore existed. Round three had reached a conclusion for two reasons:

1. The previous assumption that one condition would create one characteristic shoe wear pattern was no longer believed to be true therefore the achievement of consensus over characteristic wear pattern associations was now irrelevant.
2. Round three results demonstrated either consensual agreement or static non-agreement, indicating that further change would be unlikely in future rounds.

Although the Delphi had concluded, there was potential to improve the validity of the study. Importantly, theories had arisen more through the initial lack of consensus and the Delphi progress than through the agreements finally achieved. As validity can be enhanced by asking informants to check emerging theory (Morse and Field, 1996), presentation of statements summarising these arising theories to participants for confirmation of acceptability was seen as desirable. It was therefore proposed to present the round three results and statements of conclusion back to respondents to indicate agreement/disagreement, as a final questionnaire round.

2.42 Method

The round four questionnaire was not a true Delphi round, but instead was to test the validity of statements made from the previous rounds and of the agreements reached. In round three, different consensual levels had occurred for pattern/pattern component relationships with pathologies which could be summarised as follows:

100% agreement	-	Complete acceptance
60 – 80% agreement	-	High acceptance
40% agreement	-	Moderate acceptance
20% agreement	-	Low acceptance
0% agreement	-	Complete rejection

In round four, sections 1 and 2 (See Chapters 2.2 and 2.3) were again presented to participants along with the summary statements of consensual levels achieved and the percentage of participants in agreement. Participants were asked to show whether they agreed or disagreed with these summaries. If in disagreement participants were asked to write in their suggested amendments (Appendix 11). In this way, participants were being asked to show whether they accepted consensual agreements where achieved and whether they believed that there were valid differences of opinion where non-consensual stability existed.

For this questionnaire a third section was also prepared (Appendix 11). This presented a written overview of each rounds' findings to participants along with statements summarising the theories arising from the Delphi rounds. Participants were again asked to indicate their agreement/disagreement with these statements, stating reasons for any disagreements indicated. The seventeen statements for consideration mainly related to the following derived theories:

- Multiple wear patterns and not simply one characteristic pattern are possible with individual pathologies, although some of these patterns are more commonly occurring than others.

- Wear is primarily a product of foot function and not simply a reflection of its fixed anatomy/morphology and this function can vary widely with single pathological states.
- There are many potential wear pattern influences although some have greater influence than others.
- The Delphi exercise stimulated learning amongst participants who gained knowledge through that participation.

The questionnaire included a feedback sheet for further comment and a covering letter inviting response and providing completion instructions (Appendix 11). Questionnaires were again distributed to all eight original participants.

2.43 Results

4/8 questionnaires distributed (50%) were returned. Information was received confirming that one participant was on extended leave and could therefore not respond. Other non-responses may have been identical to those in the previous round, as numbers tallied. The potential for non-response as Delphi rounds continue is well documented (Mckenna, 1994; Fink et. al., 1984) and was therefore anticipated.

Sections 1 and 2

In section 1, respondents unanimously accepted the Delphi round three position showing consensus and equilibrium. In section 2, all but one of the respondents accepted the round three position. The disagreeing respondent, however, had re-stated the belief that where agreement had not been achieved, his perspective was the correct one. This respondent had therefore in effect re-confirmed the lack of agreement already noted over wear pattern associations.

Section 3

All participants unanimously agreed with the seventeen statements presented in this section, demonstrating participant belief in the Delphi findings.

Feedback comments

Feedback comments were received from 3/4 participants (Table 8). Two of these comments referred to personal levels of interest in the study, reflecting the motivation of the completing participants. The difficulty of the task required was reported in one comment and further support for the concluding comments in another. One participant expressed the belief that external variables were a very important consideration, again reflecting the complexity of shoe wear pattern production. The same participant also noted the value of other aspects of the shoe in studying the foot and that the outsole material type may dictate the information available through the wear pattern. Participants therefore appeared to believe that the study was valuable, but highly complex.

2.44 Conclusions

Summary of Delphi findings

In view of the unanimous acceptance of the round three re-iteration, the Delphi rounds had concluded. Similar unanimous acceptance of the theories arising from the Delphi process validated those conclusions. While questionnaire non-response causes bias, this was not thought to apply here as the most important findings related to the initial lack of consensus, with some disagreements being maintained to the final round. The findings of the project on conclusion of the Delphi rounds were as follows:

1. The previously assumed belief that one specific condition would cause one characteristic wear pattern only was incorrect, with wide ranges of wear patterns occurring with single pathologies. The previously assumed characteristic pattern associations may be those most commonly observed with a specific pathology.

2. Wear may be fundamentally a product of foot function, not simply foot anatomy/morphology or pathology and several different functions may occur with single named conditions.

3. There may be several factors which influence shoe wear patterns, some of which may have greater effect over wear than others.

4. Knowledge of shoe wear patterns is at a lower level and wear pattern formation is more complex than previously assumed, but Delphi respondents underwent a learning experience through their participation.

5. While the exact shape of shoe wear patterns is infinitely variable, patterns can be usefully defined and compared using the focal point principle.

6. While doubt exists over the complex production of wear patterns, its' use in forensic identification cannot be recommended although with improved learning through routinely assessing shoe wear patterns, podiatrists may develop improved functional understanding of this subject area.

Successive research required

Following the Delphi conclusion, the project would investigate a wider range of shoe patterns in order to determine influential factors in wear pattern production and suggest a mechanism for that production if apparent. While the Delphi had initially been planned as a pilot study in preparation for a larger Delphi exercise, the findings were sufficiently important to continue the pilot as a Delphi exercise in its' own right. While a larger survey was now required, this did not need to be a multi-round Delphi, as it was the unexpected divergent views and not the consensus which had been the key aspect of the Delphi.

3. PART THREE: FURTHER EXPLORATION AND THEORY

3.1 PRE- QUESTIONNAIRE SURVEY: A FOCUS FOR THE SHOE WEAR PATTERN QUESTIONNAIRE

Accumulative summary

A survey was undertaken prior to the main questionnaire to be distributed across NHS podiatry services throughout the U.K.. This would enable the main questionnaire to focus on a limited range of conditions which may cause characteristic shoe wear patterns and therefore improve the quality of response. The survey asked podiatrists to name up to 10 conditions for which they believed they could associate characteristic shoe wear patterns. Four conditions were named more frequently than others and would be used in the main questionnaire to follow. These conditions were pronation, hallux rigidus, pes cavus and rearfoot varus.

3.1 PRE-QUESTIONNAIRE SURVEY: A FOCUS FOR THE SHOE WEAR PATTERN QUESTIONNAIRE

3.11 Introduction

The Delphi rounds highlighted that it may not be possible to present a single wear pattern and categorically state that this is classically associated with a named condition. Delphi round 1 participants had presented diverse wear pattern possibilities which could be associated with single named conditions. Although consensus was eventually achieved, these diverse patterns had been reported by participants as being experienced with the named conditions and therefore existed. There may therefore be several distinct patterns possible for single named conditions which are the result of compensatory functioning which has never been appreciated, researched or documented. The focal point concept may enable patterns to be related to pathological causes if the patterns are related to these functional differences, but this concept was not understood by the participants as demonstrated in round three of the Delphi.

To follow up the Delphi, it was seen as desirable to collect wider depictions of patterns associated with named foot pathologies in order to determine whether varying pattern associations could be classified and whether qualitative analysis would demonstrate relationships between wear patterns and foot pathologies. Following the success of the Delphi questionnaires in capturing pattern depictions, a widely distributed single round questionnaire survey based on this design was seen as a reliable means of obtaining the required data. Despite using only eight participants in the Delphi, a considerable amount of data was generated during wear pattern synthesis. Using considerably more respondents in such a main questionnaire of outsole wear pattern experiences suggested a need to focus on a limited range of conditions. This was viewed as essential in order to keep the resultant data manageable while at the same time ensuring that participants were confident with their responses which should relate to conditions of importance to podiatry. A pre-main questionnaire survey was therefore planned as a preliminary requirement before the main questionnaire was prepared.

3.12 Method

A simple survey questionnaire was chosen to produce the information required, which was as follows:

1. The names of foot pathologies that respondents believed that they could relate specific shoe wear patterns to. The respondents were asked to name a maximum of 10 pathologies in order to keep the data manageable. They were also asked to name a minimum of three pathologies in order to avoid the possibility of only receiving minimal data from which to work. It was stressed that the conditions named must be those for which characteristic wear patterns were known through experience and not taken from direct patient observation after the questionnaire had been received as the intention was to sample wide ranges of experience and not single recorded observations. The collection of this information was the primary purpose of the survey. The pathologies to be used in the main questionnaire were intended to be those named most frequently in the pre-questionnaire replies. Justifications for this were:

   i) The highest number of respondents would then be able to return meaningful replies in the main questionnaire.
   ii) The most commonly stated conditions must be of importance to podiatry either by being frequently encountered clinically or because they were unusual and memorable and therefore important clinically on this basis.

2. Respondents were asked to provide names and contact details. This was to allow follow-up of any queries the researcher may have over replies received, if required. As this survey was not part of the questionnaire to follow, there was no anonymity requirement at this stage.

The survey was intended to reach a large number of suitable expert respondents from across the U.K., with clinical expertise or abilities suggesting experience/personal knowledge of shoe wear patterns. For this reason, it was decided that all Trusts in the U.K. known to provide a podiatry service and which would therefore provide access to high numbers of podiatrists would be included. The Society of Chiropodists and Podiatrists database of heads of NHS podiatry services was made available to enable contact to be made. An accompanying letter asked heads of service to allocate their most appropriate/experienced practitioner in this area for participation based on the premise that a departmental manager is required to know and understand the skills, abilities and specialities of all staff managed.

The previously stated assumption that "professionals are entirely conversant with the parameters of their professional practice" (Duffield, 1988/9) is fundamental to this method of obtaining experts and has been used in Delphi studies successfully (Bond and Bond, 1982; Hitch and Murgatroyd, 1983; Duffield, 1988/9; Pinyerd et. al., 1993). Participation was restricted to state-registered chiropodists/podiatrists who have specific training in recognition, treatment and prevention of conditions of the foot, which are either functionally based or exacerbated by function. All would be clinically working practitioners with direct experience of this aspect of patient care and unlike other disciplines who also have knowledge of the foot, have a specific focus on the foot alone, thereby gaining an undiluted experience and knowledge base of this aspect of the body. Respondents involved would be invited to participate in the main questionnaire, further justifying these expert selection considerations. The survey was limited to NHS Trust employees only as the project may at a later stage require validation experts independent of the panel as utilised in previous studies (Grant and Kinney, 1992).

In order to facilitate improved survey responses, explanatory accompanying letters were hand signed and stamped, addressed envelopes included. Respondents were asked to reply within three weeks of receipt. The final package consisted of:

1. Letter to heads of service requesting the allocation of an appropriate experienced podiatrist to participate in the survey.
2. Explanatory notes asking participants to name between three and ten conditions for which they could identify associated wear patterns from experience and confirming that responses would be treated confidentially.
3. A "prompt" list of possible structural/functional conditions that may affect shoe wear.

4. The questionnaire.
5. Stamped addressed envelope.
6. A checklist confirming the package contents.

(Appendix 12)

No follow up was undertaken as it was intended that the groups involved would be invited to participate in the main questionnaire survey and it was considered important to begin to set appropriate conditions to remove inhibitions in potential respondents.

3.13 Results

83/214 questionnaires were returned (39%). Thirteen respondents gave the maximum number of ten conditions for which they claimed to know wear patterns and two advised that they knew no wear patterns at all. The mean number of conditions that each podiatrist claimed to know a characteristic wear pattern for was 6.53. 66 out of 82 conditions from the "prompt" list, were named by respondents as pathologies for which wear patterns were claimed to be known (Table 9). Responses ranged from zero wear patterns known to the maximum of ten requested. When the conditions that respondents claimed to know wear marks for were placed in order of frequency (Table 9), the ten most commonly noted conditions were:

1. Pronated foot (47 respondents)
2. Hallux rigidus (46 respondents)
3. Pes cavus (35 respondents)
4. Hindfoot varus (31 respondents)
5. Forefoot valgus (23 respondents)
6. Normality (23 respondents)
7. Intoed gait (23 respondents)
8. Overloaded 2nd metatarsal (21 respondents)
9. Drop foot (19 respondents)
10. Hallux valgus (18 respondents)

Although not requested, thirteen respondents added comments to their replies which were logged and classified accordingly (Table 10)

3.14 Analysis/discussion

Response rates

Although the 39% response rate initially appeared low, the survey design had two opportunities for non-response:

(i) From heads of service.
(ii) From the participating "experts".

While response rates for postal surveys can vary from nil to over 90%, it is believed that 50 - 60% is the best that can be expected if no reminder letters are used (Kane, 1990). With the survey passing through both heads of service and nominated experts, a 25 - 36% response rate could be anticipated on this stated basis. As 39% replied, replies were above the higher expected return rate with this particular study design.

The named foot pathologies

The primary aim of the survey was to select foot pathologies on which to focus the main questionnaire. Without exception, the 10 conditions with the highest frequencies of occurrence were all commonly encountered, easy to recognise and easily understood. Podiatrists would usually recognise such conditions through visual assessment alone without the need for more in-depth joint measurement, palpation, history taking and/or further tests. Given this ease of recognition, it is probable that these conditions may have been the most frequently named because clinical time restrictions in modern NHS clinics may preclude more in-depth diagnoses. Many of the other conditions may therefore be going unrecognised with any wear pattern associations remaining unappreciated. The importance of these ten frequently named conditions to podiatry is therefore likely to be that of common clinical occurrence combined with ease of recognition.

Despite this ease of recognition, with the exception of normality there is little appreciation of the full range of pathological functioning of these conditions and therefore incomplete documented understanding of their full implications. Wear patterns associated with these conditions would be of value if they could improve understanding of associated functions. Of these ten conditions, there was a notable gap between the four most frequently named conditions and the next most commonly cited (Table 9). The four most frequently named conditions would therefore form a natural focus for the main questionnaire on the basis of frequency of occurrence, ease of understanding, manageability and natural selection.

At the lower end of the response frequency scale, other distinct patterns could be noted. The conditions named infrequently or not at all were those for which either recognition and diagnosis may not be as straightforward in busy clinical conditions (e.g. lower motor neurone weakness), or those which may not relate directly to patterns of shoe wear (e.g. painful nail disorders of the 1st toe may not affect shoe wear at all.) Some of the conditions named (e.g. Chorea, tarsal arthritis) may present with multiple variations, none of which could be attributed directly to characteristic shoe wear patterns. These three factors characterised all the infrequently named/not named foot pathologies from the "prompt list" in the survey. It was also noted that although foot strain had been linked to characteristic wear pattern depictions in chiropody texts (Hanby and Walker, 1949; Charlesworth, 1961), none of the respondents indicated knowledge of any patterns characteristically related to foot strain. Past perceived forms of foot strain conditions may therefore no longer be clinically recognised. Alternatively, respondents may not believe that there are any characteristic wear patterns related to foot strain, or if there are, they may not recognise them. This may also be an indication that no respondents were familiar with the books concerned.

Some pathologies named as having known pattern associations were not included on the "prompt" list of conditions in the questionnaire pack (Table 9). While many were synonymous terms for conditions on the "prompt" list, others were not, possibly reflecting limitations of the text used to prepare the "prompt" list (Neale, 1981). A number of respondents had named compensated forms of conditions for which wear patterns were known (Table 9). In podiatry:

> "Compensation is a change of structure, position or function of one part in an attempt by the body to adjust to a deviation of structure, position or function by another" (Root, Orien and Weed, 1977; 115)

No documented appreciation of a number of these compensated forms could be found including hallux rigidus, pes cavus, intoed gait, hallux valgus, metatarsus adductus, hypermobile foot, hemiplegic gait, out-toed gait and plantar flexed 1st and 5th toes. This may indicate that either respondents did not fully understand the conditions for which they named previously unrecognised compensations, or that unappreciated functions can exist with these conditions which respondents believed they had observed.

Comments provided by respondents

The comments provided by respondents could be classified on the basis of beliefs expressed in these comments (Table 10). One comment had simply advised that some wear pattern examples could be found in a named orthopaedic text and as such was simply providing helpful advice. Three respondents believed that information beyond shoe wear alone would be required to identify related conditions. One of these respondents echoed Ware's belief that patient examination is essential when considering wear patterns (Ware, 1920) and the other respondents believing that examination of other aspects of footwear would also be required. This was supported by two references by respondents to examination of the upper in conjunction with the shoe outsole when relating wear to some conditions. One respondent had advised that examination of both shoes of the wearer as opposed to only one would help in identifying a greater range of conditions.

Two of the respondents referred to similarities between wear patterns caused by different conditions and another believed that there were only a few conditions which could create characteristic wear patterns. This reflected some of the findings in the

Delphi rounds when respondents were asked to name possible causative conditions from depicted wear patterns.

Ten comments indicated that respondents personal knowledge levels were insufficient to answer the questions, with one respondent knowing no wear patterns and another only two. Other comments categorised in this way expressed lack of confidence and difficulties which the respondents had found in undertaking the task required. This may suggest that service heads had applied inappropriate criteria in their expert choice, or simply that the relevant knowledge did not exist within their services. Conversely, another respondent stated that conditions he had named were taken at random. This suggested either a deviation from protocol or that the respondent had personal knowledge of a multitude of characteristic wear patterns and had used a random selection to name the maximum of ten conditions.

Within the fourteen supplied "impromptu" comments, there were eleven references of an encouraging nature, which reflected personal beliefs in the value of the project. There were also four comments indicating a belief that wear patterns have potential clinical value. Another comment however advised that colleagues had been unwilling to participate. While suggesting that these podiatrists may not have possessed the knowledge required, this could also indicate that they placed minimal value on the work. Overall, the comments indicated that greater understanding of wear patterns was required and that a number of respondents felt that the work would provide a useful contribution to podiatric knowledge.

3.15 Conclusions

The primary purpose of this survey was to highlight conditions on which to focus the main questionnaire survey. In this respect, this survey was successful in highlighting the four conditions of pronation, hallux rigidus, pes cavus and hindfoot varus as being those with which respondents perceived the greatest associated wear pattern knowledge. This was possibly based on the importance of these conditions to podiatry through impact, frequency of occurrence and greatest understanding. The main questionnaire would therefore focus on these four conditions to keep resultant data manageable and to improve the response potential. Although compensatory forms for two of these conditions (pes cavus, hallux rigidus) were named in this survey, only the name of the condition would be used in the main questionnaire when asking for associated wear pattern depictions. If new compensated forms of these conditions exist, they should arise again in the following main questionnaire survey. Given the possibility of a number of pattern variations for each condition, the main questionnaire would be designed to allow several patterns to be shown for each condition, if known. If only one pattern were allowed through inflexible questionnaire design, then the possibility of capturing this data may be lost.

On the basis of this pre-questionnaire survey, the format of the main questionnaire was amended to allow for:

1. Potential masses of accumulated data for named conditions, hence the inclusion of only four "naturally selected" conditions in the main Delphi.
2. Various diverse functional forms of each foot pathology.
3. Multiple pattern associations for each foot pathology.

The basis of expertise for the main questionnaire would follow that justified for this survey, with participants being invited to respond to the main questionnaire.

3.2 SHOE WEAR PATTERN QUESTIONNAIRE: A THEORY OF SHOE WEAR PATTERN INFLUENCE

Accumulative summary

A questionnaire survey captured podiatrists' depictions of shoe wear patterns which they would characteristically associate with four named foot pathologies through experience. An extensive range of patterns resulted. Qualitative analysis of these patterns was undertaken from a hermeneutic phenomenological perspective. Completion of the hermeneutic circle suggested that patterns could indicate causative function within a known pathological context and in doing so, allowed categorisation on this basis. Several different functions were suggested by patterns associated with each of the four named pathologies. Reasons given by respondents for variations seen were predominantly compatible with, or supportive of the suggested functions having taken place. Analysis of the relationship between patterns and reasons given by respondents for pattern variations showed the strongest associations to be with functionally termed conditions A basic model was proposed to present factors important in wear pattern production. This model suggested that primary walking intention was more influential than foot pathologies in wear pattern formation and that other "external" factors could also influence shoe wear. Validation of the model in real-life situations was required to conclude the research.

3.2 SHOE WEAR PATTERN QUESTIONNAIRE: A THEORY OF SHOE WEAR PATTERN INFLUENCE

3.21 Introduction

Prior to implementation of the main questionnaire, four Delphi rounds and a pre-questionnaire survey had been carried out. The purpose of the Delphi had been to seek consensus over characteristic shoe wear patterns that may relate to defined conditions. The pre-questionnaire survey was developed directly from the Delphi findings and primarily aimed to focus the questionnaire survey thereby limiting the data to manageable proportions.

In addition to highlighting the need to focus on a limited number of conditions, the Delphi suggested that the need for anonymity should be stringently applied in the main questionnaire. During the Delphi rounds, although respondents remained anonymous to each other, their identity was known to the researcher. This was thought to be acceptable for the following reasons:

1. At the start of the Delphi, the subject was considered non-controversial.
2. The anonymity from each other was considered adequate for uninhibited responses from participants in this subject area.
3. Feedback and two-way communication may have been desirable in order to verify and discuss queries relating to the method and it's implementation.

In the event, the Delphi rounds showed surprising results from a profession claiming to understand shoe wear patterns, so a higher level of anonymity to allow uninhibited response in the main questionnaire was seen as desirable.

A "one condition, one wear pattern" relationship of shoe wear to foot pathology had been anticipated in the Delphi in line with past implied assumptions from chiropody authors. This situation was not apparent from the Delphi results with participants initially presenting a range of patterns in association with single named foot pathologies based on their own experiences. While a consensus did eventually arise, the wide range of patterns presented suggested that participants had experienced these patterns in association with the named conditions at some point. From examination of the patterns in the Delphi, the focal point method of pattern comparison had arisen. This was as a useful tool in the wear pattern comparison process, which could exclude secondary variables caused by factors such as age of footwear when comparing shoe wear patterns. The Delphi had also demonstrated that podiatrist's knowledge of shoe wear pattern formation and associations was less sophisticated than previously assumed, although responding participants supported the hypothesis that the Delphi experience had catalysed a learning process of shoe wear pattern associations.

With previous shoe wear pattern beliefs being challenged by the Delphi, there remained a need to study the association between shoe wear patterns and foot pathologies with a view to learning more about their relationships and possible causes. While the Delphi questionnaire format was useful in collecting podiatrists' experiences of shoe wear patterns, the sample was small and a wider collection of patterns and named associated conditions was required for further analysis. A follow-up questionnaire was therefore planned to collect this data from a greater number of podiatrists for in-depth analysis of themes and associations.

Due to the wide range of pattern variations now expected, there was a need to focus the main questionnaire on a more limited range of conditions. The pre-questionnaire survey had indicated four conditions that respondents overall believed they had greater wear pattern recognition knowledge of, namely:

1. Pronation
2. Hallux rigidus
3. Pes cavus
4. Rearfoot varus

The main questionnaire was therefore planned to focus on these four conditions as having the greatest chance of response success.

Pronation

> "Abnormal pronation of the foot is defined as abnormal pronation of the entire foot which occurs at the subtalar joint. While pronation of the entire foot primarily occurs at the subtalar joint, a clinically insignificant degree of pronation also occurs with dorsiflexion of the ankle joint in normal feet" (Root, Orien and Weed, 1977: 295)

The term pronation can therefore describe a normal movement of the ambulatory foot in addition to the foot pathology considered here. Abnormal (pathological) pronation is said to involve subtalar eversion, forefoot abduction and dorsiflexion and flattening of the anterior, medial and lateral arch (Minkowsky and Minkowsky, 1995). The main clinical features of abnormal pronation have been described as pes plano valgus - a flattening of the longitudinal arch combined with eversion of the foot (Neale, 1981). McCourt (1984) described many causes of abnormal pronation including rearfoot (calcaneo) valgus. Various forms of abnormal pronation have been described including mobile and rigid versions (Neale, 1981) and pathologically, pronation appears to be a somewhat generic term describing several manifestations of abnormal pronatory movement.

Hallux rigidus

> "During gait, it is generally considered that at least 65 degrees of dorsiflexion is needed at the first metatarsophalangeal joint for normal function" (Payne and Dananberg, 1997: 8)

Pathologically, varying degrees of reduced dorsiflexion can occur at the first metatarso-phalangeal joint. Where a limited range of movement is available, this is described as a state of hallux limitus. The term hallux rigidus strictly refers to complete rigidity of this joint (Neale, 1981). Root, Orien and Weed (1977) claimed several etiological factors for this condition including:

- 1st ray hypermobility,
- 1st ray immobilisation
- Excessively long 1st metatarsal
- Dorsiflexed 1st ray deformity
- Degenerative joint disease

- Trauma

Hallux limitus has been a focus of interest in podiatry, with new theories of sagittal plane facilitation challenging Roots' model of frontal plane control (Payne and Dananberg, 1997). To support their sagittal plane facilitation model, Payne and Dananberg concentrated on the effects of functional hallux limitus as a typical sagittal plane blockage, suggesting new insights into foot function. Hallux rigidus, the more extreme form of hallux restriction was therefore considered a useful pathology to include in this phase of the study, being common, easily defined and related to the topical functional hallux limitus.

Pes cavus

> "This term ("hollow foot") is used to describe a foot with an abnormally high arch. In the adult, the high arch, tight plantar fascia and retraction and clawing of the toes lead to considerable pain and disability because of secondary lesions" (Neale, 1981: 36)

Pes cavus can be congenital, functional or disease based in origin (Valmassey, 1995). Two forms are described, calcaneo-cavus and equino-cavus (Neale, 1981). Calcaneo-cavus is characterised by increased inclination of the calcaneus and resultant increase in arch height. Equino-cavus shows increased arch height through an increased forefoot declination with plantar-flexed 1st metatarsal. It has also been suggested that pronation can accompany the cavus-type foot (Neale, 1981; Valmassey, 1995). Pes cavus is a potentially disabling, serious foot condition often linked to painful secondary soft tissue lesions.

Rearfoot varus

> "This is a positional deformity demonstrated as inversion of the rearfoot relative to the ground. This is due to a combination of frontal bowing of the tibia (tibial varum) and the available range of subtalar joint pronation." (Valmassey, 1995: 62)

Although simply defined as heel inversion, uncompensated, partially compensated or fully compensated forms of rearfoot varus have been described. If uncompensated, the rearfoot remains inverted with the forefoot inverting by the same amount, possibly involving a plantar flexed 1st ray (Pickard, 1983). In partially compensated form, the calcaneus inverts to a lesser degree through a limited subtalar joint pronation (Valmassey, 1995), while fully compensated rearfoot varus allows the entire surface of the calcaneus to become plantigrade through excessive subtalar joint pronation (Pickard, 1983). Fully compensated rearfoot varus is suggested to be an under diagnosed condition as the perpendicular position attained by the calcaneus is a criteria of the normal foot at mid-stance (Chapman, 1995).

Current perspectives on podiatric biomechanics

While podiatrists have defined the four conditions selected for the main questionnaire phase, biomechanically-based explanations of the etiology and functions associated with these conditions need to be considered with caution. The biomechanical explanations of foot function offered by Root, Orien and Weed (1977) were not researched because "the practitioner cannot wait until sufficient research has been conducted to conclusively prove how the foot functions" (Root, 1977; xxiii). Instead, the work was justified by the authors as being a truth "based primarily on coherence" (Root, 1977; xxiii), explained as adding logical reasoning to go beyond facts revealed by that research which has been completed. Borthwick (1999) observed that as research literature is emerging in and around podiatry, the credibility and value of Root, Orien and Weeds' biomechanical theories (1977) is being "increasingly drawn into question". While their observations may therefore have a basis in reality, their "logical" explanations may be incorrect in the absence of evidential support.

Although Neales' text (1981) came later than that of Root, Orien and Weed (1977), there was still no research offered to support the theories of biomechanics. Instead, in his attempt to "encapsulate current concepts on the origins, diagnosis and conservative management of the common foot disorders", Neale (1981: v) included simple summaries of Root, Orien and Weeds' beliefs' (1977) in his book. The biomechanical explanations underpinning foot pathologies offered by Neale must therefore be treated with similar scepticism in the continuing absence of research evidence. This situation continued again with Valmasseys' later work (1995). Although presenting detailed and comprehensive explanations of lower limb function, Valmassey still relied on the "logical and consistent correlations (offered by biomechanics) between various structural abnormalities and the symptoms they produce" (Root, 1995; vii), as opposed to research evidence, in order to explain mechanical dysfunction.

Alternative biomechanical theories were offered by Payne and Dananberg (1997). Earlier, Dananberg (1986) had defined a "non-visible" foot condition, functional hallux limitus, in which a big toe exhibiting an adequate range of motions was said to be unable to extend during function. Payne and Dananberg (1997) found anomalies in current biomechanical theories when attempting to fit them with the "reality" which they perceived, which included the presence of functional hallux limitus. Instead of Root Orien and Weeds' "frontal plane model" (1977), Payne and Dananberg (1997) preferred to view the foot from a sagittal plane perspective, where pathological blockage of motion in the plane would reflect the foots' auto-supportive function and lead to compensatory motion and pathology at other sites. While plausible and logical, again, no research evidence was offered to support this perspective, therefore the hypothesis offered must be viewed with the same caution as that of Root Orien and Weeds' work (1977).

Root Orien and Weeds' explanations of podiatric biomechanics (1977) are therefore coming under increasing criticism and alternative theories must also be treated with scepticism in the absence of supportive research. To date, alternative, researched explanations of foot function do not exist.

3.22 Aim

The aim of this stage of the project was as follows:

> Through the collection, analysis and interpretation of podiatrists' experiences of shoe wear patterns, identify theoretical themes of association which may be present between the wear patterns and named pathologies linked to these patterns, such themes being anticipated to be functional in nature. If themes are identified, a theoretical explanation for the production of the wear patterns would be provided which could later be validated by the evaluation of actual subjects.

3.23 Method

From the Delphi findings, shoe wear patterns appeared to have a complex and multi-variable relationship with the foot and its' pathologies and there was no previous research into shoe wear pattern formation. In view of these facts, a qualitative approach to analysis was seen as the strategy of choice. Although the work would be grounded in podiatry practice, it could be seen as broadly hermeneutic. The Delphi had produced a primary message with regard to the relationship between foot pathologies and shoe wear patterns and this was not fully understood. Interpretation of this message was now required, this phase of the study reflecting an approach of a hermeneutic nature (Palmer, 1969).

The Delphi study had tested and found viable, the questionnaire format as a suitable method to produce the required data (i.e. shoe wear pattern depictions based on personal clinical experience). A questionnaire survey was therefore planned to capture podiatrists' experiences of shoe wear patterns associated with the four pathologies named in the previous survey, these conditions being those with which podiatrists believed they had the greatest familiarity of shoe wear pattern associations.

All heads of podiatry services involved in the earlier survey were again contacted. A covering letter asked that the questionnaire package be forwarded to the member of staff with the greatest shoe wear pattern interpretation expertise (Appendix 13), with the heads of service being well-placed to understand the qualities of their own staff. There are no definitions of podiatrists with shoe wear expertise, however the use of working clinicians as experts has been reflected in a number of earlier studies (Bond and Bond, 1982, Duffield, 1989, Hitch, 1983, Pinyerd et. al., 1993). The contact with a service head echoed Reed's study, where a similar method of selection eliminated researcher bias through avoiding participant pre-selection (Reed, 1990).

The questionnaire package included explanatory notes, an example sheet and the questionnaire itself (Appendix 13). Respondents were asked to sketch wear patterns with which they were familiar on blank outsole outlines for pronation, hallux rigidus, pes cavus and rearfoot varus – the pathologies selected through the pre-questionnaire survey. It was stressed that the patterns should be based on experience and not simply from direct one-off patient observations. Respondents could suggest more than one pattern if they wished, as it was now understood that several different patterns could be possible for each condition. Respondents were asked to return the completed questionnaires within three weeks of receipt by stamped, addressed envelope. The questionnaire format allowed for complete anonymity, to ensure freedom of expression without inhibition.

It has been argued that pictorial sources "are texts which can be interpreted and assessed like any other text" (Scott, 1990: 196). The wear patterns collected in the main questionnaire were therefore seen as suitable for inductive analysis, with prior unitisation, to define and separate units of data for the analysis (Krippendorff, 1980). The inductive analysis sought patterns, themes and categories from the data (Patton, 1990; 390), from which hermeneutic understanding was sought.

3.24 Findings

Overview of the returned patterns

56/214 replies were received (26%). While lower than the earlier survey, this represented an equivalent 52% return as the questionnaire passed to respondents through heads of service. The lower number of replies may have indicated low participant confidence in their ability to undertake the required task. 425 wear patterns resulted, representing means of 106.25 patterns for each pathology and 7.6 patterns (1.9/condition) for each respondent (Table 11), further suggesting that multiple pattern forms could occur with single named pathologies, contrary to previously implied beliefs.

As in the earlier Delphi questionnaires, wide pattern variations were seen both at face level and focal point level. Several named variable themes were suggested to be responsible for pattern variations (Table 12). This reflects a complex situation with many potential influences over shoe wear patterns. While respondents had been asked to provide depictions of patterns <u>based on experience</u>, there was some evidence that a number of respondents may have used direct patient observations instead. Several reasons given for pattern variations appeared too obscure or subtle for respondents to have created a personal "characteristic" basis for recognition (e.g. partially compensated rearfoot varus). Despite this possible deviation from protocol which reflected experiences in the Delphi rounds, the patterns would still have been based on experience and have a basis in reality. This does however suggest low confidence and knowledge of podiatrists in wear pattern interpretation and understanding.

The approach to the analysis

The returned patterns were transcribed onto collation sheets according to main pathology (i.e. pronation, hallux rigidus, pes cavus, or rearfoot varus) along with reference information. Qualitative analysis was then undertaken to identify themes and relationships between the patterns and associated pathologies in order to suggest how the wear patterns are produced in relation to these pathologies. Two approaches to the analysis were adopted:

1. Categorising the patterns initially by main pathology, then by pattern-form to seek associations between pattern form and main pathology.
2. Categorising the patterns initially by named variables (where given), then by pattern-form to seek associations between named variables and pattern forms.

It was anticipated that analysis from these two perspectives should clarify themes of association with variable factors which may influence shoe wear pattern formation and in doing so, induce theories relating to dominant factors in wear pattern production.

To assist with the analysis, the raw data was transcribed into a neater form with a common graphic presentation of the wear patterns. From this, 425 “cards” were prepared presenting:

1. The depicted wear pattern.
2. The focal code combination of that pattern.
3. The main pathology associated with that pattern.
4. Associated named variables.
5. An identifying code based on the respondent reference and pattern number ascribed. (Diagram 9)

Using these “cards”, the patterns were ordered according to the approaches stated above. The findings of these analyses are reported separately and in order.

3.25 Analysis by main pathology and pattern form categories to seek associations between pattern form and main pathology

Leap of hermeneutic understanding

After the initial division into the four main pathology categories, patterns were divided again into sub-categories based on predominant focal code wear pattern descriptions (Appendix 14), giving multiple focal code based sub-categories of wear pattern forms (Appendix 15). At this point it became apparent that within the main pathology context, the associated pattern forms inferred that certain foot functions had taken place in order to produce that pattern. In this, each pathology by definition suggested that certain pre-defined conditions in the form of restrictions and incompetence had been placed on the foot. Given these conditions, functions which had produced the patterns could be suggested. At this point, a so-called “leap of hermeneutic understanding” had taken place. A hermeneutic circle had been traced (Appendix 16) which included the following components of understanding:

- A means of wear pattern description – the focal point concept.
- Sub-categories of pattern forms.

- Knowledge of foot pathology definitions.
- Knowledge of normal foot function.
- Knowledge of foot anatomy.
- Knowledge that wear patterns must be functionally caused.

Completion of the hermeneutic circle had facilitated the moment of enlightenment described.

Functional analysis of the wear patterns

Subsequent to this awareness, all pattern form sub-categories were considered within their main pathology context in order to suggest the etiological function of the patterns. This required patterns to be compared with the associated pathology and a range of factors to be considered when contemplating the connecting function (Diagram 10). Each pattern form suggested a described function and it was found that different patterns would often suggest the same underlying function. Other patterns suggested more than one function (Appendix 17) with some patterns being repeated across the main pathology categories (Appendix 18). This may have been for any of the following reasons:

- The potential for pattern depictions based on experience to lose accuracy of detail distinguishing some functions.
- Two different suggested functions may have been the same function with minor variations.
- Some functions suggested may not have been possible in reality.
- The pattern given may not have related to some of the suggested functions.
- Different classes of function may produce the same wear pattern.

Through this process, various function categories were suggested for each main pathology, with 16 alternative functions being suggested for pronation, 14 for hallux rigidus, 18 for pes cavus and 13 for rearfoot varus (Tables 13 – 16)(Appendices 19-22).

Overall function as the primary shoe wear influence

The number of different functions suggested for each main pathology challenged previous perceptions, where more limited functional possibilities had been considered. This challenge also suggested how the implied "one condition, one shoe wear pattern" theory had arisen. If only one function had been anticipated with a foot pathology, only one pattern form would be expected. If, in reality multiple functions were present, then multiple pattern forms such as those observed would occur. In the example of hallux rigidus, a "classic" shoe wear pattern had previously been described (Lucock, 1967)(Appendix 2). It had been believed that when hallux rigidus is present, the forefoot supinates to avoid the stiffened 1st toe restriction (Neale, 1981). This function could be linked to the "classic" hallux rigidus wear pattern by considering the actions involved. In the absence of other functions, normal posterior-lateral heel wear would relate to normal heel strike. A stiffened 1st toe could inhibit wear at the 1st metatarso-phalangeal joint area by exerting a splinting effect. The stiff 1st toe could then provide an oblique axis with the 5th metatarso-phalangeal joint as the foot supinates to avoid the 1st toe restriction, with resultant forefoot wear relating to that axis. In the perceived absence of alternative functions, wear patterns considered to relate to hallux rigidus would have been restricted to those associated with this function alone. In more recent times, the possibility of other functions being present with hallux rigidus/limitus has been considered (Dananberg, 1986; Rzonka, Levitz, and Lue, 1984; Sherman, 1983), all based on considering compensations for 1st ray sagittal plane restriction. The functions described were amongst those suggested by the shoe wear patterns here, which indicated even more functional possibilities (Appendix 20). Other podiatrists have suggested biomechanical relationships within the foot, which were compatible with several of the functions suggested by the shoe wear patterns (Root, Orien and Weed, 1977; Neale, 1981).

Classifying the patterns by indicated function however, suggested through the number of patterns involved that some functions are more commonly occurring than others. This echoed conclusions of the earlier Delphi rounds where it was suggested that some patterns forms were more common than others. This could further account for the past misconceptions expressed in the "one condition, one wear pattern" theory, as the greater experience would have been with the more commonly encountered pattern forms.

Comparison of suggested functions with past references to associated named variables

As a validation check, the function categories suggested were compared for compatibility with past references to the named variables, which respondents believed had been responsible for wear variations. These references contained detail of stucture and function considered to be an integral part of these variables. Direct comparison of the suggested function with this information showed whether any incompatible features had been stated to be present with the variables suggesting that the function could not have taken place. In this comparison, these variables related to the suggested functions as follows:

- Directly supported the suggested function
- Indirectly supported the suggested function
- Did not contradict the suggested function
- Contradicted the suggested function

By falling into the first three categories, 99.09% of the variables named were compatible with the suggested function, with only two being in disagreement (Tables 17 – 20). Patterns directly supporting the suggested functions were those where respondents had referred to all, or part of the named function, indicating agreement with the functional cause postulated. Such direct support occurred in 78/221 of the named variables. Indirect support was provided where the named variable alluded to a factor which had been previously associated with the named function (e.g. rearfoot valgus and plantar flexed 1^{st} ray occurring with pronation). 53/221 of the named variables provided this indirect support. 88/221 named variables simply did not contradict the suggested function i.e. while not supporting the suggested function, these variables did not suggest any factor to refute that functional possibility. Such variables could refer to pathologies present which were unlikely to prevent the function suggested (e.g. plantar-flexed 5^{th} ray would not preclude "classic" hallux rigidus function from taking place). Alternatively, they could describe ambiguous factors with no apparent relationship to the stated function (e.g. polio occurring with "foot inverted throughout stance" function).

The various indirectly supporting and non-contradictory variables named suggested that respondents disagreed over factors important in shoe wear pattern production. Such variables were based in multiple systems including functional, structural, sensory and foot integrity perspectives, reflecting the lack of a common taxonomy in podiatry. Foot function may provide the potential to consider all other systems from a podiatry perspective and could therefore form a basis for podiatric terminology.

Only 2/221 named variables directly contradicted the function suggested with all other variables either being associated by previous authors with an aspect of the normal function, or being widely ambiguous and unrelated to the function. In the first of these, the variable, adducted gait had been named as being responsible for a pattern suggesting an abductory twist function with hallux rigidus (Table 18). Abductory twist is a directly opposing state to adducted gait with the term abduction relating to movement away from, and adduction relating to movement towards the median axis of the body (Makins, 1994). This may have occurred for a number of reasons:

- Respondent misdiagnosis
- Misspelling of abducted by the respondent
- The adducted gait also involved an abductory twist to improve toe off efficiency
- Adducted gait and abductory twist could share a common wear pattern
- The pattern concerned did not relate to abductory twist

Further investigation would be required to clarify this situation. It was however considered unlikely that the pattern did not relate to abductory twist, as abductory twist had been separately associated with another pattern of identical focal code.

The other disagreement related to the named variable "compensation" being associated with a rearfoot varus pattern (Table 20). The pattern had indicated that the foot had remained inverted throughout stance. Compensation for rearfoot varus however has been described as follows:

> "In practice, the foot usually everts to bring the heel and medial border of the forefoot into normal ground contact, but in doing so, it pronates and abducts at the subtalar joint" (Neale, 1981: 47)

Although not evidenced by research, this position was supported by Root, Orien and Weed (1977). The wear observed with the pattern discussed did not support such compensation having taken place, being devoid of medial forefoot wear (Table 16). This suggests respondent misdiagnosis as the cause of this discrepancy, in turn suggesting that assessment of the functioning foot has some potential for error.

Other functions were postulated, which could take place within the pathological contexts considered (Appendix 20). These functions were not supported by any of the patterns presented, but could theoretically exist according to this means of classification. Further study would be required in order to verify the existence of such functions.

Foot pathology as a secondary shoe wear influence

While there were strong indications that function was the main influence in shoe wear pattern formation, there were also signs that foot pathology could have a direct but local effect on the wear pattern by amending the intended function. In the commonly described hallux rigidus function which can be seen as "classic" (Edgar, 1976; Neale, 1981; Rendall, Thomson and Boyd, 1998), the local effect of a stiffened 1st toe forces inversion of the foot, which inhibits 1st metatarso-phalangeal joint area wear. Similarly, with pes cavus, localised 1st and 5th metatarso-phalangeal joint area wear occurred with associated plantarflexion of these joints – a variation of the metatarsal platform within the overall function suggested. Local pathology influence however often appeared to be overridden by purely functional considerations. In hallux rigidus, this was seen with the named variable, abducted gait. Here, absent 1st metatarso-phalangeal joint wear anticipated with the stiffened 1st toe did not occur. Instead, the pattern suggested that the foot avoided the 1st toe restriction by rolling over the medial aspect of the forefoot. It could be considered that the foot attempts to carry out a particular function, which may then be amended by local pathology effects. The attempted function could be described as a **primary walking intention**. The actual function produced after being subjected to the effect of other influences could be considered an overall **"holistic" function**. Where there are no such amendments to the primary walking intention, this in itself would constitute the holistic function.

The potential for "external" influence over shoe wear patterns

Within the suggested function categories, minor wear differences were noted, relating to heel wear angle variations, tip wear inclusion, site of 1st toe area wear and peripheral spread of wear (Tables 13 - 16). While many of these variations may relate to minor functional variations or pattern depiction inaccuracies, other "external" influences may be involved. It has previously been suggested for example that footwear variables could be responsible for wear pattern amendments (Ware, 1920; Korn, 1949; Gibbard, 1958a). External variable effects were not reported by the respondents and may therefore be minor, unappreciated, infrequent or absent. Such effects could corrupt the primary walking intention described above and may therefore contribute to the overall holistic function. As their effect appeared to be minor or infrequent, these variables are suggested to be less influential than foot pathologies in wear pattern formation. A basic model was proposed to suggest the relationship between these factors of wear influence (Diagram 11).

Summary

From this analysis, overall (holistic) foot function appeared to relate directly to shoe wear patterns, with foot pathology playing a secondary role to the primary walking intention in pattern formation. It is also suggested that external influences may affect pattern form. A simple model suggesting the relationship between these factors has been proposed. This is a major shift from the previous "one pathology, one wear pattern" hypothesis which appeared to reflect the most commonly occurring pattern associations. While the Delphi had showed the inadequacies of this hypothesis, the method had focused on this assumption. Qualitative analysis of wider ranges of patterns than were collected in the Delphi was required to suggest the wider themes and associations which may determine wear pattern form. Through the functional categorisation process, shoe wear patterns may have value in predicting underlying function where the pathological context is known. Comparison with named variables for compatibility demonstrated the validity of functional categorisation and highlighted terminology standardisation problems in podiatry.

3.26 Analysis by named variables (across all main pathology categories)

The shoe wear pattern depictions were also analysed by considering named variables (respondents' reasons given for wear pattern variations) as initial categories and highlighting themes noted where these variables were repeated. 26 of these named variables were referred to on more than one occasion with 13 of these occurring across more than one of the main pathologies involved (Table 21). The most frequently named variables in this respect were abductory twist, plantar flexed 1st ray, equinus, forefoot inversion/varus and abducted gait. The associated wear patterns were examined for indications of named variable influence and to investigate what this context may indicate about the linked wear pattern production.

Some named variables occurred more frequently with some main pathologies than others, implying an association when this occurred. Where this happened, strong associations with specific wear areas could be observed. An example of this occurred between the variable, equinus and the main pathology, pes cavus. Such a relationship may be feasible, as a form of pes cavus, equino-cavus has been postulated which is said to involve limited dorsiflexion at the ankle and a corresponding "springy-type" gait (Neale, 1981). Root, Orien and Weed (1977) indirectly linked pes cavus with equinus, suggesting that supination of the foot may be caused by equinus deformities and also that supination may give mechanical advantage to the peroneus longus muscle, leading progressively through plantar flexion of the 1st ray to supinated pes cavus. Similarly, the variable, rearfoot valgus was only suggested with the main pathology, pronation and rearfoot valgus can be an essential single component of pronation (Neale, 1981). A third variable, abductory twist was also linked to pronation. Although such strong associations were seen, the separate existence of variables and pathologies concerned in other examples seen implied that such conditions were not mutually dependent. This in turn shows that different forms of the main pathologies may exist. The equino-cavus form of pes cavus has already been recognised. The rearfoot valgus/pronation relationship may similarly represent a particular form of pronation, differentiated from other forms of the pathology.

If such different forms of foot pathologies do exist, this suggests that different functions may arise, along with different shoe wear patterns, if these patterns have a functional basis. Indications of a strong link between foot function and shoe wear patterns could be seen in named variables which could be viewed as functional and not structural descriptions. In the pes cavus variation, equino-cavus, the term equinus refers to a limited dorsiflexion and is related directly to a form of gait deviation – equinus gait. The wear patterns present when the equinus occurred with pes cavus showed a strong emphasis on wear across the metatarso-phalangeal joint area with relatively low incidence of heel wear – a pattern form which could indicate the equinus gait described. A strong link can therefore be seen between this gait form and the resultant shoe wear pattern. The variable, abductory twist is a purely functional description, which occurred with all four main pathologies. Again, there was a strong and consistent association between this condition and related shoe wear patterns, which showed central metatarsal area wear in 14/15 patterns, such as may result from the twisting movement of the foot involved. A similar situation was noted with the variable abducted gait, where this functional description was frequently associated with posterior lateral heel, central metatarsal and anterior medial segment outsole wear. When occurring with hallux rigidus, abducted gait demonstrated the same tendency for a strong pattern-form association, again suggesting a direct functional influence. This supports the theory that function has a stronger influence over shoe wear than anatomically referenced foot pathology.

Adducted gait describes another gait form and may therefore also be expected to produce strong wear pattern associations. Of the three examples seen, two occurred with hallux rigidus and one with pronation. While "anterior/medial segment wear" was strongly associated with adducted gait, the overall pattern of wear in the pronation example differed from those with hallux rigidus. In the pronation example, the predominant wear was of the entire medial aspect of the forefoot. In the hallux rigidus examples, the "anterior/medial segment wear" was localised in the first toe and heel areas with additional wear localised either in the central or lateral metatarsal areas (Graph 13). This may indicate two different forms of function, both described as adducted gait. With pronation, the adduction may refer to an overall adductory gait resulting from internal rotation of the lower limb – a state linked previously to pronation which has been seen as a compensating mechanism (Root, Orien and Weed, 1977). The "medial forefoot wear" observed here may be directly attributed to the pronation as this wear area was strongly associated with patterns linked to pronation in general (Graph 14).

The function classed by respondents as adducted gait occurring with hallux rigidus may either be attributed to:

- The influence of hallux rigidus and not from internal rotation of the lower limb.
- An adducted gait without attempted pronatory compensation, with hallux rigidus resulting from long term involvement of the hallux in propulsion under these circumstances.

In the former postulated circumstance, the adductory motion would arise later in the stance phase possibly in the form of an adductory twist to avoid the rigid hallux restriction. In the latter, the foot would adduct prior to attempted involvement of the hallux in propulsion with resultant long-term effects on the 1st metatarso-phalangeal joint. While further investigation would be required to confirm these explanations, two or possibly three forms of adductory gait have been suggested by wear patterns in the circumstances described. Function is therefore still justified as the main wear pattern influence, despite the two different patterns noted. The suggestion is again apparent that, foot pathology may have a direct but local influence on the wear pattern produced by a gait form.

Named variables not describing a functional state showed minimal direct influence over shoe wear patterns, with multiple pattern forms being noted. Stronger links were seen however with the main pathology, pronation, which again could be seen as a functional description. The wear patterns presented with both rearfoot valgus and forefoot inversion/varus showed strong associations with anterior medial segment and medial heel wear (Appendix 23). As there was a strong association between these wear components and the main pathology, pronation, the relationship appeared to be with pronation and not these named variables, again suggesting a functional cause. A similar situation was also noted with plantar-flexed 1st ray. In two of the 15 associated patterns only, there was no 1st metatarso-phalangeal joint area wear. In one of these patterns, the main pathology, hallux rigidus was also present, implying that the stiffened 1st toe may have prevented this wear from occurring. The second pattern was however associated with the main pathology, pronation and not hallux rigidus. This again implied that a function had occurred which had prevented wear where expected at the 1st metatarso-phalangeal joint area, further reinforcing the importance of functional influence over shoe wear.

From the limited range of patterns occurring with some of these named variables it appeared that only a limited range of functions were possible within that context. With other variables, wide variations in wear were seen, suggesting wide function possibilities. Named variables with minimal wear variability included:

- Equinus
- Rearfoot valgus (occurring with pronation)
- Forefoot inversion (occurring with hallux rigidus)
- Arthritis

From this list, there are two suggested functional implications:

1. Firstly, restricted function is apparent with equinus, arthritis and forefoot inversion/varus occurring with hallux rigidus. All terms refer to foot pathologies that are restrictive in nature. This may therefore restrict the number of functional options, hence the strong wear associations noted. Arthritis of the foot is an ambiguous description, yet the two wear patterns associated with this condition were identical. If a generalised arthritis of the foot is described, a severely restricted foot function is implied with limited functional possibilities and the strong wear pattern association noted.

2. Secondly, rearfoot valgus with pronation suggests a pathological incompetence of the foot. Though mobile, this incompetence may also serve to limit the range of functional possibilities, hence the stronger association noted with the wear pattern.

While further investigation is required, the direct relationship between function and wear is again implied and the role of restricting and incompetent conditions on available ranges of function is emphasised.

Despite the suggestion that overall function has a strong relationship with shoe wear patterns, it was noted that some of the named variables present appeared to have strong associations with localised areas of shoe wear. In some cases, this suggested that foot pathology could exert a direct but local influence over wear patterns. This situation was noted with plantar-flexed 1st ray, which showed a strong association with 1st metatarso-phalangeal joint wear. Similarly, 2nd metatarso-phalangeal joint wear was common to both patterns observed with an overloaded 2nd metatarso-phalangeal joint condition, despite overall pattern differences being present, indicating another pathologically related local effect. While overall function showed the greatest effect on wear, it again appeared that foot pathologies could also demonstrate wear influence albeit on localised basis.

It was also noted that the same wear pattern could occur with different variables across the main pathologies. This was seen with abducted gait and abductory twist patterns and could have occurred for one of four reasons:

1. The two conditions abductory twist and abducted gait could be synonymous terms.
2. Abducted gait could necessarily involve the twisting motion of abductory twist.
3. Both gait forms could be capable of producing similar wear patterns but for different reasons.
4. Respondents may have misdiagnosed gait forms of similar appearance.

Further investigation would be required into these common wear pattern forms to determine reasons for the similarities noted.

Summary

The consideration of named variable influences was useful. While direct links could not be made between patterns and many of the variables, some strong associations were noted. These were with functionally – termed conditions (e.g. abductory twist) and pathologies which suggested restrictions in function. This analysis has further supported the theory that functional description has a direct association with shoe wear patterns, with direct pathological influence being of secondary importance. The need for a common terminology to describe podiatric conditions has also been suggested.

3.27 Conclusions

The potential for loss of sensitivity in using sketched depictions of patterns was a weakness in the methodology adopted. This could be offset by the advantage of capturing patterns based on a vast number of observations. For each of the main pathology categories, the classification of wear patterns on the basis of suggested causative function indicated several possible functions for each pathology. This further refuted the previously implied "one condition, one wear pattern" theory, reflecting the findings of the earlier Delphi rounds and comparison of wear patterns presented in past podiatry/chiropody literature. Most named variables were compatible with the suggested functions, indicating that respondent's perceptions generally complied with these theoretical functions. Hypothetically extending the range of functions for each condition beyond those indicated by the depicted wear patterns suggested that additional functions may also be possible, but further investigation would be required to verify their existence. Pattern classification on the basis of indicated function showed that some functions may be more commonly occurring than others, as suggested in the earlier Delphi rounds. This may be due to restrictive or submissive factors limiting the range of functional possibilities and could account for the past misconceptions where it was believed that one condition would produce one characteristic wear pattern.

A theory of shoe wear pattern influence

While "primary walking intention" is suggested to be highly influential in outsole wear, the potential for foot pathologies to affect wear locally was also seen although less frequently. It was also suggested that "external" factors could also contribute to wear pattern form, but no respondents named such factors in their replies, suggesting that this influence may be minor. Such external factors could include features such as shoe fit and occupational factors (Diagram 12). The combined effect of primary walking intention, foot pathology and external influence can be seen as creating an overall "holistic function" and a basic paradigm linking these components was suggested (Diagram 3). A statement could be made, encapsulating these theories as follows:

"Shoe outsole patterns appear to primarily result from foot and lower limb function and this function is represented by combinations of focal points of wear: the areas from which the wear spreads. While anatomical and morphological factors (including foot pathologies) may influence wear, it is their effect on the primary walking intention which causes this influence. External factors may also influence the wear pattern, but their effect may be minor. Wear extending beyond focal points is superfluous to such interpretation"

The value of an improved understanding of shoe wear patterns

Understanding the creative mechanism of outsole wear patterns should prevent past forensic identification problems from recurring through the following:

1. Preventing the overstatement of factors unimportant to footwear identification.
2. Understanding the relationship with the functioning foot.
3. The potential for focal point combinations to suggest stronger aspects of individuality.

While written descriptions were useful in describing the components of wear, focal points describe overall wear patterns simply and with greater accuracy. The true value of focal points would be in forensic identification from shoe outsole prints exhibiting wear. The focal point system could compare exactly, the anatomical points from which wear was spreading between footwear items and could therefore show minor differences not apparent through written description. Pattern differences within each function category also have forensic identification value by suggesting higher degrees of individuality than apparent from the simple functional categorisation. These differences may represent minor functional variations or the effects of external influence. Such variations may also have clinical value, if showing an external influence with an adverse effect on foot health (e.g. short footwear). Clinical benefits of other aspects of the work centre around the use of wear patterns in the functional diagnosis of the foot. If wear patterns can be used to indicate related foot function, podiatrists could routinely evaluate this function without the use of specialised equipment. The patterns could also improve the management of local foot pathologies through the new insights offered by wear patterns into functional aspects of those conditions.

Different terminologies are used in podiatry including biomechanical, orthopaedic and neurological nomenclature. This did not give a common basis for comparison in this survey. The wear pattern influence paradigm has the potential to provide a common terminology and classification system encompassing all current perspectives. This model may also provide the following additional benefits to podiatry:

1. Through organising podiatric knowledge according to strength of influence, factors of greatest importance may be shown to the clinician.
2. Factors irrelevant to podiatry will be clarified through falling outside the model (e.g. orthopaedic or dermatological factors).
3. Factors with the greatest potential for cure and discharge occupy the lowest tier of the model (external influence), suggesting areas for improved clinical outcomes.
4. Through bringing together all conditions relevant to podiatry, the model provides a basis of a common taxonomy for podiatry.

To conclude this work, validation of the model and related theories through real-life case examples was required. The validation design needed to consider the presence and effect of external influences on wear patterns which have been suggested as having additional potential to amend the pattern form.

4. PART FOUR: GROUNDING THE THEORIES

4.1 DEVELOPING AND FOCUSING VALIDATION PHASE PARTICIPANTS: PRE-VALIDATION DELPHI ROUNDS

Accumulative summary

Validation of the project theories in real-life situations was required and the two options considered for the subject evaluation in this phase were technological equipment analysis and direct clinical assessment. The two alternative approaches were considered and the direct clinical assessment was justified as the preferred method, being capable of capturing data on a wider range of variables than could be obtained using the technological approach. Paired observations were envisaged in the validation, but clinical observer agreement levels can be poor. The Delphi technique has the potential to develop and focus participants in addition to producing group consensus. A Delphi was therefore planned to develop and focus a group from which the validation phase observers would be chosen. The Delphi would also produce statements of recognition for variables, which may be encountered in the validation phase, relating to foot pathologies, gait descriptions, ranges of movement in the foot and footwear variations.

The Delphi trends observed justified a conclusion in Round six. Only four states did not have an agreed statement of recognition at that stage and 58 Delphi statements referred to states not previously defined, many of these relating to footwear variables. Where conditions had been previously described, 11 Delphi statements did not provide enough information for comparison and 15 statements disagreed with the previous descriptions. Possible reasons for this included lack of knowledge, the possible existence of types of conditions not previously described, challenges to past perceptions, and error. A need for a common podiatric knowledge framework was suggested. Inter-observer agreement levels were evaluated after the focusing and development of the Delphi using inter-observer reliability tests.

4.1 DEVELOPING AND FOCUSING VALIDATION PHASE PARTICIPANTS: PRE-VALIDATION DELPHI ROUNDS

4.11 Introduction

The planned validation

Up to this point, the project had passed through two distinct phases, contributing to the induction of theories relating to the production, comparison and interpretation of shoe wear patterns. These theories however, were at this stage theoretical and required validation in real-life situations to provide construct validity and grounding for the project. A clinical investigation was envisaged which would place the work within the complex realities within which it would reside. Subjects with foot pathologies including hallux rigidus would attend with several pairs of their own footwear. Their shoe wear patterns would be compared using the instrumental concept while determining variables which had acted to influence potentially the wear of these shoes. The circumstances under which the instrument would give meaningful comparisons and those under which it would not would therefore be determined along with the factors which had contributed to the creation of the wear patterns observed. The procedure to be followed in this validation required the patients and their footwear to be studied clinically and in detail to confirm the presence of foot and lower limb pathologies, gait abnormalities and shoe fit and style variability. To implement this form of study, two alternative methods were considered, namely technological equipment analysis and direct clinician assessment.

Technological and clinical observation approaches to validation compared

The range of technological equipment for clinical evaluation of the foot is limited and is mainly restricted to equipment aimed at the dynamic evaluation of gait. Such equipment can be in the form of an external plate on which a subject treads (e.g. Dynamic Pedobarograph, Musgrave Force Plate, EMED systems (Anderson and Black, 1998)), or an in-shoe system which is worn as an insole (e.g. EMED and F-Scan in-shoe systems (Donaghue and Veves, 1997)). There is also a force plate system available to capture detail of ground reaction forces in three directions, although complex interpretation is required (Anderson and Black, 1998).

Both technological equipment analysis and direct clinician assessment methods however had potential limitations and disadvantages. For the technological approach these were:

- Technological instrumentation does not describe and evaluate the severity of foot pathologies and level of footwear variables.
- Shearing stress, torsion and localised friction may play a stronger role in the production of shoe wear than vertical pressure. Most of the technological equipment available to supplement gait analysis including all force plate and in-shoe systems only provides information on direct vertical pressure involved in the stance phase of gait.
- The use of technological equipment with the capacity to record factors such as shearing stress and torsion (i.e. the Kistler Force Platform) would require complex instrument validation.
- Force plate/force platform devices only provide data readings on the foot/ground interface. In considering gait type and the functioning of the entire foot, the information provided by such instruments would be extremely limited and would only partially fulfil the requirements of overall function assessment.
- Due to the permanence of the installation, appropriate technological instrumentation (i.e. the Kistler Force Platform) would not be available to the group of selected subjects (for reasons of geographic locality).
- The project was to be grounded in podiatry practice. The items of technological equipment considered were all bioengineering devices which although used by podiatrists, fall outside routine podiatry practice. In the context of podiatry practice, more meaningful results would therefore be produced by podiatrists in a manner which could be easily confirmed by clinical podiatrists in their own working environments.

Potential disadvantages with direct clinician assessment were as follows:

- The potential for diagnostic error when evaluating the presence of clinical variables.
- The evaluation of gait by clinicians is prone to observer error.

- Terminology in podiatry is not standardised, with the potential for misunderstanding in the recognition and classification of foot and lower limb pathologies.
- The investigation required footwear variable assessment including those of the foot/shoe relationship. There has been no previous work on footwear suitability criteria despite podiatrists routinely undertaking footwear examinations.
- Evaluations of footwear variables would be potentially prone to observer error.

Reducing the potential for error in clinical observation

Of these two possible approaches, clinician observation was selected as the method of subject analysis being the only means possible of confirming the presence of foot pathologies, of evaluating footwear variables and with the support of video-recording, is a justifiable method of foot function assessment during gait. This approach would also allow grounding in podiatry practice. There was, however, a potential for observer error. Technological instrument use was the only possible alternative to such observation, but was rejected due to the major practical difficulties outlined above and the limited ability of the instrumentation to fulfil the requirements of the validation phase of this study. The potential for error in using direct clinician observation, however, needed to be addressed.

In order to improve the validity of using clinical observation, the use of two experienced clinicians to undertake the assessments was envisaged to reduce the potential for incorrect diagnoses. A number of studies have however shown that observer agreement in clinical situations can be poor (Curran and Jagger, 1997; Rhodes et. al., 1995; Potter and Rothstein, 1985). Preliminary work with clinicians selected to participate in the study validation was therefore seen as desirable for the following reasons:

1. To further develop the expertise and focus of the clinical observers.
2. To achieving agreements over the recognition and definition of foot pathologies and other variable factors to eliminate potential terminology problems and ensure that observations made would be based on the same recognition criteria.
3. To verify that observational agreements amongst paired observers could be at an acceptable level prior to implementation of this method.

Delphi as a focusing and development tool

Earlier experience of the Delphi method in the research project demonstrated its' potential to address the first two considerations outlined above, namely those of development and focus and of obtaining agreement amongst participants. The Delphi success in producing consensus agreement was well known (Anderson, 1986; Gallagher et. al., 1996; Sullivan and Brye, 1993; Miles-Tapping et. al., 1990; Gruber, 1993). Although Delphi is a technique developed with the primary aim of achieving consensus amongst a group of experts, its' potential to educate its' participants has been noted by others. Linstone and Turoffs' explanation (1975) of the policy Delphi notes that where disagreements arise, Delphi can be viewed as "an educational process amongst respondents", a view also shared by Schneider (1972). Ludlow (1975) alludes to the focusing benefits of Delphi in his descriptions of a use of Delphi which included the refining of informed judgements which he believed forced respondents to evaluate "relationships not previously considered". Anderson (1986) reported that Delphi participants had been stimulated to review beneficially their work and role. The Delphi therefore appeared to be well suited to the task of developing and focusing a group in addition to its' potential to produce consensus statements sought. A Delphi exercise of a group of podiatrists selected on the basis of clinical expertise was therefore planned prior to their participation in inter-observer reliability tests and the final validation phase of the work. This was intended to develop and focus this group on the assessment task required and produce agreed statements of recognition for variables which may be encountered in the final validation phase. Other consensus producing methods were rejected because only the Delphi had such proven developmental value.

4.12 Method

A Delphi questionnaire was required to cover the areas for which consensus agreements were sought, i.e. definitions/criteria for the visual recognition of:

1. Foot/lower limb pathologies
2. Gait types

3. Described ranges of movement
4. Footwear variables

Each of these areas would form a separate and discrete section in the questionnaire to be used.

At an earlier stage of the project, a list of common foot and gait pathologies encountered in routine podiatry practice had been created (Appendix 4). The first sections in round one of this Delphi therefore sought definitions/criteria of recognition for the listed items, which included foot/lower limb pathologies and gait types. In the ranges of movement section of the proposed questionnaire, the purpose would be to seek statements of recognition for ranges of movement which may amend foot function through restriction or hypermobility. As such, broad definitions only would be required (e.g. excessive, normal and restricted movement). During clinical examination in the validation to follow, the broad classifications should be recognisable subjectively by eye, reflecting most routine clinical situations. Similarly, these would only need to apply to broad areas of the foot (i.e. forefoot, rearfoot, toes, overall foot). The Delphi questionnaire would therefore seek consensus over recognition criteria/definitions for excessive, restricted and normal ranges of movement of the forefoot, rearfoot, toes and the overall foot.

The final section of the Delphi questionnaire would seek consensus over the visual recognition of footwear variables. Aspects of shoe fit, condition and type of shoe may affect shoe wear patterns, but no previous definitions exist over what would constitute a good fit, poor fit, high heel, low heel etc. As in the previous section, broad categories such as those that would be used in standard clinical assessment would be appropriate. Possible footwear variables which could influence shoe wear patterns included:

- Heel height
- Sole thickness
- Shoe condition
- Depth of toe box
- Sole condition

- Length, width and depth
- Heel fit and toe box fit

Broad categories referring to these possible variables would relate to acceptability/ normality, excess and deficiency. On these bases, question areas to be presented to participants were defined.

It is usual practice to commence an unmodified series of Delphi questionnaires with open questions (Couper, 1984). In round one of this Delphi, participants would therefore be presented with lists of the above categories and asked to provide short working statements by which another podiatrist would recognise the same states. If there were any categories for which participants were unsure, they would not be required to respond. The task required was extensive and arduous and arrangements were made at the outset for working time to be allowed for full participation. The means of selection in the earlier Delphi, where heads of podiatry services had selected experienced podiatrists had proved to be acceptable and was again utilised. A choice of four participants was made which would allow a manageable range of paired options in the inter-observer reliability tests to follow. Participants were all chosen from the same Trust to facilitate close working together throughout the validation phase of the research. Four podiatrists agreed to participate; two clinicians with 12 years each of intensive experience of new patient assessment and two with between four and eight years experience, who had developed expertise in the speciality of biomechanics. The round one questionnaire was therefore prepared as outlined above (Appendix 24) and distributed to participants for completion.

All statements suggested by the participants would be compiled against the variables considered and this compilation would then form the basis of round two. Here, participants would study each statement given and indicate those with which they agreed. Round two and subsequent rounds also presented the proportions of participants who had supported each statement in the previous round. The rounds would continue until each category had reached any of the following states indicating that the Delphi had concluded:

- Consensus had been achieved (in the form of either 100% acceptance or 0% acceptance indicating 100% rejection).
- Stasis of proportions supporting a definition had occurred.
- Oscillation of proportions in support of a definition across the rounds was occurring

4.12 Results and analysis

Overview of Delphi rounds

In all rounds which proceeded from round one through to round six, there was 100% response by the participants. In round one, participants produced a total of 480 statements for 135 conditions/states taken from the included list and additionally suggested statements for six additional conditions/states (Table 22). Some of these statements provided identical descriptions and were therefore amalgamated in subsequent rounds. In round two, an additional 15 statements were provided by the participants. From round two to six, there was increasing consensus in terms of acceptance or recognition of the statements given (Graph 15). The Delphi appeared to have worked well in that it produced consensus with predominately monotonic change for the majority of variables under consideration. The Delphi terminated in round six with 145 statements being unanimously accepted and 178 rejected. The exercise was intended to produce statements of recognition for variable states which may be encountered in the clinical validation phase of the project. The achievement of agreement levels in excess of 70% has previously been used as criteria to conclude a Delphi exercise (Grant and Kinney, 1992). At the conclusion of round six, 97% of all variables under consideration had achieved consensual levels in excess of 70% for at least one statement being considered. A statement of recognition acceptable to all participants had therefore been produced for 97% of all variables (Graph 16), with trends of stasis relating to all other statements under consideration (Table 23). The conclusion of this Delphi exercise was therefore justified in round six. The Delphi had produced 177 statements of recognition for 137/141 (97%) variable states under consideration, only four conditions/states being without an agreed statement of recognition after round six (calcaneo-cavus, Severs' disease, talipes equino valgus, inflared foot). These were either uncommon conditions, unlikely to be encountered regularly in practice or in the case of inflared foot, represented out-dated terminology which would not be recognised by modern practitioners. This minimal lack of agreement would therefore be unlikely to cause problems in the project validation phase to be undertaken later.

Comparison of Delphi statements with past descriptions

The statements achieving consensus could be compared to previous comments made about the pathologies to which they referred in medical reference sources (Osol, 1973) and standard podiatry literature (Neale, 1981; Root, Orien and Weed, 1977) to verify whether they conformed with past opinion. Of the 177 statements produced, 58/177 (32.8%) were not described in the texts used for comparison, 42/58 of these relating to footwear variable states. Although Meyer (1861) wrote about ill fitting footwear, his thesis concentrated on the likely long term effects of ill fitting footwear as opposed to definitions and criteria. These statements may therefore be useful in providing simple clinician-based definitions based on intuition for states which have not previously been described. Where previous descriptions were available, two problems with some participant statements were immediately noted when comparisons were made. Firstly, a number of direct disagreements with previous opinion were apparent (Appendix 25), with 15/177 statements (8.47%) showing elements of disagreement with previous thinking. Secondly, 11/177 statements (6.21%) did not provide adequate information to allow comparison with previous definitions.

Where direct disagreements had occurred, this may have been due to a number of reasons. Firstly, the disagreements may have arisen due to lack of participant knowledge. An example of this could be seen in the participant description of vertical talus, stated to be "a talus in a straight position". Neale (1981) described this as a more complex tilting downward and medially of the talus in relation to the calcaneum with the head of the talus acting as a wedge between the calcaneum and the forefoot with the plantar surface having a convex "rocker bottom" appearance. While radiographs would be required to confirm some of these aspects described by Neale, the "rocker bottom" appearance would represent an important factor in the clinical recognition of this condition. With participants referring to hidden anatomy of the condition and not such a characteristic clinical sign, the suggestion is that their description is not based on experienced working knowledge through unfamiliarity, but instead, an attempted "guess" reflecting inadequate knowledge to provide the description required was made.

Secondly, disagreements may also have occurred where participants had described forms of the states or pathologies which had been unappreciated previously. For the category of classic hallux rigidus functioning gait, participants produced a statement describing "toe-off from medial border of the foot" implying an abducted foot form of gait. This conflicts with Neales' description of gait associated with hallux rigidus (1981) who implied that in functioning with hallux rigidus, the lateral border of the foot is overloaded through supination. Both opinions differed from that of Root Orien and Weed (1977) who suggested that hyperextension of the distal phalanx of the 1st toe is the means of compensation for hallux rigidus during walking for the propulsive phase of gait which involved picking the foot up flatly rather than raising the heel. These three different opinions all reflect findings in the first project Delphi, where a number of different functions associated with hallux rigidus were suggested including all three different forms of function stated here. The previously unrecognised presence of a wide range of functions associated with hallux rigidus therefore explains the different opinions expressed here which would be based on personal observation and experience.

Disagreements may also have arisen through the participants directly challenging previous definitions. Participants agreed that Tailors' bunion is a "lateral deviation and subluxation and bony exostosis of the 5th metatarsal head". While this is compatible to a point with statements given by both Neale (1981) and Root, Orien and Weed (1977), both these sources also state that the inclusion of a bursa in addition to these other symptoms is necessary for the classification of Tailors bunion. While the participants' definition may be incomplete, it may also reflect a belief based on experience that the presence of a bursa is not essential for a Tailors bunion to be described. If correct, this would represent a direct challenge to traditional beliefs, the basis on which these beliefs were founded being unclear. The agreed participant statements describing high-stepping gait also provided an example of conflict with past opinion. Again, both Neale (1981) and Root, Orien and

Weed (1977) stated that high-stepping gait is specifically associated with drop foot – a factor not included in either of the agreed participant descriptions. While there should conceivably be a reason to walk with an uneconomical high-stepping gait, participants may have believed that this reason should not be drop foot alone. A stiff foot or extreme hallux rigidus or hallux flexus could be envisaged as situations which may require some degree of high stepping in order to allow forward ambulation. It may be that past authors' experience had only associated one condition from many possible states with high-stepping gait, or that they only recognised more extreme modes of high-stepping gait. Criteria for accepting the presence of high-stepping gait has not previously been suggested, therefore in the absence of such criteria, less extreme examples of such a gait form should be accepted. The participant definition not linked to drop foot should therefore be accepted as a challenge to these past perceptions, although future work may reject their definition in favour of the traditional viewpoint. Such challenges and possible reporting of unappreciated forms of podiatric states may reflect the current state of development of podiatry. Podiatrists have in the past been trained as "technicians" with techniques and subjects being learned by rote without questioning or further thought. With the advent of degree status in podiatry, practitioners have begun to develop reflective practice and with this, the confidence to challenge past perceptions, especially when the basis for these perceptions remains unclear.

Participants may also have produced definitions which conflicted with traditional viewpoints due to error. The statements of recognition produced for restricted, normal and excessive toe movement show confusion. In the three statements produced, participants suggested definitions for <u>both</u> restricted and normal movements at the 1st metatarso-phalangeal joint as below 65° dorsiflexion and 20° plantarflexion. For 2nd and 5th metatarso-phalangeal joint movements, there is again a similar contradiction between restricted and normal descriptions given.

This error may be for two possible reasons:

1) In using "shorthand" methods to put across information, participants used the symbol < incorrectly to show "greater" when it was intended to show the correct symbol >.

2) Participants were unsure of the correct values and in "guessing" the response did not crosscheck the replies given for overlaps and gaps.

Root, Orien and Weed (1977) suggested that normal values of dorsiflexion for lesser toes and the hallux should be 65° – an angle identical to the higher values given by participants under normal toe movement. The higher value of 65° is very specific and implies some remembered taught information. An error in symbol use therefore appears to be the likely cause of some of the discrepancies noted, possibly confounded by failure to build up clinical knowledge in this area through personal observation.

A number of participant statements did not provide adequate information to allow comparison with previously expressed descriptions. In describing hallux flexus, participants referred to a state of "hyper-extended 1st – elevated from the ground". This may or may not conflict with Neales' description of this condition (1981). The brevity of wording used by participants allows opposite interpretations to be placed on the statement. Participants therefore did not always produce true statements of recognition – while they may have understood what was intended, this is not conveyed beyond their own personal understanding. This is seen again in the statement describing hammer toe, which refers to dorsiflexion of the proximal phalanx of the 2nd toe, but not flexion of the distal phalanx which is additionally specified in both the medical dictionary used (Osol, 1973) and by Root, Orien and Weed (1977). Personal understanding may have assumed this aspect of the condition but this is not conveyed in the statement. In the hemiplegic gait statement produced describing "half of body circumducting during swing phase", this suggestion arises again. While the statement produced conforms to Neales' description (1981), Neale continued, to specifically describe an arc-like dragging movement with the foot plantar-flexed and inverted and the heel being the secondary weight-bearing area without primary heel strike. These additional descriptions from Neale may be the important factors in recognition, with the produced definition lacking the required specificity.

Where participant statements did not provide adequate information to allow comparisons with previous definitions, several reasons were possible for this occurrence as follows:

- The task required was too complex for participants who had been asked to consider and describe aspects of intuitive clinical thinking.
- Participants did not possess adequate knowledge or experience to provide a full response
- Participants did not fully understand the task required.

While such statements may have been compatible with previous opinion, they did not contain adequate information to confirm this and therefore did not represent the statements of recognition sought.

The need for a common podiatric taxonomy

In considering the statements produced for the stated variables overall, it was apparent through the diversity of description approaches that many conditions encountered podiatrically are labels, which have been broadly described in the past, but not explained or defined using a single professional knowledge-base construct. The profession has instead "borrowed" labels from other medical professions and has expanded on this by creating further similar labels without systematic connection or foundation. In effect, this means that podiatry may lack common language for understanding and describing it's own focus of practice. This notion is supported further by the different and unconnected terminologies encountered in podiatry. Rearfoot varus has variously been described as calcaneo varus, rearfoot inversion, inverted calcaneum and inverted rearfoot. While all appear to describe the same condition, this may not be the case and no basis exists for determining this. In *Common Foot Disorders*, Neale (1981) alludes to this situation by attempting to explain common meanings of different terminologies, yet this is still from the perspective of considering the names as labels only. Borthwick (1999) suggested that the creation of the speciality of biomechanics may have been an attempt to address this issue and produce a system on which the practice of podiatry can be based. It has, however only achieved a limited success. While biomechanics attempts to describe normal functioning of the foot in detail and to set up a system of knowledge based on normal values, there is no research evidence for these values. It has also been suggested that pathological variations according to the system of biomechanics are encountered from step to step in individuals with clinically normal feet (Foulston, 1987). Neither does biomechanics take into account the routine conditions encountered in basic podiatry practice. Conditions such as hallux rigidus, hallux valgus, hammer toe, clawed toes etc. are not considered to be biomechanical, yet are basic conditions commonly encountered in podiatry. Furthermore, as suggested earlier in this project, hallux rigidus can be associated with a wide range of shoe wear patterns and would therefore undoubtedly have functional implications, as may other "non-biomechanical" conditions. Biomechanics does not therefore give a satisfactory foundation for knowledge required in routine podiatry practice. In the absence of such a foundation, podiatrists would have greater difficulty in providing statements of recognition for clinically encountered variables, through the lack of a common descriptive mechanism.

4.13 Conclusion

This Delphi exercise had therefore produced consensus on a number of statements of recognition for most of the variables listed. Some of these had not previously been described and many were compatible with previous descriptions. Others however differed from past definitions, representing opinion differences, lack of knowledge, error and the possibility of participants describing previously unrecognised states. A number of other descriptions were incomplete and therefore did not represent the statements of recognition sought due to knowledge deficits and unfamiliarity with uncommon conditions. These differences of opinion and descriptive deficits were valuable insights, demonstrating weakness in the professional basis of podiatry which in turn may suggest why past inter-observer tests involving podiatrists have shown poor results (Keenan and Bach, 1996; Curran and Jagger, 1997). The suggestion has been made that definitions would be improved and beneficially interconnected by the production of a common podiatric knowledge framework. Such a framework would clarify any areas unclear to podiatrists, provide a podiatric interpretation of medical states involved in the foot and would remove ambiguity from attempting to describe and define podiatric conditions. The Delphi had also been useful in ensuring that participants would be broadly interpreting the same conditions in the clinical validation phase of the project, through the production of the consensus statements achieved. Variables for which consensus had not been achieved were uncommon and less likely to be encountered in that phase. Through forcing participants to consider the listed variables across the six Delphi rounds, the benefits of developing and focusing the participants were also anticipated. This was however evaluated in a following inter-observer reliability test.

4.2 THE DIAGNOSTIC CONSISTENCY OF PARTICIPANTS: PRE-VALIDATION INTER-OBSERVER RELIABILITY TESTS

Accumulative summary

As the use of observers is prone to error, inter-observer reliability tests prior to the validation were seen as desirable, to determine whether acceptable agreements would be possible. These tests would also allow familiarisation with the assessment techniques involved and dictate optimum observer pairings, which would improve the validation work to follow.

Using standardised assessment forms, paired observers assessed 12 lower limbs and feet of subject volunteers for foot pathologies present, gait type, ranges of joint movement in the feet and footwear variations. Cohens' Kappa was used to test the correlation between agreements of the various pairs of observers. Superior agreements to previous inter-observer reliability tests involving podiatrists were achieved. This was attributed to the training and focus brought about by observer participation in the previous Delphi exercise, the selected expertise of the observers and the use of actual (as opposed to filmed or photographed) subjects in the assessment. Some recognition parameter problems were noted, suggesting that podiatry would benefit from its' own taxonomy. The observers who demonstrated superior agreements in each category were paired for the validation phase of the research.

4.2 THE DIAGNOSTIC CONSISTENCY OF PARTICIPANTS: PRE-VALIDATION INTER-OBSERVER RELIABILITY TESTS

4.21 Introduction

The justification for inter-observer reliability tests

The pre-validation Delphi exercise had been undertaken to focus and develop validation phase participants and to produce consensus statements of recognition for variables that may be encountered during validation. Both of these benefits improved the validity of the study. It had been considered desirable for the main clinical phase to use paired observers to assess independently the status of a subject in order to verify and confirm the presence of clinical variables which may influence shoe wear patterns. The use of only one observer may be prone to error and the use of two observers has been seen by Robson as a safeguard against this, considering that:

> "It is highly desirable to have more than one observer in any study involving structured observation. With a single observer, even if she shows high consistency, it may be that she is using the observation schedule in a totally idiosyncratic fashion." (Robson, 1993: 221)

The benefits of undertaking inter-observer reliability tests prior to the validation exercise were therefore as follows:

1. To allow observers to pilot the techniques and format of the final clinical validation phase.
2. To allow comparison between observers to demonstrate whether clinical observation would be at an acceptable viable level for the validation phase.
3. To demonstrate and therefore select the paired observers with the best clinical agreements for the final validation phase.
4. To further focus observers and through the potential to highlight inadequacies, promote self-improvement and therefore enhance expertise prior to the final validation phase.

Past clinical inter-observer reliability tests

Many clinical inter-observer reliability tests have been performed previously. The aim of these tests has been to compare the levels of agreement between observer clinicians over the presence of diagnosed conditions or clinical measurement-taking, both of which are prone to subjectivity and error. The results of such tests have been varied. Studies can be found with excellent and almost perfect agreements between clinicians (Pellacchia, 1996; Crowell et. al., 1994; Wilkinson and Menz, 1997; Öberg et. al., 1994). In other studies, poor agreements were demonstrated (Curran and Jagger, 1997; Keenan and Bach, 1996) and both good and bad inter-tester reliability have occurred within the same study (Gibson et. al., 1995; Rhodes et. al., 1995; Donahue et. al., 1996; Brakel et. al., 1996; Fritz et. al., 1997). The issue of the medical examiner variability implied by this has previously been highlighted (Hinchcliffe, 1997). Reasons for low levels of agreement may include:

1 Some techniques of comparison/measurement are more repeatable than others.
2 Observer selection may have been poor utilising observers with minimal skills and/or experience.
3 Terminology and recognition criteria problems may exist within a profession.
4 Some professions may have a poor diagnostic foundation.
5 Observers may have misunderstood the level of accuracy required.
6 The task required of the observers may have been too difficult.
7 Observers may have been asked to use unfamiliar methods.
8 Observers may have developed personal parameters of recognition in the absence of professional guidance which may vary between observers (i.e. observers have not been "calibrated").
9 Inadequate observer training for the task required.

Inter-observer reliability studies in podiatry reviewed

Of the inter-observer reliability papers studied, two involved the testing of podiatrists' clinical judgements/diagnoses (Curran and Jagger, 1997; Keenan and Bach, 1996). In both papers, poor reliability was initially found. This was of concern as the use of observers in this phase of the project was considered the preferred option for reasons stated previously. Additionally, shoe wear pattern interpretation and comparison methods would be of greater value if they could be undertaken by any competent podiatrist without requiring additional supportive technology.

One of the studies of podiatrists inter-observer reliability (Keenan and Bach, 1996) had involved the use of a video-camera system. The involvement of a video camera had also been considered for the final phase of the shoe wear pattern project. In Keenan and Bachs' study, subjects were videotaped walking for rearfoot motion assessment. Clinicians then assessed the videotapes for abnormal rearfoot pronation with the agreements between clinicians then being tested for reliability. Other work involving video-taped assessment of gait has found poor reliability (Krebs et. al., 1985; Eastlack et. al., 1991), although these papers had focused on sagittal plane hip and knee movements and not the foot. Keenan and Bach found poor reliability in their own study and concluded that on the basis of their findings, the isolated use of video assessment of subtalar/rearfoot motion was not supported as a reliable clinical tool. Feedback from participating clinicians had however suggested problems with the research design as follows:

1 Restricted camera angles hindering assessment.
2 The study did not resemble a normal clinical situation causing assessment difficulties.
3 Video assessment produced only two-dimensional views of rearfoot movement for assessment.
4 It would be unusual for a clinical evaluation of normal versus abnormal to be made on video assessment alone with a clinical decision also being based on joint palpation and standing and resting assessments.

In Curran and Jagger's paper (1997), slides of common foot and leg conditions were presented to podiatrists along with a textual description of the subjective symptoms and anatomical level of the condition to be diagnosed. The slides included skin and nail conditions and structural states of the foot and lower limb.

Curran initially found poor inter-observer agreement. The observers were then given access to an expert computer system, which had been designed for this trial to assist the clinicians' diagnoses. While using this system for a second inter-observer trial with the same slides, significant improvements in agreements occurred. The two conditions with the lowest levels of agreement in the first round increased from 12.5% to 75% and from 42.5% to 87.5% agreement respectively. The paper stated that there was poor agreement between podiatrists in diagnosing common conditions of the foot and leg, concluding that this could be improved with the use of an expert system. Study limitations acknowledged included:

1) Undertaking diagnoses using a photographic medium only.
2) Difficulty in placing anatomical landmarks.
3) No access to the patients concerned.
4) Not taking levels of experience into account resulting in possible novice participation.

Despite the poor agreements seen in these tests of podiatrists' diagnostic and assessment skills, the use of such observers was still considered to be the method of choice in the clinical validation. Careful planning with precautions based on the experiences of these previous papers was however considered to be essential in order to produce acceptable agreements for reasons of validity.

Curran and Jagger had noted that poor levels of experience amongst participants may have affected the results. For this reason, experienced participants had been selected for the validation study. Prior participation in the Delphi with the production of consensus statements of recognition would also be expected to improve the terminology and parameter problems of recognition suggested as contributing to poor levels of agreement, by "calibrating" the participants through this exercise. Curran and Jagger had also found that an expert system could significantly improve agreements. The use of such a system could be seen as having two benefits in improving diagnoses:

1. Firstly, by providing a defined protocol for participating observers to follow, a consistent approach had been forced on observers. The consensus statements produced in the Delphi rounds similarly represented such a consistency. A similar consistent basis for clinical assessment was therefore in existence for the four observers involved with the potential to produce enhanced levels of agreement. The use of Currans' system was not possible, being a pilot device limited to ten conditions only.

2. Secondly, in proving a set, repeatable approach to diagnosis, the expert system would also provide learning and developmental benefits for users of that system, further contributing to improved agreement levels. The use of the Delphi had also provided learning and developmental benefits. This application of Delphi before the clinical validation phase could therefore provide similar improvements to those of the expert system.

In both previous papers (Curran and Jagger, 1997; Keenan and Bach, 1996), podiatrists had been required to make diagnostic/assessment judgements from videotape or slide only (supported by textual statements in Curran's paper). This must be considered difficult in the absence of a real life subject. Both slide and videotape are two-dimensional representations, which cannot be manipulated, viewed from different angles and positions, or questioned for clarity. This would severely limit the diagnostic/assessment abilities of clinicians, who would normally have full access to subjects and would be free to manipulate/test joint movements, question subjects and assess conditions from any angle and in any conceivable manner. In the validation phase of the study, clinicians would therefore be given full access to subjects to prevent similar limitations from occurring. Although a video-recording would be involved in this phase, this would not be the sole source of assessment. Its' purpose instead would be to add a further dimension to assessments, allowing visualisation from an angle otherwise impossible to achieve (i.e. from floor level). It would also allow replay if required, allow observers to examine from two different positions simultaneously (as they placed themselves apart from the video camera) and serve as a record which could be revisited later, if required.

Finally, in Curran and Jagger (1997) and Keenan and Bachs' work (1996), observers had not been given the opportunity to familiarise with the techniques involved. Prior to the planned inter-observer reliability test, participant observers would be given the opportunity to practice the techniques involved to eliminate the potential for negative bias through unfamiliarity. The inter-observer reliability tests themselves would further reinforce this familiarity prior to the final validation phase.

4.22 Aim

The aims of this phase of the research were as follows:

1) To determine whether observers can achieve acceptable agreements over subject assessments following the focusing Delphi exercise and therefore verify the feasibility of this method of observer assessment prior to the final validation phase.
2) To determine optimum observer pairings for the final validation phase.

This should also act as a pilot for the validation work to follow, allowing observers to rehearse the techniques to be employed and potentially further improve the level of agreements attainable in that phase.

4.23 Method

The four participants who had completed the pre-validation phase were invited to participate in the inter-observer reliability study. A series of meetings was arranged to explain the planned procedure in detail, to answer any observer queries and to provide observers with copies of all paperwork involved. This would ensure that observers were fully conversant with the task required. Two half-day practice sessions were prepared at the chosen venue for observers to rehearse their assessment techniques and familiarise with the setting. Forms were prepared to standardise the assessment procedure with separate sections for the assessment of both subject and footwear (Appendix 26).

For the subjective aspects of the assessment (e.g. footwear fit, joint movement), categories used were those of the preceding Delphi rounds. Observers were given the statements of recognition obtained from these Delphi rounds for reference along with the reference list of foot/lower limb pathologies used in the previous Delphi work, for memory aid.

Subject volunteers were sought from podiatry patients. Paired observers used individual professional judgement supported by the previously agreed definitions to work through the assessment forms, recording their diagnostic findings in each category. Observers were informed that they would be monitored randomly and covertly for reliability of assessment. This was to take account of the findings of Taplin and Reid (1973) who had studied the conditions under which optimum reliability of assessment could be obtained. The process continued until all four observers had assessed the left and right limbs of six patients – 12 limbs in total). It was stressed to observers that assessments must be made independently and without conferring.

Comparisons were made between all possible pairings of the observers for each separate assessment category. Of the statistical tests available for analysis of the relationship between variables, Cohen's Kappa is the test of choice where the relationship between variables sought is that of concordance on a nominal scale of measurement (Meyer, 1995). This test was used to analyse the strength of correlation between the various pairs of observers across all sections of the assessment procedure with the results being used to optimally pair observers for the final validation phase.

In conjunction with the previous Delphi exercise, the inter-observer reliability tests and precautions taken would contribute to reducing potential weaknesses caused by using clinical observers. These tests would demonstrate whether acceptable agreements could be achieved and enable optimum observer pairings to be produced.

Ethical considerations

The patient assessment protocol was granted ethical approval from the North Sheffield Research Ethics Committee. Each participating patient received an information sheet explaining the research procedure and written consent was given by all subjects.

4.24 Results

Observations were carried out on 12 lower limbs and feet of six subjects as planned. The four observers made assessments of 15 classes of variables, giving six different observer pairings and 90 inter-observer comparisons for analysis. The proportions of agreements between all possible observer combinations were stated and Cohen's Kappa values calculated for each proportion of agreement (Appendix 27). The Kappa interpretation system suggested by Lowe (1993: 126) and which was similar to that of Armitage (1987: 405) was used in preference to the values interpretations suggested by Robson (1993: 223). This was because greater sensitivity was reflected by Lowes' and Armitages' system, which in any event did not amend the actual Kappa value. The agreements ranged from poor to perfect as follows:

7 agreements were poor (8%)
15 agreements were slight (17%)
19 agreements were fair (21%)
17 agreements were moderate (19%)
4 agreements were substantial (4%)
28 agreements were perfect (31%)
(Table 24)

The results were examined for:

1) The highest levels of agreement reached between each pair of observers in terms of numbers of substantial/perfect agreements per observer pairing.

2) For the lowest levels of agreement reached between each pair of observers in terms of numbers of poor/slight agreements per observer pairing
(Table 24)

Observer pairing 2/4 achieved the highest levels of substantial/perfect agreements, with 53% of their agreements at this level (13% being substantial and 40% perfect) (Table 24). This observer pairing also had the lowest number of poor/slight agreements, with 7% of their agreements being at this level (7% poor, 0% slight). The results could also be considered from the perspective of the single podiatrist who had achieved the highest levels of agreement in the observer pairings (Table 25). Podiatrist 4 individually had the highest number of substantial/perfect agreements with 40% of agreements at this level (4% substantial, 36% perfect). Podiatrist 4 also had the lowest number of poor/slight agreements with 13% of agreements being at this level (4% poor, 9% slight).

Conversely, observer-pairing 1/2 had the most poor/slight agreements, with 40% of their judgements being at this level (27% poor, 13% slight). This pairing also produced the lowest number of substantial/perfect agreements, with 27% of their judgements at this level (7% substantial, 20% perfect). Podiatrist 1 individually had the most poor/slight agreements with 33% of judgements at this level (13% poor, 20% slight). Podiatrist 1 also had the lowest number of substantial/perfect agreements with 31% of agreements at this level (4% substantial, 27% perfect).

Pairing with podiatrist 1 therefore suggested the lowest possibility of agreement and with podiatrist 4, the highest. Podiatrist 1 was the observer with the least clinical experience in the group and podiatrist 4 was the most experienced, being a clinical biomechanics specialist with a long history of intensive development.

4.25 Discussion

Comparison with previous inter-observer reliability studies in podiatry

It has been suggested that:

> "It is misleading to compare values of k from different studies where the prevalences of the categories differ" (Armitage, 1987: 407). (k=Kappa)

However, it would be of value to compare other aspects of this study with the two previous podiatry inter-observer reliability studies as both initially demonstrated poor Kappa agreements, suggesting that podiatrists have less than adequate clinical recognition skills.

The tasks required of the observers in the pre-validation study were more complex than those required in Currans' study, where slides of single designated conditions were shown to the observers. In the pre-validation inter-observer study, observers were presented with subjects potentially exhibiting multiple pathologies of the whole foot. In Currans' study, observers knew that they were only required to diagnose one condition in a specified area. However, in this study, observers were required to list as many conditions as they could appreciate for a single patient observation. Participant observers could therefore potentially overlook pathologies present, resulting in a disagreement. Furthermore, 15 distinct areas of the foot and lower limb were being examined. This represented a potentially more difficult task than Currans' work, where observers were only required to diagnosis one condition in a specified area of the foot in ten presented situations. The results can't be compared directly with Currans' because of the wider ranging, less limited and more complex task facing observers in this study which would have reduced the Kappa value. However, despite the more complex task facing the observers, the level of agreement was higher than in Currans' pre-software assisted diagnoses, although lower than those he achieved with software assistance. This suggested superior unassisted diagnostic agreements to Curran. This could be ascribed to both the use of experienced clinicians (as supported by the higher agreements seen with the most experienced clinician involved) and the developing and focusing Delphi exercise undertaken prior to the inter-observer study. A direct comparison of the Delphi with Currans' expert system to improve agreements would be a useful future study.

Comparisons can also be made with Keenan and Bachs' study (1996). While Currans' observers were limited to one diagnostic condition, Keenan and Bach's observers analysed motion, where, as in the pre-validation inter-observer study, several variable factors may have been present. The task required of Keenan and Bachs' observers was however still potentially easier with their observers assessing the degree to which a single pathology was present. The Kappa value noted by Keenan and Bach was 0.19 reflecting poor agreements, including one pair of observers with agreements less than those expected by chance. On re-testing, Keenan and Bach recorded a highest Kappa of 0.59, which was of a similar order to the value of 0.64 achieved between observers 2/4 in the pre-validation inter-observer study. Keenan and Bach's improvement may have arisen through improved familiarity and focus gained during their primary evaluation. This was a similar benefit to that sought from the Delphi exercise. Again, despite the more complex task required in this study, the pairing of observers 2/4 reflected higher levels of agreement than that seen by Keenan and Bach. As suggested, these superior results may be attributed to the training and focus brought about by the Delphi, the selected expertise of the observers and the benefits of involving actual subjects in the assessment.

Given the more complex task required of observers in this study, the results were better than expected when compared to these other two papers and appeared to have been assisted by the selection of experts and the prior Delphi exercise.

Terminology and classification problems experienced by participants

The potential for terminology and recognition parameter problems also became apparent with some observers reporting minor pathologies which others did not recognise, despite the previous Delphi exercise being undertaken. This was particularly noted with the states of hallux limitus, inverted 1st toe, elevated 1st toe and 1st toe lipping. Whenever one of these states occurred, it was only ever noted by one of the paired observers, suggesting that either one observer did not view the state as pathological, or that the condition had been overlooked. It has also been previously suggested that pronation, pes planus and reduced arches are terms that describe a wide spectrum of foot conditions of similar appearance but different cause. (Neale, 1981). In this study, participant observers classified these conditions in diverse ways, with observer 1 classifying pronation variously as an inner longitudinal arch pathology, forefoot pathology, foot type and a whole-foot pathology (Table 26). Observers also repeatedly claimed observation of various combinations of these possibly synonymous or mutually exclusive conditions in the same subject (Table 27). This indicates that either observers experienced difficulty in classifying these condition, or that previous definitions of these conditions were not accepted, despite the Delphi use to focus agreements. There had been concerns that the Delphi had not always produced definitions accurate enough to allow cross observer agreement in some areas. The parameter, classification and terminology problems may therefore have been due to:

- Inadequate definitions being produced by the Delphi.
- Failure by observers to refer to the Delphi statements for clarification.
- Limitations of the classification systems of podiatry.

This suggests that future work may be required on podiatry classification. The better than expected results overall, however indicated that participation in the Delphi exercise had been beneficial.

Observer characteristics which may have influenced reliability

The results in this pre-validation study showed that the lowest areas of agreement occurred between observers 1 and 2 and that observer 1 specifically, produced the lowest agreements throughout. Although observer 1 had a good academic and career history, this was the least experienced observer. Observers 2 and 3 had near-identical levels of experience and produced similar agreements in this study, while observer 4 had the most clinical experience and was the only observer to have developed a clinical speciality, namely biomechanics. This observer participated in the highest agreements seen between observers and observer pair 2/4 produced the highest overall agreements. Clinical experience may therefore be an important factor in the consistent recognition of pathologies and other variables affecting the foot. Another influencing factor may have been the specialisation in biomechanics. Clinical biomechanics usually requires evaluation of the foot and gait to a level beyond that required in routine podiatry. Enhanced skills of structural and functional recognition may therefore accumulate as a result of following this speciality which is functionally based.

4.26 Conclusions

The use of experienced podiatrists and pre-operation of a Delphi exercise to focus and educate appear to have been worthwhile in terms of improving inter-observer agreements in preparation for the validation phase. The Delphi had also been expected to eliminate problems of parameter recognition, terminology and classification and although the Delphi may have beneficially influenced this, there was evidence that this was still present in some areas. The task required of participants at the Delphi stage may have been too difficult, requiring the textual description of a process of complex, sometimes abstract recognition. The results of the inter-observer tests produced agreements at higher levels than expected from previous work involving podiatrists, despite the tasks required of observers in this project being more complex. Optimum agreements seen were at an adequate level to justify the use of paired observers in the validation phase. While both the Delphi exercise and the selected use of expertise appeared to have raised the proportions of agreement above those expected, this was below the levels achieved with Currans' software programme. This programme, however is not yet available for use and the superior results obtained by Curran with this programme may also reflect the simpler task required. It was also apparent that clinical experience was a major factor in achieving superior results, with the experienced biomechanical expert producing the best agreements overall.

As a result of the findings of these inter-observer agreement tests, the observers who demonstrated superior agreements in each category were paired for the validation phase of the project (Table 28).

4.3 VALIDATION: GROUNDING THEORIES OF SHOE WEAR PATTERN INFLUENCE IN THE REALITY OF PODIATRY PRACTICE

Accumulative summary

The theories produced during the research, which related to the focal point concept and model of shoe wear influence required validation in real-life situations, i.e. the reality of podiatric practice. Testing of the focal point instrument was involved in this phase using subjects with known foot conditions (including hallux rigidus) and who attended with all owned footwear for assessment. The many variables which could influence shoe wear were considered and assessment of the subjects was planned to determine the presence, level and effect of these variables. The subject assessment included paired observations of foot pathologies, shoe fit and function, video analysis of foot function and subject interview to determine the footwear history. The questions addressed in the validation were:

- Can the focal point instrument clarify, differentiate between and show shoe wear patterns in reality?
- Is the shoe wear influence model justified?

Three subjects attending with 22 items of footwear were assessed and any wear pattern differences found were compared with the variable differences present.

4.3 VALIDATION: GROUNDING THEORIES OF SHOE WEAR PATTERN INFLUENCE IN THE REALITY OF PODIATRY PRACTICE

4.31 Introduction

Validating the project theories

Prior to this final validation phase, the project had produced an instrumental device to aid the interpretation of shoe wear patterns (Diagram 3) and a basic model to suggest levels of influence over shoe wear pattern formation (Diagram 11). Together, the model and instrument represent the following outline theoretical statement:

"Shoe outsole patterns appear to primarily result from foot and lower limb function and this function is represented by combinations of focal points of wear: the areas from which the wear spreads. While anatomical and morphological factors (including foot pathologies) may influence wear, it is their effect on the primary walking intention which causes this influence. External factors may also influence the wear pattern, but their effect may be minor. Wear extending beyond focal points is superfluous to such interpretation"

To satisfactorily conclude the project, the theories generated should be validated and generalizeable.

> "Validity is concerned with whether the findings are "really" about what they appear to be about. Are any relationships established in the findings "true", or due to the effect of something else?" (Robson, 1993: 66)

This can be simplified as:

> "validity refers to the extent to which the research findings represent reality." (Morse and Field, 1996: 200.)

To establish validity, the applicability of the theories to real life situations must be demonstrated. Theory limitations must be shown, which requires testing within the context to be applied. In doing this, the theories would also become grounded. It has been stated that:

> "A well-constructed grounded theory will meet four central criteria for judging the applicability of theory to a phenomenon: fit, understanding, generality and control" (Strauss and Corbin, 1990: 23).

To be grounded, a theory must therefore be "placed" into and understood within the context within which it will be used, in this case, the reality of podiatry practice, with the conditions within which the theories apply being made explicit.

The entire project had previously dealt with highly theoretical concepts using wear pattern depictions based on participants' experiences. While useful in collecting wide experiences of wear patterns, the detail required in the final project phase had not been made available by this means. While patterns provided had allowed theory formation, podiatrists involved did not appear to appreciate the factors of importance suggested by these patterns and would be unable to substantiate these theories. Validation in real-life situations was therefore required to conclude the project through actual testing of the focal point instrument, using subjects with known foot conditions. Due to the ambiguities regarding the definitions and parameters of foot conditions and normality, the simple condition hallux rigidus was considered appropriate for subjects to present with in at least one foot.

External variables with the potential to affect shoe wear patterns

The presence and effects of variables are fundamental to this study. As clinical variables including foot/lower limb pathologies, gait and ranges of joint movement have a direct relationship with foot function, they were included in the project validation through their potential to amend function and therefore, shoe wear patterns. While foot pathology and gait-form variables had been considered in-depth in this study, external variables had not, although many sources of influence were envisaged (Diagram 12).

External variables for inclusion were:

- Footwear age
- Predominant surface that the shoe has been worn on (hard/soft)
- Orthotic use with the shoe
- Predominant ambulatory mode with the shoe (i.e. walking/running)
- Specific shoe purpose (i.e. Sports/occupation/activity-specific use)
- Stair use
- Psychological aspects of wear (i.e. feelings about the shoe)
- Multiple shoe ownership
- Shoe fit
- Habit

The justification for considering footwear age was provided by Barnett and co-researchers (1956), who noted different chronological stages of wear, commencing with initial light wear which they described as primary wear. Bodziak also noted that:

> "The wearing of a shoe is a continuous process that is constantly changing the outsole of the shoe" (Bodziak, 1990: 319)

Similarly, there is an intuitive belief that sole material and surface walked on may influence the rate of wear. Facey and co-authors (1992a) believed that forensic scientists need to understand what happens when a subject moves from "hard to soft shoes" and Dalton (1982) presented a short discourse considering the effect of friction on skin which referred to frictional effect variations on different forms of surface.

Several influential external variables (confounding variables) could also be envisaged. The first was the use of orthotics with footwear. The project theories were based around the findings that wear patterns were functional and not simply anatomical/morphological in origin. Two types of foot orthoses exist - functional and accommodative.

Functional orthoses attempt to:

> "limit abnormal midtarsal and subtalar joint motion; immobilise the subtalar or midtarsal joint complex; increase subtalar joint motion; cant the foot in a more functional or stable position; compensate for any lower extremity malalignment; and support ("balance") any existing forefoot deformity" (Losito, 1995: 280)

These are attempts to amend foot function, which if effective may also amend the wear pattern. Accommodative orthoses "redistribute vertical and shearing forces away from painful areas" (Losito, 1995: 280). Again, this redistribution could affect weight-bearing forces acting during stance with potential wear pattern influence. The possible influence of orthotics on wear patterns of the footwear under investigation were therefore considered.

The predominant mode of ambulation (walking or running) and specific shoe purpose may also potentially influence shoe wear patterns. The different biomechanical actions of walking and running were described by Nuber (1988). During running, these include major vertical force increases, which are not bi-peaked as in walking, decreased stance phase, lost double limb support, increased ankle dorsiflexion/plantarflexion and changed muscle group function of the lower limb. Such functional changes may therefore amend a functionally caused wear pattern. Similarly, functional differences may relate to different sports and work based occupational activities. Studies of standing feet have shown peak pressure pattern differences between walking and standing, with minimal toe involvement in standing (Cavanagh, Rodgers and Iiboshi, 1987). Occupational activities can require long standing periods, potentially affecting shoe wear patterns through these amended peak pressure distributions. Other occupational activities may require the foot to function in more obviously different ways (e.g. driving, machinery operating). These considerations also apply to ascending/descending stairs where the altered function may influence wear patterns if performed frequently.

The effect of personality/psychological status over gait has been previously considered. Gerard (1920) referred to opinions that gait could be characterised according to the personality. Amongst other postulations, he referred to beliefs' that:

> "A calculating and curious person toes out considerably… shiftiness and hesitancy is indicated by a swaying walk…; knock kneed individuals will be frequently found to be cranky…; noisy walk indicates a boisterous nature…; men who lean towards the right are alleged cynics and sarcastic in their mode of speech" (Gerard, 1920: 4-5)

Although unsubstantiated and open to scepticism, the psyche may affect the gait cycle. Medical texts have referred to links between psychological states and the motor system with for example slow, faltering and weary behaviour being associated with clinical depression (Houston, Joiner and Trounce, 1975). A possible link between function and psychological status was therefore considered as another potential wear influence.

As it was apparent that wear patterns differed between individuals, the possibility of multiple shoe ownership was also considered. If footwear owners create different classes of wear pattern, patterns may be amended when shoes are worn by more than one individual. Equally, one owner with multiple footwear may demonstrate different outsole wear patterns. Awareness of this possibility was therefore required when comparing wear patterns of shoes with common ownership during the validation phase.

Shoe fit may also potentially amend shoe wear patterns. Studies have reported many problems and factors to consider when fitting shoes to feet (Hicks, 1988; Rossi, 1988; Korn, 1949; Collazo, 1988). Shoe fitting is a complex procedure. Fitting systems have been described considering 21 aspects of fit (Hicks, 1988) and 37 factors influencing shoe fit have been defined, suggesting that a perfect fit cannot be attained (Rossi, 1988). Shoe fitting problems may also influence function and shoe wear. Korn (1949) referred to wear implications of incorrect fit. These include treading over the outside forepart of the shoe through shoe and sole shape mismatch, isolated sole wear with excessively narrow shoes and rapid toe end wear with short shoes. Lucock (1980) also noted a potential for tip wear through short fit. The validation procedure therefore considered shoe fit variables in relation to wear patterns.

Finally, the effects of habit may potentially influence wear patterns. Although literature does not refer to footwear affectation through habitual behaviour patterns, a past forensic podiatry case has indicated this possibility (Gunn, 1999). Here, a habitual practice of elevating the heel while standing had deformed the shoe back and formed two sets of toe imprints on the insole, creating the illusion of multiple ownership. It is conceivable that other personal habits may amend outsole wear, therefore personal habit was considered as another possible wear pattern influence.

4.32 Aim

In the theory validation, measurements and observations considered all these potential influencing factors, allowing analysis of their effect on wear patterns. By considering the presence, levels and effects of all variables present, valid conclusions could be produced on the wear pattern production mechanisms, which were anticipated to reflect the stated theories. This demonstrated the wear influence hierarchy principle, giving the project construct validity and grounding the theories in podiatry practice, allowing validated theory generalisation. To conclude the project, the following research questions were relevant:

1. **Can the instrument clarify, differentiate between and show shoe wear pattern similarities in reality?**
2. **Is the wear influence model justified (i.e. is wear in reality fundamentally a product of foot function with foot pathology and external factors showing decreasing influence respectively?**

To answer these questions, several approaches were incorporated (Table 29).

4.32 Method

As this work involved podiatry patients, ethical approval was required. Subjects were not to be exposed to any clinical risk by participating. Any urgent conditions encountered would have been treated immediately. Personal anonymity was respected and the principle of informed consent to participation applied. Subjects were advised of their right to withdraw from the study at any time. Permission was sought to video record subjects' feet walking with care taken to maintain anonymity. Permission was sought to tape record interviews with the tapes being destroyed on the project conclusion. Objections to video or audio recording would have been respected.

The instrumental concept and wear pattern model of influence were validated on podiatry patients including those exhibiting hallux rigidus. Subject access was obtained through the community podiatry service in Sheffield. Selecting staff sought three patients exhibiting hallux rigidus whether present in isolation or with other pathologies. These patients were asked whether they would be willing to attend for research interview and clinical assessment. An invitation to attend was sent to volunteer subjects (Appendix 28). Respondents received an appointment letter (Appendix 29) and information sheet (Appendix 30), detailing the planned research and requesting attendance with currently owned footwear. Subjects were required to bring all owned footwear and outsole wear patterns were evaluated with the instrument, to show variations. The type and level of potentially influencing variables were investigated and defined. Here, clinical assessment by paired podiatrists showed foot pathologies present, shoe/foot interface variations and the holistic gait form adopted by the subject. A pro-forma based on to that of the inter-observer reliability trial was used for the assessment procedure (Appendix 31). Any wear pattern deviations found were compared with variable differences present. Observation and video recording allowed patterns and function to be compared together. Research interview with each subject determined the history of each footwear item including the presence of external variable factors described earlier.

The data were analysed qualitatively for focal point similarities and differences and themes and effects of wear influence, to allow theory generalisation with stated limitations. At the same time, function predictions based on the wear pattern forms seen within internal and external contexts could be shown. This analysis allowed the following to be demonstrated:

- Pattern similarities and differences between subjects and between commonly owned footwear (by overall pattern and focal code descriptions).
- The relationship between primary walking intention, foot pathologies and external influences and wear patterns.

This would validate the shoe wear influence model and the ability of the focal point instrument to clarify and differentiate wear patterns. Exclusion factors to successful instrument use in the form of confounding variables were summarised in a generaliseable statement following analysis. This would ground the theories in the complex relationships within which they lie and therefore in podiatry (and forensic podiatry) practice, achieving construct validity.

4.33 Results

The three subjects attended with 22 items of footwear for examination (two subjects with four pairs each and one subject with three pairs). The footwear varied in type and style and included bespoke hospital shoes, hand made shoes, high street shoes and slippers, with widely varying use. Subjects and footwear items were studied in order to address the above research questions and validate the work.

The aims of this project stage were answered as shown in Table 29.

4.34 Analysis 1. Can the instrument clarify, differentiate and show similarities between shoe wear patterns?

Could the wear patterns be shown instrumentally for all footwear items examined?

Initially, outsoles were assessed using the instrumental principle, to determine whether wear patterns could be identified and whether the same patterns occurred across footwear of common ownership (Appendix 32). On one pair of shoes belonging to subject three, the pattern could not be determined. This was due to the outsole material showing even forefoot area wear through apparent low abrasion resistance, with no discernible heel wear due to a very recent repair. Two circumstances were therefore represented where instrumental wear pattern interpretation was unusable – extreme and zero wear situations. Extreme wear may still demonstrate patterns on multi-layered or deeply textured outsoles, but those in question were not of this type. Extreme smooth wear and absent wear situations would therefore prevent shoe wear pattern interpretation. All other footwear items examined showed wear patterns distinguishable through the instrumental principle.

Were different patterns suggested between individuals and between items of footwear by the instrument?

The instrument showed similarities and some differences between footwear items of respective sides for the same individual and differences between subjects (Table 30). While wear patterns of left and right feet of each subject differed, the overall tendency was for the same pattern focal codes to be seen for footwear of the same side of the same subject. Same side differences were seen in subject one only, where the following amendments were noted:

- Footwear items 1-3 (left and right) included posterior medial heel wear in addition to the posterior lateral wear noted across all footwear items.
- Footwear item 1-4 (right), showed wear of the entire lateral and no other aspect of the outsole.
- Unlike left footwear items none of the right footwear showed 1st metatarso-phalangeal joint area wear.

What variables had caused the same side pattern differences seen in footwear of subject one?

Many variables were found to be acting on all footwear items by the interview and clinical examinations (Table 31; Table 32). The identification of these variables and the level to which they had been present allowed influencing factors to be shown. Five variable differences were found to be have acted on footwear items 1-3 (left and right):

- No history of bespoke insole use,
- No history of stair use
- No history of outside use,
- Reduced walking activity
- Lack of footwear stiffness.

These variations may have resulted in the posterior medial heel wear seen with footwear 1-3 (left and right). Reduced walking activity and absent outside use were dismissed as reasons for this wear as they related to the amount of footwear use only. While stair use involves different functioning than walking, subject two had also avoided footwear use on stairs, but did not exhibit such posterior heel wear. Lack of stair use was therefore not believed to be responsible for this wear. Barefoot gait assessment showed the subject walking with normal heel strike and subsequent rapid heel eversion, which could be orthotically controlled by medial heel support. Such rapid eversion in the absence of an insole could cause the posterior medial heel wear seen in items 1-3. Through constant orthotic use, this wear would be absent in the other footwear items. The difference would be further exacerbated by the reduced support offered by items 1-3 (slippers) over outdoor footwear. Orthotic use in all but footwear items 1-3 would therefore account for this wear difference.

The amended wear pattern of footwear item 1-4 (right) showing lateral wear of the entire outsole differed from all other right shoes. Only one variable factor occurred with this footwear item alone – an orthopaedic steel plate fitted within the outsole. Assessment showed that walking in this footwear item deviated from the subject's barefoot gait through the foot remaining inverted throughout stance. The wear differences seen here could therefore be attributed to the steel plate presence.

The effect of external variable influences

The two pattern-amending variables seen were major sources of external influence – one being the absence of a custom made orthotic device (always present in other owned footwear) and the other, the permanent steel plate influence. No other externally caused amendments were noted, despite many variables being present. Through the inability of most external variables to amend the wear pattern, it appears that variables must act for a major proportion of the shoes' life to affect a pattern. They must also exert a major influence on foot function. If such powerful influences are not present to this level, then common wear patterns are anticipated for commonly owned footwear. If outsole material allowed wear pattern appreciation, the focal code combination of that common pattern could be recorded. While pattern differences were noted between the individuals studied, patterns of shoe 1-1 (right) and all right footwear of subject two were similar (Appendix 32). Patterns may therefore not represent unique individuality, but instead could be classed according to the holistic function producing the pattern if the functional link can be shown in reality.

Summary

The instrument enabled wear patterns to be distinguished, with the exception of footwear with excessive, or zero wear. Subjects exhibited the same pattern across all footwear unless functionally influencing and constantly present variables were present. These patterns are believed to represent classes of related function and not uniqueness.

4.35 The analysis of foot function

To justify the model of wear influence, observed (holistic) function must be seen to relate directly to shoe wear with a higher order function (primary walking intention) being shown to have precedent over the direct effects of pathology. External influences needed to be shown to have less frequent effects than both intended function and pathology. To analyse the direct relationship of holistic function to shoe wear, function was assessed in three different ways:

1. In the context of the internal and external variables present, the pattern was used to suggest the causative function.
2. By paired gait observations of function.
3. By frame by frame examination of the video recording of the subject's holistic function for comparison with the above function evaluations.

This three-way assessment was planned to allow function assessment triangulation, validating the method of function assessment using shoe wear patterns within the variable context stated above. The function assessment of the paired observers however disagreed with the other two methods of assessment, suggested that such observations were inadequate for this task. This led to an additional exercise being undertaken, where observers also examined the video records, frame by frame and agreed with the conclusions produced from that analysis, rejecting their earlier assessments. This additional task ensured that triangulation was maintained.

In the main questionnaire phase, consideration of observed shoe wear patterns in an associated pathology context had suggested various categories of function, which may have produced those patterns. In this validation phase, the context was widened by also considering external variables present. This form of functional assessment was validated by comparing functions suggested by the wear patterns with the other functional assessments undertaken thereby demonstrating the relationship between wear and function.

In determining whether wear patterns supported the direct connection between holistic function and wear, the video still frames were examined individually to show the function which had taken place. The video record had greater potential for accuracy and detail than podiatrists' observations, capturing still, sequential images for later examination and eliminating the possibility of inaccurate speculation and observational error. This also demonstrated some direct effects of pathology on function supporting the secondary effect of pathology in wear pattern formation. For all subjects, such assessments were made barefoot for clarity and to show greater functional detail. Observations were also made with footwear items 1-4 (left and right), where the right shoe had demonstrated a markedly different wear pattern (Appendix 32) and the left shoe contained an orthotic to control foot function.

Problems experienced with paired observations of function

In the paired podiatrist assessment of subject function, disagreements occurred between the observers over the function each had perceived. Even when in agreement, observers functional assessments often differed from those suggested by the wear patterns and from the components of function clearly shown in the still video frames (Table 33). Agreements related to more obvious aspects of function (e.g. pronation), without recording more subtle components (e.g. rapid heel eversion, hallux limitus restrictions), which were consistently suggested by the shoe wear patterns and seen on the still video frames.

To support the conclusion that direct subject observation was inaccurate, the observers involved were later shown the still video frames and statements summarising the displayed functions (Appendix 33). The observers confirmed that they agreed with 25/28 of these conclusions, which often contradicted their original assessment, supporting the recorded and wear pattern functional assessments. This presented concerns over using clinical observation alone in functional analysis and highlighted the value of using wear patterns routinely in foot function assessment. The three disagreements related to the suggested left foot functioning of subject one (Table 33)(Diagram 13), specifically statements suggesting that hallux limitus (alone) had been responsible for restricting full foot pronation (Appendix 34). Although both observers accepted this fact for the right foot, in the presence of a less extreme hallux limitus, they were unsure whether this factor alone would restrict pronation. One observer was also unsure whether such a restriction had taken place, while the other accepted that a restriction had occurred, but was unsure of the reason for this. For the same foot shod, both observers noted that orthotic control may have caused the restriction noted. Unlike the observers, the researcher had been familiar with the subjects' wear patterns. This knowledge may have either caused bias, or alternately may have demonstrated the value of considering wear patterns to assist with such judgements. It would however be probable that the foot had represented a less extreme example of the restriction agreed in the right foot.

4.36 Analysis 2. Is the model of wear influence justified; Do shoe wear patterns relate to observed (holistic) functions?

The functional assessment of subjects and relationship of functions to wear patterns is discussed below. For each subject, the outsole wear patterns (Appendix 32) were used to suggest causative functions within context, then compared to the video frame analysis for confirmation.

SUBJECT ONE - Function suggested by individual wear patterns

Footwear items 1-1 (left) and 1-4 (left) One external variable present had potential influence over these footwear items - permanent orthotic use to control pronation. The internal variables present included pronation with pes planus (suggesting a pronounced pronation) and slight hallux limitus. In this context, the wear patterns suggested some orthotic success in controlling pronation, with normal heel strike wear and wear extending across the metatarsal area. However, anteriorly, some medial wear pattern emphasis with absent anterior lateral border wear and wear accentuation at the 1st toe apex suggested some late pronation, partially restricted by the hallux limitus (Diagram 13).

Footwear item 1-1 (right). Two influential external variables were present here – an orthotic to control pronation and shoe rocker sole to assist with the hallux rigidus restriction. The internal variable context included pronation with pes planus (a pronounced pronation), with a more severe hallux limitus than the left foot. Again, in this context, normal heel strike with orthotic control of pronation was suggested by the outsole wear pattern. Absent 1st metatarso-phalangeal joint wear suggested that the hallux limitus had halted the pronatory movement, with a forced "classic" hallux rigidus function causing forefoot inversion (Diagram 13). Rocker sole effects were suggested to be minimal as absent 1st metatarsophalangeal joint area wear indicated continuing forefoot inversion.

Footwear items 1-3 (right and left)._ Here, lack of orthotic use changed the external context differed from the previous footwear items. The pattern in footwear 1-3 (left) suggested a normal heel strike instantly everting through uncontrolled pronation. Attempted recovery and/or pronatory limitation by the slight hallux limitus was suggested by the wear pattern extending across the metatarso-phalangeal joint area with accentuated distal 1st toe area wear (Diagram 13). In footwear item 1-3 (right), a similar rapid eversion following heel strike was suggested, with hallux limitus restricting pronation and a "classic" hallux rigidus function occurring later in stance (Diagram 13).

Footwear item 1-4 (right). While the internal context remained the same as the right footwear items considered above, a major external context variation was present in the form of a fitted orthopaedic steel plate. The pattern varied considerably, with lateral outsole wear only. The suggested function was one of a foot in fixed inversion throughout stance, which in context would have been "forced" by the steel plate. The force pathway would therefore remain lateral throughout stance (Diagram 13).

SUBJECT ONE - Barefoot function observed in video analysis

Left foot. The freeze frame playback showed a normal heel strike followed by rapid heel eversion, with the foot abducted and hallux limitus restricting full foot pronation. This exactly matched the function suggested by outsole wear pattern 1-3 (left), although attempted recovery from pronation was not noted with pronatory control relating to the 1st toe restriction alone. Heel eversion control, although not discernible through the footwear would justify the wear differences noted with insole use, with forefoot function remaining unchanged.

Right foot. This freeze frame playback again showed normal heel strike with rapid eversion, but with the foot straight, not abducted. Later in stance, hallux limitus restricted pronation with a "classic" hallux rigidus function following and inversion along the 5th metatarsophalangeal joint, 1st toe axis. No abductory twist occurred. Again, the footwear item 1-3 (right) wear pattern correlated with this observed function. Heel eversion control with insole use would justify heel wear differences between these and other footwear items, again with forefoot function remaining unchanged.

SUBJECT ONE - Function with footwear items 1-4 (left and right) observed in video analysis

These observations were made as shoe 1-4 (left) contained an orthotic and 1-4 (right), a rocker sole, steel orthopaedic plate and amended wear pattern.

Left foot. With the shod foot, the function was not as detailed, however a normal heel strike with rapid eversion was clearly seen, with hallux limitus restricting pronation. While function compatible with that suggested by the wear pattern was apparent, the detail required to show the orthotic delaying eversion after heel strike as suggested by the wear pattern was not available.

Right foot. The foot was clearly shown inverting throughout stance, with no medial ground contact, reflecting the function suggested by the wear pattern.

SUBJECT TWO - Function suggested by individual wear patterns

All left footwear. All left footwear exhibited a common wear pattern for this subject and the only potentially influencing external variable was an orthotic used in all footwear. The internal context included pathological variables related to pronation, inversion and hallux rigidus with elevated 1st toe (Table 32). Lateral heel wear present suggested an initial inverted abducted heel strike. Forefoot wear indicated a maintained forefoot inversion throughout stance, avoiding the hallux rigidus restriction, with the elevated 1st toe avoiding 1st toe weight bearing (Diagram 13).

All right footwear. As in the left foot, all footwear exhibited a common pattern and the same external and internal variables applied. No pronation was suggested by the wear pattern, implying the 1st toe restriction and/or insole control over the rearfoot eversion. In the forefoot, "classic" hallux rigidus function was again suggested, implying a forefoot inversion less pronounced than the left foot, with 1st toe ground contact and associated inversion (Diagram 13).

SUBJECT TWO - Function observed in barefoot video analysis

Left foot. The video frames showed the foot abducted during stance, with inverted forefoot, a function fully reflected by the wear pattern.

Right foot. The foot was shown abducting with "classic" hallux rigidus function, again as suggested by the wear pattern within the contexts stated.

SUBJECT THREE - Function suggested by individual wear patterns

All left footwear. All left outsoles demonstrated the same wear pattern, with permanent orthotic use in the shoes. Lateral and anterior medial heel, 1st, 2nd and 3rd metatarso-phalangeal joint and tip of the central toe area wear was seen. The internal context included pronatory factors, hallux rigidus with elevated 1st toe and inverted forefoot (Table 32). In this context, the pattern suggested an abducted heel strike with rapid eversion and pronounced pronation without successful orthotic control. Central metatarsal area focused wear may have suggested an abductory twist creating a more extreme abduction. Absent wear focus of the 1st toe area suggested that toe-off occurred from the medial aspect of the 2nd toe and not the elevated hallux (Diagram 13).

All right footwear. All right outsoles exhibited the same wear pattern. Wear occurred in lateral and anterior lateral heel, 1st to 4th metatarsophalangeal joint and tip of central toe areas. An orthotic was permanently worn, while the internal context included pronation factors, elevated 1st toe and forefoot inversion (Table 32). In this context, the wear suggested an abducted heel strike with eversion and pronation occurring later than in the left foot through more successful insole control. In the forefoot, a possible abductory twist was again suggested with the incompetent elevated 1st toe leading to toe-off from the medial aspect of the 2nd (Diagram 13).

SUBJECT THREE - Function observed in barefoot video analysis

Left and right feet. Both feet were abducted and pronated during function, with 1st ray incompetence leading to 2nd toe toe-off, again reflecting the function suggested by the wear pattern contextually. The possible abductory twist suggested by the pattern was not seen, indicating that precision is not always possible when using wear patterns as function indicators.

Summary

Function suggested by the wear patterns within context consistently related to that noted in the video frames. While occasional imprecision occurred, function still related broadly to that observed (i.e. for subject three, the patterns may have suggested abduction or abduction with abductory twist). Wear patterns consistently gave more accurate function assessments than simple observations, justifying their routine use diagnostically. The wear pattern and function relationships observed with these subjects related closely to those suggested in the main questionnaire phase, supporting the validity of this earlier work. This suggests that routine shoe wear pattern consideration would give good diagnostic indication of foot function. The close relationship between wear patterns and foot function justifies their use in forensic identification. The need to interpret a pattern within internal and external contexts however precludes their use in isolation. The forensic value would be in relating an individual on examination to a wear pattern, through the function predicted within context.

4.37 Analysis 3. Is the model of wear influence justified; Does a hierarchy of influence over wear pattern form exist involving primary walking intention, foot pathology and external factors?

While the relationship between patterns, holistic function and effects of external influence has been discussed, the justification for siting pathological factors as a secondary influence over primary walking intention in the model requires further consideration. When present, foot pathologies would need to relate consistently and directly to wear patterns to exert greater pattern influence than the primary walking intention. This did not occur in the subjects studied. Despite hallux rigidus/advanced hallux limitus occurring in 4/6 feet examined (Table 32), varied wear patterns resulted (Appendix 32), suggesting that the condition was not the primary influential factor. Comparisons with foot function showed that with "classic" hallux rigidus function, hallux rigidus could directly influence the pattern. Subject two exhibited bilateral hallux rigidus, but demonstrated different left and right outsole patterns - right relating to "classic" hallux rigidus function with 1st toe involvement and left to a marked forefoot inversion, with the 1st toe avoiding ground contact. While subject three had different left and right outsole patterns, forefoot patterns were similar and functionally related to abducted gait – again without direct 1st toe influence.

Different patterns and functions therefore occurred with hallux rigidus/limitus. Although the pathology occasionally exerted a direct influence, this was a local effect only with primary walking intentions avoiding direct pathological influence in several examples, supporting primary walking intention as the leading wear pattern influence.

Other pathologies occurred in addition to hallux rigidus. Although observers had noted a genu valgum condition in subject three, this did not appear to affect the wear pattern produced, which could be explained without reference to genu valgum. Similarly, the state tibial varum occurred in all subjects. Although related inversion of the foot may conceivably cause lateral wear, this only occurred in footwear item 1-4 which could be linked directly to the steel plate present. In subject two, left shoe wear patterns and function however showed forefoot inversion, possibly related to tibial varum. This did not occur to the same extent in the right foot (which exhibited a "classic" hallux rigidus function), or in subject three, suggesting that the primary walking intention had overridden direct tibial varum influences here.

Observers had noted pronation present in all subjects. There is doubt however whether pronation should be seen as a specific foot pathology. Pronation is a normal foot movement component (Bevans, 1992), but has been seen as pathological when excessive, or occurring when supination is expected (Bevans, 1992; Root, Orien and Weed, 1977). Static standing foot assessment can show pronation (Root, Orien and Weed, 1977; Neale, 1981), but as the position achieved after abnormal pronatory movement. Pathological pronation is therefore an abnormal function recognisable in static stance through the position attained and not a primary foot pathology. The main questionnaire patterns suggested different manifestations of pronatory function (e.g. simple pronation, fixed pronated position, accompanying abductory twist etc.. The three subjects here all pronated, and also showed variable functions in the video frame assessment. Pronation can therefore be seen as a variable class of functions and not a specific foot pathology, with these functions representing different forms of primary walking intention.

Elevated 1st toe, however is a foot pathology, seen bilaterally in subjects two and three. In subject two, this pathology may have influenced left outsole wear only, but this foot also functioned with marked forefoot inversion, to which the forefoot wear was directly attributed. In subject three, video assessment showed wear pattern influence from both elevated 1st toes preventing 1st toe involvement in toe-off. The 1st toe pathologies had therefore directly influenced wear locally, again secondary to the primary walking intention. Minor toe pathologies were also present in these subjects with no relationship being apparent with the wear patterns, indicating minimal influence.

Subjects also demonstrated varied static heel and forefoot positions in relation to a theoretical norm (i.e. inversion and eversion). While subject two had bilaterally increased heel and forefoot inversion, only the right wear pattern reflected heel inversion, and the left pattern, the forefoot inversion. In subject three, an increased heel eversion was not shown in the immediate heel strike wear component, but may have led to a pronation with anterior wear influence. A forefoot inversion present was not apparent in wear patterns of either foot. Again, variable wear patterns occurring with these states suggesting that their influence was secondary to the dynamic primary walking intention. Any direct effects occurring represented single wear pattern components, highlighting the need to consider the foot in its' broadest dynamic sense, avoiding single element focus. Foot pathologies again did not necessarily show directly related wear patterns, with primary walking intentions predominating.

While some direct pathology influences over function and wear patterns occurred, this was not consistent and was secondary to the primary walking intention. Conditions present, previously described as pathologies could be classed into pure local pathologies, functional descriptions and descriptions of biomechanical/structural relationships. This supports the need to address podiatry terminology to either differentiate between or to commonly classify these states by functional effect. Positional differences between functions adopted and static structural descriptions demonstrated the need to consider the foot dynamically when investigating wear pattern correlations.

Of all true pathologies present, 1st toe pathologies had the greatest influence over holistic function and therefore wear patterns, with lesser toe pathologies showing no wear influence. The 1st toe normally has a key role during toe-off therefore such influence would be expected. As seen, however, the primary walking intention could still override the effects of these pathologies on wear patterns.

While numerous external variables were present, most had no wear pattern influence, which usually related to the primary walking intention, sometimes with direct pathological involvement. There were, however two exceptions – both in subject one, where orthotic absence and steel plate presence both related to pattern amendments. These were major permanent external influences which had affected both function and patterns as orthotic and orthopaedic devices. This extreme, permanent nature, along with the lack of effect from other external influences justified ranking external variables below pathologies in the model. Foot pathologies, ranked second to primary walking intention demonstrated more direct effects than external influences and did not need to be extreme to affect wear patterns.

Summary

Several holistic functions were noted. Some produced related patterns from primary walking intention alone without direct pathological effect. Other forms exhibited pathological involvement (e.g. "classic" hallux rigidus function), which only represented secondary amendments to the pattern produced, partially contributing to the holistic function. External variables only affected the wear patterns, if present at all times and of an extreme nature and some of these variables may have exerted an effect on the rate of wear only (e.g. footwear material, surface walked on). The basic model of wear influence is therefore justified and can be expanded to reflect the presence of different variables which may influence either the amount, or the form of wear, while at the same time separating walking and non-walking influences (Diagram 14).

4.38 Conclusions

Some problems became apparent in the validation study. Observers usually agreed over gait observations, however agreements often differed from functions demonstrated in the video frame assessment. The video frame analysis was later mostly accepted by these observers who therefore rejected their unassisted conclusions. While highlighting this potential for error in clinical practice, these incorrect observations had been made to assist with functional analysis and were therefore unhelpful. The video recording was made as a simple record to allow triangulation, but proved to have a central function analysis role. If anticipated, the method applied would have incorporated dual angle cameras for more detailed analysis.

The validation phase demonstrated, supported and expanded the theories being tested. The instrumental device enabled wear patterns to be described and compared but was ineffectual with shoes with absent or excessive wear. Differences in degrees of wear are an example of "non-confounding variable" influence, i.e. those not amending focal point combinations. As seen here however, such variables can impair wear pattern clarity therefore being an important consideration in wear assessment. Care was also needed when determining which sites were producing wear, especially with regard to heel focal points. The instrument had value in the description and comparison of wear patterns for identification purposes, but within the limitations stated.

Within the variable context, patterns described by the instrument were effective in suggesting the causative function, although loss of precision occurred with abduction/ abductory twist interpretation. This reflected main questionnaire findings, where single patterns occasionally suggested several functions. The wear influence model applied, with primary walking intention being the main factor in wear pattern formation, with foot pathologies sometimes having direct, but secondary influence and external factors also demonstrating influence. The low influence of external factors is justified by the presence of many variables of which only two extreme examples had wear pattern implications. Variables amending focal point combinations can be considered "confounding" and may be intrinsic, where function is amended through an internal effect while walking, and extrinsic, which would include alternative functioning (e.g. running) and external effects (e.g. footwear restrictions). Podiatry terminology problems were highlighted, as current terms do not distinguish between true local pathologies, functional variations and biomechanical/ structural relationships.

Wear pattern use in identification is supported. If patterns can be clarified and compared with suspected footwear owners, then shoes and wearers could be associated through function suggested by the pattern. The value of this process in identification would improve through research into functional individuality, which would presently be a class characteristic. If some functions are unusual, greater individuality could be shown by the wear pattern. This however, appears unlikely as the main questionnaire suggested limited classes of function within pathological contexts.

The direct, predictable relationship of shoe wear patterns to foot function suggests that wear patterns have value in clinical diagnosis. They have added value over foot pressure measuring devices in outlining the three-dimensional foot function and in not requiring expensive diagnostic equipment. Research is however required into the clinical management required by these classes of function. For example, traditionally, rocker bars or plantar metatarsal pads to facilitate "rocking" have been recommended in conservative hallux rigidus management (Edgar, 1976; Tuck, 1976). Varying functions associated with hallux rigidus suggest that this may only be appropriate in some cases (e.g. with "classic" hallux rigidus function) and that alternative approaches are required.

The validation exercise demonstrated that the proposed instrument and wear influence theories allow wear pattern description and interpretation in reality, within the limitations of readability and where there is a known context. The functional analysis of shoe wear patterns was therefore grounded in podiatry practice with applications of comparison and functional diagnosis being shown.

Accumulative summary

The study was unique and while alternative approaches could have been taken, different findings may have resulted. Reliance on podiatrists' knowledge and understanding throughout the study showed this knowledge to be lower than expected, but this improved with the focus and reflection gained through participation in the research. The proposed model of shoe wear influence presented a new perspective on foot function, which may be of greater relevance to podiatry practice than biomechanical theory. While professional craft knowledge and expertise in podiatry was revealed in the research, it is suggested that there has been a problem in translating this knowledge into a form that can be learned. The research has succeeded in this task with the production of the wear pattern evaluation instrument and model of shoe wear influence. The "one condition, one wear pattern theory has been replaced by a "function, pattern" theory. This allows the prediction of function in podiatry diagnosis and suggests a taxonomy on which podiatry practice could be based. In forensic identification, a means of pattern comparison has been demonstrated and an additional link with the shoe owner through causative function can be made. The clinical and forensic values of shoe wear patterns have the potential to be improved further with additional research.

4.4 CONCLUSIONS

4.41 Limitations and alternative approaches to the project

With the benefit of hindsight, some aspects of the project could have been undertaken differently. While the aim of the initial Delphi study was to produce consensus, this did not initially occur. Although the most important findings of the Delphi related to the initial lack of consensus, a similar lack of wear pattern agreement occurred with the larger main questionnaire, suggesting that the project could have commenced at this stage, without the Delphi. Insights provided by the Delphi participants would, however have been lost and the wear pattern comparison instrument produced during the Delphi rounds could not have been initially available to facilitate the analysis of the main questionnaire.

While the questionnaire surveys provided valuable data, they were depictions of, and not actual wear patterns and therefore held an additional potential for error. To have used actual patterns collected directly would not however have provided the insights obtained by the methods actually used into the state of professional knowledge in podiatry.

For the validation phase, the use of several video-recorders from different angles as opposed to one, to record components of movement in subjects' feet would have allowed easier subsequent analysis if this had been anticipated. Participating observers did, however, broadly agree with the freeze frame analysis undertaken.

The study was, however unique. If an alternative course had been taken during the project, different insights and findings may have arisen, with those occurring here not being seen.

4.42 The state of development of professional knowledge in podiatry

Knowledge limitations shown in podiatry

Professional knowledge and experience in podiatry were used throughout the research to formulate shoe wear pattern theories and validate them. The prevailing hypothesis was the"one condition, one wear pattern" hypothesis, which implied that different foot conditions (e,g, conditions affecting the big toe, like hallux rigidus and hallux valgus) would create observably different but specific shoe wear patterns. Although the primary focus was shoe wear pattern analysis, reliance on podiatrists' understanding and experience elucidated the current state of knowledge in podiatry. The initial Delphi exercise demonstrated that previously published interpretations of wear patterns were inaccurate in suggesting that a "one condition, one pattern" state existed.. There was also evidence that participants' own level of understanding was limited and lower than anticipated. In the pre-validation phase, Delphi participants aimed to produce statements of recognition for podiatric conditions, joint movement variations and foot/shoe match (Chapter 4.1, p. 80). This task proved difficult and many participants did not produce true statements of recognition. Other participants' statements disagreed with previously accepted non-researched textbook definitions, possibly indicating confidence in their own schemata (Elstein, 1979), or personal concepts and theories for problem solving, to challenge the authority of authors. Better results from subsequent inter-observer reliability tests than from similar tests previously undertaken with podiatrists (Curran and Jagger, 1997; Keenan and Bach, 1996) were attributed to work undertaken with this group to focus and stimulate development through the Delphi. Finally, participants' knowledge was found to be inadequate when independent pairs of observers reached agreement about descriptions of functions which proved to lack adequate detail when compared to sequential video frame analysis.

This revealed that knowledge in podiatry was lower than anticipated and could be improved through participation in activity that stimulated focus and reflection and resulted in the project producing an understanding in advance of that perceived to be attainable at the outset. This may be attributed to the stage of development of podiatry which is a relatively new profession first founded under a national body in 1912 (Dagnall, 1987). From that date, podiatry fervently sought full professional recognition with a specialist professional knowledge basis. Dagnall (1985) saw Charlesworths' book (1935) as demonstrating a striving for a wider scope of practice. Neale (1985) believed that the hallmark of a profession is the possession and utilisation of a corpus of specialist knowledge and skills and viewed refinements in orthotics and local anaesthesia as the principal technical advances in podiatry to help achieve these aims. Larkin (1983) noted that chiropodists had a need to prove their worth and that, at his time of writing, chiropodists had not developed their own science.

The challenge to biomechanics

Borthwick (1999) recently suggested that the development of biomechanics reflected a desire to establish a firm and rational basis for professional knowledge and status, later distinguishing between the older perceptions of foot mechanics and biomechanics, while noting that biomechanical theory and practice has been increasingly drawn into question. Traditional Rootian biomechanics are being challenged by new perspectives, particularly those of Dananberg (1986). While the SWaMP research showed compatibility with biomechanical theory, the holistic function-reflecting model proposed and validated presented a perspective within which Dananbergs' observations would be neatly encompassed. Dananbergs' work considered how foot function could circumvent blockages in the sagittal plane specifically from a proposed functional hallux limitus state (Payne and Dananberg, 1997). Such blockages would represent examples of the pathology hierarchy in the proposed model, with the foot function circumvention representing the primary walking intention. Dananbergs' observations included those involving direct effects of functional hallux limitus (1993) and those without any direct effect from this condition (Payne and Dananberg, 1997) and therefore comply with the theory represented by the model. Biomechanics may represent factual observations, but these observations may not integrate as a system useful to working clinical podiatrists.

In the haste to establish itself as a profession, podiatry may have incorrectly placed too great an emphasis on theoretical biomechanics instead of developing a simple working explanation of clinical function. Eraut (1994) referred to a similar situation in orthopaedic surgery, where working orthopaedic surgeons could not make specific, theoretical knowledge from biomechanical engineering and instead used simple implicit images to retain tacit knowledge required in practice without requiring explicit knowledge of exact formulae. In the podiatry situation, the proposed model of understanding is simple to convey and conceptualise, and directly relevant to practice, while remaining compatible with biomechanical principles.

Forms of professional knowledge in podiatry

Eraut (1994) distinguished between theoretical and practical knowledge in professions. While the technical knowledge basis of podiatry did not provide an explanation for shoe wear pattern formation, similar limitations were noted in the practical knowledge of all participants, which did, however improve through participation. Again, past podiatry authors, Delphi participants and questionnaire respondents were all shown to have poor understanding of wear patterns and little experience in using them. While the claimed authority of authors of textbooks is very worrying, several factors may have contributed towards this. As a relatively new and under-resourced profession with a limited research base, podiatry may not yet have developed to a level allowing deeper understanding. Fleming (1994) described tacit knowledge as being acquired through experience, which in turn requires reflection on that experience. Eraut (1994) referred to expert performance as being ongoing and non-reflective. Expertise is therefore developed through gaining experiences with reflection to the point where reflection is no longer required. As podiatry requires a high degree of skill in instrument manipulation, it may be possible that podiatrists perceive personal expertise on a basis of physical dexterity which may then limit self reflection of diagnostic aspects of treatment, echoing the traditional model of chiropody practice. As it has been shown that podiatrists achieve immediate patient satisfaction through pain relief (Redmond, Allen and Vernon, 1999), reflection may be based on this instant success, ceasing with the gaining of expertise in this treatment, and, therefore limiting more detailed and long term care reflection. This again suggests that podiatry, in common with other health care professions, is in an immature state of development of professional knowledge.

Knowledge is understood to consist of "scientific" or empirically derived and theoretical knowledge and "pre-scientific" knowledge or knowledge of every day practices (Frolov 1984). According to Parry (2000), educators and educationalists in the health care professions have only lately begun to articulate the distinction between knowledge that underpins practice and enables action and professional 'know how' that is inherent in action. While *knowing that* (Ryle, 1949), the publicly available propositional knowledge for teaching and learning, includes articles in professional journals, audit reports, course handouts and so on; it has largely been borrowed from cognate areas with better developed research and scholarship. *Knowing how* is non-propositional knowledge acquired by practitioners through practice and experience and may be tacit knowledge (Polyani, 1967), what practitioners know but cannot tell.

Understanding "tacit" knowledge in podiatry; a model to inform clinical decision making

The incorrect gait observations agreed by participants in the validation phase imply that the practical knowledge basis of podiatry is not well developed. Eraut (1994) described medicine as a field where decisions have to be made under conditions of considerable uncertainty. The implication is that podiatry has followed the medical model in striving for professionalisation, focusing on the person and ignoring more distant, but potentially valuable footwear assessments which could have reduced uncertainty. Consequently, interpretations were incorrect in the validation phase, due to inadequate detail being discernible through simple participant observation. Without specialised equipment, shoe wear patterns could be used to give greatly improved evaluations of function to inform diagnostic and subsequent treatment decisions. This suggests that a specific podiatry model of clinical decision making would have greater value than one mimicking the medical professions.

Podiatry knowledge may, have been lower than expected in this study due to the relative infancy of the profession, impaired reflective development, the questionable basing of professional expertise on biomechanical theory as opposed to a more practically oriented model involving footwear considerations, and possible over-emphasis on the medical model of decision making in functional diagnosis. Professional craft knowledge and expertise in podiatry was however revealed. Eraut (1994: 15) asserted that there is "increasing acceptance that important aspects of professional competence and expertise cannot be represented in propositional form and embedded in a publicly accessible knowledge base". The challenge therefore is to identify what might be revealed and the possible strategies for doing so, with the problem lying in the translation of "tacit" professional craft knowledge into a form which can be taught and learned. The research has succeeded in this task, producing the wear pattern evaluation instrument and model of shoe wear influence as the foundations of propositional understanding.

4.43 The thesis summarised

The final validation phase grounded the project theories through demonstrating their applicability in real life situations within the context of podiatry practice. In doing so, the theory limitations of wear pattern legibility and potential for amendment were demonstrated. The theories were also expanded by providing further insight into the level to which external factors must be present in order to influence function and therefore shoe wear patterns. Together, the instrumental device (to aid the interpretation of shoe wear patterns) (Diagram 3) and the model (to suggest levels of influence over shoe wear pattern formation) (Diagram 14) represent the following theoretical statement:

"Shoe outsole wear patterns primarily result from foot and lower limb function and this function is represented by combinations of focal points of wear; the areas from which the wear spreads. While anatomical and morphological factors (including foot pathologies) may influence wear, it is their effect on the primary walking intention which causes this influence. External factors may also influence

the wear pattern, but must be present to a proportionally high degree to exert an effect. Wear extending beyond the focal points is superfluous to such interpretation."

The presence and effects of variables are fundamental to the understanding of shoe wear patterns. Two forms of variable were shown which could influence shoe wear patterns, i.e.:

- **Non-confounding variables** (those which do not amend focal point combinations, but act on the peripheral spread of wear). Examples may include footwear age, shoe sole material and predominant surface walked on (e.g. carpet, hard tarmac).

- **Confounding variables** (those which amend focal point combinations). These may be considered intrinsic (holistic function variations including pathology effects) or extrinsic (from external influences and non-walking functions and are non-pathology related). Intrinsic variables would include alternative functions with defined pathologies and direct effects of foot pathologies. They occupy the top two tiers of the model representing a hierarchy of shoe wear pattern influence (Diagram 14). Extrinsic variables would include footwear restrictions, habit, occupation or chosen changes in ambulatory form (e.g. running) and occupy the bottom tier of this hierarchy.

4.44 The future value of shoe wear patterns in podiatry

The accepted "one condition, one wear pattern" hypothesis has been disproved and replaced by a "function, pattern" theory which has greater value in podiatric diagnosis. This theory offers podiatrists a taxonomy that is based in podiatry rather than medicine. This provides a more relevant paradigm (i.e. the model of wear pattern influence) on which to base the practice of podiatry, which shows the factors of greatest influence over the functioning foot. This taxonomy also suggests the foot problems which should be amenable to remedy (i.e. factors of external influence) and those which may require longer term, more complex intervention (i.e. primary walking intention factors). By understanding the context within which a wear pattern has formed, the podiatrist can use the pattern to predict the causative function, with greater accuracy than by direct observation and at less cost than methods of analysis using force plate technology. This means that improved functional assessment in routine clinical situations will allow clinicians to be more effective in patient management where functional control or amendment is required. While the technique cannot be used if wear is not present or discernible, or where the pattern may have been amended by extrinsic factors, there is a potential for the development of rapid wearing temporary outsoles which may be used to provide wear pattern information quickly and cost-effectively. In time, it is conceivable that computer programmes could be written to provide the function prediction automatically when wear pattern co-ordinates and contextual data are entered into the programme, providing an accurate basis for required orthotic manufacture. Further research is however now required into the optimum treatments required by each class of foot function.

4.45 The future value of shoe wear patterns in forensic identification

It is now possible for shoe wear patterns to have limited use in forensic identification. The instrumental device allows patterns to be compared and conclusive statements to be made as to whether two separate patterns have the same pattern form or not, improving the value of shoe wear patterns at class characteristic level. This is however again dependent on patterns being present and discernible. Further research is required into the frequency of occurrence of pattern forms; if some patterns prove to be highly individual, then their value in identification will be enhanced.

While forensic scientists would benefit from being able to interpret shoe wear patterns in isolation (i.e. from a footprint or shoe without the availability of the owner), the research has demonstrated that this cannot be undertaken with certainty. The enhanced knowledge of shoe wear pattern production will however prevent repetition of the past errors in the forensic field, involving attempted pattern interpretation. If a pattern can be discerned and a suspected wearer of the footwear found and examined, then the shoe and wearer could be associated through the function suggested by the pattern.

A functional match could provide identification support, but again currently as a strong class and not a unique characteristic. The use of the predictive effect of shoe wear patterns in this way would be valuable in not requiring the shoe producing a print to be found in order to provide a potential link with the owner. Further research into the frequency of occurrence of pattern forms and holistic function could enhance the value of this assessment technique in identification further, if unusual forms of function can be demonstrated.

4.46 Further research

Many areas for further research are suggested by the study. Professionally, the relevance of Rootian biomechanics to clinical practice requires in-depth investigation, as does the suggestion that self-reflection may cease in podiatry to its' detriment, when instrument manipulation expertise is gained. In podiatry practice, research is now required into whether the various forms of function noted in this study can be accurately classified and similarly, whether the model of wear influence can form the basis of a taxonomy system for conditions and influences encountered in practice. While the predictive value of wear patterns has been validated, comparison with more detailed function assessment techniques is now indicated and studies of the nature of the forces acting on the outsole in producing wear patterns would be of interest. Forensically, the levels of individuality expressed by wear patterns now require investigation and comparison of the functionally produced wear patterns with insole impressions for possible correlation would be useful. Finally, there is a potential for useful technologies to be developed from the theories including rapid wearing outsoles and predictive software systems of analysis to assist with diagnoses and scanning techniques to provide instant wear pattern coding references for interpretative use.

This first formal study of shoe wear patterns which highlighted the immature stage of professional development of podiatry has produced knowledge which will improve the value of wear pattern assessment in clinical and forensic situations. This value now has the potential to improve further as additional research and development is undertaken in this area.

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THE FUNCTIONAL ANALYSIS OF SHOE WEAR PATTERNS: THEORY AND APPLICATION

Denis Wesley Vernon

A thesis submitted in partial fulfilment of the requirements of Sheffield Hallam University for the degree of Doctor of Philosophy

September 2000

Vol. 2

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ILLUSTRATIONS

DIAGRAMS

DIAGRAM 1 Comparison of past published wear pattern sketches

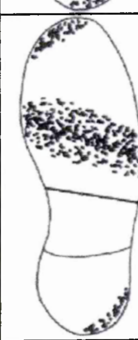
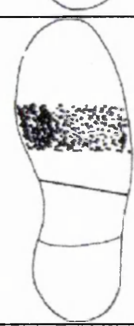
	Outsole wear patterns depicted for foot pathologies by author				
Foot pathology	Gibbard	Hanby and Walker	Turchin	Napier	Lucock
Normal foot					
Hallux rigidus					
Hallux valgus					
Overloaded metatarsals					
Pes cavus					

DIAGRAM 2 Sequence of progression of the research

Phase	Methodology	Methods	Findings
Phase 1 - Description	Consensus survey	Delphi technique	Wide ranges of patterns can be associated with single foot pathologies Patterns can be described and compared instrumentally using focal point concept
⇓			
Phase 2 - Interpretation	Surveys	Questionnaire (with inductive analysis)	Hierarchy of wear influence factors suggested – 1. Primary walking intention 2. Foot pathology 3. External factors *(in descending order of influence)*
⇓			
Pre-grounding preparation	*Consensus survey* *Case study observation*	*Delphi technique* *Inter-observer reliability trials*	*Broad agreements only achieved* *Challenge to previous definitions* *High levels of agreement seen through Delphi focusing exercise and expert selection*
⇓			
Phase 3 - Grounding	Case study	Structured observation Semi-structured interview	Focal point concept validated Model of influence validated and expanded

DIAGRAM 3 Instrument for the description and comparison of shoe wear patterns

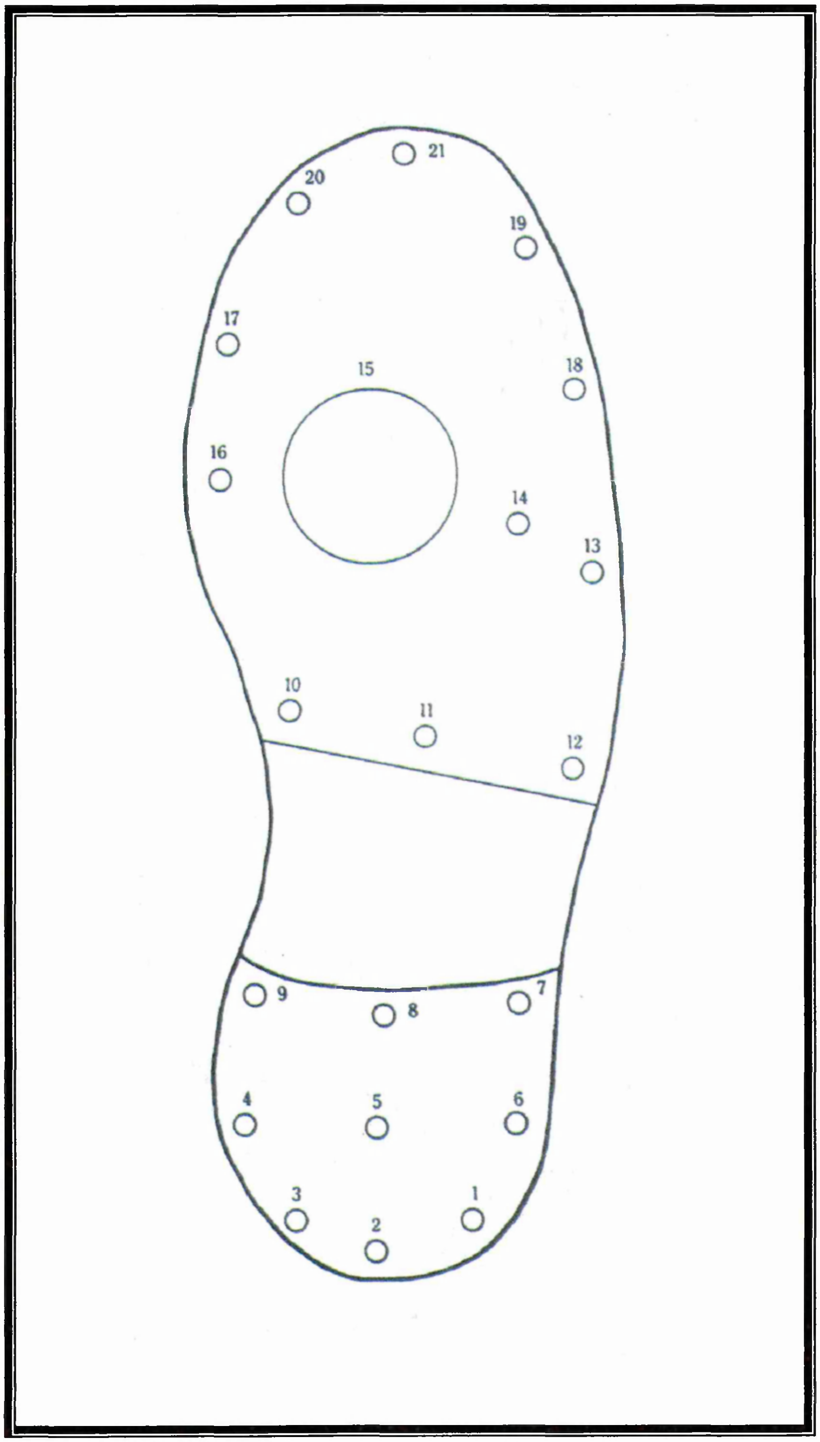


DIAGRAM 4 Blank outsole outlines which participants provided wear pattern depictions on

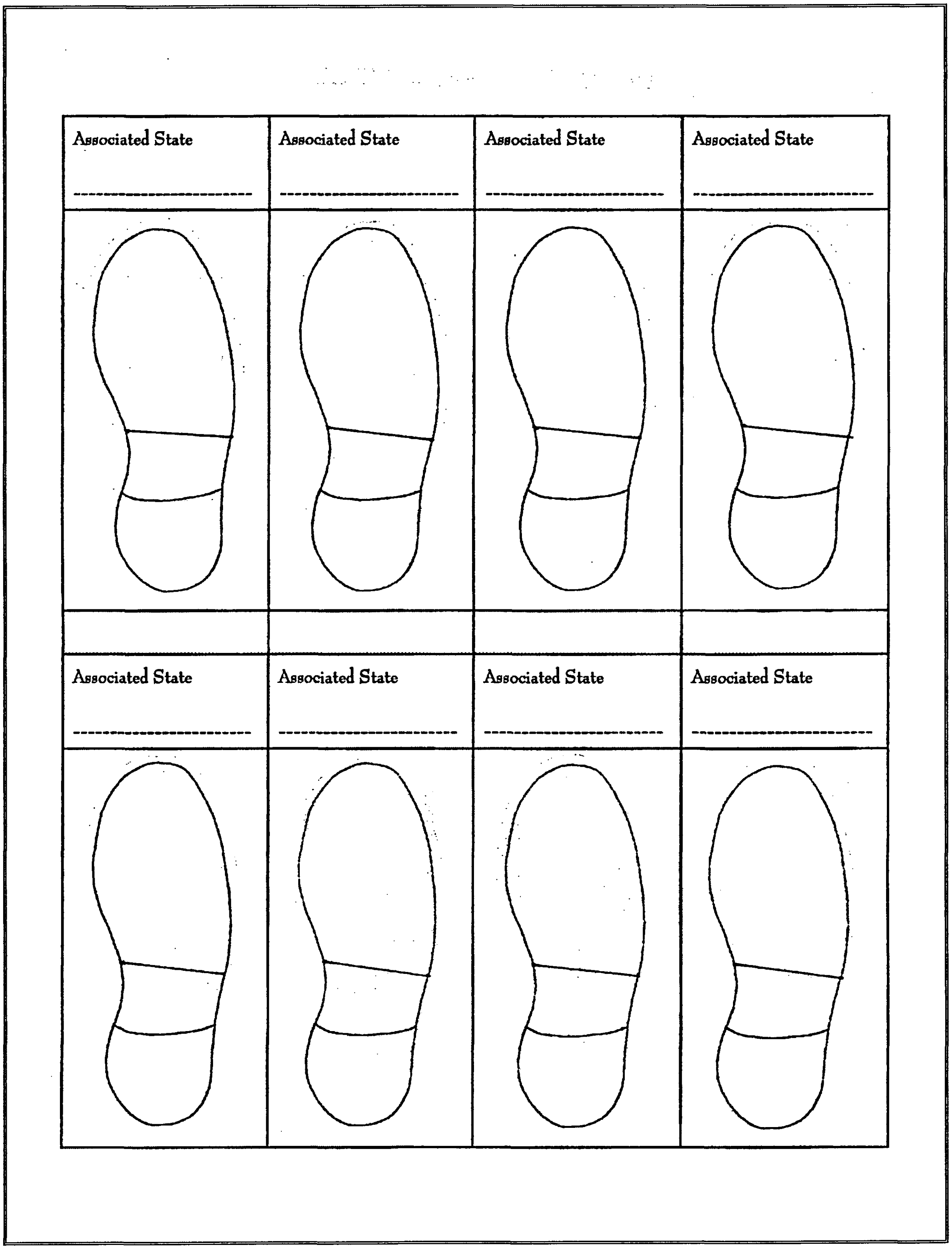
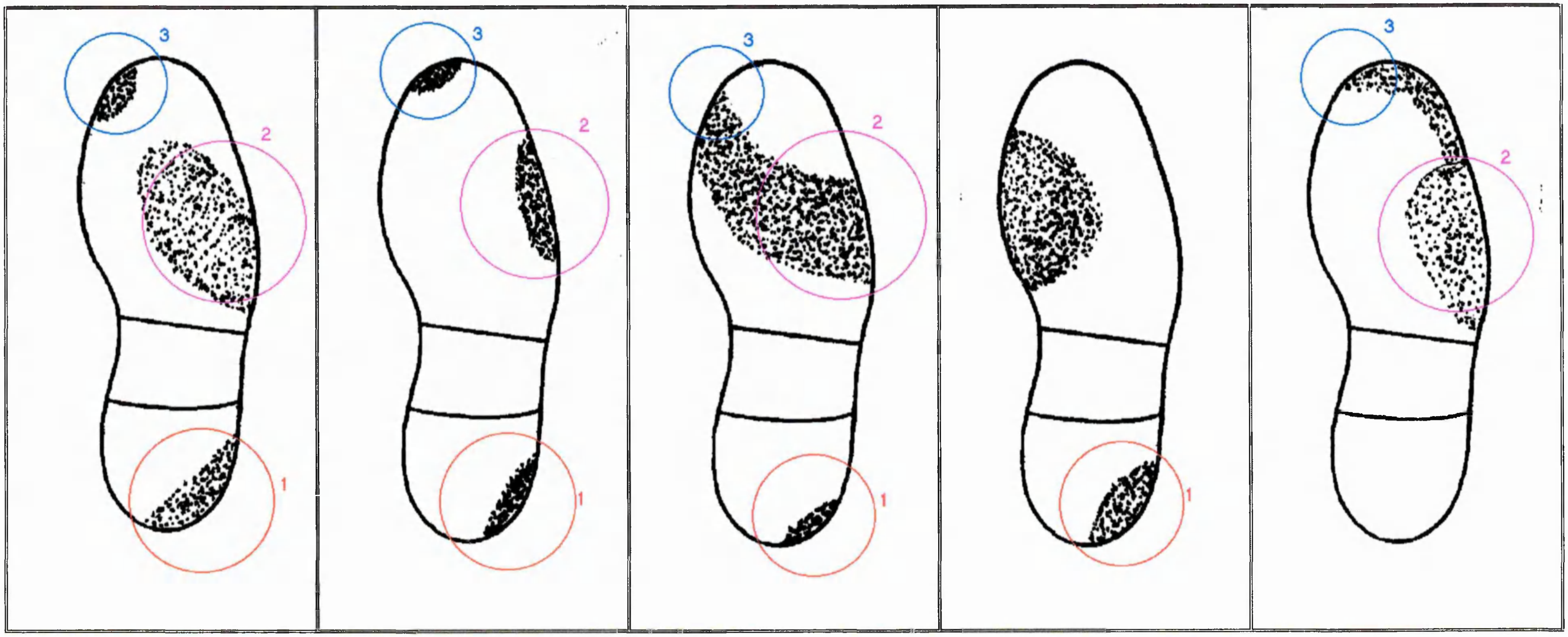


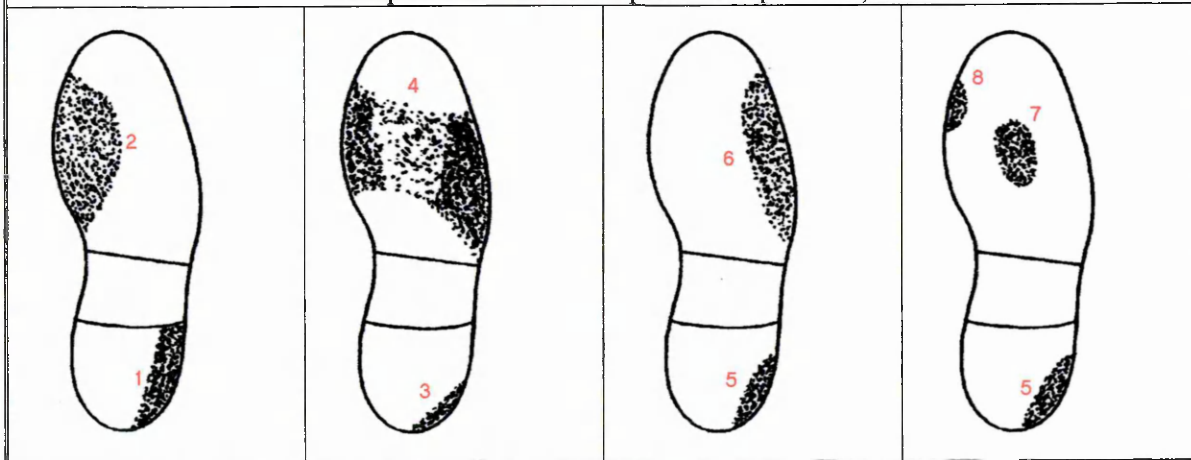
DIAGRAM 5 Example of common wear areas presented by respondents for hallux rigidus



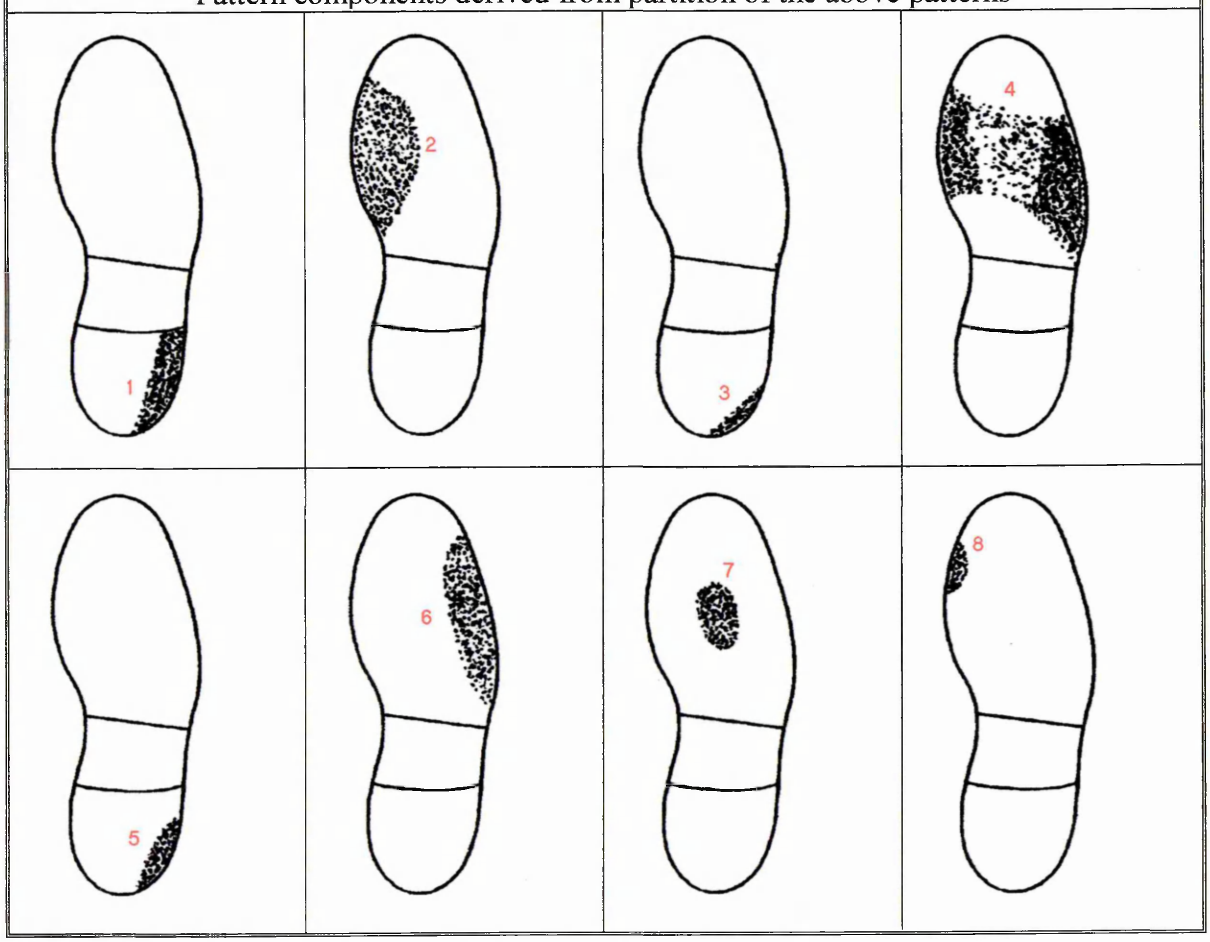
1 (Wear Post./lat. heel)
2 (Wear of 5th MPJt)
3 (Wear of 1st toe area)

DIAGRAM 6 Examples of breakdown of patterns into pattern components

Rearfoot Varus pattern examples prior to separation into pattern components (with components numbered prior to separation)



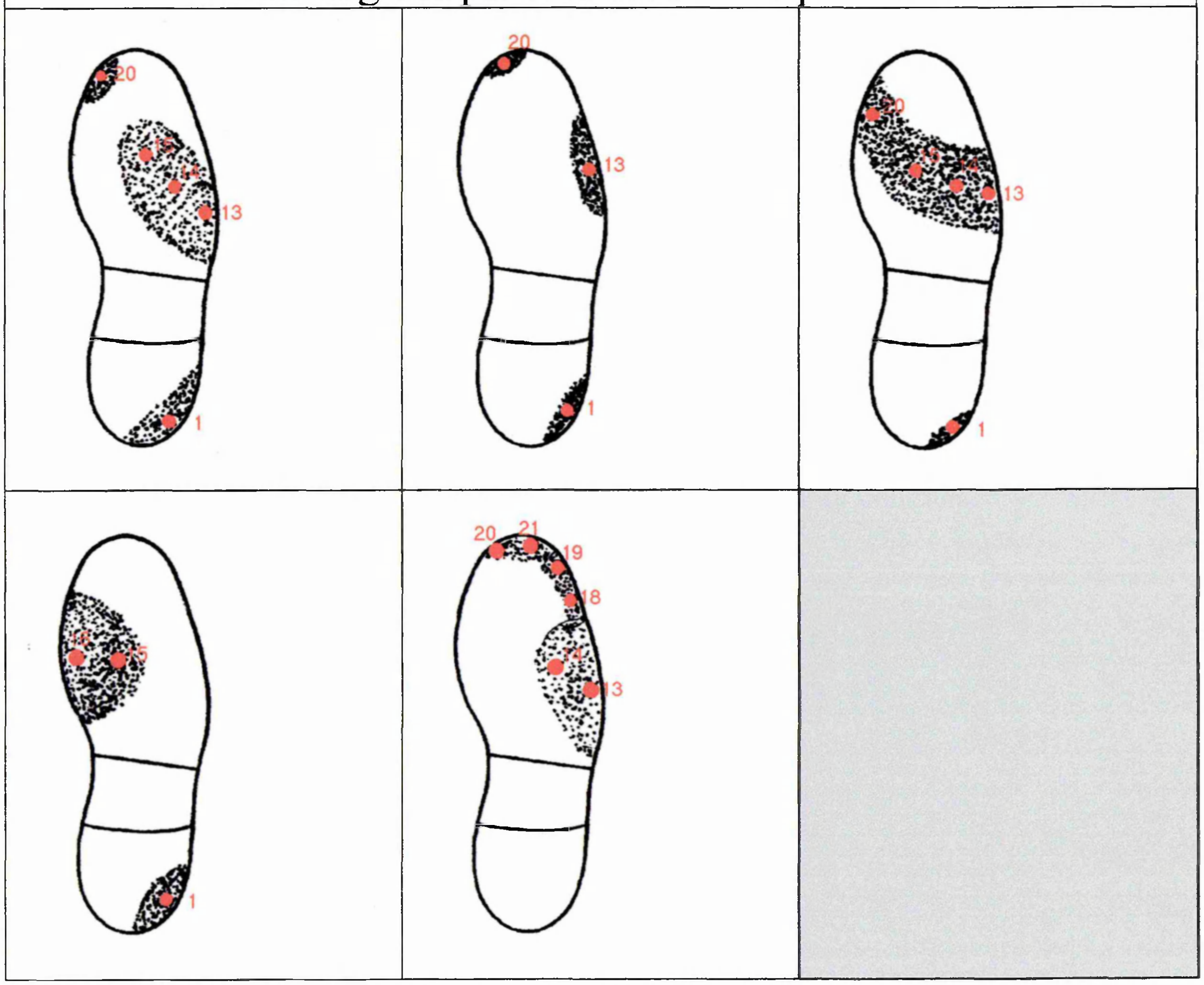
Pattern components derived from partition of the above patterns



1,2,3, etc. = pattern component numbers

DIAGRAM 7 Similarities observed between the locations of wear pattern components of the shoe outsole

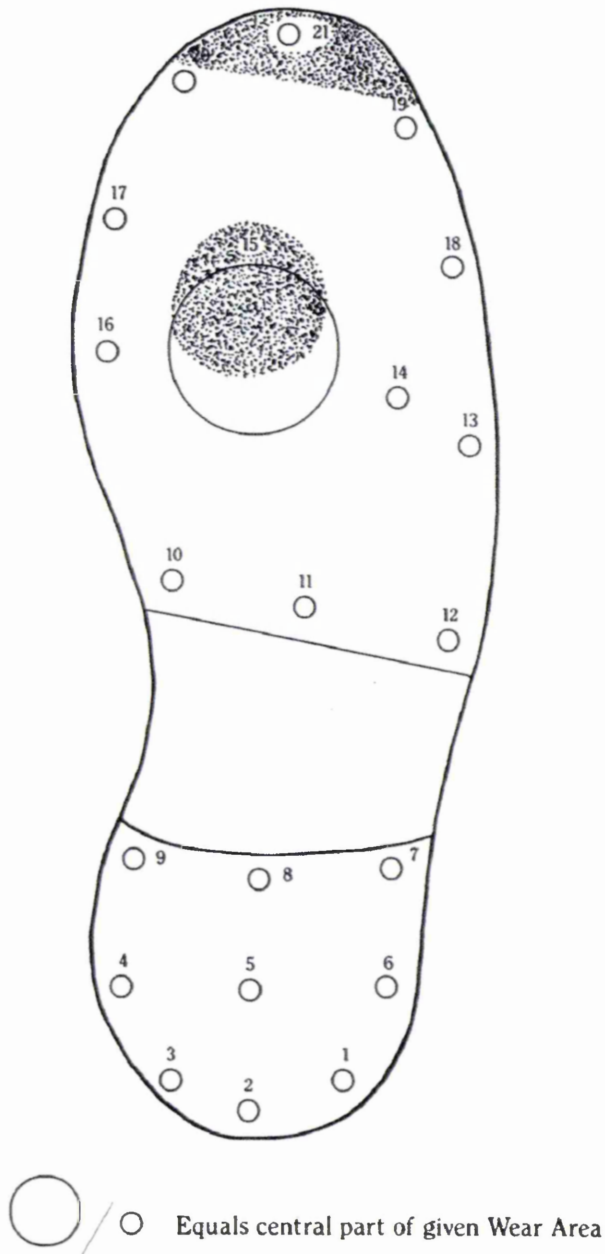
Hallux rigidus patterns used in Delphi round 2



= Focal points, i.e. positions suggested within pattern components from which the areas of wear appeared to have spread.

1,13,20, etc. = Common numbers across patterns suggest common focal point positions.

DIAGRAM 8 Example of instrument in use with pattern 7



Code recorded = 15/21

DIAGRAM 9 Collation card used for data analysis

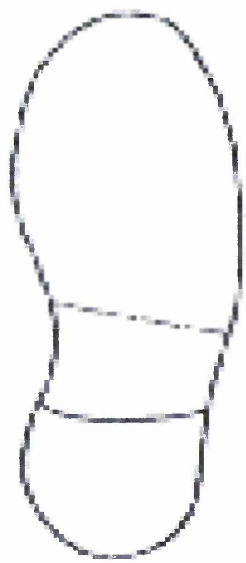
I/D *(e.g. HR 48/3)*
Sub Theme *(e.g. Abducted gait)*
FPCode *(e.g. 1/9/16/17/20)*


DIAGRAM 10 Factors considered when contemplating functions associated with wear patterns within a known context

In order to classify foot function the following aspects were considered :

<table>
<tr><th>ASPECT FOR CONSIDERATION</th><th>MINUS</th><th colspan="2">CENTRAL DESCRIPTION</th><th>PLUS</th><th>ADDITIONAL COMMENT</th></tr>
<tr><td>Gait Angle</td><td>Adducted</td><td colspan="2">Normal</td><td>Abducted</td><td></td></tr>
<tr><td>Rearfoot Inclination</td><td>Inverted</td><td colspan="2">Normal</td><td>Everted</td><td>Everted = Unstable</td></tr>
<tr><td>Forefoot Inclination</td><td>Inverted</td><td colspan="2">Normal</td><td>Everted</td><td>Everted = Unstable</td></tr>
<tr><td>Heel to Forefoot Angle</td><td>Low</td><td colspan="2">Normal</td><td>High</td><td></td></tr>
<tr><td>Torsional Effects</td><td>Adductory Twist</td><td colspan="2">Normal</td><td>Abductory Twist</td><td></td></tr>
<tr><td>Forefoot Curvature</td><td>Concave</td><td colspan="2">Normal</td><td>Convex</td><td></td></tr>
<tr><td rowspan="3">DIRECT PATHOLOGICAL EFFECT</td><td colspan="3">Anticipated</td><td colspan="2">Not anticipated</td></tr>
<tr><td colspan="3">Restrictive (Pathology allows effect by causing deviation)</td><td colspan="2">Submissive (Pathology allows effect through excessive passivity)</td></tr>
<tr><td colspan="2">Corrected (Opposing sign through foot attempting to do the opposite)</td><td colspan="2">Controlled (indirect sign through other aspect of foot attempting control)</td><td>Accommodated (no sign – anticipated)</td></tr>
</table>

(This system may have the potential to form the basis of a sub-classification system for the podiatric description of states affecting the foot).

DIAGRAM 11 Basic model of hierarchical relationship of shoe wear influence

	Source of influence	Descending order of influence
Holistic function	Primary walking intention	↓
	Foot pathology	
	External factors	

DIAGRAM 12 Shoe wear pattern influences

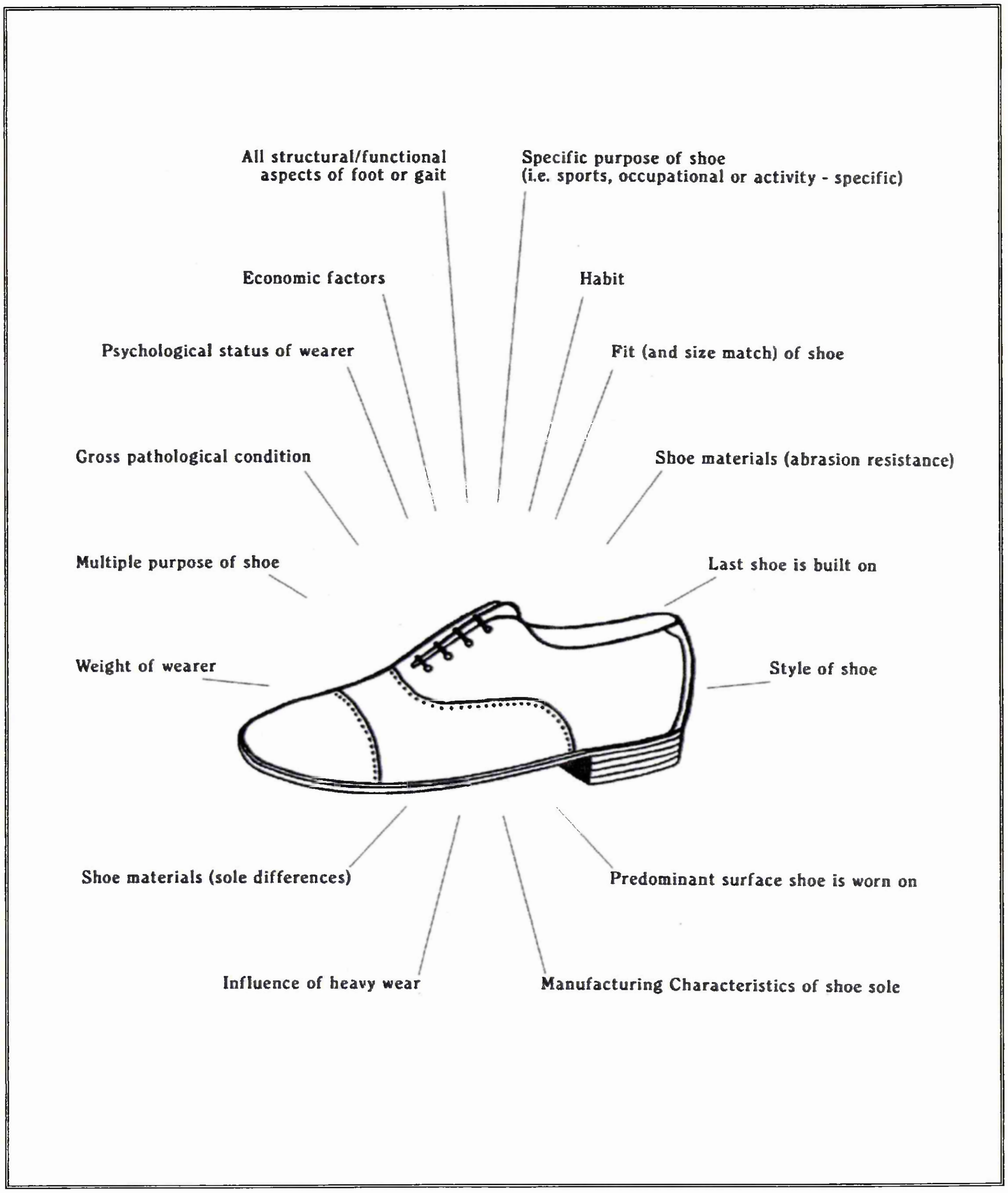


DIAGRAM 13 Functions suggested for subjects examined in the validation phase

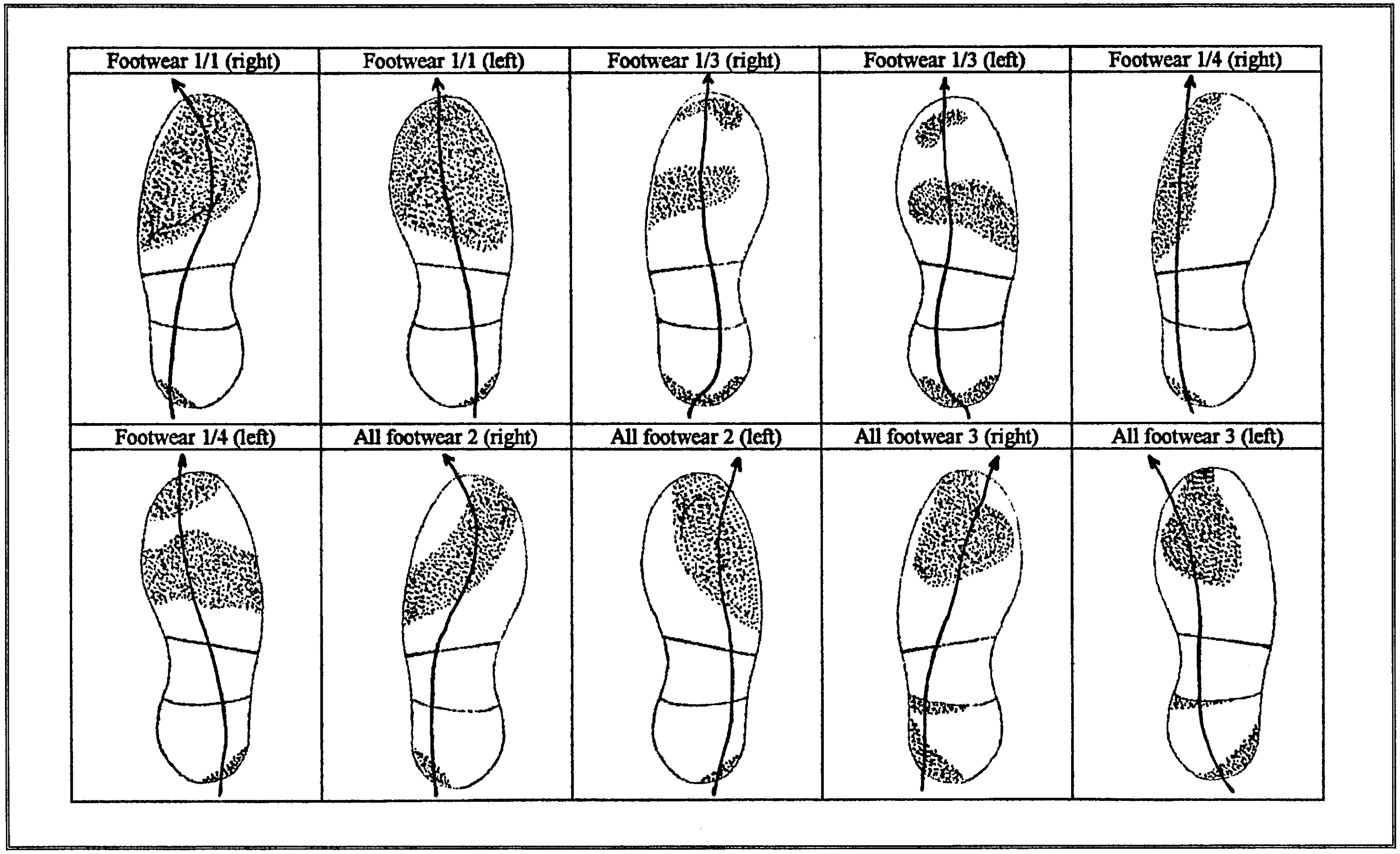
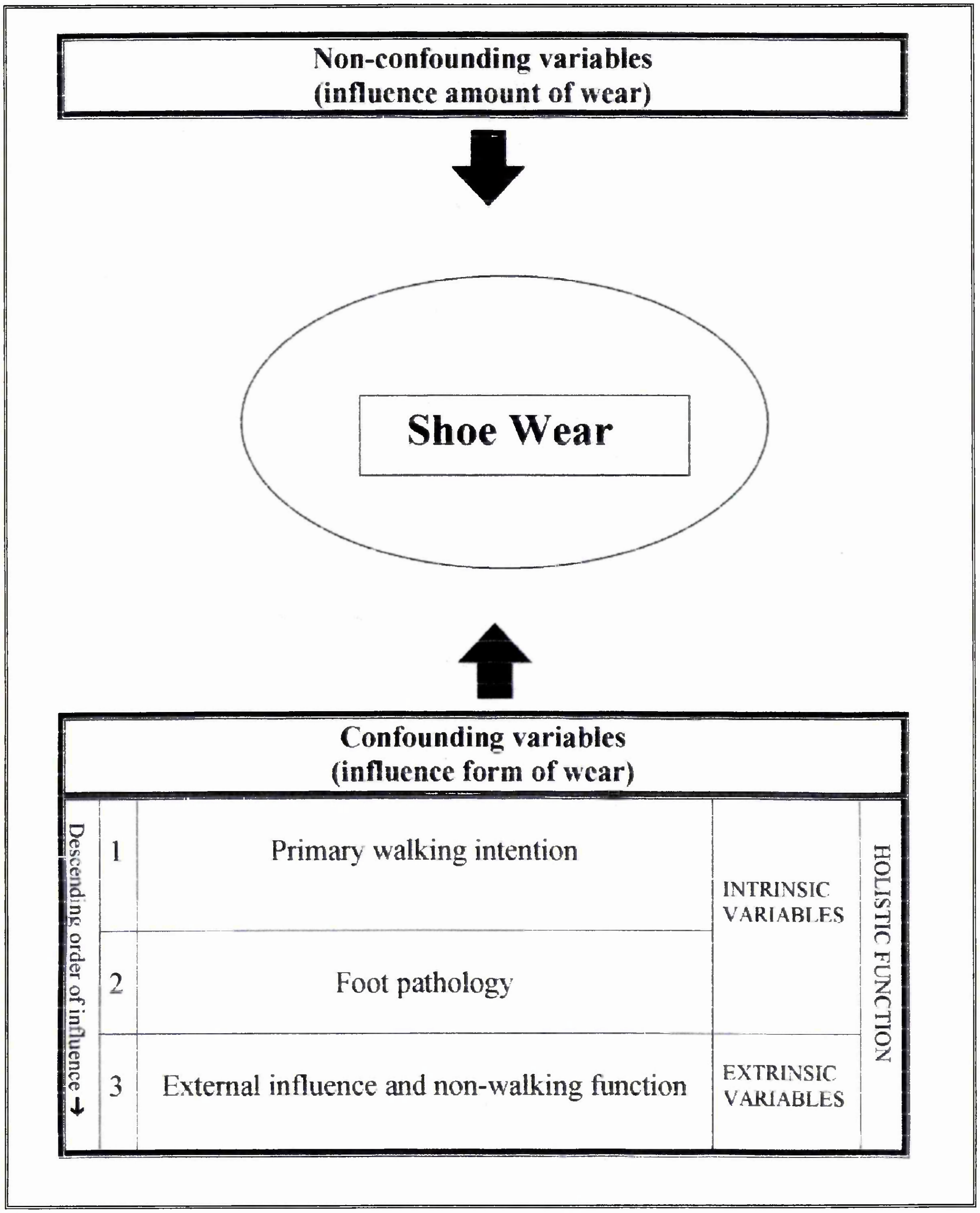
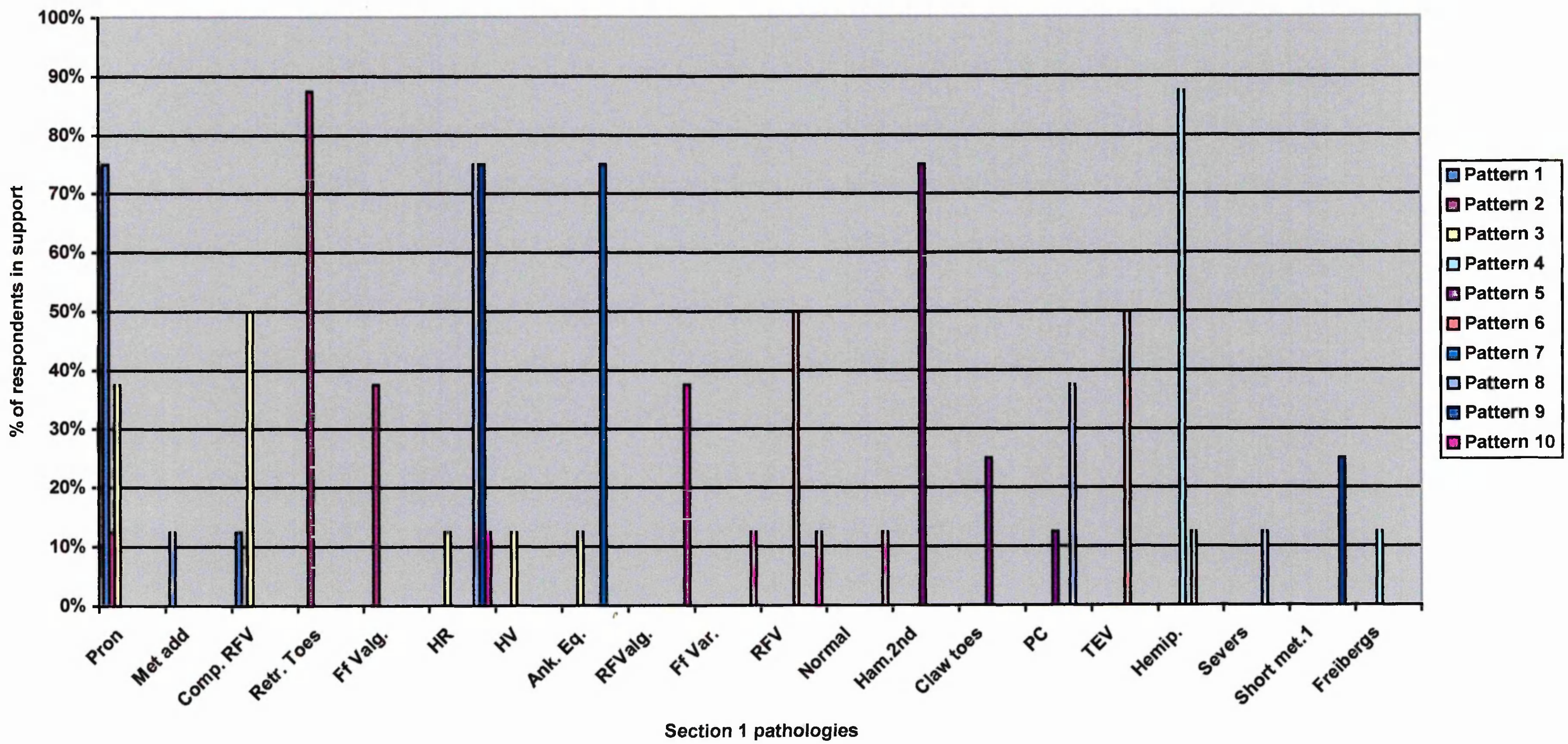


DIAGRAM 14 Model of shoe wear pattern influence

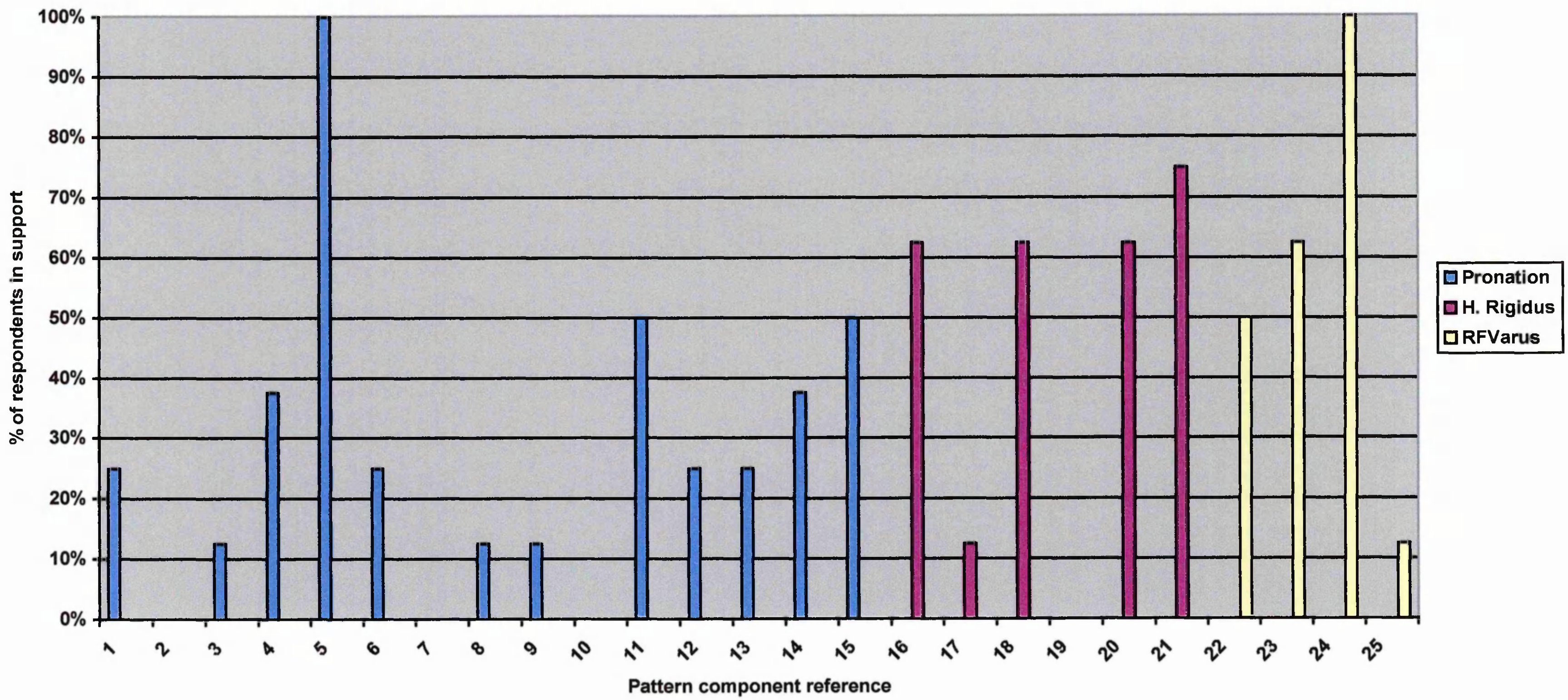


GRAPHS

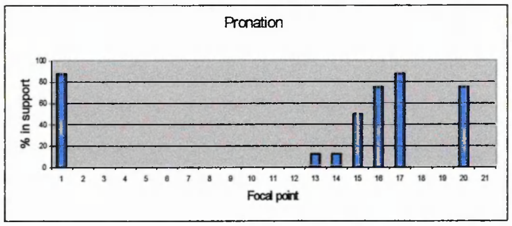
GRAPH 1 Face level consensus in Delphi round 2, section 1

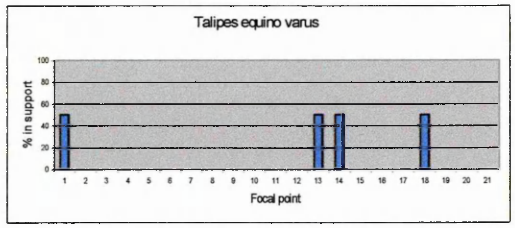


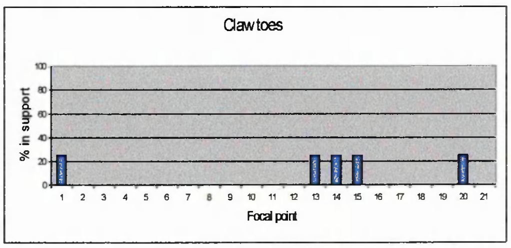
GRAPH 2 Face level consensus in Delphi round 2, section 2

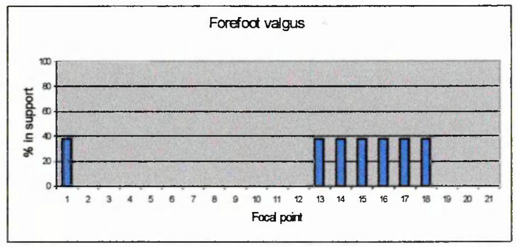


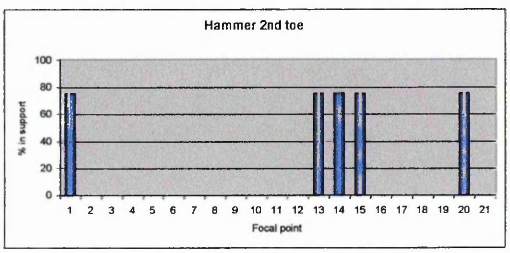
GRAPH 3 Hidden levels of focal point consensus in Delphi round 2, section 1

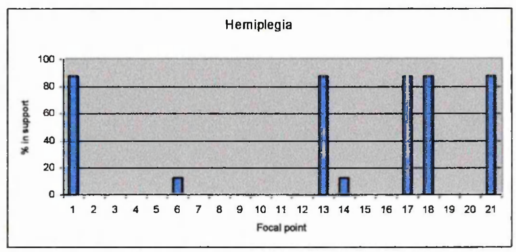


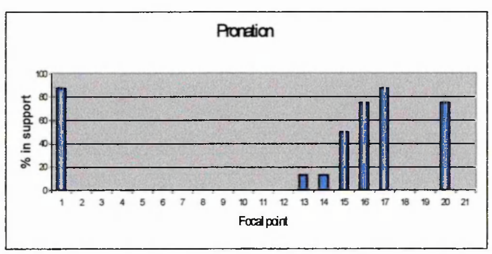




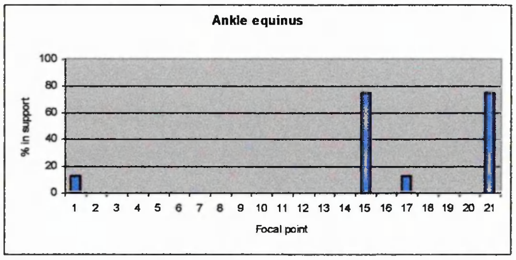


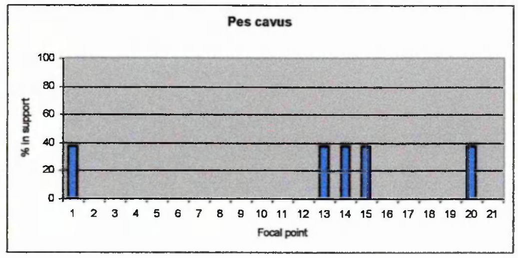


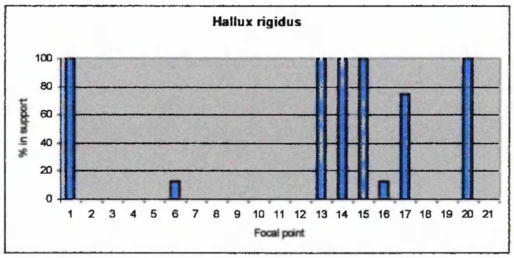


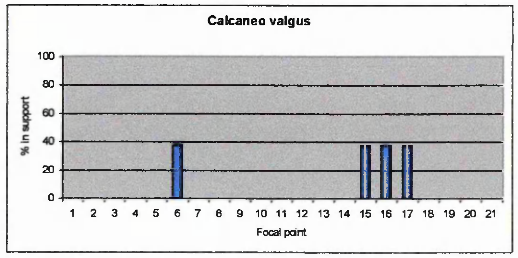


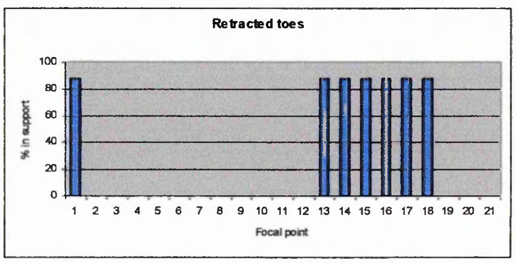
GRAPH 3 - contd.

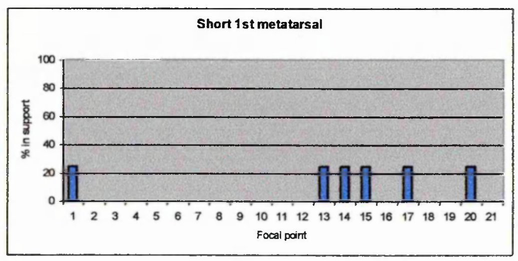


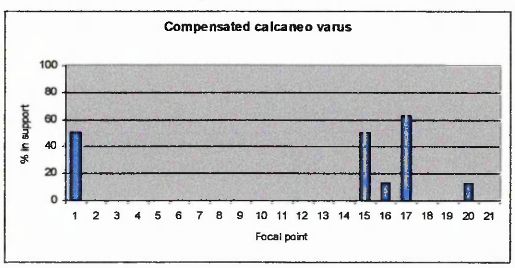












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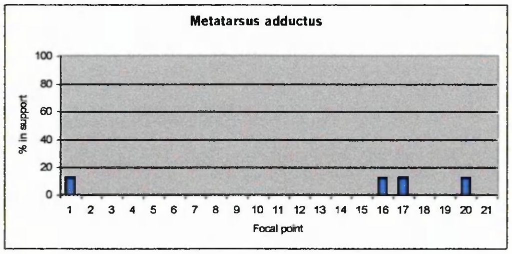
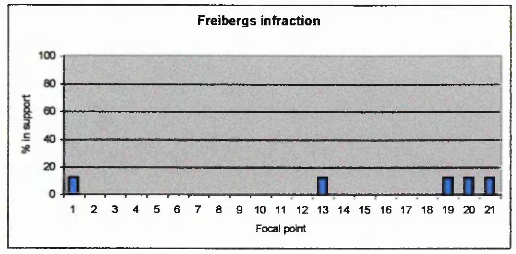
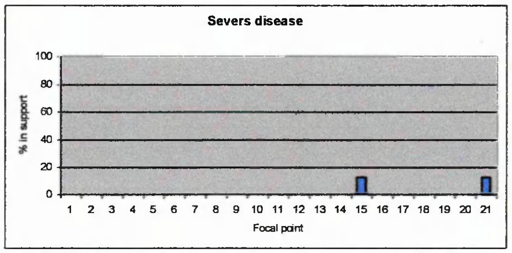
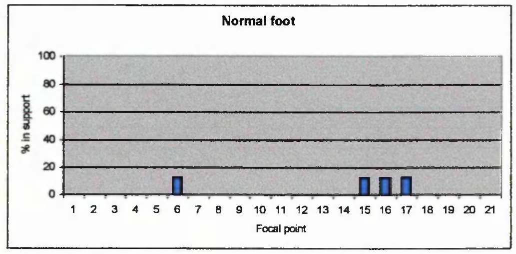
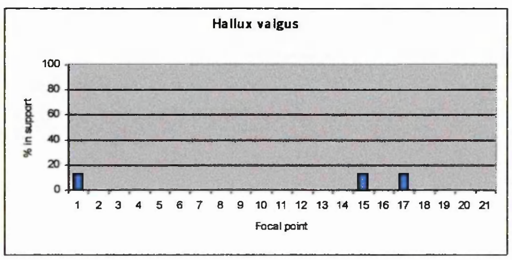
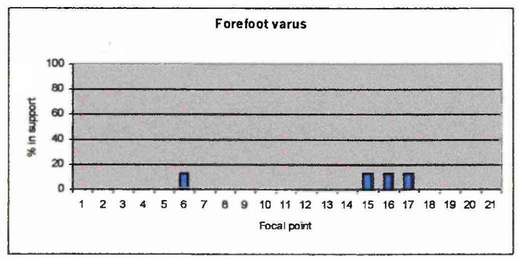




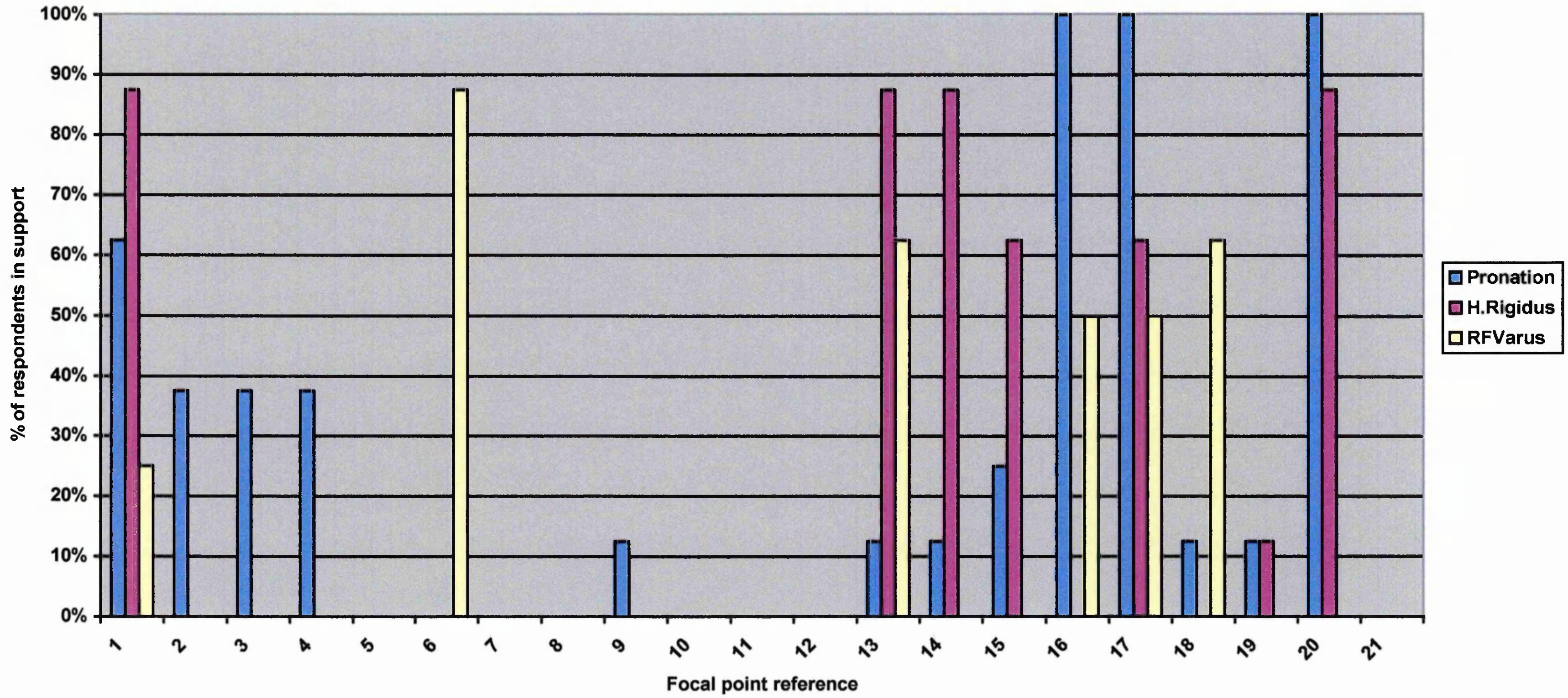




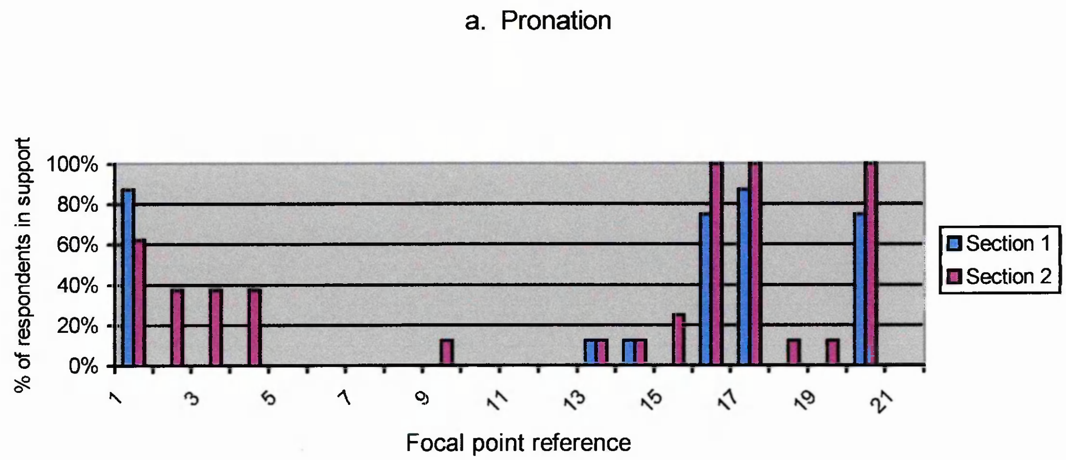


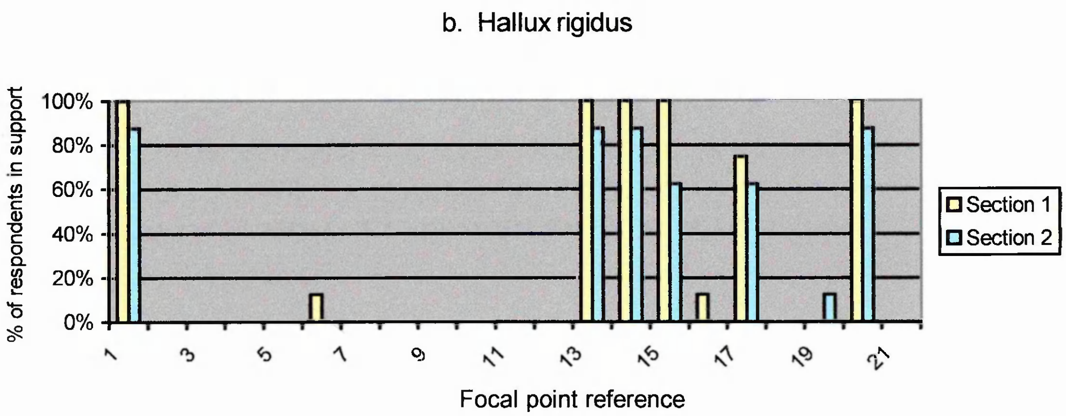


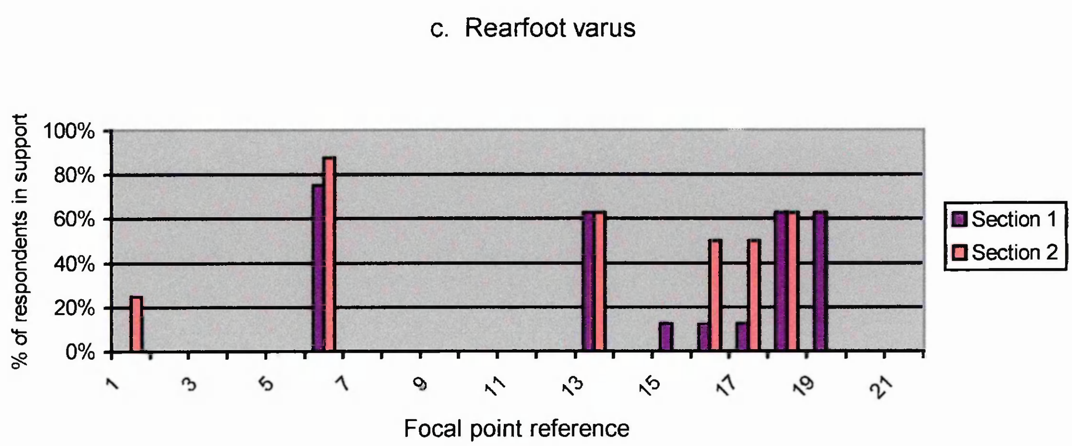
GRAPH 4 Hidden levels of focal point consensus in Delphi round 2, section 2



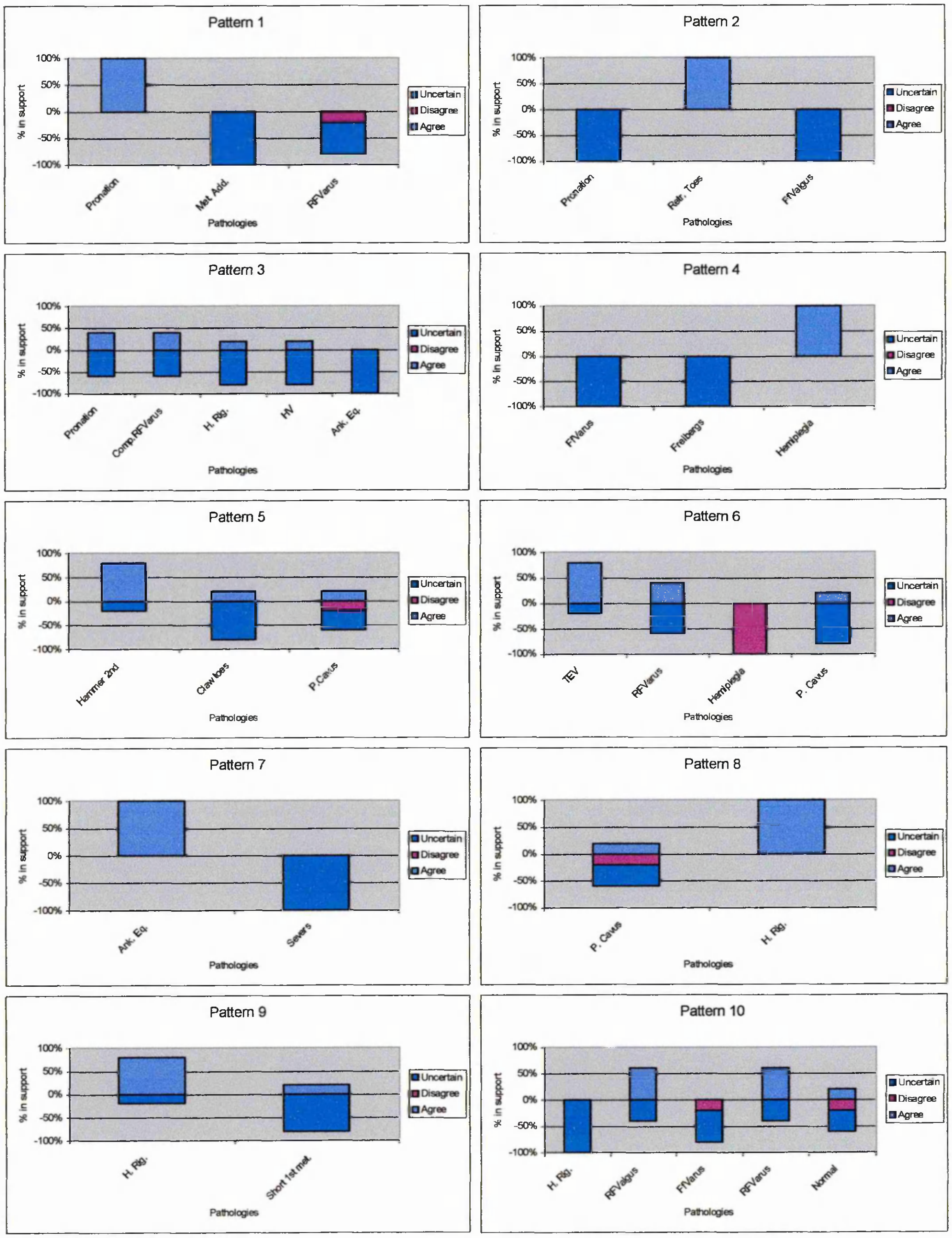
GRAPH 5 Comparison of focal point agreements between pathologies common to sections 1 and 2, Delphi round 2



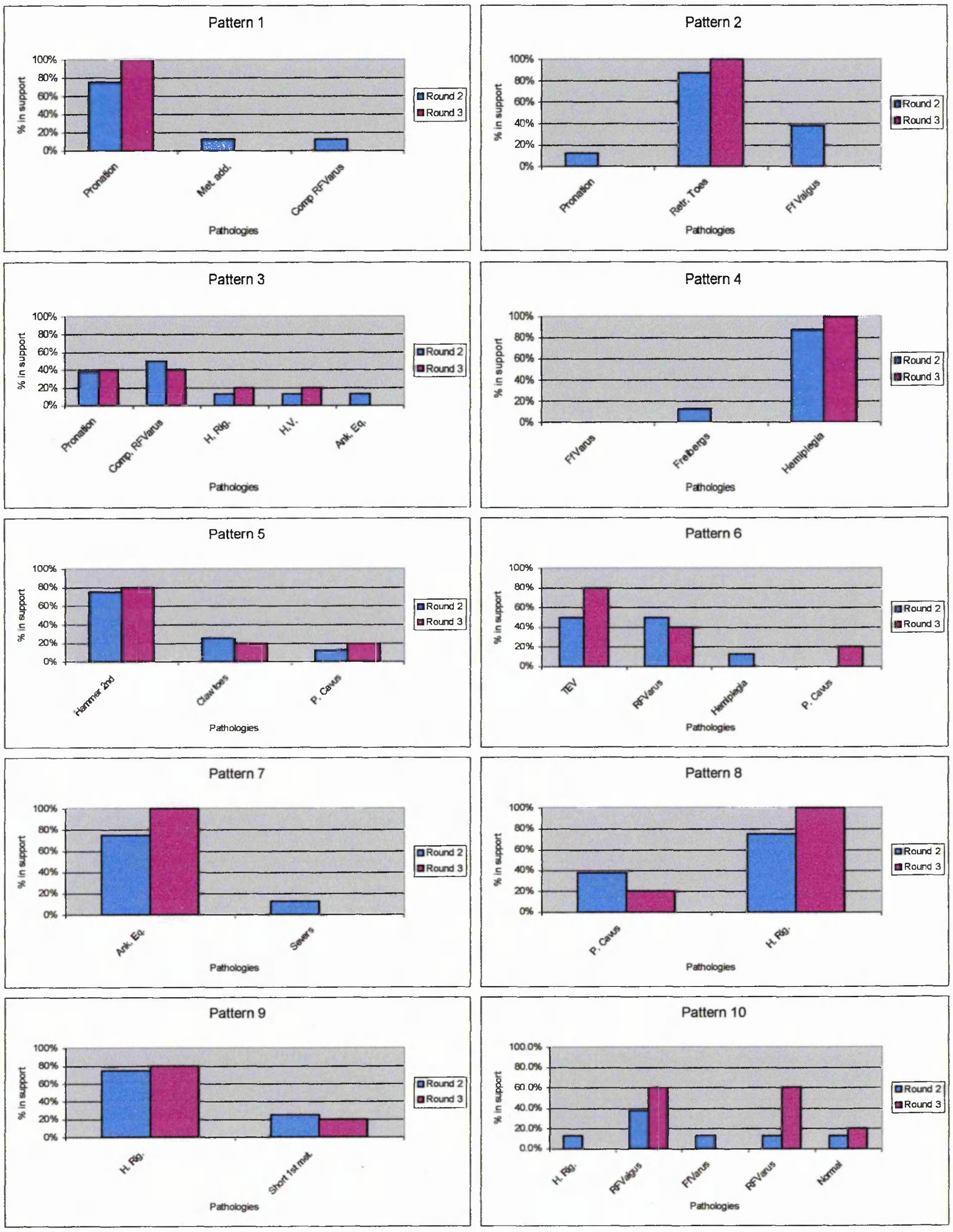




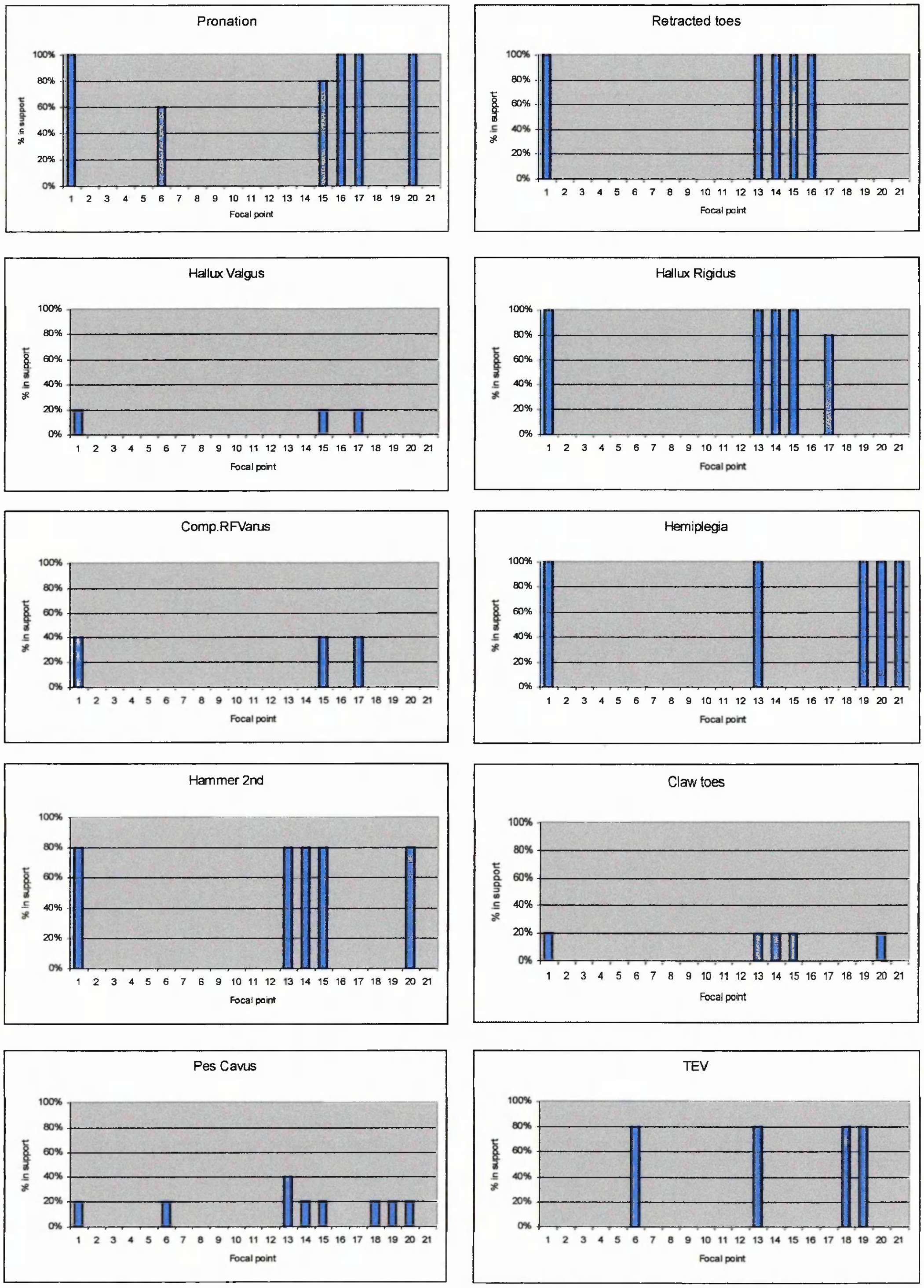
GRAPH 6 Delphi round 3, section 1 face consensus achieved



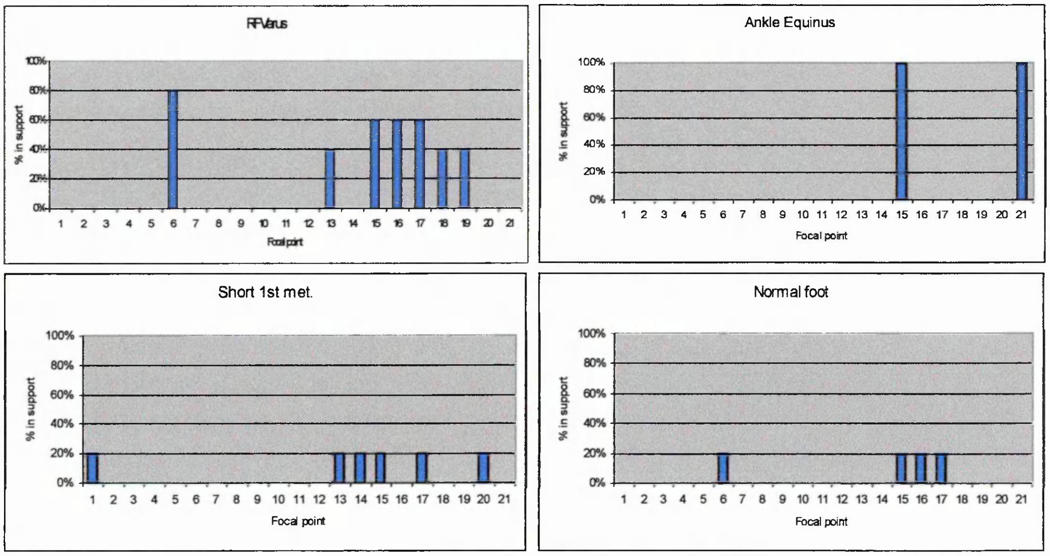
GRAPH 7 Delphi round 3, section 1 – comparison of face level consensus with round 2, section 1



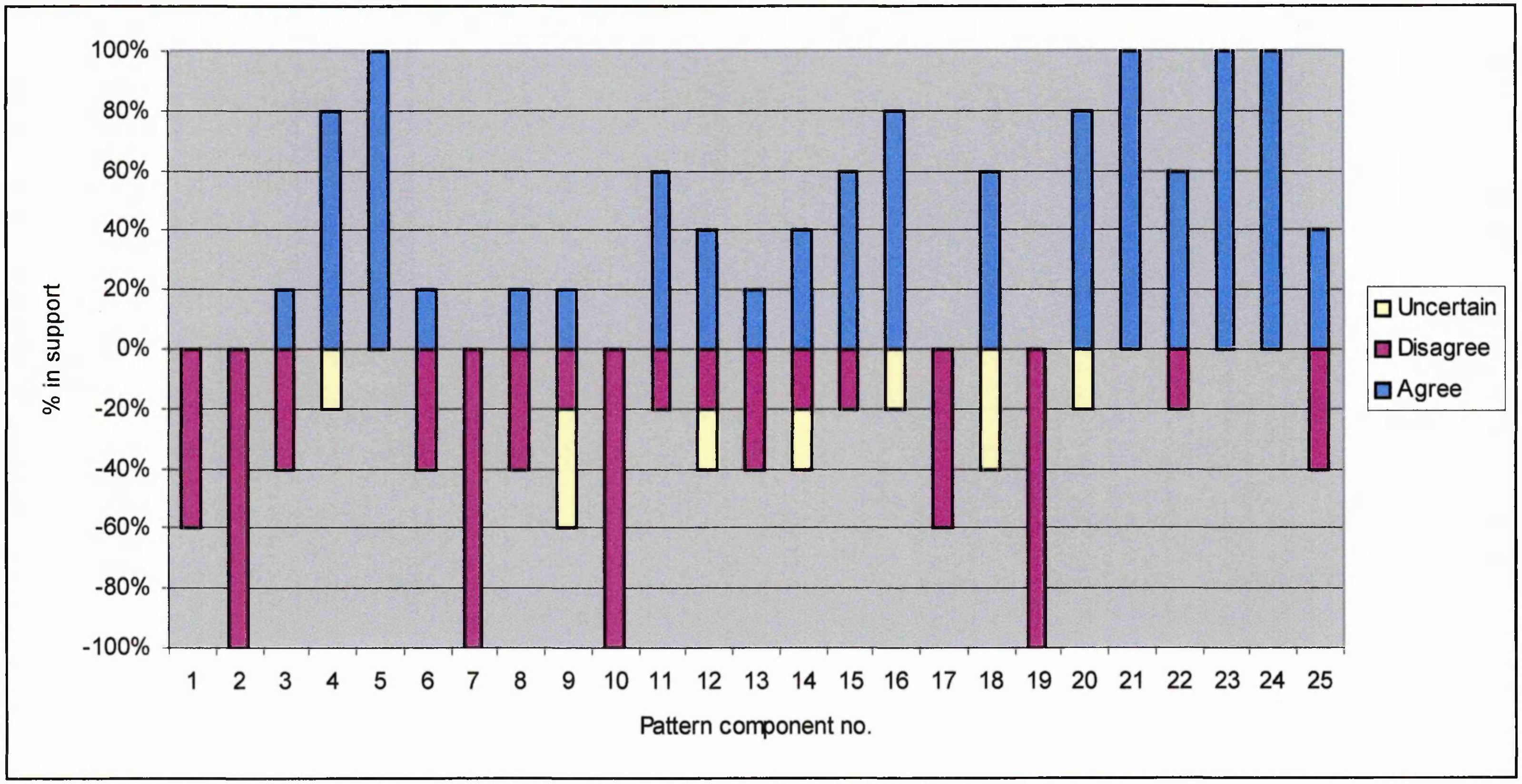
GRAPH 8 Delphi round 3, section 1, focal point consensus



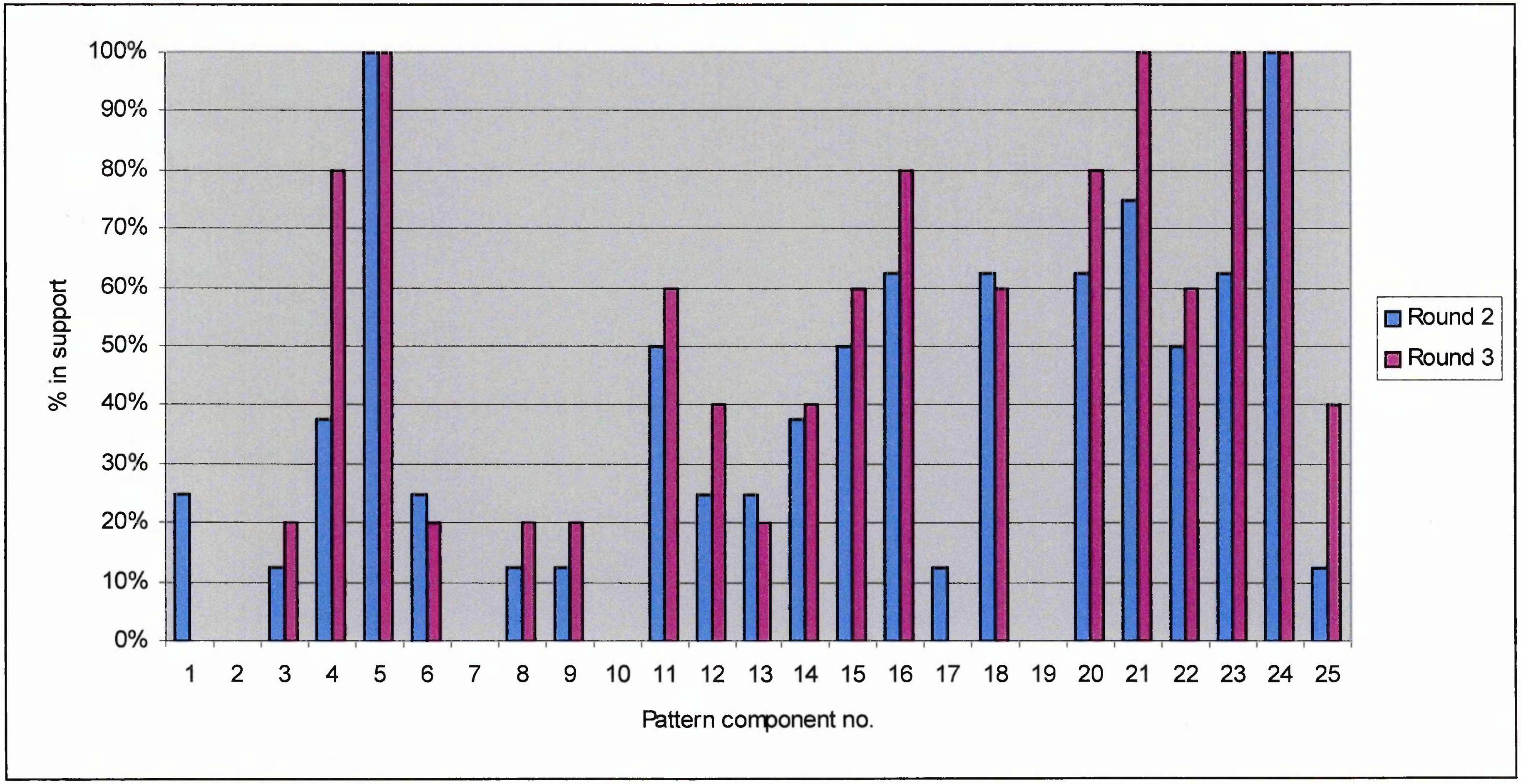
GRAPH 8 – contd.



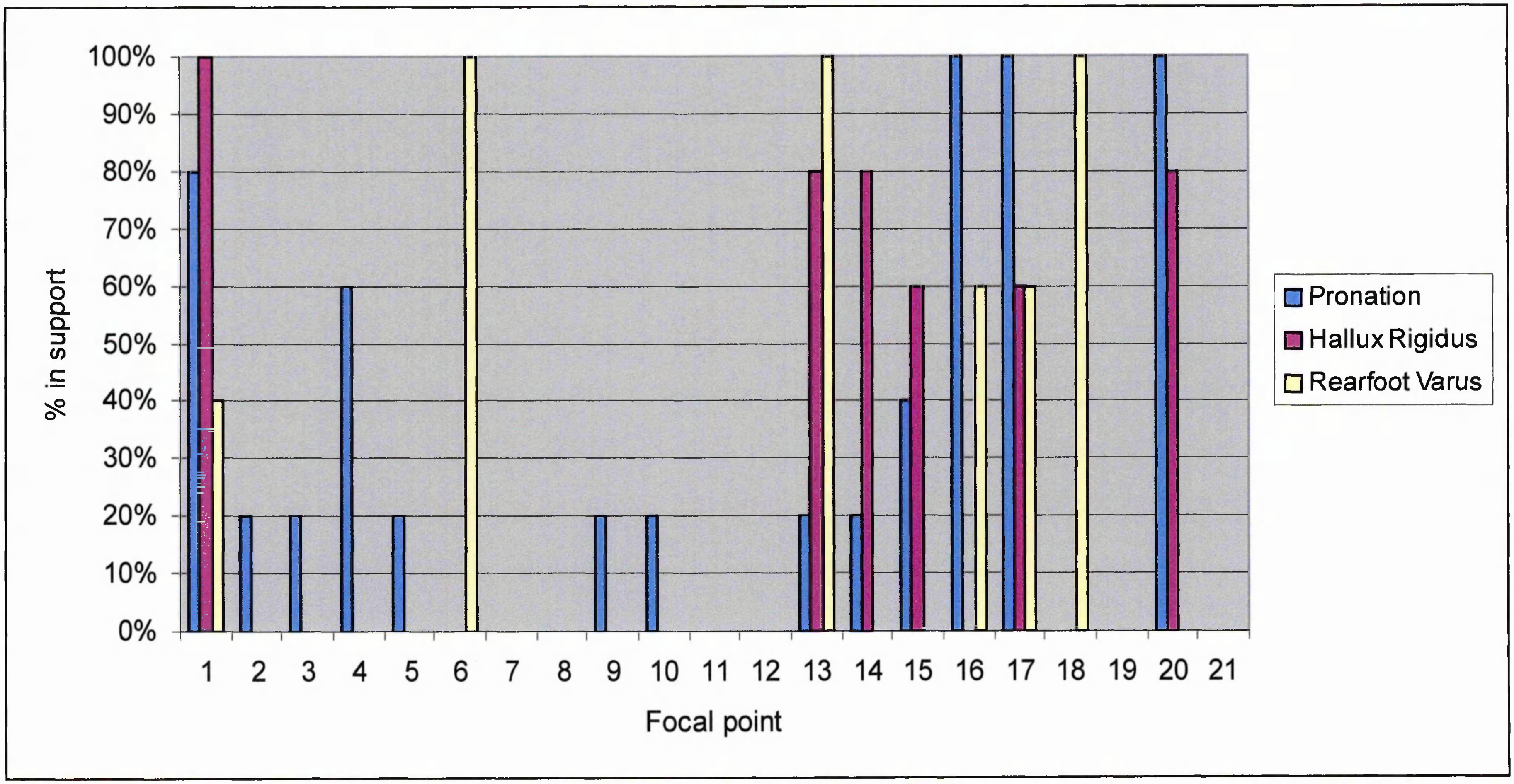
GRAPH 9 Delphi round 3, section 2 - face consensus



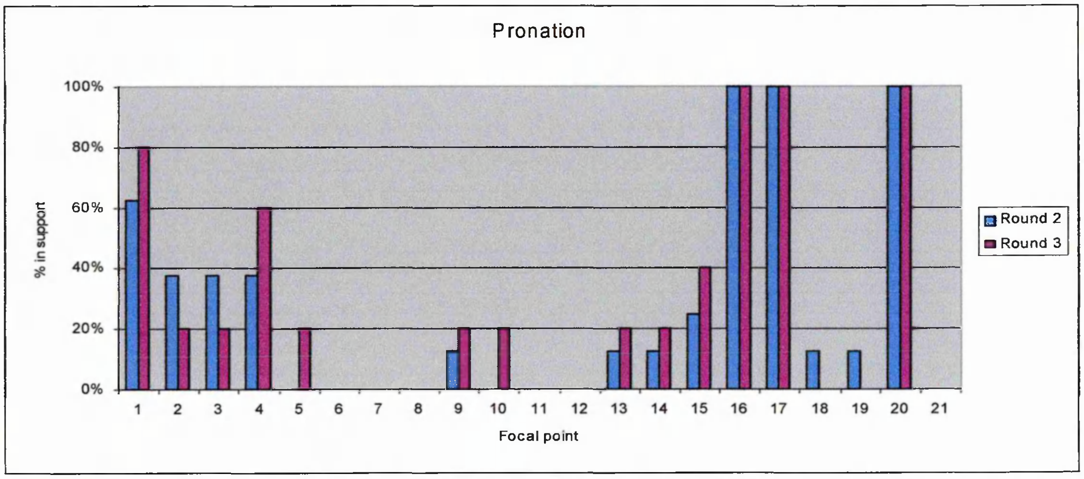
GRAPH 10 Delphi round 3, section 2 – comparison of face level consensus with round 2, section 2

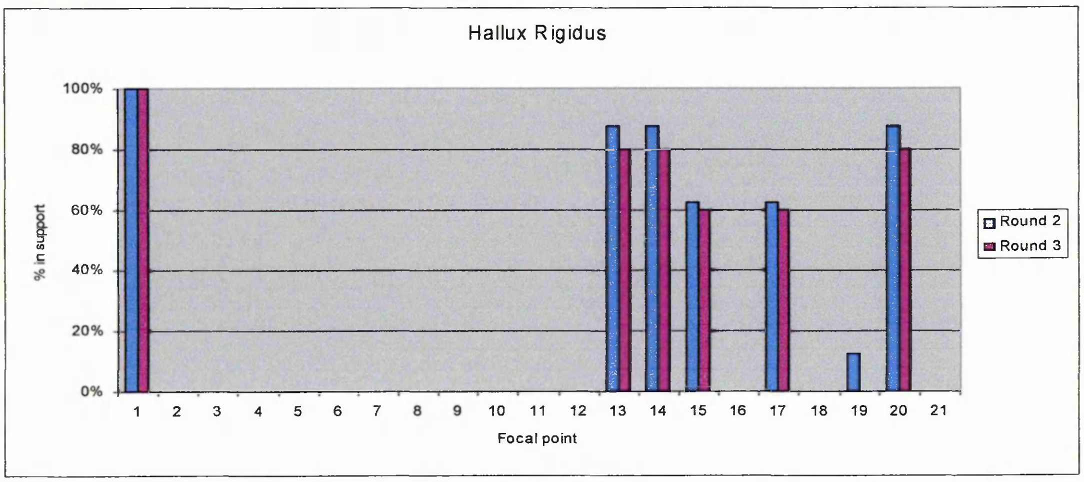


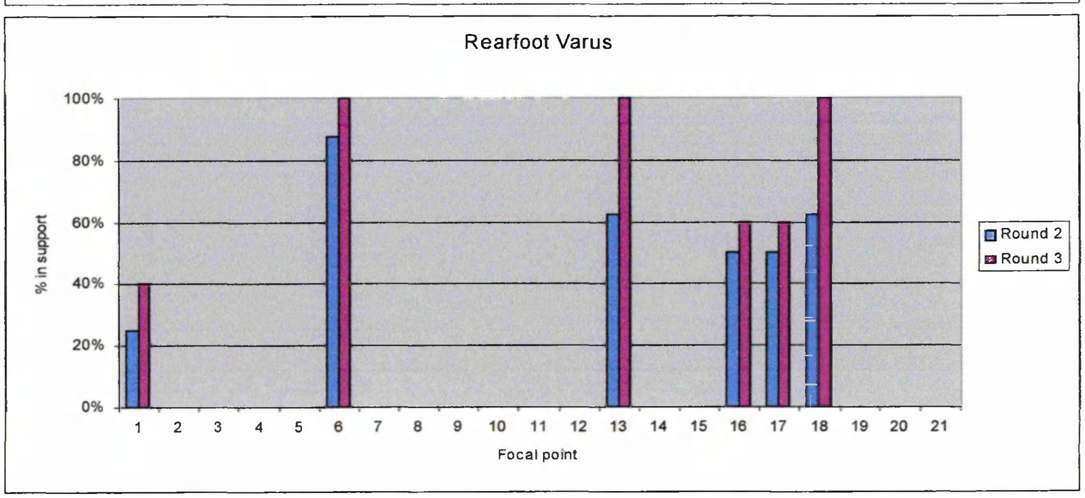
GRAPH 11 Delphi round 3, section 2 – focal point consensus



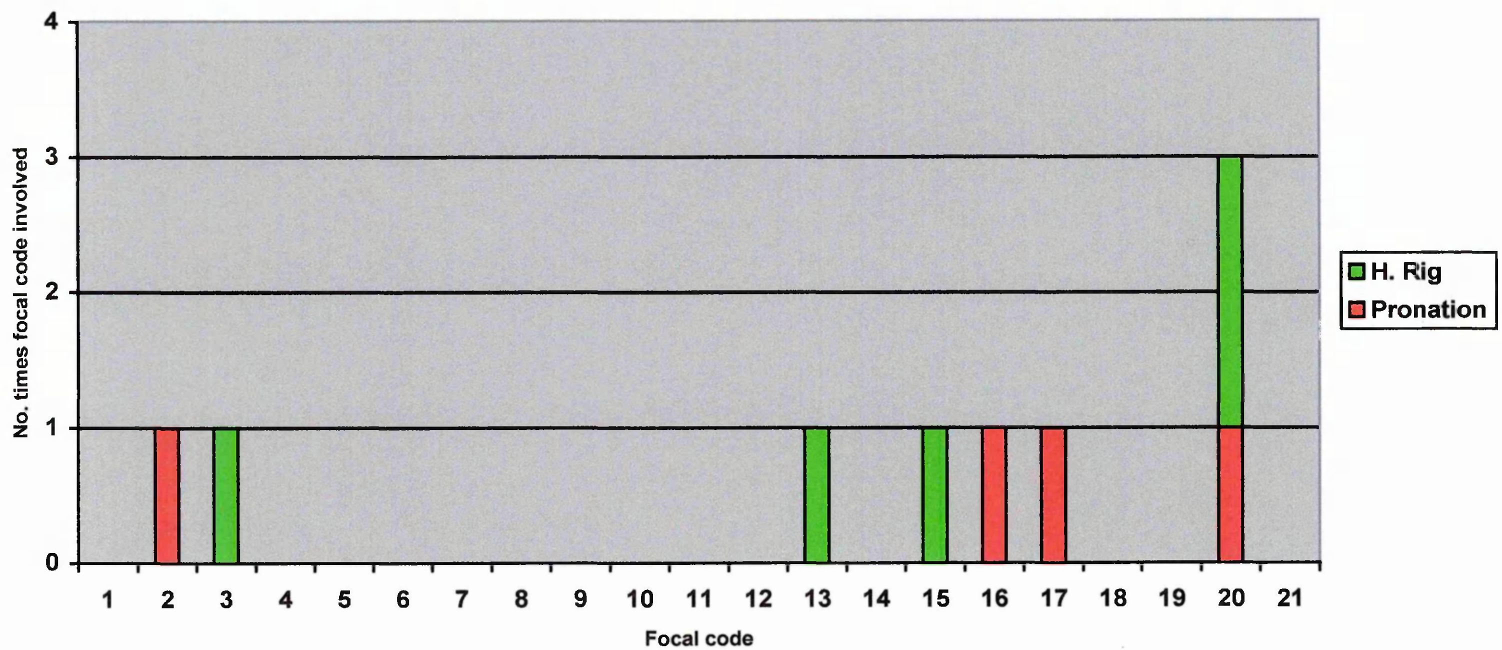
GRAPH 12 Delphi round 3, section 2 – comparison of focal point consensus with round 2, section 2



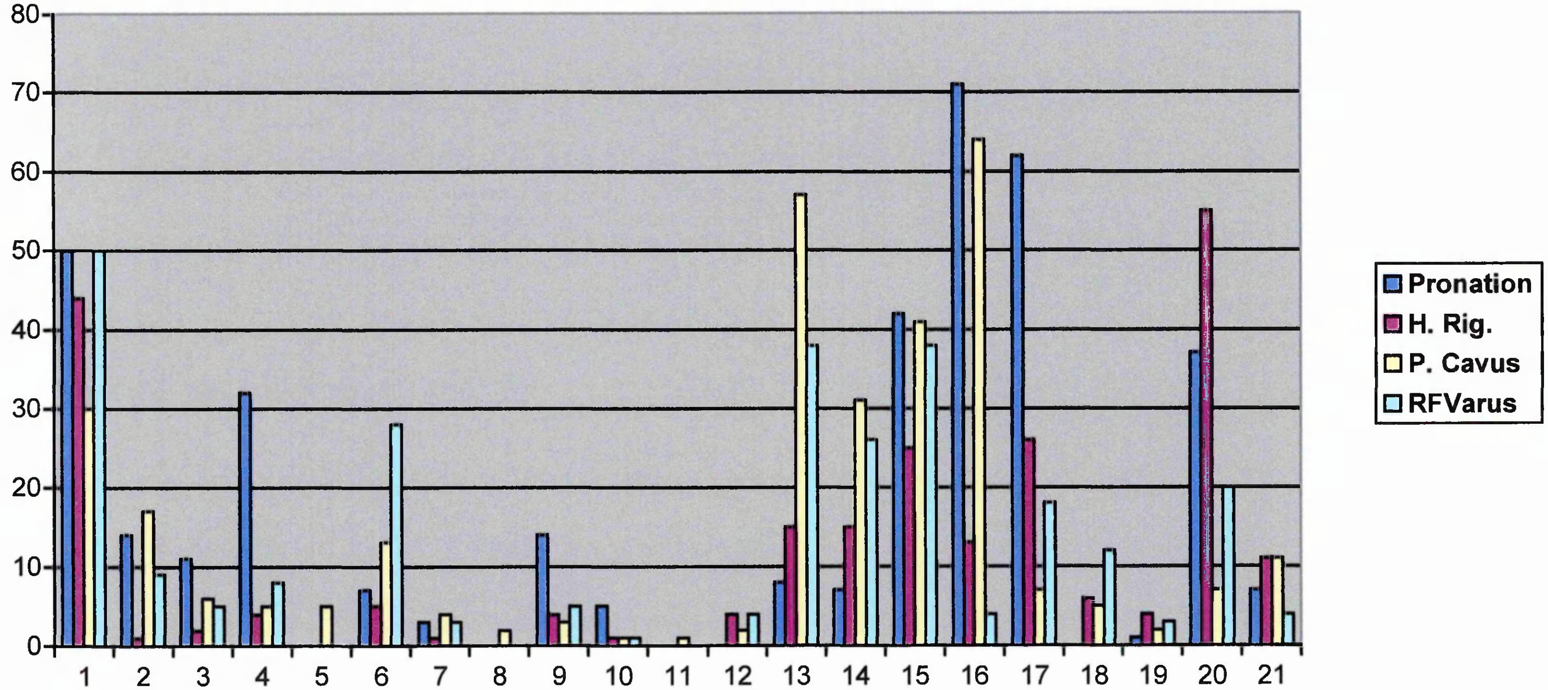




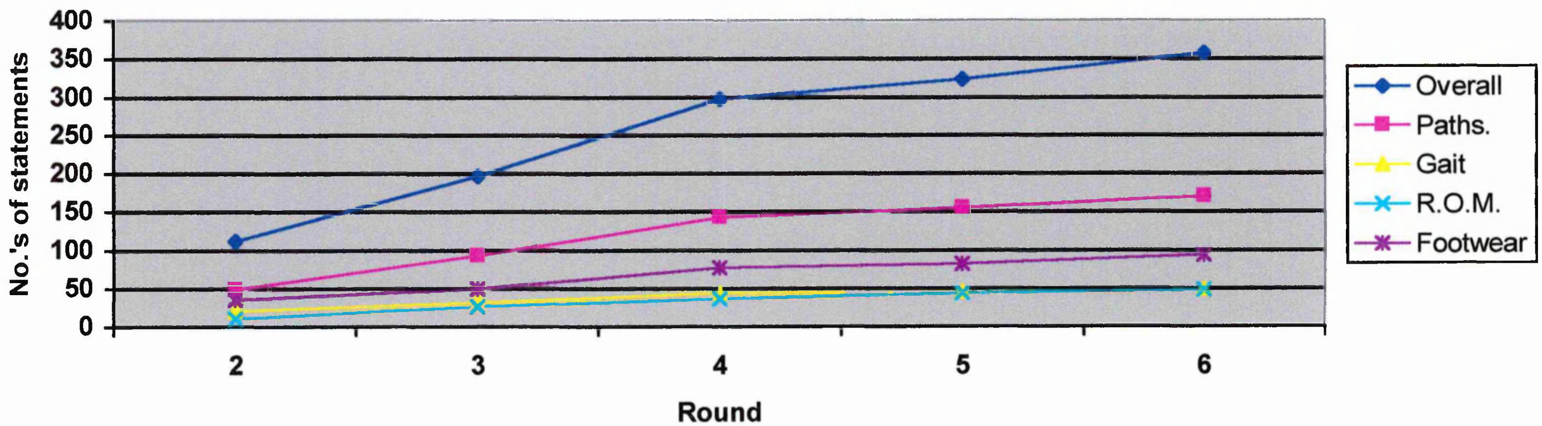
GRAPH 13 The strength of focal code relationships with 2nd condition, adducted gait



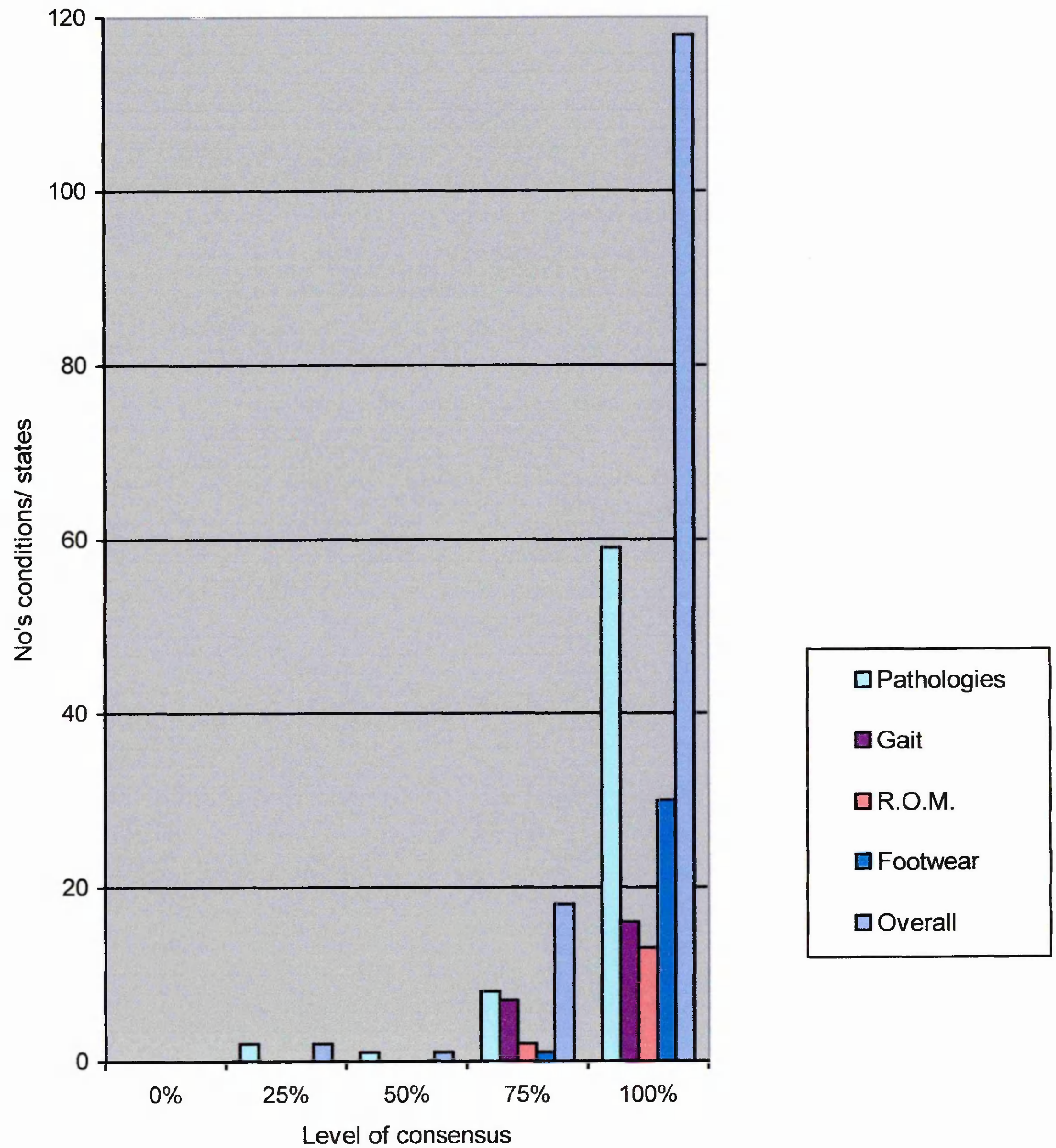
GRAPH 14 The strength of focal code relationships of the four main pathologies



GRAPH 15 Statements with 100% and 0% consensus, pre-validation Delphi rounds 2 - 6



GRAPH 16 Highest levels of consensus reached in pre-validation Delphi round 6 for conditions/states considered



TABLES

TABLE 1 Pathologies for which wear patterns were given by Delphi round 1 participants

Pathology	No. responses	Pathology	No. responses
Calcaneo-valgus/pronated foot	12	Charcot-Marie-Tooth disease	1
Hallux rigidus	5	Claw toes	1
Rearfoot varus	4	Foot drop	1
Hallux valgus	3	Forefoot varus	1
Parkinsonism	3	Freibergs infraction	1
Ankle equinus	2	Genu valgum	1
Forefoot valgus	2	Genu varum	1
Hemiplegia	2	Hammer 2nd toe	1
In-toed gait	2	High stepping gait	1
Pes cavus	2	H'mobile 1st and 5th mets.	1
Retracted toes	2	Metatarsus adductus	1
Severs disease	2	Out toed gait	1
Talipes equino varus	2	Rheumatoid arthritis	1
Ataxic gait	1	Short 1st metatarsal	1
Charcot joint	1		

TABLE 2 Number of responses for each pathology showing wear in specific areas of the outsole

	No. of responses showing wear in each area of the outsole (expressed as proportion of total patterns received for each pathology)														
Pathology	**Toe areas**				**Metatarsal head areas**				**Heel areas**						
	Apex of 1st	Apex of 2,3,4	1st	5th	1	2/3	4	5	Ant.	Ant. med.	Ant. lateral	Post. med	Post. Lat	Central	Post.
Calc.valg./Pron.	6/12		8/12		8/12	5/12	3/12	3/12	1/12	5/12		5/12			3/12
H.Rig.	4/12			2/5	1/5	3/5	3/5	4/5					5/5		
RF varus			3/4	2/4	4/4	3/4	1/4	2/4			1/4		4/4		
H.Valgus	1/3		1/3	1/3	2/3	3/3	2/3	2/3		1/3		1/3	2/3		
Parkinsons	2/3	1/3	2/3	2/3	3/3	3/3	3/3	3/3	1/3	1/3	1/3	1/3	1/3	1/3	2/3
Retracted toes					2/2	2/2	2/2	2/2					1/2		
Ankle equinus		2/2				2/2		1/2					1/2		
Forefoot. valgus	1/2		1/2	1/2	1/2	1/2	1/2	1/2					2/2		
Intoed gait		2/2		1/2		1/2	1/2	2/2			1/2		2/2		
Talipes Eq. Varus				2/2		1/2		2/2			2/2		1/2		
Severs disease	1/2	2/2	1/2			2/2	1/2	1/2							
Hemiplegia		2/2		1/2		1/2	1/2	2/2					1/2		
Pes cavus	1/2	2/2			1/2	1/2	1/2	2/2			1/2		2/2		

TABLE 3 Patterns for which additional pathologies were suggested in Delphi round 2

Pattern reference	Additional suggested causative conditions
1	Partially compensated rearfoot varus
3	Ankle equinus Hallux rigidus Hallux abductor valgus
5	Pes cavus
6	Hemiplegia
10	Forefoot varus Rearfoot varus Normal foot

TABLE 4 Anatomical references for focal codes – the positions from which outsole wear would spread

Focal code no.	Anatomical area represented by focal code
1	Posterior lateral heel
2	Posterior heel
3	Posterior medial heel
4	Medial heel
5	Central heel
6	Lateral heel
7	Anterior lateral heel
8	Anterior central heel
9	Anterior medial heel
10	Anterior inner longitudinal arch
11	Centre of foot
12	Base of 5th metatarsal
13	5th metatarso-phalangeal joint
14	4th metatarso-phalangeal joint
15	2nd/3rd metatarso-phalangeal joint
16	1st metatarso-phalangeal joint
17	1st toe
18	Tip of 5th toe
19	Tip of 4th toe
20	Tip of 1st Toe
21	Tip of 2nd, 3rd and 4th Toes

TABLE 5 Areas covered by section 1 patterns, Delphi round 2

Pattern	Anatomical areas involved (with code)	Focal code combination
1	Posterior/lateral heel area (1.) 1st metatarso-phalangeal joint (16.) 1st toe (17.) Tip of 1st toe (20.)	1/16/17/20
2	Tip of 5th toe (18.) 1st toe (17.) 1st metatarso-phalangeal joint (16.) 2nd/3rd metatarso-phalangeal joint (15.) 4th metatarso-phalangeal joint (14.) 5th metatarso-phalangeal joint (13.) Posterior lateral heel area (1.)	1/13/14/15/16/17/18
3	1st toe (17.) 2nd/3rd metatarso-phalangeal joint (15.) Posterior lateral heel area (1.)	1/15/17
4	Tip of 2nd, and 3rd toes (21.) Tip of 1st toe (20.) Tip of 4th toe (19.) Tip of 5th toe (18.) 5th metatarso-phalangeal joint (13.) Posterior lateral heel area (1.)	1/13/18/19/20/21
5	Tip of 1st toe (20.) 2nd/3rd metatarso-phalangeal joint (15.) 5th metatarso-phalangeal joint (13.) Posterior lateral heel area (1.)	1/13/15/20
6	Tip of 4th toe (19.) Tip of 5th toe (18.) 5th metatarso-phalangeal joint (13.) Lateral heel area (6.)	6/13/18/19
7	Tip of 2nd, and 3rd toes (21.) 2nd/3rd metatarso-phalangeal joint (15.)	15/21
8	Tip of 1st toe (17.) 2nd/3rd metatarso-phalangeal joint (15.) 4th metatarso-phalangeal joint (14.) 5th metatarso-phalangeal joint (13.) Posterior-lateral heel area (1.)	1/13/14/15/17
9	Tip of 1st toe (20.) 1st toe (17.) 2nd/3rd metatarso-phalangeal joint (15.) 4th metatarso-phalangeal joint (14.) 5th metatarso-phalangeal joint (13.) Posterior-lateral heel area (1.)	1/13/14/15/17/20
10	1st toe (17.) 1st metatarso-phalangeal joint (16.) 2nd/3rd metatarso-phalangeal joint (15.) Lateral heel area (6.)	6/15/16/17

TABLE 6 Areas covered by section 2 pattern components, Delphi round 2

Component no.	Focal code		Component no.	Focal code
1	20		14	1
2	17		15	1
3	16		16	20
4	16		17	19
5	16/17/20		18	13/14/15/17/20
6	13/14/15/16/17/18/ 19/20		19	16
7	13/14/15/16		20	13/14
8	15		21	1
9	9		22	16/17
10	7/8/9		23	13/18
11	4		24	6
12	3		25	1
13	2			

TABLE 7 Focal points marked by respondents in Delphi round 3

Respondent no.	No. points marked/ respondent	No. matching focal point positions	No. not matching focal point positions	Focal points matched
1	0	0	0	-
2	41	27	14	1/4/6/9/13/14/15/16/17/18/20/21
3	36	30	6	1/13/14/15/16/ 17/18/20/21
4	44	37	7	1/6/13/14/15/16/17/19/20/21

TABLE 8 Delphi round 4 – respondent comments

Section	Pattern/ component no.	Comment	Classification of comment
Feedback	N/A	*"Thank you for allowing me to participate, I've found it very stimulating and interesting."* *"The concluding comments appear to be a very healthy conclusion."*	Personal interest in the study. Expression of support for the conclusions
2	9	*"Associated with pronation"*	Reinforces personal pattern interpretation belief.
2	14	*"Associated with pronation"*	Reinforces personal pattern interpretation belief.
2	15	*"Associated with pronation"*	Reinforces personal pattern interpretation belief.
2	22	*"Associated with condition"*	Reinforces personal pattern interpretation belief.
Feedback	N/A	*"Completion did take a little longer than a few minutes!"* *"Results should be nteresting."*	Alludes to difficulty of required task. Personal interest in the study.
Feedback	N/A	*"I think the statement in no. 8 is very significant and ..."* *"...that the sole and upper materials are very important as well."* *"A soft foam rubber type sole I think will give much more information than a hard leather sole."*	Refers to the potential for many influences to affect shoe wear patterns. Refers to the effect of the foot on other components of the shoe. Refers to material influence on wear pattern clarity.

TABLE 9 Conditions named by respondents in descending order in the pre-questionnaire survey.

Frequency of conditions named by respondents in pre-questionnaire survey							
Condition	No. Responses	Condition	No. Responses	Condition	No. Responses	Condition	No. Responses
Pronated foot*	47	Retracted toes	8	Plantar digital neuritis	2	Ataxic gait	0
Hallux rigidus*	46	Metatarsus adductus*	7	Plantar flexed 1st ray* !	2	Calcaneal apoph.	0
Pes cavus*	35	Hindfoot valgus*	7	Pyramidal neuro. disorders	2	Calcaneal bursitis	0
Hindfoot varus*	31	Charcot joints	6	Leg length discrep. !	1	Calcaneal spur	0
Forefoot valgus*	23	Claw toes	5	Metatarsus primus elevatus*	1	Calcaneo-cavus	0
Normality	23	Genu varum*	5	Calcaneal gait	1	Chorea	0
Intoed gait*	23	Hypermob.foot*	5	Hallux flexus	1	Equino-cavus	0
Overloaded 2nd met.*	21	Bow legs	5	L'r motor neur. weakness	1	Equino -varus	0
Drop foot	19	Genu valgum*	5	Metatarsus primus varus*	1	Foot strain	0
Hallux valgus*	18	Abduction	4	Post-operative states	1	Freiberg's infraction	0
Forefoot varus*	17	Calcaneo-varus*	4	Talipes calcaneo varus	1	Inflared foot	0
Ankle equinus*	16	Hemiplegic gait*	4	Pl. fl. 1st and 5th rays !	1	Kohlers disease	0
Rheum. Arthritis	14	Short 1st metatarsal*	4	Red. long. and trans. arches	1	Painful nail disorders of 1st .	0

TABLE 10 Respondent comments analysis from the pre-questionnaire survey

Comment received	Classification of comment
"There are some examples of shoe wear marks in a book called Clinical Orthopaedic Examination."	Helpful advice (re: where to find published examples of wear patterns)
"I felt I could identify more conditions if you also had the corresponding shoe."	
"...would also require to be examined."	Information beyond shoe wear alone required to identify related conditions
"It is extremely difficult to isolate conditions from the shoes alone. Patient examination is absolutely necessary."	
"...as many of the abnormalities you have listed present with similar sole marks."	
"All (3 conditions) give a similar picture."	Wear patterns are similar with different pathologies
"... sorry, upper of shoe."	Upper of shoe also affected
"...the upper"	
"I apologise for my inability to help you, but I don't pay enough attention to shoe wear marks to be able to offer any valuable contribution."	
"I am afraid that I would only feel confident in identifying shoe wear in the (2) cases shown above - I know that this falls short of the minimum of 3 conditions requested."	
"...but realise that if you want some in-depth knowledge of this, I am not able to give it as I no longer have a clinical role in the department."	
"...and I am sorry that I was unable to give you a more positive answer."	
"As I did this however I became increasingly aware that I would have great difficulty in naming - with any certainty - specific conditions from shoe or footwear wear marks."	
"Although not quite what you asked for I have concluded and presented below the only situations in which I could confidently predict what wear marks would develop."	
"...but as your questionnaire proves, this is not as easy as might first be thought."	
"...but as to the certainty of predicting which distinct entity is responsible for precipitating these wear marks - well that's what your research is for."	Personal knowledge levels insufficient to answer the questions
"I would be unable to make a differential diagnosis on biomechanical abnormalities."	

"I have asked at my staff meeting for anyone who would be willing to fill this form in with you and I'm afraid that I got no takers."	
"Best wishes"	Belief in project value
"I wish you every success in your investigations"	
"Good luck with your survey"	

TABLE 11 Total and mean numbers of patterns given for each pathology in main questionnaire

Total and mean no. patterns for each pathology		
Condition	Total no. patterns	Mean no. patterns given by each respondent for each pathology
Pronation	129	2.3
Hallux rigidus	85	1.5
Pes cavus	104	1.9
Rearfoot varus	107	1.9
Overall total	425	7.6

TABLE 12 Numbers of named variables given in main questionnaire

Numbers of named variables given/condition	
Main condition	No. second-named conditions given
Pronation	71
Hallux rigidus	32
Pes cavus	49
Rearfoot varus	49
Total	201

TABLE 13 Functional analysis of data relating to patterns occurring with pronation

Function	No. supporting patterns	Common wear components	Function implied from the wear pattern within the pathological context	No. variables compatible with	Wear variations noted
Foot pronated prior to heel strike and throughout stance	27	Medial heel Medial met.	Med. heel wear implies pronation before heel strike. Med. met. wear suggests pronation is maintained	19/19	Heel wear Tip wear
Foot pronated before heel strike with attempted recovery through supination	5	Medial heel Central met.	Med. heel wear implies pronation, central met. wear suggests attempted recovery	5/5	Met. wear 1st toe area
Foot pronates rapidly on contact and remains pronated	5	Lat. or post. heel Medial heel Med. Met. area	Heel wear suggests rapid change from inversion to eversion with eversion. Med. met. wear suggests pronation is maintained throughout stance	2/2	Degrees of heel inversion/eversion
Foot pronates rapidly on contact with attempted recovery through forefoot supination	5	Medial and lateral heel Central met.	Heel wear suggests rapid change from inversion to eversion, central met. wear suggests attempted recovery	2/2	
Foot contacts normally with mid-stance pronation and no attempt to recover	24	Post. lat. heel Med. forefoot	Heel wear suggests normal heel strike. Med. forefoot wear suggests later pronation	3/3	1st toe area Heel differences Med. met. differences
Foot contacts normally with late pronation	4	Post. lat. heel 1st and 5th MPJt	Heel wear suggests normal heel strike. 1st MPJt wear suggest pronation and 5th MPJt wear suggests that this has been late	4/4	Central met. wear presence/absence 1st toe area wear presence/absence
Foot contacts normally with later pronation and attempt to stabilise with functional hallux limitus	18	Post. lat. heel (in 14/18 patterns) 1st toe area Absent 1st MPJt (in 17/18 patterns)	Pronation only known through reported context. Absent 1st MPJt wear with 1st toe wear suggests that hallux limitus has prevented full pronation from taking place.	11/11 (with 1 pattern having 2 theoretical causes	Heel wear differences Met. area differences 1st toe wear variations Tip wear inclusion
Heel equinus causing centralised heel contact and later pronation to compensate	8	Post. heel Med. forefoot	Post. heel wear suggests central heel strike such as may be related to equinus. Med. forefoot wear suggests later pronation	4/4	Met. wear variations 1st toe wear variations One pattern with ILA wear
Heel equinus causing no heel contact and later pronation to compensate	7	Absent heel strike related wear	No heel wear = no heel strike. Reported pronation and med. forefoot wear (where present) suggest later pronation	3/3 (but no supportive links offered)	Medial forefoot wear tendency Across met. wear tendency Absent forefoot wear
Heel equinus causing no heel contact and later abductory twist to compensate	5	Absent heel wear Localised at MPJt	No heel wear = no heel strike. Localised MPJt wear implies abductory twist	4/4	1st and 2nd met. involvement differences
Foot lands and remains in inversion to compensate for pronation	2	Post. lat./ lat. heel Lat. forefoot wear	Lateral wear throughout implies inversion at heel stike, maintained throughout stance.	1/1	Degrees of lat. heel wear
Foot lands in inversion to compensate for pronation, then pronates fully	8	Lat.inclined heel Med. forefoot/met.	Lat. inclined heel wear suggests inversion at heel strike. Med. forefoot/ met. wear implies later eversion through pronation has occurred.	4/4	Lat. spread of heel wear Spread of med. met. wear Tip wear
Foot inverts on heel strike, then	2	Lat. extended heel and	Normal, laterally extended heel wear implies inversion	1/1	-

TABLE 14 Functional analysis of data relating to patterns occurring with hallux rigidus

Function	No. supporting patterns	Common wear components	Function implied from the wear pattern within the pathological context	No. variables compatible with	Wear variations noted
"Classic" hallux rigidus function	30	1st toe area wear Absent 1st MPJt wear Central/lat. met. area wear	1st toe wear implies 1st toe restriction encountered. Absent 1st MPJt wear implies splinting effect of stiff 1st toe. Central/lat. met. wear suggests necessary inversion to avoid 1st toe restriction.	10/11	Heel wear variations Spread of central/lat. MPJt wear 1st toe wear variations Tip wear
Abducted gait	13	Ant. med. forefoot wear	Ant. med. forefoot wear suggests take-off from medial border of forefoot while foot is abducted	2/2	Heel wear absence 1st MPJt wear absence 2nd/3rd MPJt absence 1st toe wear variations Tip wear
Pronation with abducted gait	7	1st toe area wear Med. heel wear (6/7 patterns)	Med. heel wear implies foot landing in pronation and abduction 1st toe wear indicates maintained abduction	4/4	Heel wear variations 1st MPJt involvement Central MPJt wear 1st toe wear variations
No med. or lat. deviation from normal gait pathway	18	Focus of wear towards distal aspect of 1st toe Absent lat. met. wear (16/18 patterns)	Absent lat. met. wear indicates lack of inversion. Wear focused on distal aspect of 1st indicates continued lack of medial or lateral deviation	6/6	Absent/amended lat. inclined heel wear Met. involvement Distal 1st toe variations Tip wear
Abductory twist	10	Localised MPJt wear 1st toe area wear	Localised MPJt wear indicates abductory twist. 1st toe wear suggests following medial toe-off	4/5 (The 5th variable contradicting)	Absent heel wear MPJt wear variations 1st toe involvement
Compensatory supination/inversion of the foot	3	Lateral heel wear Lateral forefoot wear	Lat. wear throughout suggests maintained inversion	1/1	Post. spread of heel wear Ant. spread of forefoot wear 1st toe area Tip wear
Forefoot inversion	15	Lateral forefoot wear Post. lat. heel wear (13/15 patterns)	Normal heel wear indicates normal heel strike (Where no heel wear is shown, heel strike could be absent) Lat. forefoot wear implies later inversion of forefoot	6/6	Absent heel wear Lat. forefoot variations
Abducted gait with eversion	6	Med. heel wear (5/6 patterns) 1st toe wear (5/6 patterns)	Medial heel wear suggests medial heel strike. Medial wear throughout suggests maintained medial pathway, in turn suggesting an abducted, everted foot	2/2	Absent heel wear Heel wear variations 1st MPJt+ toe wear

Adducted gait	2	5th MPJt area wear	Pattern 1 = medial heel + 5th MPJt + apex of 1st toe wear suggesting an initial adduction moving laterally Pattern 2 = no heel wear + 1st MPJt + ant. lat. wear indicating a laterally inclined force pathway and therefore	1/1	Med. heel wear Apex of 1st toe wear Absent heel wear 1st MPJt wear

TABLE 15 Functional analysis of data relating to patterns occurring with pes cavus

Function	No. supporting patterns	Common wear components	Function implied from the wear pattern within the pathological context	No. variables compatible with	Wear variations noted
Normal force pathway in the transverse plane with no toe-off propulsion	44	Heel wear (varied) Metatarsal wear (varied)	Heel wear suggests heel strike has taken place Met. wear suggests met. weight bearing Absent anterior wear suggests absent toe-off Tip wear suggests scuffing	17/20	Heel wear differences Met. wear variations Tip of 1^{s} wear Tip wear
Normal force pathway with forefoot loading from dropped forefoot, no heel strike and no toe propulsion	16	Absent heel wear Absent wear ant. to met. area 1st + 5th MPJt wear	Absent heel wear suggests no heel strike. Absent anterior wear suggests no toe-off 1st+5th MPJt wear suggests accentuated weight bearing of that area	7/7	Presence of wear across met. area
Foot inverted throughout stance	5	Lat. heel wear Lat. forefoot wear	Lat. heel wear suggests inversion on heel strike Lat. forefoot wear suggests inversion is maintained	2/2	Degree of lat. heel wear Ant. spread of lat. forefoot wear 1st MPJt wear Tip wear
Foot inverted and abducted throughout stance	5	Lat. heel wear Lat. forefoot wear	Lat. heel wear suggests inverted + abducted position. 5th MPJt wear suggests inversion	2/2	Degree of lat. heel wear Ant. spread of lat. forefoot wear 1st MPJt wear Tip wear
Foot inverted on heel strike with a normal force pathway at the forefoot	4	Lat. heel wear 1st and 5th MPJt wear	Lat. heel wear suggests inversion at heel strike 1st and 5th MPJt wear suggests reversion to normal inclination later in stance	1/1	Post. spread of heel wear 4th MPJt wear 1st toe variations
Normal heel strike, inverted forefoot	7	Post. lat./post. heel wear 5th MPJt wear Absent 1st MPJt wear (6/7 patterns)	Heel wear shows normal heel strike Post. lat. extended 5th MPJt wear or absent 1st MPJt wear indicates forefoot inversion	3/3	Post. heel wear Central MPJt wear Localised 1st MPJt wear Toe/tip wear 5th toe wear
Normal or inverted heel, everted forefoot	14	Post. lat./lat. heel wear Med. forefoot wear	Various heel wear forms suggest either normal or inverted heel strike. Medial forefoot wear (either of 1st MPJt only, or with medial emphasis) suggests everted forefoot	5/5	Heel wear variations Involvement of 2nd to 5th MPJt wear 1st toe wear variations 5th toe area wear
Everted heel and forefoot	2	Medial heel wear 1st MPJt wear Absent lateral wear	Medial wear emphasis throughout suggests medial weight-bearing and therefore eversion throughout stance	2/2	Heel wear differences
Everted heel, inverted forefoot	1	Medial heel wear Wear across MPJt area Tip wear	Medial heel wear suggests everted heel Wear across MPJt area suggests foot later inverts from this position	-	-
Feet abducted	5	Post. heel wear	Posterior heel wear suggests normal heel strike with later	2/2	Inclusion and siting of 1st toe wear

TABLE 16 Functional analysis of data relating to patterns occurring with rearfoot varus

Function	No. supporting patterns	Common wear components	Function implied from the wear pattern within the pathological context	No. variables compatible with	Wear variations noted
Foot inverted on heel strike, remaining inverted throughout stance	30	Post. lat./ lat. heel wear 5th MPJt wear Absent 1st MPJt wear	The predominately lateral wear suggests a maintained inversion throughout stance	10/10	Degrees of lat. heel wear Extension of lat. forefoot wear 1st toe and tip wear
Foot inverted on heel strike, reverting to normal inclination at the forefoot	9	Post. lat./post. heel wear 1st and 5th MPJt wear	Heel wear shows strike of at least normal inversion. 1st and 5th MPJt wear shows normal inclination through medial and lateral weight bearing	10/10	Central MPJt wear Ant. spread of 5th MPJt wear Greater or lesser degrees of post. heel wear
Foot inverted on heel strike followed by pronation	15	Lat./post. lat. heel wear Med. forefoot wear	Laterally inclined heel wear implies a heel inversion at heel strike Medial forefoot wear suggests that the foot has pronated with subsequent medial weight bearing emphasis	7/7	Lat. inclination of heel wear 1st toe, central and lat.MPJt wear Ant. med. heel wear
Foot inverted and abducted throughout stance	32	Post. lat./lat. heel wear No 1st MPJt wear 5th MPJt wear (25/32 patterns)	Laterally inclined heel wear with absent 1st MPJt wear and 5th MPJt wear (when present) suggest forefoot inversion, possibly with abducton	6/12	Lat. heel wear inclination 1st toe area wear Ant. spread of lat. forefoot wear MPJt areas involved
Foot inverted and abducted throughout stance with walking on heels	13	Lat. heel wear Absent central MPJt. Wear Absent medial forefoot wear	Lat. heel wear suggests inversion and abduction at heel strike. Absent central and medial forefoot wear suggests minimal weight bearing at these sites with walking on heels	1/1	Lat. heel wear spread Lat. post. forefoot wear involvement
Foot inverted and adducted (intoed) throughout	13	Post. lat./lat. heel wear Lat. forefoot wear Absent med. forefoot wear	Lat. heel and forefoot wear imply inversion of the foot throughout stance. Complete absence of med. wear suggests that an adductory position has prevented wear on this aspect of the shoe	2/2	Degrees of lat. heel wear Lat. forefoot wear spread Tip wear
Foot pronates prior to heel strike to compensate for rearfoot varus, remaining pronated	10	Post./med. inclined heel wear Med. met. wear	Medially inclined wear implies medial heel strike with weight bearing remaining medial such as may be caused by pronation before or just on weight bearing	6/6	Angles of med. heel wear Ant. med. heel wear Spread of med. forefoot wear
Foot lands in pronation, going into rearfoot varus to compensate	3	Lat. forefoot wear Central MPJt wear Absent 1st MPJt wear Med. heel wear (2/3 patterns)	Medial or absent heel wear implies pronation prior to heel strike. Laterally biased forefoot wear suggests later inversion	2/2	Absent heel wear Central MPJt. wear 1st toe are wear Tip wear
Foot lands in inversion, then pronates with abductory twist to compensate	11	Post. lat./lat. heel wear Central MPJt wear	Heel wear implies an inverted heel strike. Central met. wear suggests that this inversion has not been maintained in the forefoot – a situation requiring pronation. Localised central MPJt wear implies abductory twist	5/5	Lat. heel variations Central met. variations Ant. med. heel wear

TABLE 17 Levels of support offered by named variables for function categories suggested with pronation

Pattern ref.	Named variable	Level of support	Pattern ref.	Named variable	Level of support
1. Heel equinus causing centralised heel contact and later pronation to compensate					
PRON 43/3	Intoed gait	NC	PRON 34/1	Pron. from h.s.	NC
PRON 18/2	Equinus	DS	PRON 23/2	Severe. Fixed	NC
PRON 44/2	Rearfoot valgus	IS	PRON 50/2	Comp. H'bobile	IS
PRON 53/4	Red. STJ movement	NC	PRON 48/2	Genu valgum	IS
2. Foot pronated prior to heel strike and throughout stance					
PRON 51/4	Heel eq. Mid-tarsal pron.	NC	PRON 6/2	Fixed pron.	DS
PRON 18/3	Pron. from h.s.	DS	PRON 20/3	F'f varus	NC
PRON 14/2	Rigid	DS	PRON 16/2	Pes planus	DS
PRON 8/3	F'f varus	NC	PRON 28/2	Pes planus	DS
PRON 17/2	Pron. from h.s.	DS	PRON 51/2	Rearfoot valgus + pl. fl. 1st ray	IS
PRON 11/2	Rearfoot valgus	IS	PRON 2/2	Severe	IS
PRON 5/2	Rearfoot valgus	IS	PRON 15/2	Severe	IS
3. Foot pronated prior to heel strike with attempt to recover via supination					
PRON 13/2	H'mobile 1st ray	NC	PRON21/3	Severe with MPJt involvement	NC
PRON 21/2	Severe pron. from h.s.	DS	PRON 31/3	Pron. from h.s.	DS
4. Foot pronates rapidly and remains pronated throughout stance					
PRON 54/4	Fixed	DS	PRON 54/3	Pron. from h.s.	DS
5. Foot pronates rapidly on contact and attempts to recover via forefoot supination					
PRON 26/2	Tib. sesamoiditis	IS	PRON 26/3	Abductory twist	NC
6. Foot contacts normally with mid-stance pronation and no attempt to recover					
PRON47/4	Hypermobile	NC	PRON 34/4	Fully comp.	NC
PRON52/2	Comp. Rearfoot varus	DS			
7. Foot contacts normally with late pronation					
PRON 34/3	Partially comp.	NC	PRON 21/4	Abductory twist	NC
PRON 50/4	Partially comp.	NC	PRON 21/1	Late 2ndary pron.	DS
8. Foot contacts normally with late pronation and attempt to stabilise via functional hallux limitus					
PRON 32/2	Functional hallux limitus	DS	PRON 35/2	Abductory twist	NC
PRON 46/2	Rolling off med.border	IS	PRON 31/2	Abductory twist	NC
PRON11/4	Comp. Rearfoot and RF varus	NC	PRON 20/2	Abducted gait	NC
PRON 43/1	H'mobile 1st ray	IS	PRON 24/2	H. lim. + d'flexed 1st met.	DS
PRON 37/2	Abductory twist	NC	PRON54/2	H'mobile	IS
PRON 11/3	Abductory twist	NC			
9. Heel equinus causing no heel contact and later pronation to compensate					
PRON 47/3	Pron. f'foot	IS	PRON 12/2	Comp.	IS
PRON 32/3	Pron. from h.s	NC			
10. Heel equinus causing no heel contact and later abductory twist to compensate					
PRON 32/4	Abductory twist	DS	PRON 22/2	H'mobile 1st ray	NC
PRON 5/3	Pl. fl. 1st ray	NC	PRON 17/3	Abductory twist	DS
11. Foot lands in inversion to compensate for pronation and remains inverted throughout stance					
PRON 34/2	Rearfoot varus	DS			
12. Foot lands in inversion to compensate for pronation, then later pronated fully					
PRON 51/1	Severe	NC	PRON 43/2	Severe	IS
PRON 51/3	Rearfoot varus + pl. fl. 1st ray	DS	PRON 50/3	HAV	NC
13. Foot inverts on heel strike, then later pronates fully					
PRON 28/4	Equinus. Full comp.	NC			
14. Foot in fixed pronation and walking on heels in abduction with early lift					
PRON 25/2	Comp. rearfoot varus	IS			
15. Abductory twist					
PRON 42/2	D'flexed 1st+5th MPJts	NC	PRON 11/3	Abductory twist	DS
PRON 8/2	Pl. fl. 2nd+3rd MPJts	NC	PRON 53/2	Pl.fl. 1st ray	NC
PRON 16/3	Partial comp.	IS	PRON 20/2	Abducted gait	IS
PRON 35/2	Abductory twist	DS	PRON 31/2	Abductory twist	DS
PRON 43/1	H'mobile 1st ray	NC	PRON 24/2	H. Lim. + d'flexed 1st met.	IS
PRON 37/2	Abductory twist	DS			
16. Foot abducted					
PRON 34/4	Fully comp	NC	PRON 43/1	H'mobile 1st ray	NC
PRON52/2	Comp.RF varus	NC	PRON 35/2	Abductory twist	IS
PRON 51/1	Severe	NC	PRON 37/2	Abductory twist	IS
PRON 35/3	Arthritis	NC	PRON 11/3	Abductory twist	IS
PRON 31/2	Abductory twist	IS	PRON 50/3	HAV	IS
PRON 54/2	H'mobile	NC			

(DS = Direct support IS = Indirect support NC = Not contradicted C = Contradicted)

TABLE 18 Levels of support offered by named variables for function categories suggested with hallux rigidus

Pattern ref.	Named variable	Level of support	Pattern ref.	Named variable	Level of support
1. Classic hallux rigidus function					
HR 16/2	Pain in hallux	IS	HR 26/2	Pl. fl. 5th ray	NC
HR 51/2	Pain in hallux, 5th+MPJt loading+ff inv. varus	DS	HR 29/2	Partial comp	NC
HR 25/2	5th MPJt loading	IS	HR 20/2	Equinus	NC
HR 42/2	Forefoot inv. varus	DS			
2. Abducted gait					
HR 32/4	Abducted gait	DS			
3. Pronation with abducted gait					
HR 48/3	Abducted gait	DS	HR 31/2	Fixed rearfoot deformity	NC
HR 12/2	Excessive pron.	DS			
4. No medial or lateral deviation from normal gait pathway					
HR 14/2	Large exo. 1st met.	NC	HR 5/2	Excess wear prox.phal. 1 med.	IS
HR 11/3	IPJt extn.	IS	HR 8/2	Os. arthritis	NC
HR 14/1	IPJt extn.	IS			
5. Abductory twist					
HR 23/1	Adducted gait	C	HR 46/2	Abductory twist	DS
HR 32/2	Abductory twist	DS	HR 50/2	Overloaded 2nd MPJt	IS
6. Compensatory supination/inversion of the foot					
HR 5/3	Supination	DS	HR 53/2	Pain in hallux	IS
HR 11/2	Supination	DS	HR 31/3	Pl.fl. 1st	IS
7. Forefoot inversion					
HR 32/3	Late lat. load transfer	IS			
8. Abducted gait with eversion					
No variables named with patterns suggesting this function					
9. Adducted gait					
HR 48/4	Adducted gait	DS			
10. Stamping gait					
No variables named with patterns suggesting this function					
11. Adductory twist					
No variables named with patterns suggesting this function					
12. Calcaneal gait					
HR 32/4	Abducted gait	NC			
13. Walking predominately on heels					
HR 32/4	Abducted gait	NC			
14. Vertical toe off					
No variables named with patterns suggesting this function					

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TABLE 19 Levels of support offered by named variables for function categories suggested with pes cavus

Pattern ref.	Named variable	Level of support	Pattern ref.	Named variable	Level of support
1. Normal force pathway with increased forefoot loading and no toe off propulsion due to pes cavus					
PC 13/1	Forefoot valgus	NC	PC 48/3	Flexible 1st	NC
PC 18/2	Rigid pl. fl. 1st+5th MPJts	DS	PC 20/2	Shuffling	NC
PC 24/2	Rigid pl. fl. 1st+5th MPJts	DS	PC 54/2	Calc.cavus	NC
PC 42/1	Rigid	NC	PC 8/2	Some MPJt mobility	NC
PC 51/2	Pl. fl. 1st+5th MPJts	DS	PC 6/2	Mobile 1st + 5th rays	NC
PC 2/2	Inc. 1st + 5th ray angle	DS	PC 42/3	Fully comp.	NC
PC 26/3	Pl. fl. 2nd	IS	PC 8/3	Trigger 1st	IS
PC 55/2	Rigid	NC	PC 29/2	Comp.	NC
PC 42/2	Part. comp.	NC	PC 43/2	Flexible 1st	NC
PC 13/2	Prominent mets.	DS	PC 26/2	MP Elevatus	DS
2. Normal force pathway, forefoot loading, no toe off due to pes cavus+ no heel strike through dropped forefoot					
PC 46/2	Inc. shear	IS	PC 1/3	Equinus. Pl. fl. f'foot	DS
PC 5/2	Rigid	NC	PC 27/2	Short TA	DS
PC 54/3	Equino-cavus	DS	PC 13/3	F'foot equinus	DS
PC 5/3	With equinus	DS			
3. Foot inverted throughout stance					
PC 51/4	Rigid sup. calc.	DS	PC 28/2	Polio/cva	NC
4. Foot inverted and abducted throughout stance					
PC 51/4	Rigid sup. calc.	DS	PC 28/2	Polio/cva	NC
5. Foot inverted on heel strike, normal force pathway					
PC 33/2	Rigid	NC			
6. Normal heel strike, inverted forefoot					
PC 31/3	Pl. fl. 1st	NC	PC 24/3	F'f equinus + d'fl. 1st+5th mets.	NC
PC 15/2	Lat. bearing	DS			
7. Normal or inverted heel, everted forefoot					
PC 12/2	Rigid	NC	PC 48/1	+ RFV	DS
PC 1/2	Pl. fl . 1st ray	DS	PC 48/4	Abducted gait	NC
PC 28/3	Developed + clawing of toes	NC			
8. Everted heel and forefoot					
PC 12/3	Flexible	NC	PC 51/3	Pl. fl. 1st	DS
9. Everted heel, inverted forefoot					
No variables named with patterns suggesting this function					
10. Feet abducted					
PC 12/2	Rigid	NC	PC 48/4	Abducted gait	DS
11. Feet adducted					
No variables named with patterns suggesting this function					
12. No heel strike due to dropped forefoot and inverted forefoot					
PC 32/2	Excess lat. load	DS			
13. Dorsiflexion of foot with lead bearing (heavily) on heel					
No variables named with patterns suggesting this function					
14. No heel strike due to dropped forefoot and inverted heel					
PC 47/3	Rigid + abd. twist	NC	PC 47/4	Abd. twist	NC
15. Abductory twist					
PC 47/3	Abd. Twist	DS	PC 22/2	Mobile	NC
PC 47/4	Abd. twist	DS			
16. Adductory twist					
PC 53/2	Comp.	NC			
17. Shuffling gait					
No variables named with patterns suggesting this function					
18. Foot placed down and lifted vertically, with dragging of toes at toe off due to retraction					
PC 47/2	Pronation	NC			

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TABLE 20 Levels of support offered by named variables for function categories suggested with rearfoot varus

Pattern ref.	Named variable	Level of support	Pattern ref.	Named variable	Level of support
1. Foot inverted on heel strike, remaining inverted throughout					
RFV 24/2	Part. comp. + pl. fl. 1st	NC	RFV 16/2	Part. comp.	NC
RFV 52/4	Rigid	DS	RFV 48/1	Rigid	DS
RFV 35/2	Part. comp.	NC	RFV 52/3	Part. comp.	NC
RFV 53/4	V. little comp.	DS	RFV 20/3	Abducted gait	NC
RFV 53/2	Part. comp.	NC	RFV 12/2	Comp.	C
2. Foot inverted on heel strike, reverting to normal inclination at forefoot					
RFV 53/3	Pl. fl. 1st ray	DS	RFV 34/3	Part. comp.	DS
RFV 26/3	Uncomp. + pl. fl. 1st	DS	RFV 1/1	Comp. by STJ pron.	DS
RFV 24/2	Part. comp. + pl. fl. 1st met.	DS	RFV 42/2	Comp.	DS
RFV 2/3	Part. comp.	DS	RFV 24/1	Comp.	DS
3. Foot inverted on heel strike, followed by pronation					
RFV 18/2	Pl. fl. 1st ray	IS	RFV 5/2	Comp.	DS
RFV 34/4	Comp.	DS	RFV 51/2	Comp. by STJ pron.	DS
RFV 11/2	Comp.	SD	RFV 52/2	Comp.	DS
RFV 1/2	Pl. fl. 1st ray	IS			
4. Foot inverted throughout with abduction					
RFV 34/2	Fixed RFV	DS	RFV 20/2	Abd. Gait. Equinus	DS
RFV 52/4	Rigid	DS	RFV 31/2	Abd. twist	IS
RFV 35/2	Part. comp.	NC	RFV 48/1	Rigid	DS
RFV 53/4	V. little comp.	DS	RFV 52/3	Part. comp.	NC
RFV 53/2	Part. comp.	NC	RFV 12/2	Comp.	NC
RFV 35/3	Comp.		RFV 20/3	Abd. gait	DS
5. Foot inverted throughout stance with abduction and walking on heels					
RFV 8/2	Part. comp.	NC			
6. Foot inverted throughout with adduction (intoeing)					
RFV 34/2	Fixed RFV	DS	RFV 52/4	Rigid	NC
7. Foot pronated prior to heel strike and throughout stance					
RFV 11/3	Comp.	IS	RFV 33/3	Comp.	IS
RFV 7/2	Pl. fl. 1st ray		RFV 55/2	Part. comp.	IS
RFV 18/4	Comp.	IS	RFV 28/3	Comp.	IS
8. Foot lands in pronation, then transfers to inversion to compensate					
RFV 51/3	O'loaded 2nd MPJt	NC	RFV 31/3	Pron. from h.s.	DS
9. Foot lands in inversion, the pronates with abductory twist to compensate					
RFV 18/3	Part. comp.	IS	RFV 13/2	Flexible f'foot	NC
RFV 23/2	Part. comp.	IS	RFV 5/3	Part. comp.	IS
RFV 54/3	Part. comp.	IS			
10. Inversion with heel equinus leading to no heel strike and pronation					
RFV 6/1	Comp.	IS			
11. Inversion with heel equinus leading to no heel strike and compensation via abductory twist					
RFV 22/2	Comp. by STJ pron.	IS	RFV 32/2	Comp.	IS
12. Forefoot supination (or adductory twist)					
RFV 6/2	Part. comp. Rigid	IS			
13. Compensatory eversion with abduction					
RFV 32/3	Comp.	IS			

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TABLE 21 Named variables repeated across patterns given

Named variable	Frequency of occurrence with named pathologies			
	Pronation	Hallux rigidus	Pes cavus	Rearfoot varus
1. Abducted gait	1	2	1	2
2. Abductory twist	8	4	2	1
3. Adducted (intoed) gait	1	2	0	0
4. Arthritis	1	1	0	0
5. Calc. varus/inversion	2	0	2	0
6. Comp. pes cavus	0	0	3	0
7. Comp. pronation	3	0	0	0
8. Comp. rearfoot varus	3	0	0	18
9. D'flexed 1^{st} + 5^{th} Mets.	1	0	1	0
10. Equinus	3	1	7	1
11. Fixed/severe pronation	19	1	0	1
12. Forefoot inversion/varus	3	5	0	0
13. HAV	1	1	0	0
14. Hallux limitus	2	0	0	0
15. Hypermobile 1^{st} ray	3	0	0	0
16. Hypermobile pronation	3	0	0	0
17. IPJt extn.	0	2	0	0
18. Mobile pes cavus	0	0	3	0
19. Overloaded 2^{nd} MPJt	0	1	0	1
20. Painful hallux	0	3	0	0
21. Part. comp. pronation	3	0	0	0
22. Part. comp. rearfoot varus	0	0	0	15
23. Pl. fl. 1^{st} met/ray	4	1	3	6
24. Rearfoot valgus	4	0	0	0
25. Rigid pes cavus	0	0	6	0
26. Rigid pl. fl. 1^{st} + 5^{th} MPJts	0	0	2	0
TOTAL	65	24	30	45

TABLE 22 Number of statements produced in the pre-validation Delphi round 1

Section	No. statements produced	No. variables listed	Additional variables suggested	Mean no. statements/ variable
Foot/gait Pathologies	233	139	3	1.64
Gait types	66	19	3	3
Ranges of movement	62	15	0	4.13
Footwear	119	31	0	3.84
All sections	480	204	6	2.29

TABLE 23 Patterns of change for statements overall in pre-validation Delphi rounds

No. statements	Type of change
36	Oscillatory
68	Monotonic, increasing consensus
239	Monotonic, decreasing consensus
23	None - Remained static throughout
111	None - Agreed in Round 2

TABLE 24 Interobserver agreement levels achieved for paired observers

Agreement	Pair 1/2	Pair 1/3	Pair 1/4	Pair 2/3	Pair 2/4	Pair 3/4
Poor	4/15 (27%)	1/15(7%)	1/15(7%)	0/15 (0%)	1/15(7%)	0/15 (0%)
Slight	2/15 (13%)	5/15 (33%)	2/15 (13%)	4/15 (27%)	0/15 (0%)	2/15 (13%)
Fair	5/15 (33%)	3/15 (20%)	3/15 (20%)	1/15(7%)	2/15 (13%)	5/15 (33%)
Moderate	0/15 (0%)	1/15(7%)	4/15 (27%)	5/15 (33%)	4/15 (27%)	3/15 (20%)
Substantial	1/15(7%)	1/15(7%)	0/15 (0%)	0/15 (0%)	2/15 (13%)	0/15 (0%)
Perfect	3/15 (20%)	4/15 (27%)	5/15 (33%)	5/15 (33%)	6/15 (40%)	5/15 (33%)

TABLE 25 Levels of agreement achieved by individual podiatrists

Agreement	Podiatrist 1	Podiatrist 2	Podiatrist 3	Podiatrist 4
Poor	6/45 (13%	5/45 (11%)	1/45 (3%)	2/45 (4%)
Slight	9/45 (20%)	6/45 (13%	11/45 (25%)	4/45 (9%)
Fair	11/45 (25%)	8/45 (18%)	9/45 (20%)	10/45 (22%)
Moderate	5/45 (11%)	9/45 (20%)	9/45 (20%)	11/45 (25%)
Substantial	2/45 (4%)	3/45 (7%)	1/45 (3%)	2/45 (4%)
Perfect	12/45 (27%)	14/45 (31%)	14/45 (31%)	16/45 (36%)

TABLE 26 Classifications given by observers for pronation, pes planus and reduced arches

Classifications given by observers for pronation					
Observer	ILA Pathology	Foot type	Whole foot pathology	Forefoot pathology	Gait abnormality
1	1	9	2	4	0
2	0	8	0	0	5
3	4	8	4	0	2
4	2	7	3	0	4

Classifications given by observers for pes planus					
Observer	ILA Pathology	Foot type	Whole foot pathology	Forefoot pathology	Gait abnormality
1	5	0	3	0	0
2	0	3	0	0	0
3	1	2	1	0	0
4	1	3	3	0	0

Classifications given by observers for reduced arches					
Observer	ILA Pathology	Foot type	Whole foot pathology	Forefoot pathology	Gait abnormality
1	0	0	0	0	0
2	6	0	0	0	0
3	0	0	0	0	0
4	1	0	0	0	0

TABLE 27 No. occasions that pronation, pes planus and reduced arches were associated with the same subject, by individual observers

Conditions observed together/ subject	No. observations/observer for each combination			
	Observer 1	Observer 2	Observer 3	Observer 4
Pronation + Pes Planus	6	1	1	1
Pronation + Reduced Arches	0	4	0	0
Pes Planus + Reduced Arches	0	0	0	0
Pronation, Pes Planus + Reduced Arches	0	2	0	1

TABLE 28 Observer pairings to be used in the validation phase of the project

Condition/state to be assessed	Observer pairing selected for the assessment
Lower limb pathology	1 v 2
ILA pathology	1 v 4
Foot type	1 v 4
Heel pathology	2 v 4
Forefoot pathology	2 v 4
Hallux pathology	2 v 3
Lesser toe pathology	2 v 4
Whole foot pathology	2 v 4
Ankle pathology	2 v 4
Gait pathology	2 v 4
Range of joint movement	2 v 4
Shoe fit	1 v 3
Shoe dimensions	1 v 4
Shoe condition	2 v 4
Amount of shoe wear	2 v 4

TABLE 29 The relationship of the research aims in the validation phase, to the analysis approach adopted

Research aim	Approach to meeting research aim
Determine whether the instrument can clarify, differentiate and show similarities between shoe wear patterns in reality?	♦ Show whether the wear pattern can be presented by the instrument for every item of footwear examined. Show reasons for the grid failing to present a pattern form.
	♦ Determine whether different patterns are suggested between individuals and items of footwear by the instrument. Show reasons for differences occurring.
Determine whether the model of wear influence is justified (i.e. is wear in reality fundamentally a product of holistic foot function with foot pathology demonstrating a lower influence than primary walking intention and external factors a lower influence than foot pathology)?	♦ Show whether the overriding holistic function is suggested by the wear pattern within the given contexts and therefore whether patterns observed support functions present in reality. ♦ Demonstrate whether or not wear relates consistently and directly to foot pathologies when present. ♦ Determine what external variables have been present, whether these have influenced the wear pattern and under what circumstances this influence has occurred.

TABLE 30 Repeated wear pattern focal codes in footwear examined during the validation phase

Footwear item reference	Footwear item reference: 11L	11R	12L	12R	13L	13R	14L	14R	21L	21R	22L	22R	23L	23R	24L	24R	31L	31R	32L	32R	33L	33R
11L		✖	-	-	✖	✖	✓	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖
11R	✖		-	-	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖
12L	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12R	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13L	✖	✖	-	-		✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖
13R	✖	✖	-	-	✖		✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖
14L	✓	✖	-	-	✖	✖		✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖
14R	✖	✖	-	-	✖	✖	✖		✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖
21L	✖	✖	-	-	✖	✖	✖	✖		✖	✓	✖	✓	✖	✓	✖	✖	✖	✖	✖	✖	✖
21R	✖	✖	-	-	✖	✖	✖	✖	✖		✖	✓	✖	✓	✖	✓	✖	✖	✖	✖	✖	✖
22L	✖	✖	-	-	✖	✖	✖	✖	✓	✖		✖	✓	✖	✓	✖	✖	✖	✖	✖	✖	✖
22R	✖	✖	-	-	✖	✖	✖	✖	✖	✓	✖		✖	✓	✖	✓	✖	✖	✖	✖	✖	✖
23L	✖	✖	-	-	✖	✖	✖	✖	✓	✖	✓	✖		✖	✓	✖	✖	✖	✖	✖	✖	✖
23R	✖	✖	-	-	✖	✖	✖	✖	✖	✓	✖	✓	✖		✖	✓	✖	✖	✖	✖	✖	✖
24L	✖	✖	-	-	✖	✖	✖	✖	✓	✖	✓	✖	✓	✖		✖	✖	✖	✖	✖	✖	✖
24R	✖	✖	-	-	✖	✖	✖	✖	✖	✓	✖	✓	✖	✓	✖		✖	✖	✖	✖	✖	✖
31L	✖	✖	-	-	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖		✖	✓	✖	✓	✖
31R	✖	✖	-	-	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖		✖	✓	✖	✓
32L	✖	✖	-	-	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✓	✖		✖	✓	✖
32R	✖	✖	-	-	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✓	✖		✖	✓
33L	✖	✖	-	-	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✓	✖	✓	✖		✖
33R	✖	✖	-	-	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✓	✖	✓	✖	

<u>Key to table</u>

✓ = Focal code (i.e. pattern) match

✖ = Focal code (i.e. pattern) mismatch

\- = Could not compare due to legibility

TABLE 31 Comparison of level and type of external variables acting on different outsoles of footwear examined

External Variable	Footwear item present in																					
	Left											Right										
	1/1	1/2	1/3	1/4	2/1	2/2	2/3	2/4	3/1	3/2	3/3	1/1	1/2	1/3	1/4	2/1	2/2	2/3	2/4	3/1	3/2	3/3
Pain MPJt 1	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-
Heel pain	-	-	4	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bespoke insole	4	4	-	4	-	-	-	3	4	4	4	4	4	-	4	-	-	-	3	4	4	4
Rocker sole	-	-	-	-	-	-	-	-	-	-	-	4	4	-	4	-	-	-	-	-	-	-
Steel plate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-
Walking	3	3	1	4	1	1	3	2	3	3	3	3	3	1	4	1	1	3	2	3	3	3
Use outside	4	4	-	4	4	4	4	4	2	2	3	4	4	-	4	4	4	4	4	2	2	3
Stair use	1	1	-	1	-	-	-	-	1	1	1	1	1	-	1	-	-	-	-	1	1	1
Amount used	3	3	1	3	2	2	3	2	3	3	3	3	3	1	3	2	2	3	2	3	3	3
Shoe stiffness	2	2	-	3	-	-	-	-	-	-	-	3	3	-	3	-	-	-	-	-	-	-
Shoe feels too large	3	3	1	4	-	-	-	-	4	4	-	3	3	1	4	-	-	-	-	4	4	-
High swing	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-
Non-bespoke insole	-	-	-	-	3	3	3	-	-	-	-	-	-	-	-	3	3	3	-	-	-	-
Wedge	-	-	-	-		4	-	-	-	-	-	-	-	-	-	-	4		-	-	-	-
Driving	-	-	-	-	2	2	2	3	-	-	-	-	-	-	-	2	2	2	3	-	-	-
Standing	-	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-	-	1	2	-	-	-
Support	-	-	-	-	-	2	3	-	-	-	-	-	-	-	-	-	2	3	-	-	-	-
Plate in foot	-	-	-	-	-	-	-	-	4	4	4	-	-	-	-	-	-	-	-	-	-	-
Dancing	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-
Kneeling	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1
General foot pain	-	-	-	-	-	-	-	-	4	4	4	-	-	-	-	-	-	-	-	-	-	-
Toe pain	-	-	-	-	-	-	-	-	4	4	4	-	-	-	-	-	-	-	-	4	4	4
High heel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Thick sole	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shallow toe box	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Shoe short	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	4	4
Shoe too long	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Inadequate width	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Too wide	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Inadequate depth	-	-	-	-	4	4	4	4	4	4	4	-	-	-	-	4	4	4	4	4	4	4
Heel fit too loose	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Toe box tight	-	-	-	-	4	4	4	4	4	4	4	-	-	-	-	4	4	4	4	4	4	4

<u>Key to scores allocated</u>

$\boxed{-}$ = Variable not present

$\boxed{1}$ = Variable present/has been present to low degree

$\boxed{2}$ = Variable present/has been present to moderate degree

$\boxed{3}$ = Variable present/has been present to moderately high degree

$\boxed{4}$ = Variable present to high degree/permanently

TABLE 32 Comparison of type of internal variables acting on different outsoles of footwear examined

Internal Variable	Foot present in					
	Left			Right		
	1	2	3	1	2	3
Genu Valgum	-	-	✓	-	-	✓
Tibial Varum	✓	✓	✓	✓	✓	✓
Pronation	✓	✓	✓	✓	✓	✓
Abduction	-	✓	-	-	✓	-
Pes Planus	✓	✓	✓	✓	✓	
Hallux Rigidus	-	✓	✓	-	✓	-
Hallux Limitus	✓	-	-	✓	-	-
Elevated 1st toe	-	✓	✓	-	✓	✓
Short 2nd toe	-	-	✓	-	-	-
Minor pathology 4th + 5th	✓	✓	✓	✓	✓	✓
Clawed toes	-	✓	-	-	✓	✓
Pain in 1st toe	-	-	✓	-	-	-
Medial metatarsal pain	-	-	✓	✓	-	-
Metatarsal area pain	-	✓	-	-	✓	✓
Calcaneal area pain	✓	-	-	-	-	-
Mid-foot area pain	-	-	-	-	-	-
Reduced dors./pl. ankle ROM	✓	-	-	✓	-	-
Inverted calc.	-	✓	-	-	✓	-
Everted calc.	-	-	✓	-	-	✓
Increased forefoot inversion	-	✓	✓	-	✓	✓
Increased 2nd toe ROM	-	-	✓	-	-	-
Increased 3rd toe ROM	-	-	✓	-	-	-
Increased 4th toe ROM	-	-	-	-	-	-
Normal heel strike	-	-	-	-	-	-
Lateral heel strike	-	-	-	-	-	-
Lat/central heel strike	-	-	-	-	-	-
Normal heel strike + rapid eversion	✓	-	-	✓	-	-
Heel inversion	-	-	-	-	-	-
Heel eversion	-	-	-	-	-	-
Abducting of foot	✓	✓	✓	-	✓	✓
Foot straight	-	-	-	✓	-	-
Pronation	-	-	✓	-	-	✓
H. Lim. Preventing pronation	✓	-	-	✓	-	-
H. Rig. preventing pronation	-	-	-	-	-	-
Classic H. Rig. function	-	-	-	✓	✓	-
Medial roll off	-	-	-	-	-	-
Forefoot inverting throughout stance	-	-	-	-	-	-
Inverted forefoot	-	✓	-	-	-	-
Incompetent 1st ray ⇒ 2nd toe-off	-	-	✓	-	-	✓

(✓ = variable present - = variable not present)

TABLE 33 Comparison of observations with video frame analysis

	Function analysis		
Function being assessed	Podiatrist 1 Observations	Podiatrist 2 Observations	Video recorded function
Subject 1 (left foot)	Pronation Foot abducted Abductory twist	Pronation Foot abducted Abductory twist	Normal heel strike with rapid heel eversion. Foot abducted. Hallux limitus restricting pronation
Subject 1 (right foot)	Lateral heel strike Foot straight Abductory twist	Lateral heel strike Foot straight	Normal heel strike with rapid eversion, No abduction Hallux limitus restricting pronation with "classic" hallux rigidus function following
Subject 1 + footwear 1-4 (left)	Pronation Foot abducted Abductory twist	Pronation Foot abducted	Normal heel strike with rapid eversion Pronation restricted due to hallux limitus
Subject 1 + footwear 1-4 (right)	Lateral heel strike Foot straight Abductory twist	Lateral heel strike Foot straight	Foot inverted throughout stance, with no medial ground contact
Subject 2 (left)	Lateral heel strike Pronation Abducted foot Medial roll off Abductory twist Clawing of toes 2 to 5	Lateral heel strike Pronation Medial roll off Clawing of toes 2 to 5 Walks with 1st elevated	Foot abducted during stance, with inverted forefoot
Subject 2 (right)	Lateral heel strike Pronation Abducted foot Medial roll off Abductory twist Clawing of toes 2 to 5	Lateral heel strike Pronation Medial roll off Clawing of toes 2 to 5 Walks with 1st elevated	Foot abducted with "classic" hallux rigidus function
Subject 3 (left)	Pronation Abducted foot Medial roll off Abductory twist Walks with 1st elevated	Lateral heel strike Pronation Medial roll off	Foot abducted and pronating during function 1st ray incompetence leading to toe-off via the 2nd toe
Subject 3 (right)	Pronation Abducted foot Medial roll off Abductory twist Walks with 1st elevated	Lateral heel strike Pronation	Foot abducted and pronating during function 1st ray incompetence leading to toe-off via the 2nd toe

APPENDICES

APPENDIX 1 Papers presented by podiatrists at forensic science conferences

International Association for Identification, 79th Educational Seminar, July 24 - 30, 1994, Phoenix, Arizona

DiMaggio J., "The foot and shoe: an important but overlooked identification combination,"
Gunn N., "Footwear identification proofs by pathology in leg or foot reflected into insole and outsole wear characteristics,"
Vernon D.W., "The pathologies of the foot and gait and their effect on shoe wear marks,"

International Association for Identification, 80th Educational Seminar, July 23 - 28, 1995, Costa Mesa, California

DiMaggio J., "Forensic podiatry,"

International Association for Identification, 81st Educational Seminar, July 21 - 27, 1996, Greensborough, North Carolina

Vernon D.W., "Current findings in a Delphi study of shoe wear marks,"
DiMaggio D., "Foot uniqueness and it's forensic applications: a preliminary study".

International Association for Identification, 82nd Educational Seminar, July 27 – August 1st, 1997, Boston, Massachusetts

Vernon D. W., "Towards greater understanding of the interpretation, interrelationship and variables affecting shoe wear patterns".

Canadian Identification Society Annual Conference, July 1 – 5, 1998, Kitchener, Ontario.

Vernon D. W., "Forensic podiatry "

International Association for Identification, 83rd Educational Seminar, July 19 - 25, 1998, Little Rock, Arkansas

DiMaggio J., "Does the shoe fit? A podiatrists' view"
Vernon D. W., Gunn N., "Forensic podiatry – an overview", (poster presentation)

International Association for Identification, 84th Educational Seminar, July 11 - 17, 1999, Milwaukee, Wisconsin.

DiMaggio J. "Forensic podiatry and barefoot evidence examination".
Gunn N., "The cats paw case"
Vernon D. W., "An assessment of outsole wear patterns of footwear with common ownership"

Forensic Podiatry/ Barefoot evidence Conference 2000, May 5-7, 2000, Scottsdale, Arizona

Gunn N., "A quarter century of pioneering in forensic podiatry"
Dimaggio J., "What is forensic podiatry? The basics"
Braver R., "Getting started – A new dimension in podiatry"
DiMaggio J., "The specifics of forensic podiatry – protocols, procedures and the evaluation"
Vernon W., "The shoe wear pattern project"

International Association for Identification, 85th Educational Seminar, July 23 - 29, 2000, Charleston, West Virginia.

DiMaggio J., "Barefoot evidence – the forensic podiatrists role"

APPENDIX 2 Shoe wear and its' use in diagnosis, 1979: Salford College of Technology, Northern College of Chiropody – student information sheet

SALFORD COLLEGE OF TECHNOLOGY

Northern College of Chiropody

Shoe Wear and Its use in DIAGNOSIS

Wear on a normal shoe:

1. Posterio-lateral border of the heel
2. Under the tread line of the shoe
3. Under the phalanges
4. Slight tip wear

No area of wear is excessive when compared with the rest of the shoe.

What are the functions of the toes?

1. To assist balance
2. To 'spring' the foot forward in walking (To take-off)

What will happen if the toes cease to function?

1. The foot will 'roll off the tip of the shoe' producing excessive wear.

EXCESSIVE wear on the tip of the Shoe

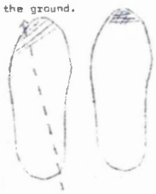
is caused by:

1. Loss of toe function - associated with weak foot or debility.
2. Short shoes and socks which prevent the toes from working.
3. Shoes that are too long will catch their toes on the ground.

DEVIATION in Tip Wear will occur with

1. Rigid or static flat foot.
2. Hallux Valgus

Caused by the patient walking 'across' their foot to compensate for the stiffness.



Sole wear

caused by the two extremes of mobility (movement)

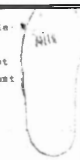
1. Rigidity
2. Hypermobility

N.B. They may be related to similar deformities

Rigid Flat Foot

Hypermobile Flat Foot

What differences in wear would you expect to find between Rigid and Mobile deformities ?



Rigid deformities produce highly localised wear marks. Hypermobile deformities produce diffused wear marks.

If in Hypermobile feet the converging sides of the shoe may prevent the 1st and 5th metatarsal segments from moving forwards, the thrust on the 2nd 3rd and 4th will be exaggerated.

In extreme cases i.e. the court shoe, the thrust will be confined to the 2nd met.head only.

The foot may be elongated more along the inner than the outer border; especially if the shoe is inflared!

In these cases the wear mark under the 1st met. head will be less marked or start further forward.

The constant rubbing to and fro' of the met. heads in the shoe produces a ridging of the inlay and a special type of callous formation.

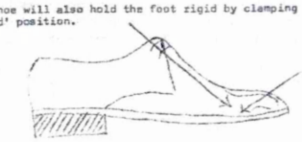
see Hanby & Walker. Ch. VI pp 68-71.

Wear Marks in Rigidity

A foot may be rigid in a shoe for two reasons:

1. The foot itself is rigid
2. The shoe holds the foot in a rigid position

The short shoe will also hold the foot rigid by clamping the toes in a 'clawed' position.



When the foot elongates under weight-bearing pressure is extended from both directions on the met-heads.

Both these 'types' of rigidity result in a localised wear mark, across the met-heads.

Wear marks associated with foot strain:

Foot strain is the result of debility, or lack of power within the muscles of the leg and foot.

To compensate for this loss of power some muscles 'overpull', holding the foot in a supinated position so as to maintain the integrity of the long arch of the foot.

The result of this inversion is that the body weight is transfered to the outer border of the foot and toes resulting in wear marks in this area.

HALLUX RIGIDUS OR FLEXUS:

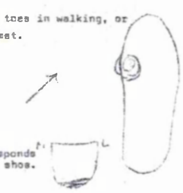
Similar wear marks to the above will be found with H.R. & H.F. with exaggerated wear under the HALLUX.

It will also be seen that the 'toe-spring' of the shoe will have been flattened out on the medial side to a point co-inciding with the distal end of the proximal phalanx of the HALLUX. From this point the toe will be up-turned.

PIVOTING

This arises when the patient avoids flexing the toes in walking, or is perhaps unable to and 'swivels' off the 1st met.

concentric rings.

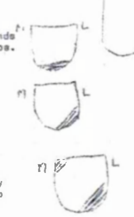


Wear Marks on the Heel of the Shoe

Normal wear: The wear mark on the heel corresponds with the angle of impact of the shoe.

In foot strain: causing overpull of the muscles supporting the arch the weight is displaced laterally.

The muscle supporting the arch may be able to support the 'overpull' under full weight-bearing. If they cannot, the foot will collapse onto its' medial border (usually in the severe cases of foot strain) throwing the weight onto the front of the heel.



RIGIDITY OF THE FOOT

causes wear marks on the posterior border of the heel.

ABNORMAL Wear of the heelseat of the shoe:

1. If the heel seat overlaps all around the shoe, the foot is too big for the shoe.
2. Overlap of the heel seat on the inner border indicates a permanent valgus position of the foot on weight-bearing and balance.
3. Overlapping of the heel seat on the outer border indicates foot strain, the body-weight being transfered along the outer border of the foot and shoe.

Wear Marks on the upper of the shoe:

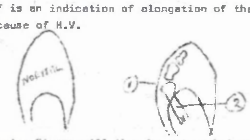
Hypermobility:

is frequently reflected in a lengthening of the medial border of the foot.

This elongation will enlarge the opening above the vamp, the contour of the opening developing an irregular shape.

If the thrust forward is very exaggerated in the hypermobile foot the head of the 1st met. will show itself on the vamp in a position anterior to normal.

This in itself is an indication of elongation of the arch and a predisposing cause of H.V.



Friction and Shearing Stress will then be set up between the foot and the shoe in two areas:

1. The medial side of the vamp.
2. Under the edge of the vamp.

The protrusion of an H.V. or a Bursa will cause creasing of the vamp of the shoe in front of the joint, causing an Hd. to form.

Therefore, Hypermobility of the foot can result in:

1. H.V.
2. Bursitis.

APPENDIX 3 Functional possibilities of the foot suggested to occur in association with hallux limitus/hallux rigidus

	Author		
Functional mechanism	Dananberg	Rzonka (1984)	Sherman (1993)
Pronation	✓ (Payne and Dananberg, 1997)		
Pronation with abduction			✓
Abducted gait		✓	
Forefoot inversion (Forefoot Varus)	✓ (Dananberg, 1986)	✓	
Supination		✓	✓
Premature lift off	✓ (Dananberg, 1986)		
Vertical toe off with secondary bipedal stance	✓ (Dananberg, 1986)	✓	
Hyperextension of 1st interphalangeal joint		✓	

✓ = function suggested by author

APPENDIX 4 Delphi round 1 package

Delphi round 1 covering letter

Podiatry and Chiropody Service **CommunityHealth Sheffield**
Fulwood House
Old Fulwood Road
Sheffield
S10 3TH
0114 - 2716767

Dear Sir/Madam

I am a state-registered chiropodist conducting research into shoe wear patterns as part of the requirement for a M.Phil/Ph.D study at Sheffield Hallam University. I am collecting patterns of shoe wear patterns with a view to placing these on an instrument which could be used to translate the meaning of wear patterns when placed over a shoe sole outline exhibiting wear patterns. This has potential value in chiropody teaching, clinical diagnosis and in crime scene examination where worn shoe prints are found. The project is known as the SWaMP (shoe wear mark) project.

The chosen technique for collecting wear patterns is by Delphi questionnaire to pull-in information that experienced chiropodists have on causes of shoe wear patterns. Participants would be required to sketch shoe wear patterns on sole outlines on an initial questionnaire and this information would be collated and presented to participants in order to arrive at a consensus regarding shoe wear pattern causes. Participants are required who have considerable clinical knowledge and experience.

I am therefore writing to 10 heads of Trust podiatry/chiropody services and schools of podiatry to request participation in this questionnaire phase of the project. I would be grateful if you could choose a very experienced chiropodist from your staff to participate in the questionnaire rounds, giving them the enclosed explanatory notes and questionnaire to complete which can then be returned to me in the stamped, addressed envelope for collation.

Thank you for your anticipated help in this project.

Yours faithfully

D. W. Vernon
SWaMP Project Research Student
Sheffield Hallam University.

Delphi round 1 enclosure list

The questionnaire package contains the following :

1. Covering letter

2. Explanatory notes

3. Example sheet

4. List of structural/functional states of the foot and gait

5. Questionnaire front sheet

6. Questionnaire follow-up sheet

7. Feedback sheet

8. Stamped, addressed envelope

DWV 29/4/95

Delphi round 1 explanatory notes

SWaMP Project Delphi Questionnaire - Explanatory Notes

Thank you for assisting in this project by completing the questionnaire rounds involved in this technique. The purpose of this project is to determine what the current level of knowledge is of shoe wear patterns as related to the various pathological states of foot and gait. This is being evaluated as part of a M.Phil/Ph.D. research project known as the SWaMP (shoe wear mark) project at Sheffield Hallam University.

In this initial questionnaire, you are asked to sketch up to 10 wear patterns with which you are familiar on the diagrams provided. Please state the associated condition on the adjacent line. In the follow up/s, you will be shown the sum of the results of the previous round and asked whether you would wish to modify your response in light of these results. In the final round, you will be shown the summary of the round two results and asked to give your level of certainty of these results.

In this first round, please show as many wear patterns as you can up to a maximum of 10 and return the questionnaire to me in the pre-paid envelope.

A list of several structural/functional states of the foot is enclosed for your assistance along with an example sheet showing the preferred style of representing the wear marks. If you have any problems with the questionnaire, please contact me on :

Daytime - 0114 - 2716767
Evenings - 01663 - 734414

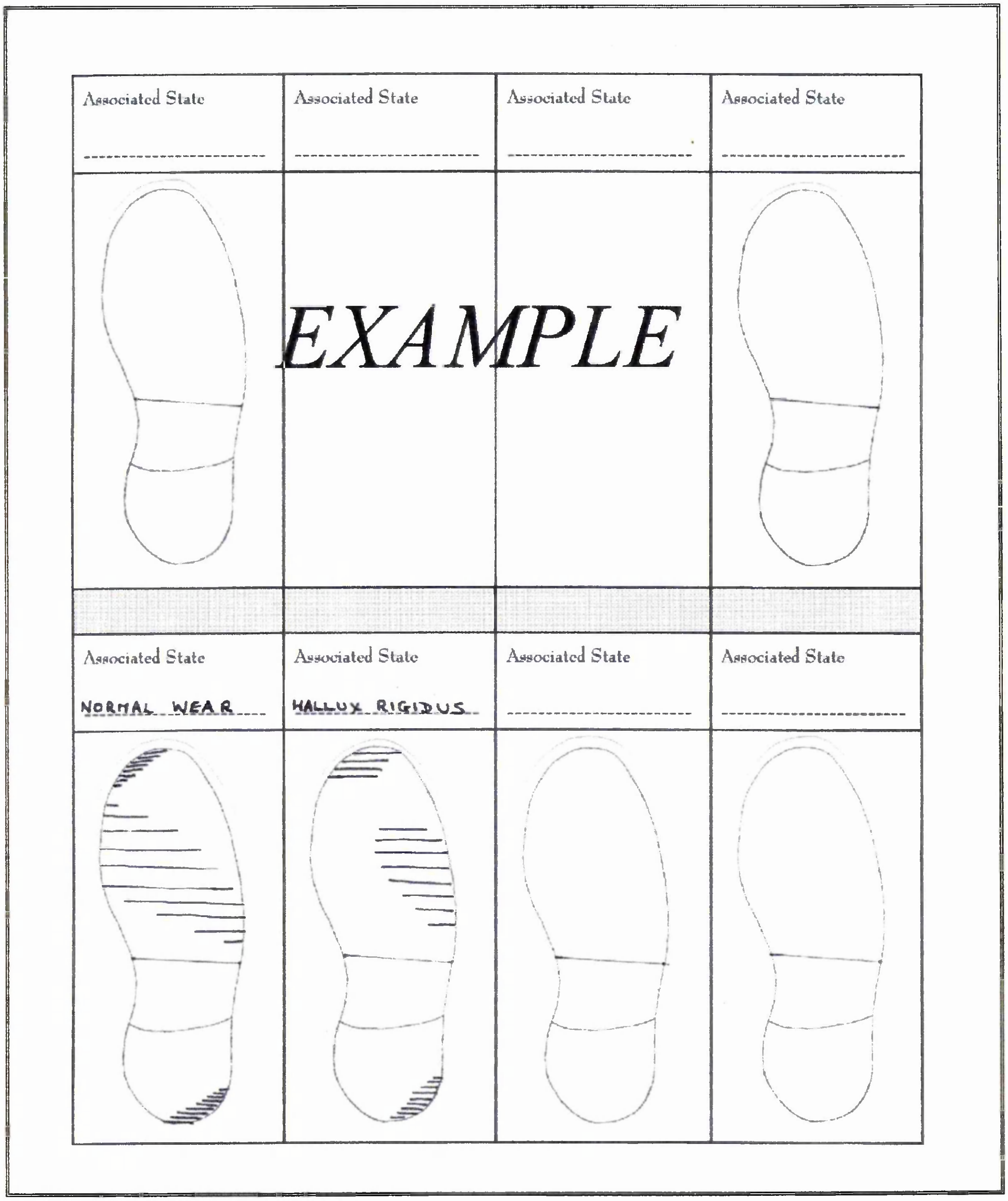
If you have any comments to make about the questionnaire, please list these on the enclosed feedback sheet.

Thank you once again for your assistance.

D. W. Vernon
SWaMP Project Research Student
Sheffield Hallam University.

APPENDIX 4 - contd.

Delphi round 1 example sheet



APPENDIX 4 - contd.

List of structural/functional states sent to participants

ABDUCTION	ABDUCTION AND EVERSION
ADDUCTION	ADDUCTION AND EVERSION
ANKLE EQUINUS	ATAXIC GAIT
BOW LEGS	CALCANEAL APOPHYSITIS
CALCANEAL BURSITIS	CALCANEAL EVERSION
CALCANEAL GAIT	CALCANEAL SPUR
CALCANEO-CAVUS	CALCANEO-VALGUS
CALCANEO-VARUS	CALCANEO-VARUS (COMPENSATED)
CHARCOT JOINTS	CHOREA
CLAW TOES	DIGITI QUINTI VARUS
DROP FOOT	EQUINO-CAVUS
EQUINO-VARUS	EXCESSIVE ANKLE DORSIFLEXION
FOOT STRAIN	FOREFOOT VALGUS
FOREFOOT VARUS	FREIBERG'S INFRACTION
GENU VALGUM	GENU VARUM
HALLUX FLEXUS	HALLUX RIGIDUS
HALLUX VALGUS	HAMMERED 2ND TOE
HEMIPLEGIC GAIT	HIGH STEPPING GAIT
HINDFOOT VALGUS	HINDFOOT VARUS
HYPERMOBILE 1ST AND 5TH MPJTS	HYPERMOBILE FOOT
INFLARED FOOT	INTOED GAIT
KOHLERS DISEASE	LOWER MOTOR NEURONE WEAKNESS
METATARSUS ADDUCTUS	METATARSUS PRIMUS ELEVATUS
METATARSUS PRIMUS VARUS	OUT-TOED GAIT
OVERLOADED 2ND MET.	PAINFUL NAIL DISORDERS OF THE 1ST TOE
PARAPARESIS	PARAPLEGIC GAIT
PES CAVUS	PES PLANO-VALGUS
PLANTAR DIGITAL NEURITIS (MORTON'S TOE)	PLANTAR FASCIITIS
PLANTAR FLEXED 1ST AND 5TH TOES	PLANTAR FLEXED TOES
POST-OPERATIVE STATES	PRONATED FOOT
PYRAMIDAL NEUROLOGICAL DISORDERS	REDUCTION OF LONGITUDINAL AND TRANSVERSE ARCHES
RETRACTED TOES	RETRO-CALCANEAL BURSITIS
RHEUMATOID ARTHRITIS	SEVERS DISEASE
SHORT 1ST METATARSAL	SHORT 5TH METATARSAL
SHUFFLING GAIT IN PARKINSONISM	SPLAYING OF THE METATARSALS
TAYLORS BUNION	TALIPES CALCANEO VALGUS
TALIPES CALCANEO VARUS	TALIPES EQUINO VALGUS
TALIPES EQUINO VARUS	TARSAL ARTHRITIS
VERTICAL TALUS	WADDLING GAIT

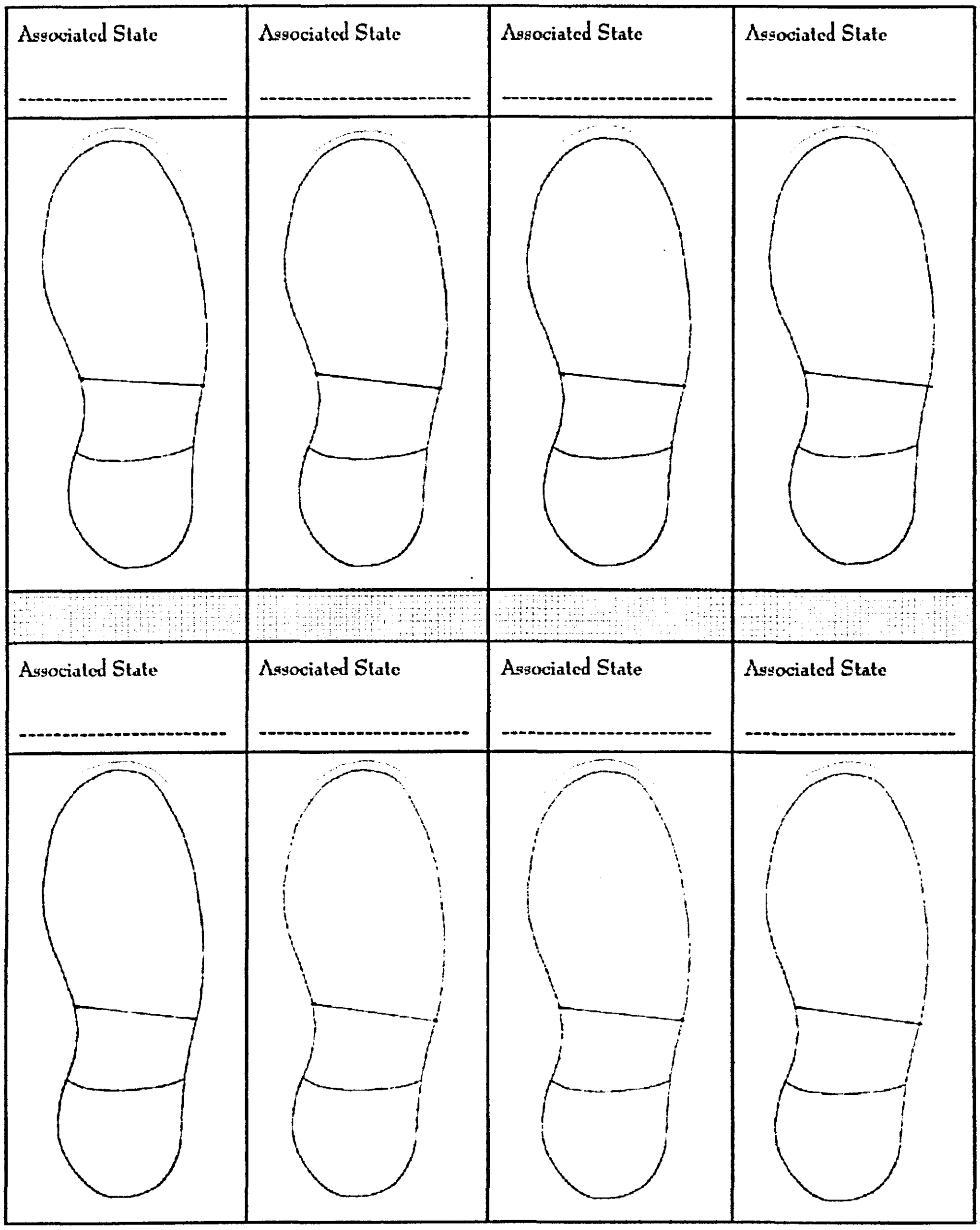
APPENDIX 4 - contd.

Delphi round 1 questionnaire

SWaMP Questionnaire

Name: **Tel:**

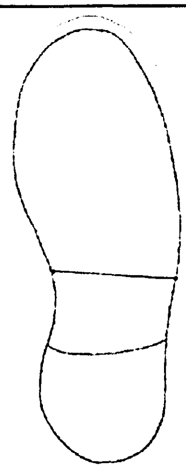
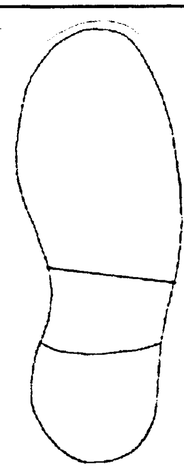
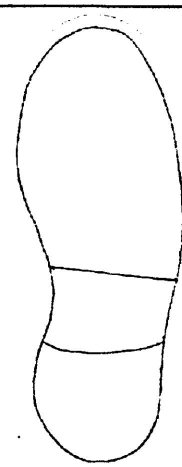
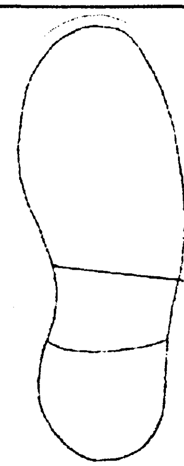
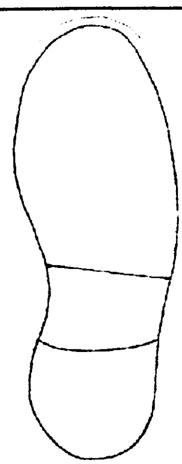
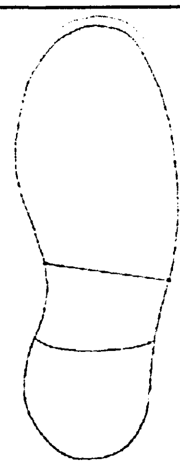
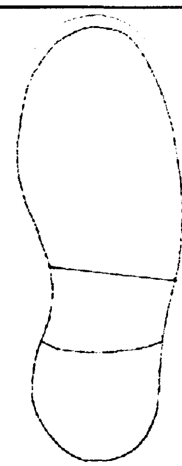
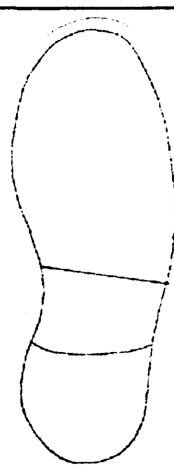
Trust address:



APPENDIX 4 - contd.

Delphi round 1 questionnaire follow up sheet

SWaMP Questionnaire (contd.)

Associated State ----------------------	Associated State ----------------------	Associated State ----------------------	Associated State ----------------------
			
Associated State ----------------------	Associated State ----------------------	Associated State ----------------------	Associated State ----------------------
			

APPENDIX 4 - contd.

Delphi round 1 feedback sheet

SWaMP project feedback sheet

Name of participant :

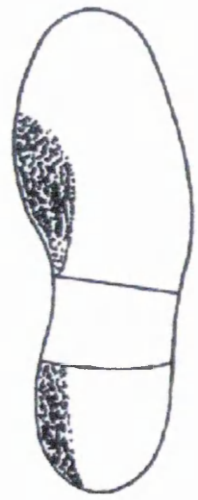
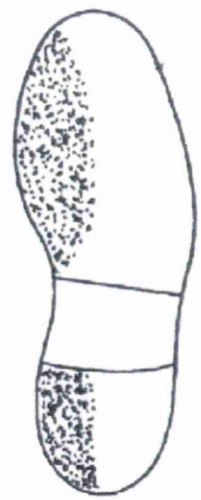
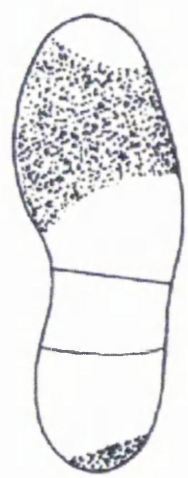
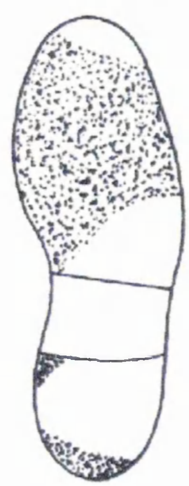
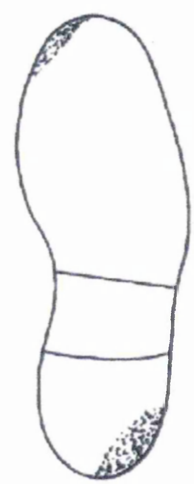
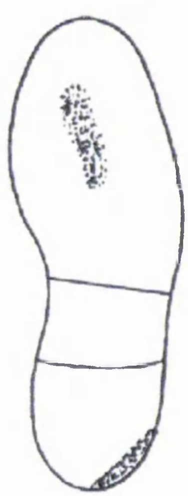
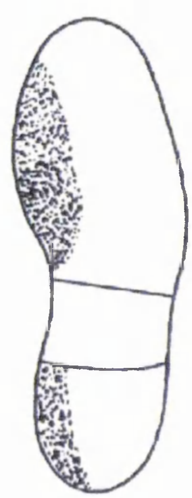
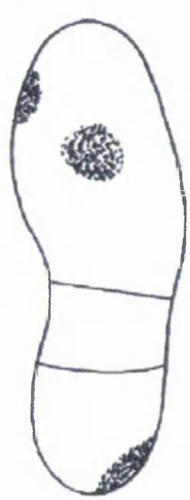
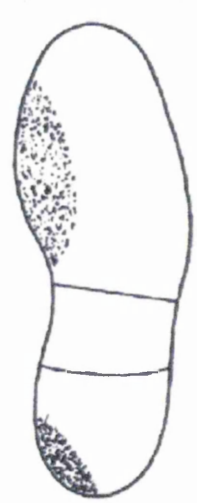
I have the following comments to make on the questionnaire :

(Please continue on separate sheet if necessary)

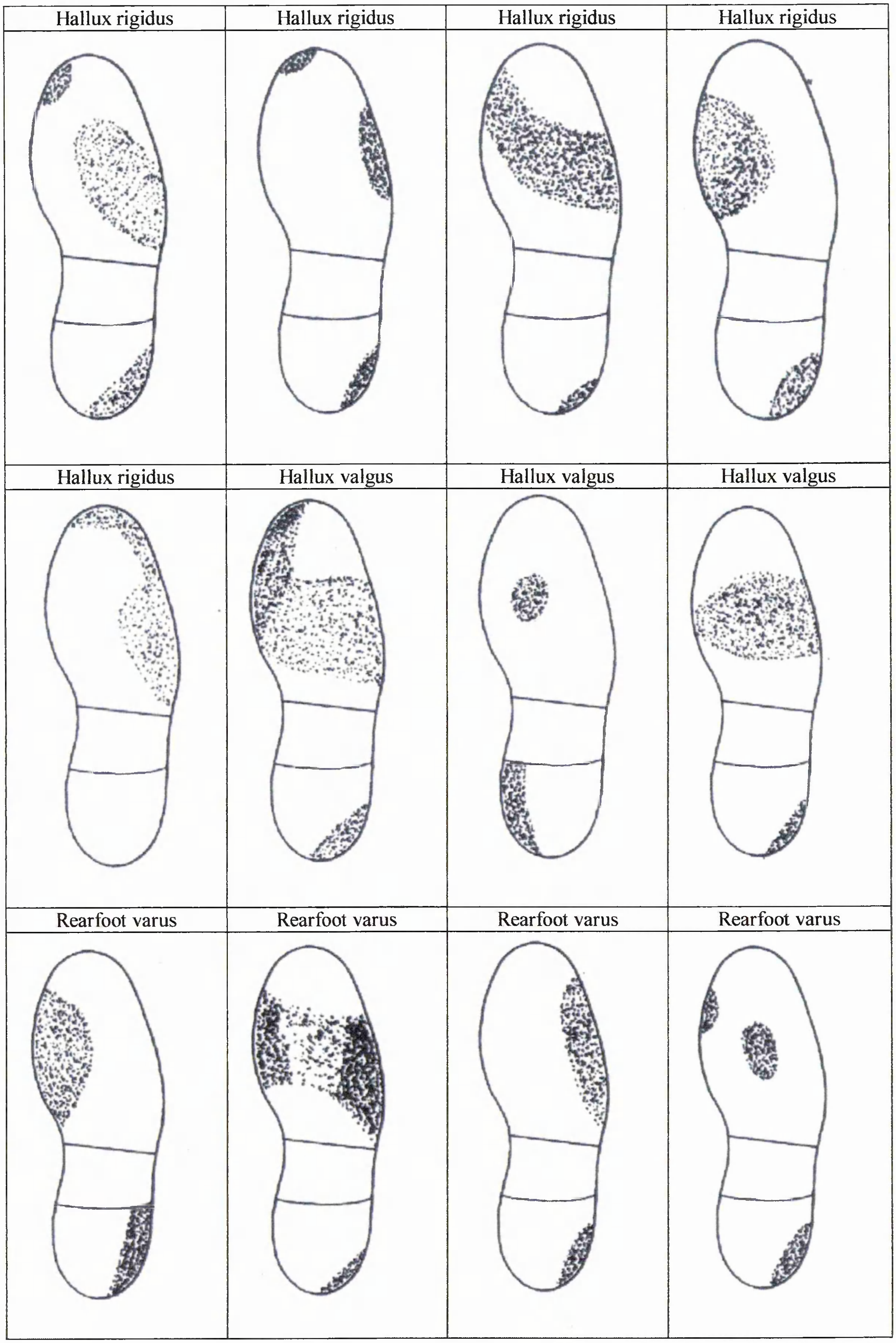
Thank you for your assistance.

D. W. Vernon
Research student
SWaMP project
Sheffield Hallam University

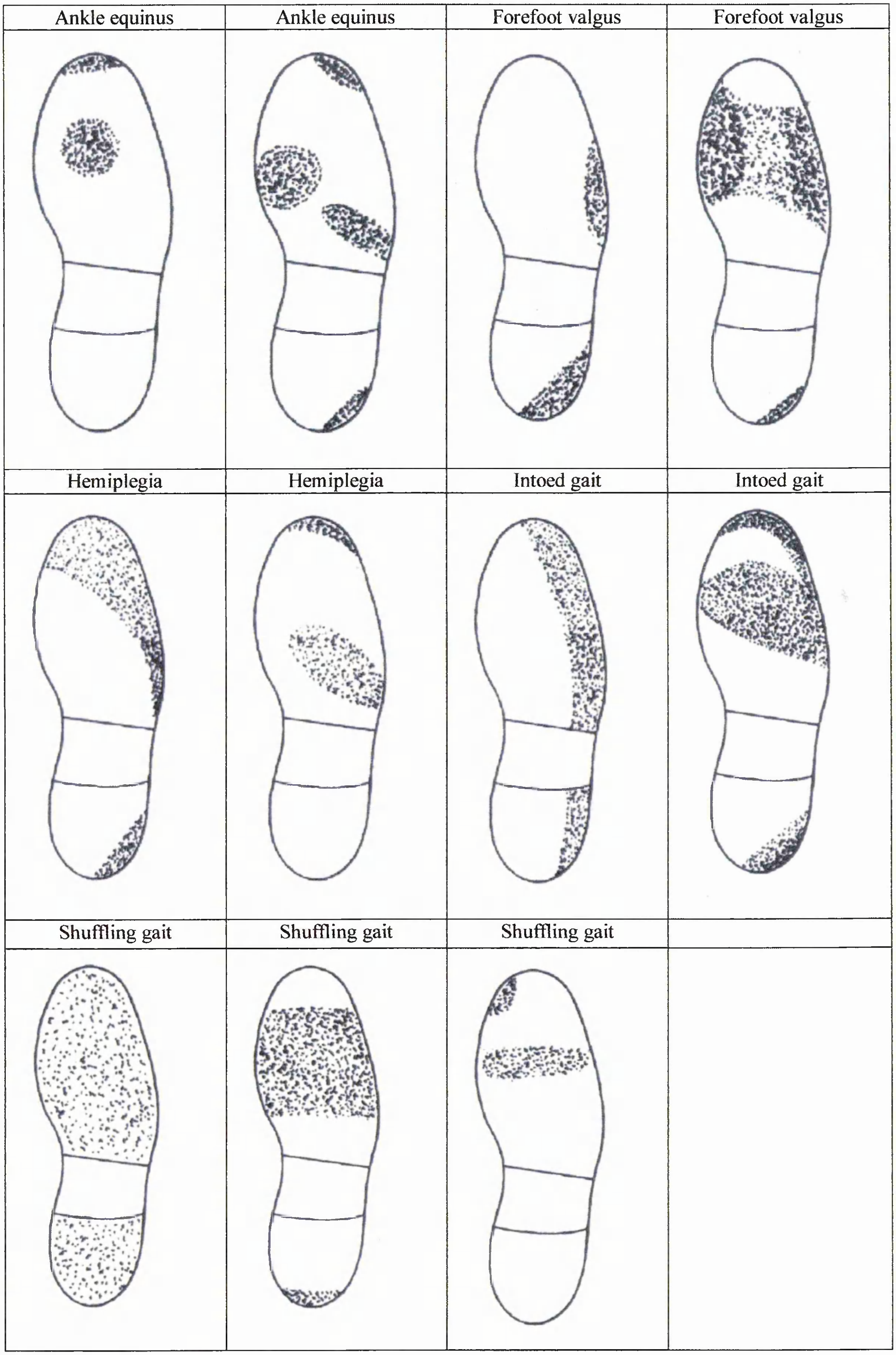
APPENDIX 5 Wear patterns for pathologies identified by more than one respondent

Calc. valgus/Pronation	Calc. valgus/Pronation	Calc. valgus/Pronation	Calc. valgus/Pronation
			
Calc. valgus/Pronation	Calc. valgus/Pronation	Calc. valgus/Pronation	Calc. valgus/Pronation
			
Calc. valgus/Pronation	Calc. valgus/Pronation	Calc. valgus/Pronation	Calc. valgus/Pronation
			

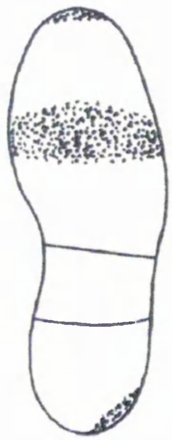
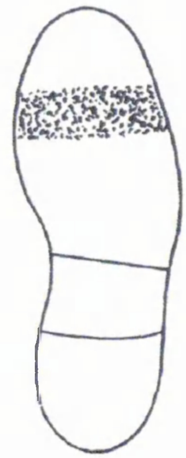
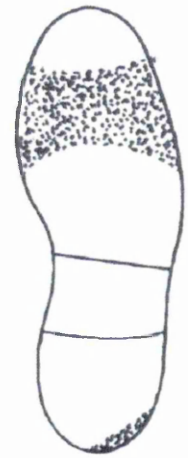
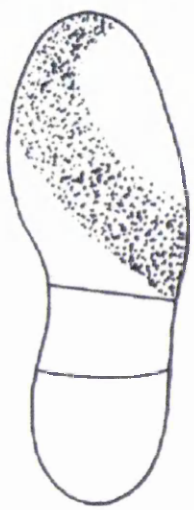
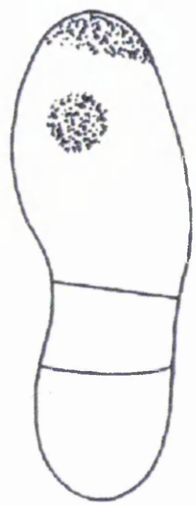
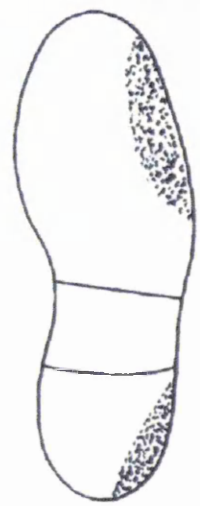
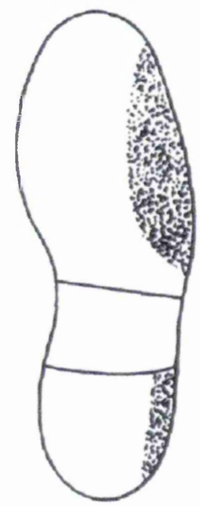
APPENDIX 5 - contd.



APPENDIX 5 - contd.



APPENDIX 5 - contd.

Pes cavus	Pes cavus	Retracted toes	Retracted toes
			
Severs disease	**Severs disease**	**Talipes equino varus**	**Talipes equino varus**
			

APPENDIX 6 Delphi Round 2 – Questionnaire package

The round 2 questionnaire package contains the following:

1. Explanatory notes

2. Key to section 2

3. Questionnaire round 2 - sections 1 and 2

4. Feedback sheet

5. Stamped, addressed envelope

DWV 24/5/95

Questionnaire round two - explanatory notes

Thank you for completing round one of the questionnaire. The purpose of round one was to collect a maximum of 10 characteristic shoe wear mark patterns from each participant. The results of the questionnaire have been collated and consensus is now sought in round two over a number of the patterns given. There are two sections in round two which you are asked to complete.

In section one, a characteristic wear mark pattern given by round one participants is shown. You are asked to indicate which of the given conditions that this wear mark relates to. You may mark as many possibilities as you wish for each condition.

In section two, a number of characteristic patterns given by round one participants have been broken down into separate wear area components. The percentage of replies given for each named condition which indicated wear in that area is shown along with the actual number of respondents that this percentage represents. You are asked to indicate which of these wear components you agree with in order to make up a total wear pattern. You may amend the response you gave in round one if you wish to do so. A key to section two is enclosed for your reference.

I would be grateful if you could respond within three weeks of receipt of this round two. As in the first round, if you have any comments regarding the second round, please list these on the enclosed feedback sheet.

If you have any problems with the questionnaire, please contact me on :

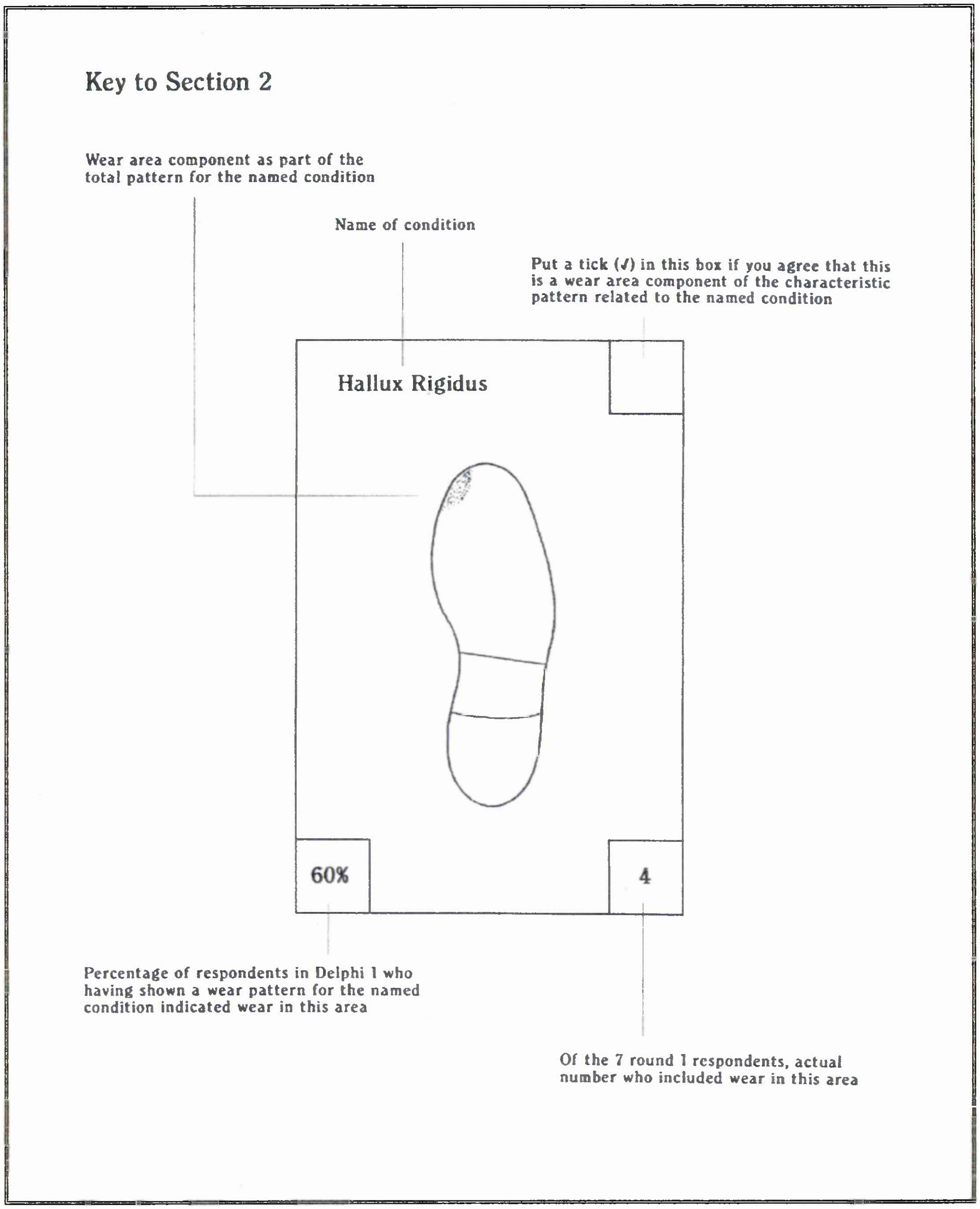
Daytime - 0114 - 2716767
Evenings - 01663 - 734414

Thank you once again for your assistance.

W. Vernon
SWaMP Project Research Student
Sheffield Hallam University.

APPENDIX 6 – contd.

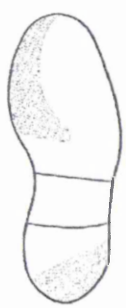
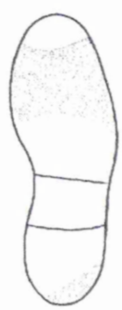
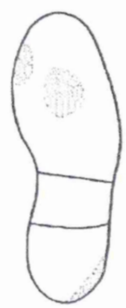
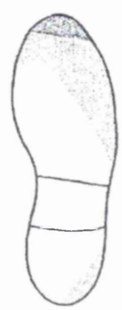
Round 2, section 2 key



APPENDIX 6 – contd.

Delphi round 2, section 1a

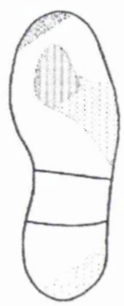
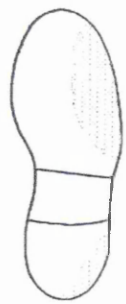
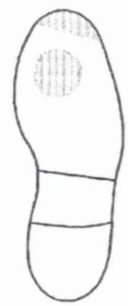
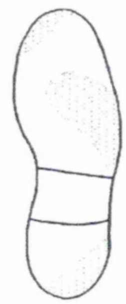
Section 1. Wear patterns given in Round 1 under more than one 'pathology' heading. Please tick ✓ relevant boxes.

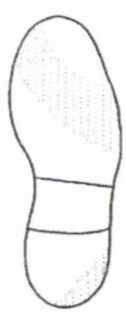
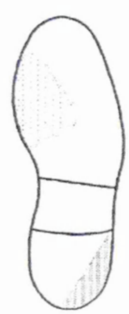
PATTERN 1.	PATTERN 2.	PATTERN 3.	PATTERN 4.
			
Pronated Foot ☐ Metatarsus Adductus ☐ Neither of these ☐ Other condition/s (please state) ☐	Pronated Foot ☐ Retracted Toes ☐ Forefoot Valgus ☐ None of these ☐ Other condition/s (please state) ☐	Pronated Foot ☐ Calc. Varus (compensated) ☐ Neither of these ☐ Other condition/s (please state) ☐	Forefoot Varus ☐ Freiberg's Infraction ☐ Hemiplegia ☐ None of these ☐ Other condition/s (please state) ☐

APPENDIX 6 – contd.

Delphi round 2, section 1b

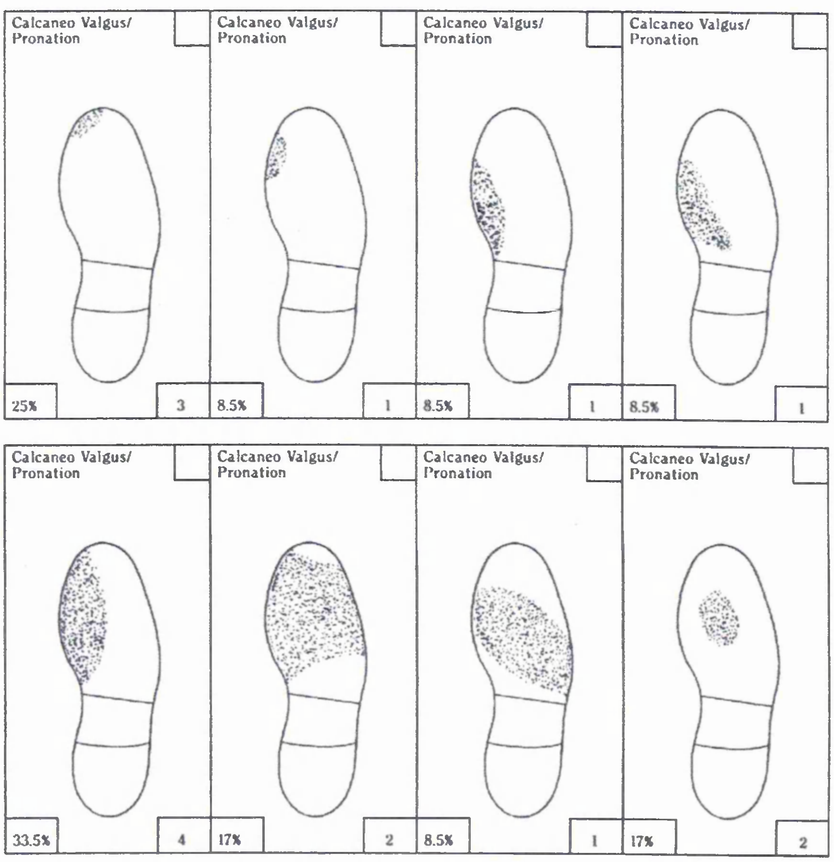
Section 1 (continued)

PATTERN 5.	PATTERN 6.	PATTERN 7.	PATTERN 8.
			
Hammer 2nd toe ☐ Claw toes ☐ Neither of these ☐ Other condition/s (please state) ☐	Talipes Equino Varus ☐ Rearfoot Varus ☐ Neither of these ☐ Other condition/s (please state) ☐	Ankle Equinus ☐ Severs disease ☐ Neither of these ☐ Other condition/s (please state) ☐	Pes Cavus ☐ Hallux Rigidus ☐ Neither of these ☐ Other condition/s (please state) ☐ ....

PATTERN 9.	PATTERN 10.	PATTERN 11.	PATTERN 12.
			
Hallux Rigidus ☐ Short 1st Metatarsal ☐ Neither of these ☐ Other condition/s (please state) ☐	Hallux Rigidus ☐ Rearfoot Valgus ☐ Neither of these ☐ Other condition/s (please state) ☐	☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ....

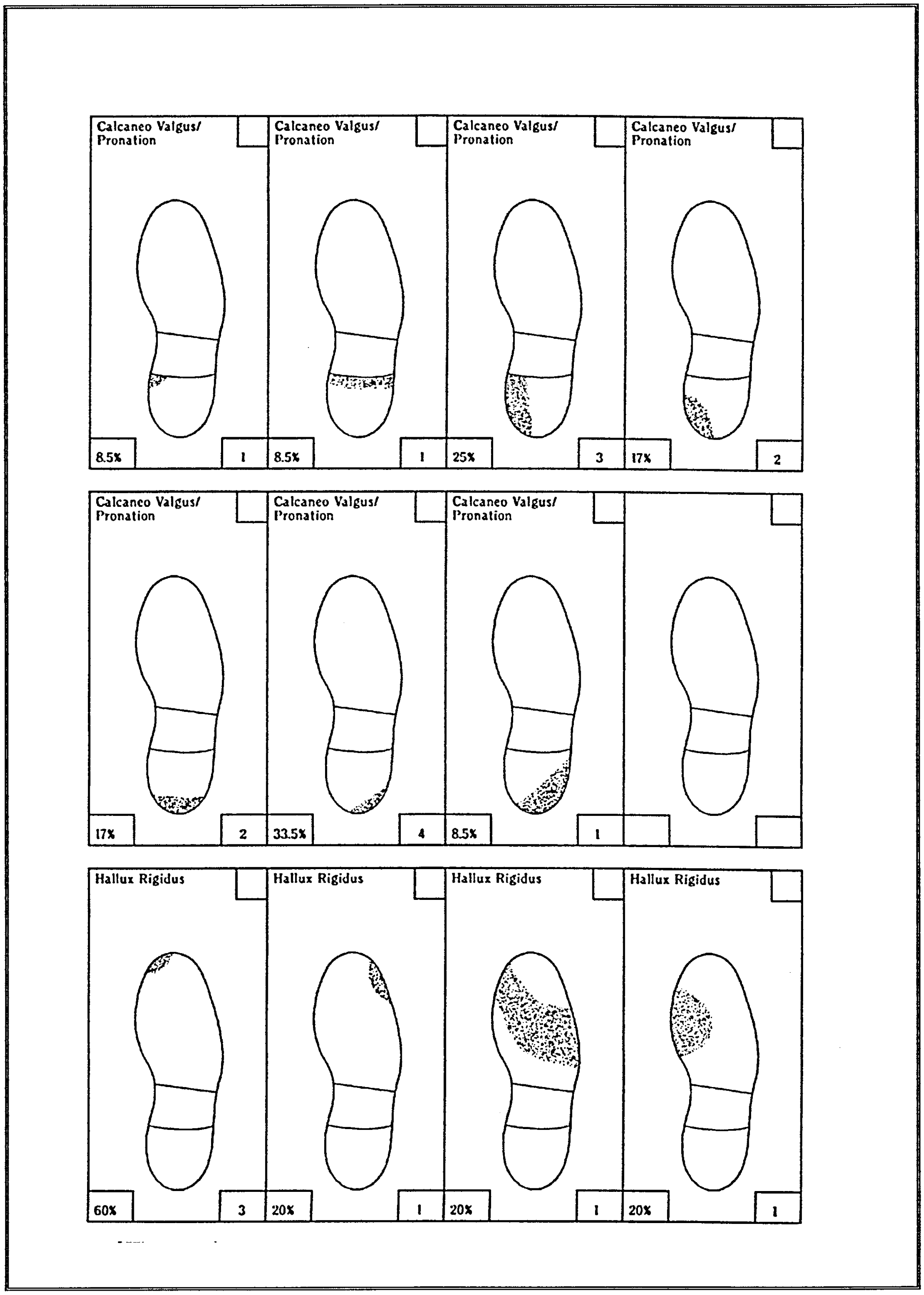
Delphi round 2, section 2a

Possible wear area components which make up a total characteristic wear pattern for named pathologies are indicated. Please tick those with which you are in agreement.
(See Key for explanation).



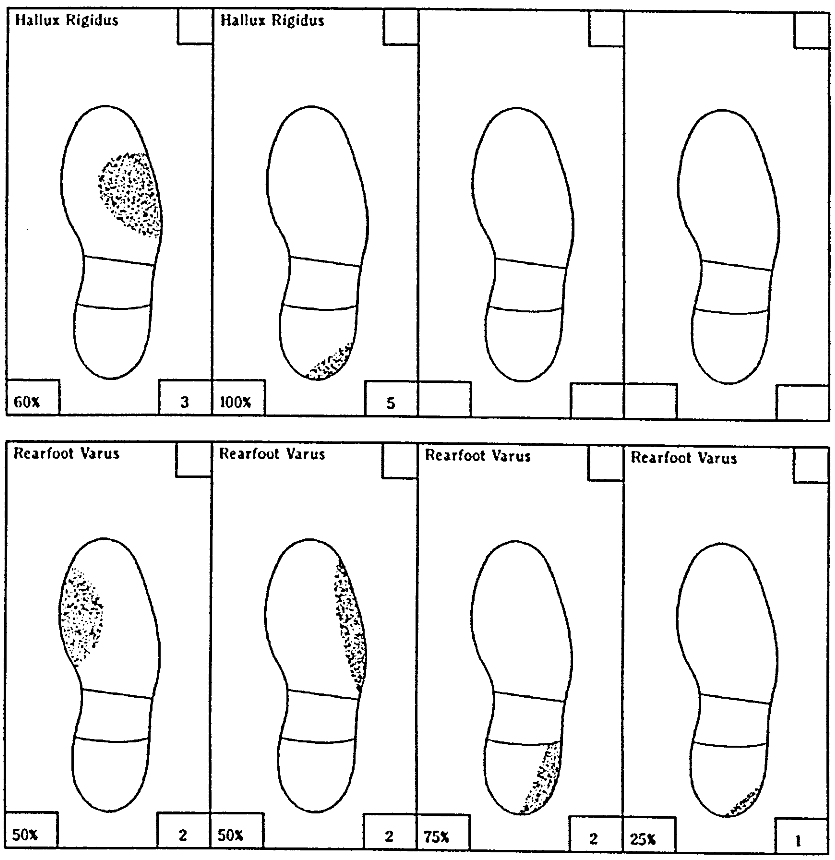
APPENDIX 6 – contd.

Delphi round 2, section 2b



APPENDIX 6 – contd.

Delphi round 2, section 2c



APPENDIX 6 – contd.

Round 2 feedback sheet

Name of participant :

I have the following comments to make on round 2 :

(Please continue on separate sheet if necessary)

Thank you for your assistance.

D. W. Vernon
SWaMP project research student
Sheffield Hallam University

APPENDIX 7 Delphi round 3 questionnaire package

The SWaMP round 3 questionnaire package contains the following :

1. Explanatory notes
2. Example sheet/key to Section 1
3. Example sheet/key to Section 2
4. Questionnaire Round 3 - Sections 1 and 2
5. Feedback sheet
6. Stamped, addressed envelope

DWV 27/3/96

Explanatory notes

SWaMP Project Round 3 - Explanatory Notes

The results of the SWaMP Round two questionnaire have now been collated and analysed. Round three is now presented and again consists of two sections.

In **Section 1**, the patterns which you commented on in Round two are shown along with the percentage of responses given for each possible associated condition.

In **Section 2**, the pattern components for named conditions which you commented on in Round 2 are shown along with the percentage of responses given for each component.

Please study these sections carefully and tick the response or responses that you are in agreement with. If you wish to amend your response in light of these results, please do so. If you wish to mark a response that represents a minority viewpoint (i.e. one that had less than 30% agreement), please briefly state your justification for this, continuing on a separate sheet if necessary. Finally, would you please mark with crosses the points from which you believe wear to be spreading on each pattern.

A key/example sheet for each section is enclosed for your reference.

I would be grateful if you could respond within three weeks of receipt of this round three. As in previous rounds, if you have any comments regarding this round, please list these on the enclosed feedback sheet.

If you have any problems with the questionnaire, please contact me on :

Daytime - 0114 - 2716767
Evenings - 01663 - 734414

Thank you once again for your assistance.

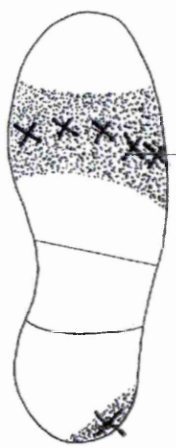
D.W. Vernon
SWaMP Project Research Student
Sheffield Hallam University.

APPENDIX 7 – contd.

Section 1 example sheet

SWaMP Questionnaire Round 3

Key/example to Section 1



Pattern depicted

(X = Focal point(s) from which the wear is spreading)

Levels of agreement in Round 2

Suggested causes of pattern

Retracted Toes	85%	
Forefoot Valgus	41%	
Pronated foot	14%	

Tick here if in agreement and cross any possibilities that you would dispute strongly

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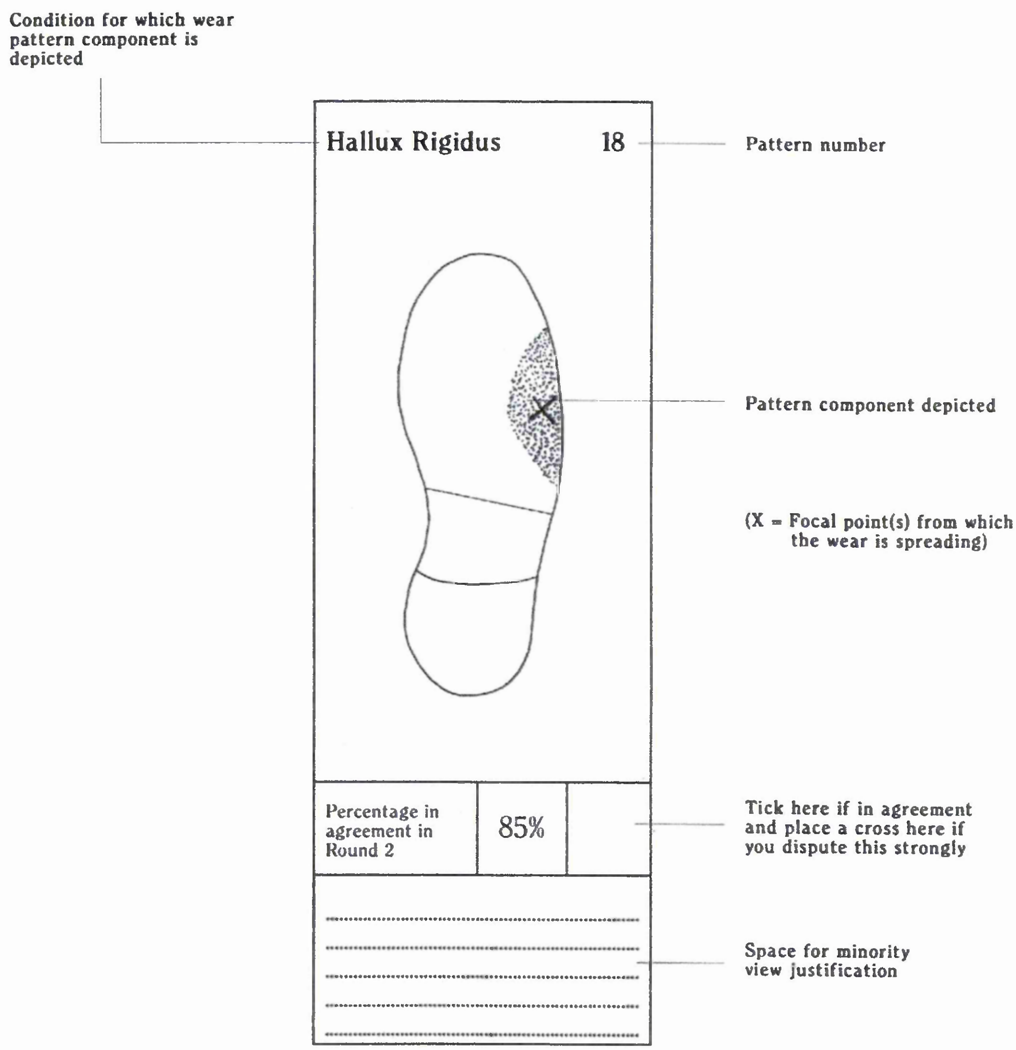
Space for minority view justification

APPENDIX 7 – contd.

Section 2 example sheet

SWaMP Questionnaire Round 3

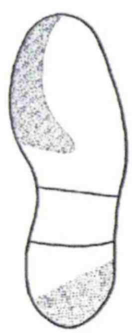
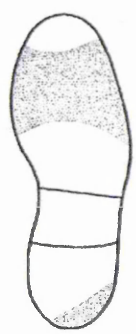
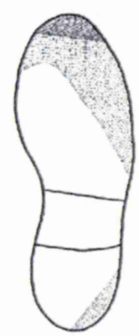
Key/example to Section 2



<u>Section 1</u>

SWaMP Questionnaire Round 3 Section 1

This section shows wear patterns given in Round 1 under more than one 'pathology' heading which you commented on in Section 1 of the last Round. Please consider each pattern again in light of the percentage agreement seen in this last round and tick (✓) the conditions with which you are in agreement. You may alter your response from that given in the last Round. If you wish to express a minority viewpoint (i.e. support a condition for which there has been less than 30% of participants in agreement), please give a brief justification/explanation of your belief. If there are any possible responses with which you are in strong disagreement, please mark these with a cross (X). On the diagram, will you please mark (X) the focal points from which you believe the wear to be spreading.

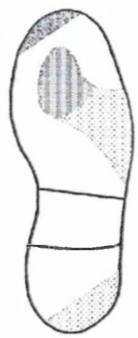
PATTERN 1			PATTERN 2			PATTERN 3			PATTERN 4		
											
Pronated foot	75%		Pronated foot	12%		Pronated foot	37%		Freibergs Infraction	12%	
Metatarsus Adductus	12%		Retracted toes	87%		Compensated Calcaneo Varus	50%		Hemiplegia	87%	
Calcaneo Varus	12%		Forefoot Valgus	37%		Hallux Rigidus	12%				
						Hallux Valgus	12%				
						Ankle Equinus	12%				
....			....			....			....		

APPENDIX 7 – contd.

<u>Section 1 (contd.)</u>

SWaMP Questionnaire Round 3 Section 1 (contd.)

PATTERN 5



Hammer 2nd toe	75%	
Claw toes	25%	
Pes Cavus	12%	

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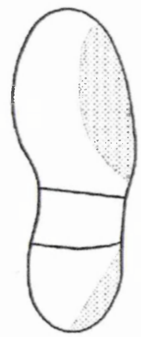
PATTERN 6



Talipes Equino Varus	50%	
Calcaneo Varus	50%	
Hemiplegia	12%	

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PATTERN 7

Ankle Equinus	75%	
Severs Disease	12%	

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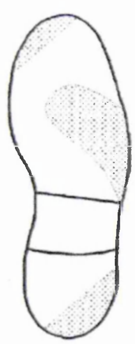
PATTERN 8



Pes Cavus	37%	
Hallux Rigidus	75%	

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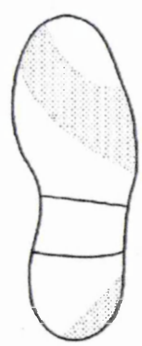
PATTERN 9



Hallux Rigidus	75%	
Short 1st Metatarsal	25%	

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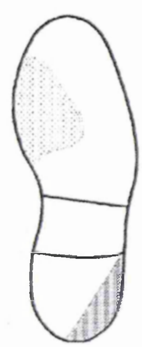
PATTERN 10



Hallux Rigidus	12%	
Calcaneo Valgus	37%	
Forefoot Varus	12%	
Calcaneo Varus	12%	
Normal Foot	12%	

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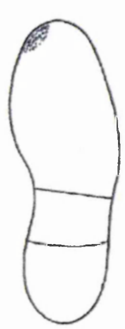
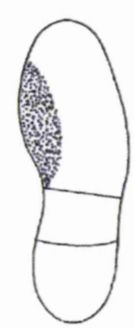
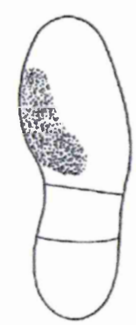
....
....

APPENDIX 7 – contd.

Section 2

SWaMP Questionnaire Round 3 Section 2

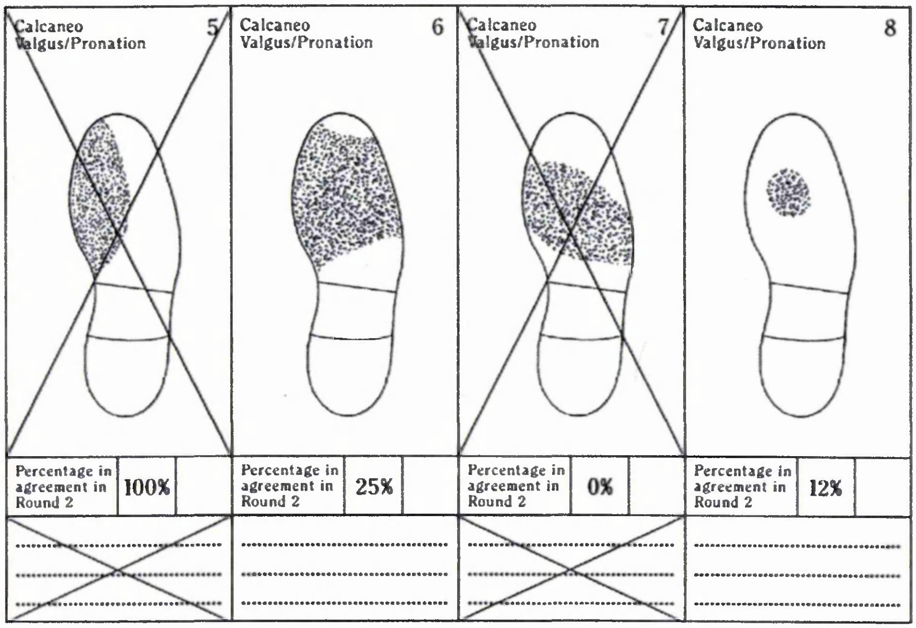
This section shows components of wear patterns given in Round 1 Section 2 which you commented on in the last Round. Please consider each pattern again in light of the percentage agreement seen in this last round and tick (✓) the pattern components which you are in agreement with. You may alter your response from that given in the last Round. If you wish to express a minority viewpoint (i.e. support a pattern component for which there has been less than 30% of the participants in agreement), please give a brief justification/explanation of your belief. If there are any possible responses with which you are in strong disagreement, please mark these with a cross (X). Those components in boxes crossed through have achieved either 100% or 0% agreement and do not require an answer, but are provided for your reference only. On the diagram, will you please mark (X) the focal points from which you believe the wear to be spreading.

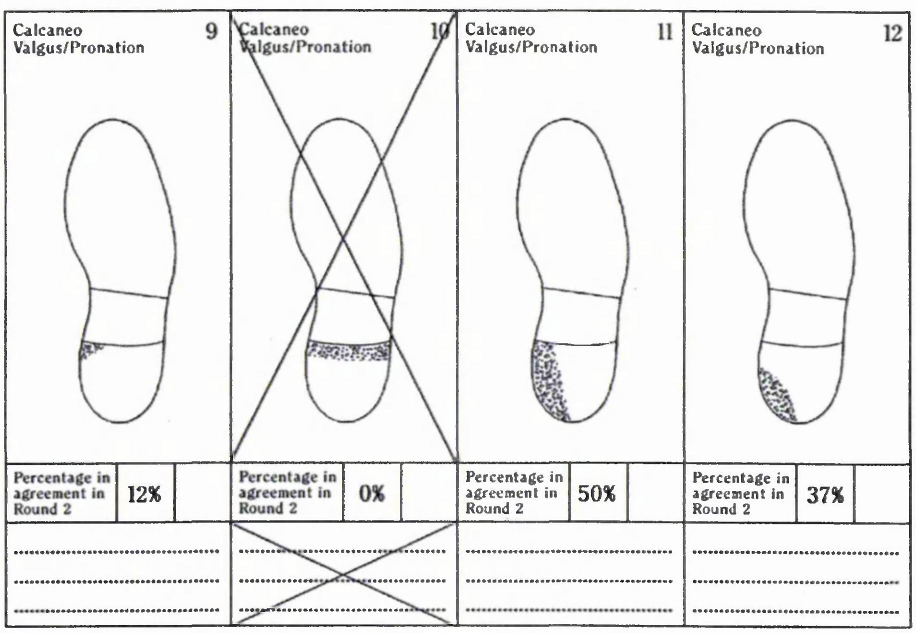
Calcaneo Valgus/Pronation 1	Calcaneo Valgus/Pronation 2	Calcaneo Valgus/Pronation 3	Calcaneo Valgus/Pronation 4
			
Percentage in agreement in Round 2: 25%	Percentage in agreement in Round 2: 0%	Percentage in agreement in Round 2: 12%	Percentage in agreement in Round 2: 37%
....	....	....	....

APPENDIX 7 – contd.

Section 2 (contd.)

SWaMP Questionnaire Round 3 Section 2 (contd.)



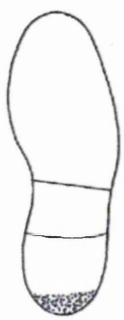


APPENDIX 7 – contd.

Section 2 (contd.)

SWaMP Questionnaire Round 3 Section 2 (contd.)

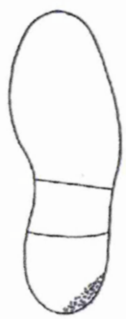
Calcaneo Valgus/Pronation 13



Percentage in agreement in Round 2	25%	

....
....
....

Calcaneo Valgus/Pronation 14



Percentage in agreement in Round 2	37%	

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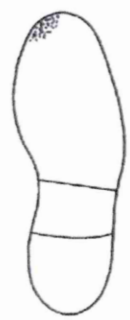
....
....

Calcaneo Valgus/Pronation 15

Percentage in agreement in Round 2	50%	

....
....
....

Hallux Rigidus 16



Percentage in agreement in Round 2	62%	

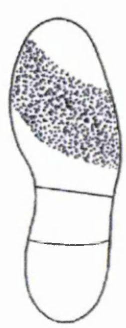
....
....
....

Hallux Rigidus 17

Percentage in agreement in Round 2	12%	

....
....
....

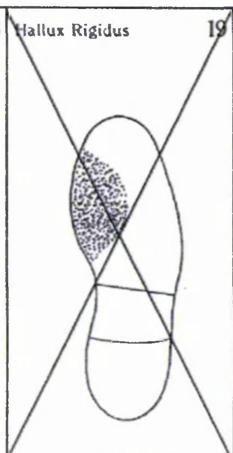
Hallux Rigidus 18



Percentage in agreement in Round 2	62%	

....
....
....

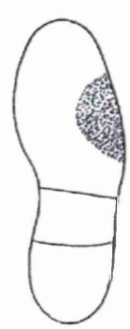
~~Hallux Rigidus 19~~



Percentage in agreement in Round 2	0%	

~~..~~
~~..~~
~~..~~

Hallux Rigidus 20

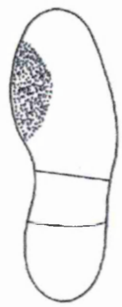
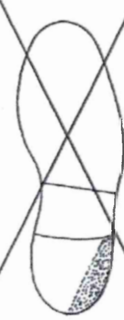


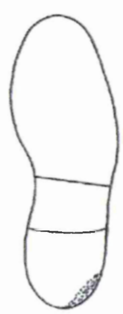
Percentage in agreement in Round 2	62%	

....
....
....

Section 2 (contd.)

SWaMP Questionnaire Round 3 Section 2 (contd.)

Hallux Rigidus 21	Rearfoot Varus 22	Rearfoot Varus 23	Rearfoot Varus 24
			
Percentage in agreement in Round 2: 75%	Percentage in agreement in Round 2: 50%	Percentage in agreement in Round 2: 62%	Percentage in agreement in Round 2: 100%
....	....	....	....

Rearfoot Varus 25			
			
Percentage in agreement in Round 2: 12%	Percentage in agreement in Round 2: %	Percentage in agreement in Round 2: %	Percentage in agreement in Round 2: %
....	....	....	....

Feedback sheet

SWaMP Project round 3 feedback sheet

Name of participant :

I have the following comments to make on round three :

(Please continue on separate sheet if necessary)

Thank you for your assistance.

D. W. Vernon
Research student
SWaMP project
Sheffield Hallam University

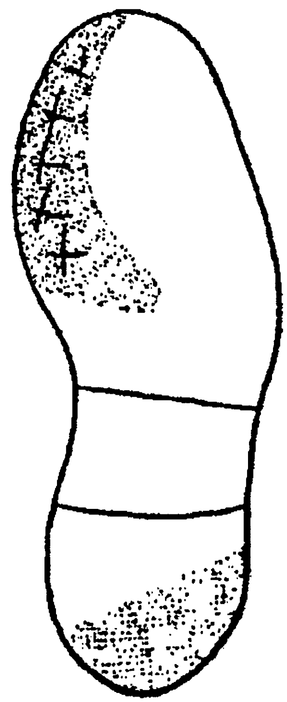
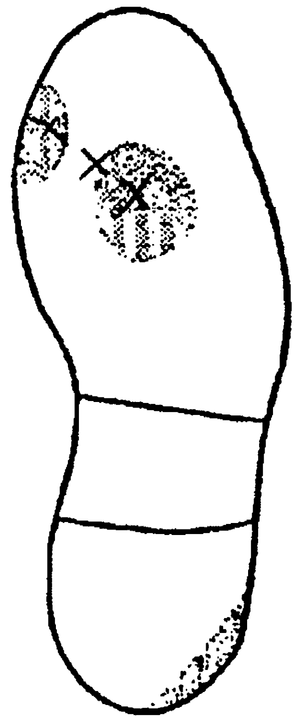
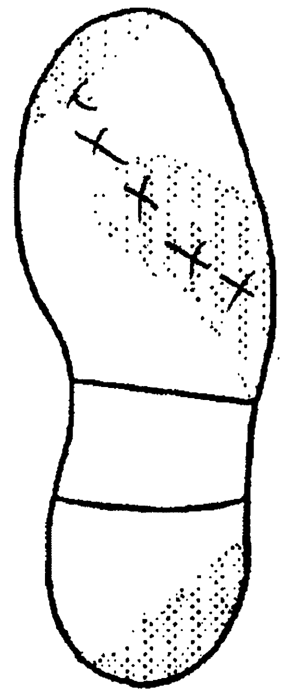
APPENDIX 8 Delphi round 3 – analysis of respondent comments given to justify viewpoints

Comment	Categories	Themes identified from grouping of categories	Inference
"no weight bearing"	Force pathway components	Factors affecting shoe wear patterns	Wear patterns can be influenced by variations in the force pathway
"taking weight instead"			
"toe off"			
"at heel strike"			
"heel strike" (X4)			
"compensation"	Compensation	Factors affecting shoe wear patterns	
"Uncompensated"			
"Valgus"	Foot pathology	Factors affecting shoe wear patterns	Wear patterns can be influenced by foot pathology
"Pes cavus"			
"valgus/pronation"			
"severely"	Severity (of condition)	Factors affecting shoe wear patterns	Wear patterns can be influenced by severity of a condition
"Mild case"			
"Normal"			
"amount of"			
"Pes Cavus"	Alternative pathology	Same wear pattern can be associated with different pathologies	Same wear pattern can be associated with different pathologies
"Cerebral Palsy"			
"distal wear"	Local site of wear	Contribution of local factors to shoe wear pattern formation	Local factors and local components of wear can have a direct effect on the overall wear pattern
"Anterior wear only"			
"at lat side"			
"Heel area only"			
"Wear on the medial border"			

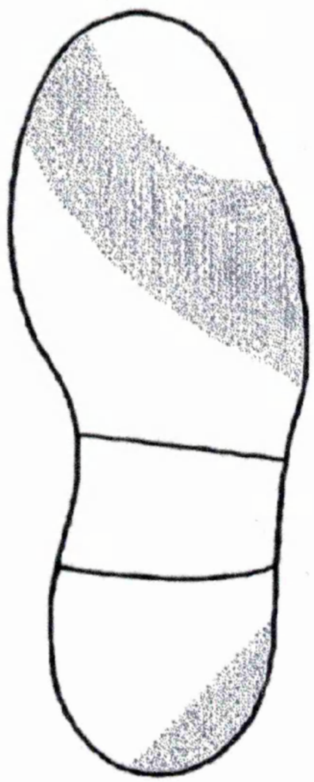
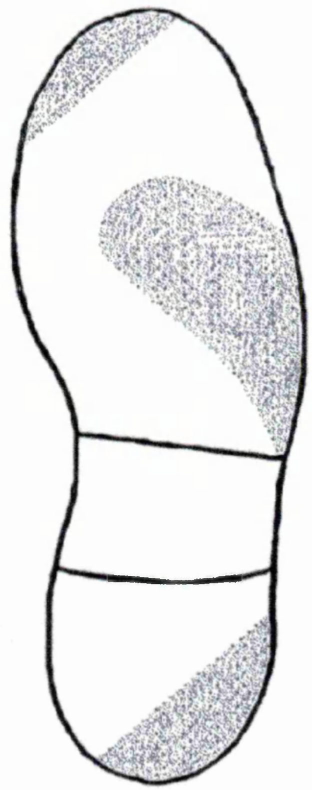
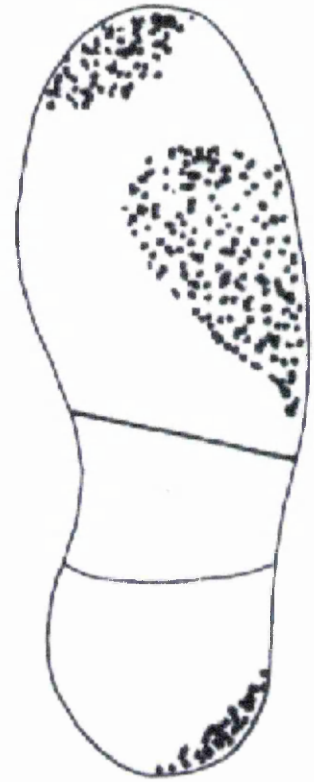
APPENDIX 8 – contd.

"medial" (X2)	Local site of wear	Contribution of local factors to shoe wear pattern formation	Local factors and local components of wearcan have a direct effect on the overall wear pattern
"component of"			
"on medial border"			
"Wear towards the medial border of the heel"			
"Too dense"	Variations in amount of wear	Amount of component wear varies with different pathologies	
"Excessive wear"			
"Greater wear"			
"on 1st M. Hd. – 2nd met head"	Description of local anatomical position	Contribution of local factors to shoe wear pattern formation	
"1st ray"			
"Incompetent 1st ray"			
"hallux"			
"Calcaneo valgus"			
"Valgus heel"			
"Could also be"	Strength of relationship between pathology and wear	Level of certainty of relationship between pathology and wear	Certainty of relationship between pathology and wear can vary
"indicative of"			
"normally would only give"			
"Depends"			
"This might be a"			
"indicates"			
"causing oblique creasing shoe upper"	Effect on other parts of shoe	Other effects of factors involved in shoe wear production	Factors influencing wear patterns can affect other aspects of footwear

APPENDIX 9 Delphi round 3; marking centres from which wear was spreading - examples of markings which did not comply with the focal point principle

Pattern 1	Pattern 3	Pattern 8
		

APPENDIX 10 Comparison of agreed pattern associations for hallux rigidus in Delphi round 3, section 1, with previously published hallux rigidus pattern

Pattern 8	Pattern 9	Lucock (1980)
		

APPENDIX 11 Delphi round 4 questionnaire package

The SWaMP project round four questionnaire package contains the following:

1. Covering letter

2. Explanatory notes

3. Questionnaire round four, sections 1, 2 and 3

4. Feedback sheet

5. Stamped, addressed envelope

Covering letter

Podiatry and Chiropody Service

Community Health Sheffield
Fulwood House
Old Fulwood Road
Sheffield
S10 3TH
0114 - 2716767

Dear Sir/Madam

Thank you for your participation to date in the SWaMP project. The information that you have provided in the three previous questionnaire rounds has now been studied in detail and a number of preliminary conclusions have been made on the basis of the findings. These conclusions are now presented in the enclosed package. They summarise agreements reached between participants' in the last round and also include summary statements that I have made from the data examined. In order to conclude this stage of the project, I now need to present these findings to participants for final comment.

I would therefore be grateful if you could read through the three sections enclosed and either confirm your acceptance of the conclusions made on the basis of this study or state any areas of disagreement based on your own experiences.

Please note that although the package appears bulky, this is because of the volume taken up by graphic aspects of the package. It is envisaged that completion of this reply should only take a few more minutes of your time.

I would be grateful if you could complete and return this round in the envelope provided within three weeks of receipt of the package.

Thank you for your continuing help in this project.

Yours faithfully

D. W. Vernon
SWaMP Project Research Student
Sheffield Hallam University.

APPENDIX 11 - contd.

Explanatory notes

SWaMP project round four - explanatory notes

The results of the SWaMP round three questionnaire have now been collated and analysed and based on the results of this and information obtained in previous rounds, a number of conclusions have been made. These are in the form of agreements reached and comments stated on observations made over the three rounds. Round four is now presented for your comments and consists of three sections.

In **Section 1**, the patterns which you commented on in round three, section 1 are shown along with statements indicating whether participant agreement over associations between patterns and named conditions has been reached. As in previous rounds, the percentage of responses given for each possible associated condition is shown.

In **Section 2**, the pattern components for named conditions which you commented on in round three, section 1 are shown along with statements indicating whether participant agreement over associations between components and named conditions has been reached. As in section 1, the percentage of responses given for each possible associated component is shown.

In **Section 3**, a number of statements are presented, based on observations made on the information that has been provided by participants in the previous three rounds.

In round four, you are asked to consider the information presented in each section and to show whether you are in agreement with the conclusions presented. If you disagree with any of the conclusions made, please show which of the patterns, pattern component associations or statements you would disagree with and give a brief explanation of your alternative perspective.

I would be grateful if you could respond within three weeks of receipt of this round four. As in previous rounds, if you have any other comments regarding this round, please list these on the enclosed feedback sheet. If you would like a copy of the final report on the questionnaires, please tick the box on the feedback sheet.

If you have any problems with the questionnaire, please contact me on :

Daytime - 0114 - 2716767
Evenings - 01663 - 734414

Thank you once again for your assistance.

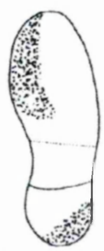
D.W. Vernon
SWaMP Project Research Student
Sheffield Hallam University

APPENDIX 11 – contd.

Delphi round 4, section 1a

This section shows agreements/rejections reached by participants in Round 3, Section 1. Please consider these and if you would agree with them overall, tick ✓ the box indicating agreement at the end of this section. If you disagree with any of the pattern associations/rejections, tick the box indicating disagreement, cross out any items you are in disagreement with and write in your alternative perspective.

Pattern 1



Accepted as being associated with :

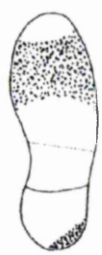
Pronated Foot (**Complete acceptance** by 100% of participants)

Rejected as being associated with :

Metatarsus Adductus (0% of participants in support)

Calcaneo-Varus (0% of participants in support. Disputed by 20%of participants)

Pattern 2



Accepted as being associated with :

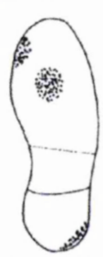
Retracted toes (**Complete acceptance** by 100% of participants)

Rejected as being associated with :

Pronated Foot (0% of participants in support)

Forefoot Valgus (0% of participants in support)

Pattern 3



Accepted as being associated with :

Pronated Foot (**Moderate acceptance** by 40% of participants)

Comp. Calc. Varus (**Moderate acceptance** by 40% of participants)

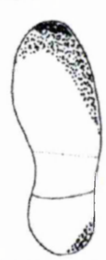
Hallux Rigidus (**Low acceptance** by 20% of participants)

Hallux Valgus (**Low acceptance** by 20% of participants)

Rejected as being associated with :

Ankle Equinus (0% of participants in support)

Pattern 4



Accepted as being associated with :

Hemiplegia (**Complete acceptance** by 100% of participants)

Rejected as being associated with :

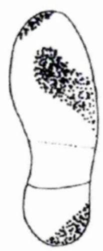
Forefoot Varus (0% of participants in support)

Freibergs Infraction (0% of participants in support)

APPENDIX 11 – contd.

Delphi round 4, section 1b

Pattern 5



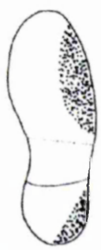
Accepted as being associated with :

Hammer 2nd toe (**High acceptance** by 80% of participants)
Claw toes (**Low acceptance** by 20% of participants)

No agreement reached for association with :

Pes Cavus (**NO CONSENSUS** with 20% of participants accepting the association and 20% disputing it)

Pattern 6



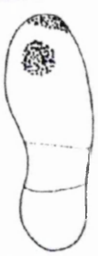
Accepted as being associated with :

Talipes Eq. Varus (**High acceptance** by 80% of participants)
Calc. Varus (**Moderate acceptance** by 40% of participants)
Pes Cavus (**Low acceptance** by 20% of participants)

Rejected as being associated with :

Hemiplegia (Disputed by 100% of participants)

Pattern 7



Accepted as being associated with

Ankle Equinus (**Complete acceptance** by 100% of participants)

Rejected as being associated with .

Severs disease (0% of participants in support)

Pattern 8

Accepted as being associated with .

Hallux Rigidus (**Complete acceptance** by 100% of participants)

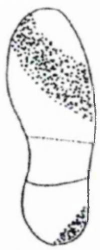
No agreement reached for association with .

Pes Cavus (**NO CONSENSUS** with 20% of participants accepting the association and 20% disputing it)

APPENDIX 11 – contd.

Delphi round 4, section 1c

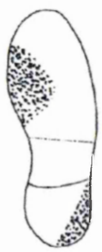
Pattern 9



Accepted as being associated with :

Hallux Rigidus (High acceptance by 80% of participants)
Short 1st Metatarsal (Low acceptance by 20% of participants)

Pattern 10



Accepted as being associated with :

Calcaneo Valgus (High acceptance by 60% of participants)
Calcaneo Varus (High acceptance by 60% of participants)

Rejected as being associated with :

Hallux Rigidus (0% of participants in support)
Forefoot Varus (0% of participants in support. Disputed by 20%of participants)

No agreement reached for association with :

Normal Foot (NO CONSENSUS with 20% of participants accepting the association and 20% disputing it)

A.) I agree with the associations/rejections shown above as determined in the 3 previous questionnaire rounds ☐

B.) I disagree with the associations/rejections shown above as determined in the 3 previous questionnaire rounds ☐

(Please tick one of the above boxes as appropriate)

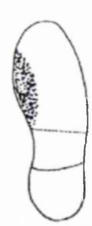
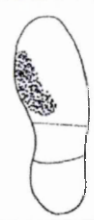
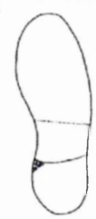
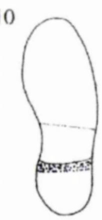
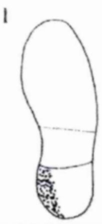
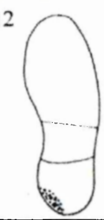
(N.B. If you have ticked box B. to show disagreement, please make any amendments clearly in the relevant section/sections)

APPENDIX 11 – contd.

Delphi round 4, section 2a

This section shows agreements reached by participants in Round 3 Section 2. Please consider these and if you would agree with them overall, please tick ✓ the box indicating agreement at the end of this section. If you disagree with any of the pattern associations or rejections, please tick the box indicating disagreement, cross out any items you are in disagreement with and write in your alternative perspective.

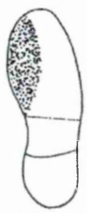
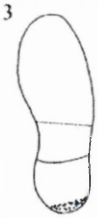
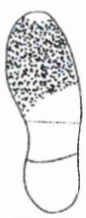
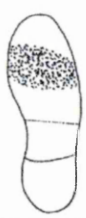
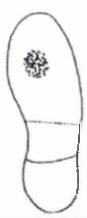
A. Pattern components associated with Calcaneo Valgus/Pronation

1		Rejected as being associated (0% of participants in support. Disputed by 60% of participants)
2		Rejected as being associated (0% of participants in support. Disputed by 100% of participants)
3		No agreement reached for association (NO CONSENSUS with 20% Of participants accepting the association and 40% disputing it)
4		Accepted as being associated (High acceptance by 80% of participants)
9		No agreement reached for association (NO CONSENSUS with 20% Of participants accepting the association and 20% disputing it)
10		Rejected as being associated (0% of participants in support. Disputed by 100% of participants)
11		No agreement reached for association (NO CONSENSUS with 60% Of participants accepting the association and 20% disputing it)
12		No agreement reached for association (NO CONSENSUS with 40% Of participants accepting the association and 20% disputing it)

APPENDIX 11 – contd.

Delphi round 4, section 2b

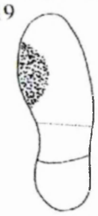
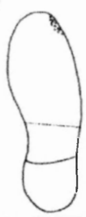
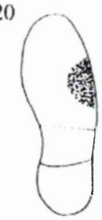
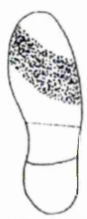
A. Pattern components associated with Calcaneo Valgus/Pronation (contd.)

5		Accepted as being associated (Complete acceptance by 100% of participants)	13		No agreement reached for association (NO CONSENSUS with 20% Of participants accepting the association and 40% disputing it)
6		No agreement reached for association (NO CONSENSUS with 20% Of participants accepting the association and 40% disputing it)	14		No agreement reached for association (NO CONSENSUS with 40% Of participants accepting the association and 20% disputing it)
7		Rejected as being associated (0% of participants in support. Disputed by 100% of participants)	15		No agreement reached for association (NO CONSENSUS with 60% Of participants accepting the association and 20% disputing it)
8		No agreement reached for association (NO CONSENSUS with 20% Of participants accepting the association and 40% disputing it)			

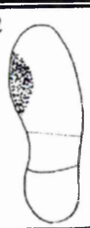
APPENDIX 11 – contd.

Delphi round 4, section 2c

B. Pattern components associated with Hallux Rigidus

16		Accepted as being associated (High acceptance by 80% of participants)	19		Rejected as being associated (0% of participants in support. Disputed by 100% of participants)
17		Rejected as being associated (0% of participants in support. Disputed by 60% of participants)	20		Accepted as being associated (High acceptance by 80% of participants)
18		Accepted as being associated (High acceptance by 60% of participants)	21		Accepted as being associated (Complete acceptance by 100% of participants)

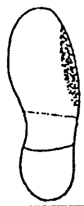
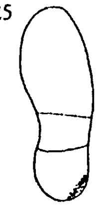
C. Pattern components associated with Calcaneo Varus

22		No agreement reached for association (NO CONSENSUS with 60% Of participants accepting the association and 20% disputing it)	24		Accepted as being associated (Complete acceptance by 100% of participants)

APPENDIX 11 – contd.

Delphi round 4, section 2d

C. Pattern components associated with Calcaneo Varus (contd.)

23		Accepted as being associated (Complete acceptance by 100% of participants)	25		No agreement reached for association (NO CONSENSUS with 40% of participants accepting the association and 40% disputing it)

A.) I agree with the associations/rejections shown above as determined in the 3 previous questionnaire rounds ☐

B.) I disagree with the associations/rejections shown above as determined in the 3 previous questionnaire rounds ☐

(Please tick one of the above boxes as appropriate)

(N.B. If you have ticked box B. to show disagreement, please make any amendments clearly in the relevant section/sections)

APPENDIX 11 – contd.

SWaMP questionnaire round 4, section 3

SWaMP questionnaire round 4, section 3

This section shows statements made at the end of the three rounds of questionnaire which you have participated in. The stages that the questionnaire has passed through have been :

Round 1 - Participants freely showed depictions of wear patterns that they would associate with named pathologies. When these were examined, wide ranges of patterns were observed in association with single named pathologies and some patterns were repeated across different pathologies. This was unexpected in light of previous publications which alluded to single characteristic pattern associations only.
Round 2 - Round one patterns which had been repeated across pathologies were presented back to participants. In a separate section, for pathologies where a wide range of patterns had been given, these patterns were separated into components and presented back to participants. In both sections, statistical information showing the proportion of participants who had supported each association was given and participants asked to show which associations they would support in light of the information presented. Replies showed a move towards agreement, however when patterns and pattern components were considered on the basis of the points from which the wear was spreading as opposed to the usual consideration of the full wear area, closer, more specific agreements were observed.
Round 3 - Round two patterns and pattern components were presented again to participants together with statistical information showing the proportion of participants who had supported each association in round two. A major shift towards agreement was noted, with participants tending to form agreement over so-called previously suggested classic wear pattern associations.

The following statements are made on the basis of findings from the previous three rounds. Please consider these and if you would agree with them overall, please tick ✓ the box indicating agreement at the end of this section. If you disagree with any of the statements, please tick the box indicating disagreement, cross out any items you are in disagreement with and write in your alternative perspective.

May I suggest that you read each statement out loud and spend a minute or two considering each one in detail.

SWaMP questionnaire round 4, section 3 (contd.)

SWaMP questionnaire round 4, section 3 (contd.)

1. *"The previously assumed belief that one specific condition will cause one characteristic wear pattern only is incorrect, with single conditions being capable of producing a range of wear patterns."*

....

2. *"Although a range of wear patterns can occur with single named conditions, previously assumed characteristic patterns may be the most commonly observed patterns associated with that condition."*

....

3. *"The agreements reached in Round 3 of the questionnaires relate to the most commonly occurring wear patterns associated with each condition concerned."*

....

4. *"When several different wear patterns can occur with single named conditions, this implies that several different modes of function are occurring with these conditions."*

....

5. *"If a range of patterns and not one characteristic pattern only are possible with single named conditions, the absence of a characteristic pattern would not necessarily imply the absence of the associated condition."*

....

6. *"When more than one pathology is present, some pathologies can have greater influence over the type of wear pattern which will be created than others."*

....

7. *"Wear is a primary product of foot function and not simply of it's fixed anatomy/morphology, although these factors can have a secondary influence on wear."*

....

8. *"Wear can be amended/influenced by external factors (e.g. shoe style, shoe fit, sports and occupational activity, habit)."*

....

SWaMP questionnaire round 4, section 3 (contd.)

SWaMP questionnaire round 4, section 3 (contd.)

9. "Wear patterns can be usefully interpreted and compared by considering the points from which the wear is spreading (focal points). These points relate to specific anatomical positions of the foot."

....

10. "Participants were more confident of their opinions in round 3 of the questionnaires than they were in round 1"

....

11. "Participants found the task of sketching wear patterns from memory as in round 1 more difficult than that of commenting on a given wear pattern as in the subsequent rounds."

....

12. "In round 1, some participants may have showed wear patterns taken from direct patient observation for the purpose of the questionnaire."

....

13. "The reduced number of responses from participants in round 3 may have been because the request to justify minority opinions over associated wear patterns was too difficult."

....

14. "Where agreements have not been reached in round 3, this may be because the patterns depicted are uncommon and outside the experience of some participants."

....

15. "Where agreements have not been reached in round 3, misdiagnosis of the associated condition by some participants may have been a contributory factor."

....

16. "Where agreements have not been reached in round 3, this may be because there is no one commonly expected pattern, but instead a wide range of uncommon patterns in association with the named conditions."

....

17. "The questionnaires stimulated an awareness of wear patterns and caused participants to look at wear pattern associations more closely, which in turn led to greater understanding of wear patterns."

....

APPENDIX 11 – contd.

SWaMP questionnaire round 4, section 3 (contd.)

A.) I agree with the statements made above as determined from the three previous questionnaire rounds ☐

B.) I disagree with the statements made above as determined from the three previous questionnaire rounds ☐

(Please tick one of the above boxes as appropriate)

(N.B. If you have ticked box B. to show disagreement, please state clearly, the reason for disagreement, by the relevant statement/statements)

SWaMP project round four feedback sheet

Name of participant :

I have the following comments to make on round four :

(Please continue on separate sheet if necessary)

If you would like a copy of the final report on the questionnaires, please tick the box below
Please send me a copy of the final questionnaire report when completed

☐

Thank you for your assistance.

D. W. Vernon
Research student
SWaMP project
Sheffield Hallam University

APPENDIX 12 Pre-questionnaire survey package

The SWaMP questionnaire package contains the following :

1. Covering letter

2. Explanatory notes

3. List of structural/functional states of the foot and gait

4. Questionnaire

5. Stamped, addressed envelope

DWV 20/1/96

Covering letter

Podiatry and Chiropody Service

Community Health Sheffield
Fulwood House
Old Fulwood Road
Sheffield
S10 3TH
0114 - 2716767

Dear Sir/Madam

I am a state-registered chiropodist conducting research into shoe wear marks as part of the requirement for a M.Phil./Ph.D. study at Sheffield Hallam University. This project is being undertaken in the belief that if the marks were placed on a grid, they would be useful in chiropody/podiatry teaching, clinical diagnosis and in crime scene examination where worn shoe prints are found. The project is known as the SWaMP (shoe wear mark) project.

As there is currently no basic information available on shoe wear marks, I initially require experienced chiropodists to name conditions for which they have knowledge of wear marks in order to provide a focus for the study.

I am therefore writing to all heads of Trust podiatry/chiropody services to request participation in the project. I would be grateful if you could choose an appropriate experienced chiropodist from your staff to participate in the questionnaire, giving them the enclosed explanatory notes and questionnaire to complete which can then be returned to me in the stamped, addressed envelope for collation.

Thank you for your anticipated help in this project.

Yours faithfully

D. W. Vernon
SWaMP Project Research Student
Sheffield Hallam University

APPENDIX 12 – contd.

Explanatory Notes

SWaMP Project Questionnaire - Explanatory Notes

Thank you for assisting in this project. I am a state-registered chiropodist undertaking research into shoe wear marks as part of the requirement for a M.Phil./Ph.D. study at Sheffield Hallam University. This project is being undertaken in the belief that if shoe wear marks were placed on a grid, they would be useful in chiropody/podiatry teaching, clinical diagnosis and crime scene evaluation where worn shoe prints are found. The project is known as the SWaMP (shoe wear mark) project. As there is currently no basic information available on shoe wear marks, I initially require experienced chiropodists to name conditions for which they have a knowledge of wear marks in order to provide a focus for the study.

In this initial questionnaire, you are asked to name any of the conditions from the enclosed list for which you can identify the associated shoe sole wear marks. Please name 3 or more conditions but only up to a maximum of 10. ***It is important that you only name conditions for which you already have wear mark knowledge/experience.***

Your response will be received in confidence and your anonymity will be respected at all times.
Please could the questionnaire be completed and returned to me within 3 weeks of receipt in the pre-paid envelope. If you have any problems, please contact me on :

0114 - 2716767 (Daytime)

Thank you once again for your assistance.

D. W. Vernon
SWaMP Project Research Student
Sheffield Hallam University.

List of structural/functional states sent to participants

ABDUCTION	ABDUCTION AND EVERSION
ADDUCTION	ADDUCTION AND EVERSION
ANKLE EQUINUS	ATAXIC GAIT
BOW LEGS	CALCANEAL APOPHYSITIS
CALCANEAL BURSITIS	CALCANEAL EVERSION
CALCANEAL GAIT	CALCANEAL SPUR
CALCANEO-CAVUS	CALCANEO-VALGUS
CALCANEO-VARUS	CALCANEO-VARUS (COMPENSATED)
CHARCOT JOINTS	CHOREA
CLAW TOES	DIGITI QUINTI VARUS
DROP FOOT	EQUINO-CAVUS
EQUINO-VARUS	EXCESSIVE ANKLE DORSIFLEXION
FOOT STRAIN	FOREFOOT VALGUS
FOREFOOT VARUS	FREIBERG'S INFRACTION
GENU VALGUM	GENU VARUM
HALLUX FLEXUS	HALLUX RIGIDUS
HALLUX VALGUS	HAMMERED 2ND TOE
HEMIPLEGIC GAIT	HIGH STEPPING GAIT
HINDFOOT VALGUS	HINDFOOT VARUS
HYPERMOBILE 1ST AND 5TH MPJTS	HYPERMOBILE FOOT
INFLARED FOOT	INTOED GAIT
KOHLERS DISEASE	LOWER MOTOR NEURONE WEAKNESS
METATARSUS ADDUCTUS	METATARSUS PRIMUS ELEVATUS
METATARSUS PRIMUS VARUS	OUT-TOED GAIT
OVERLOADED 2ND MET.	PAINFUL NAIL DISORDERS OF THE 1ST TOE
PARAPARESIS	PARAPLEGIC GAIT
PES CAVUS	PES PLANO-VALGUS
PLANTAR DIGITAL NEURITIS (MORTON'S TOE)	PLANTAR FASCIITIS
PLANTAR FLEXED 1ST AND 5TH TOES	PLANTAR FLEXED TOES
POST-OPERATIVE STATES	PRONATED FOOT
PYRAMIDAL NEUROLOGICAL DISORDERS	REDUCTION OF LONGITUDINAL AND TRANSVERSE ARCHES
RETRACTED TOES	RETRO-CALCANEAL BURSITIS
RHEUMATOID ARTHRITIS	SEVERS DISEASE
SHORT 1ST METATARSAL	SHORT 5TH METATARSAL
SHUFFLING GAIT IN PARKINSONISM	SPLAYING OF THE METATARSALS
TAYLORS BUNION	TALIPES CALCANEO VALGUS
TALIPES CALCANEO VARUS	TALIPES EQUINO VALGUS
TALIPES EQUINO VARUS	TARSAL ARTHRITIS
VERTICAL TALUS	WADDLING GAIT

Pre-questionnaire survey

SWaMP Project Questionnaire

Name ....

Employing Trust ....

Work Address ....

....

Tel. No. ....

Please list a minimum of 3 and a maximum of 10 conditions for which you could identify characteristic shoe sole wear marks based on experience and knowledge of these marks.

	Condition
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

Please return the form to : Wesley Vernon
Podiatry and Chiropody Service
Community Health Sheffield
Fulwood House
Old Fulwood Road
Sheffield
S10 3TH

APPENDIX 13 Main questionnaire package

The 2nd SWaMP questionnaire package contains the following :

1. Covering letter

2. Explanatory notes

3. Example sheet

4. Questionnaire

4. Stamped, addressed envelope

DWV 4/6/96

Covering letter

Podiatry and Chiropody Service
Community Health Sheffield
Fulwood House
Old Fulwood Road
Sheffield
S10 3TH
Tel.: 0114 - 2716767

Dear Sir/Madam

Thank you for participation in the initial SWaMP project questionnaire that I distributed earlier this year. The results of the questionnaire have now been collated. They show that Podiatrists have knowledge/experience of certain shoe wear mark patterns that relate to conditions affecting the foot and/or gait.

The next phase of the research is to explore Podiatrist's experience of some of these shoe wear marks further. I would be grateful if you could forward the enclosed questionnaire package to the appropriately experienced Podiatrist whom you chose for participation in the initial questionnaire for completion and return.

Thank you again for your help with this project.

Yours faithfully

Wesley Vernon
SWaMP Project Research Student
Sheffield Hallam University.

Explanatory Notes

SWaMP Project 2nd Questionnaire : Explanatory Notes

Thank you for participation in the initial SWaMP project questionnaire that I distributed earlier this year. The collated responses showed that Podiatrists have experience of certain shoe wear mark patterns that relate to conditions affecting the foot and/or gait. Of the replies received, the four most common conditions participants said that they had shoe wear mark knowledge of were:

1. Pronated Foot
2. Hallux Rigidus
3. Rearfoot Varus
4. Pes Cavus

I would now like to invite you to participate in an exercise to explore Podiatrist's experience of these shoe wear marks further. A questionnaire form is enclosed on which blank shoe outsoles are presented with the above named conditions. Participants are required to sketch the wear pattern or patterns that they would associate with these named conditions on the blank outsoles. An example is included for your reference showing the preferred style of representation. If more than one wear pattern is known for each condition, please sketch the pattern that you believe is the most commonly occurring first and place any subsequent patterns in decreasing order of frequency of occurrence. ***It is essential that patterns are drawn from experience and not from direct patient observation or theoretical knowledge.*** If you wish to show even more wear patterns for the named conditions than there is space for, please photocopy the sheet as required. All replies will be received and dealt with anonymously.

I would therefore be grateful if you would complete the enclosed questionnaire and return this to me within three weeks of receipt. A stamped addressed envelope is enclosed for your assistance.

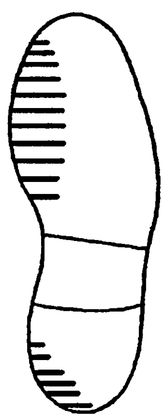
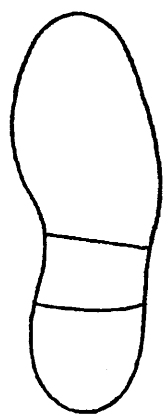
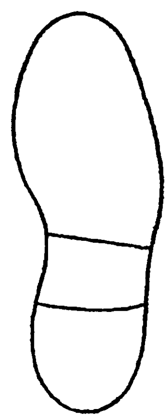
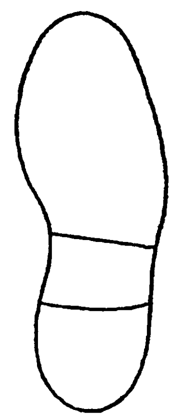
Thank you again for your help with this project.

Yours faithfully

Wesley Vernon
SWaMP Project Research Student
Sheffield Hallam University.

APPENDIX 13 – contd.

Example sheet

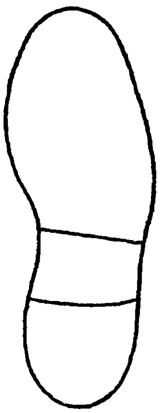
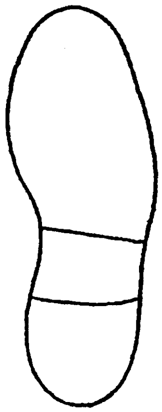
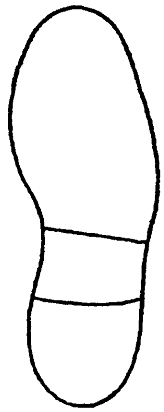
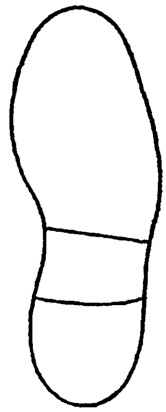
SWaMP 2nd Questionnaire Example			
Pronated foot			
			
Reason for variation ------------------------	Reason for variation ------------------------	Reason for variation ------------------------	Reason for variation ------------------------

2nd SWaMP Questionnaire

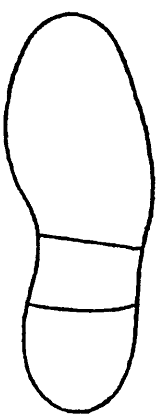
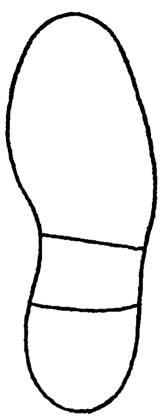
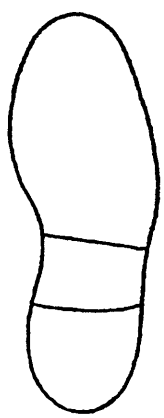
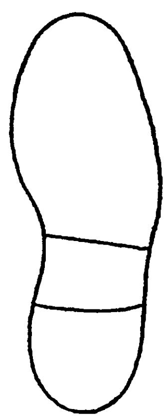
2nd SWaMP Questionnaire

Please sketch the wear marks that you would associate with the named conditions on the blank outsole outlines using the preferred style shown on the example sheet. If you associate more than one pattern with a condition, state the reason for the difference (e.g. compensation) and place the patterns in order of frequency of occurrence with the most commonly occurring pattern first.

Pronated Foot

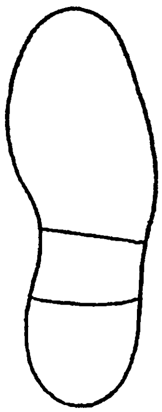
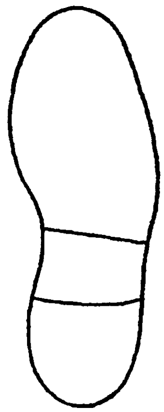
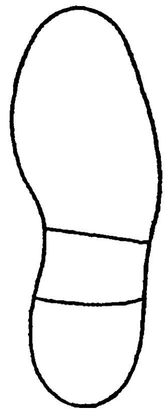
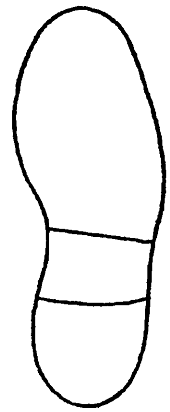
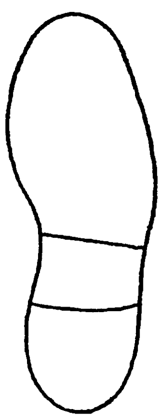
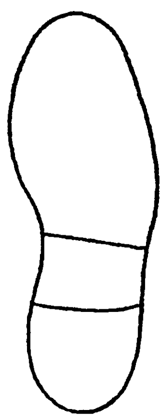
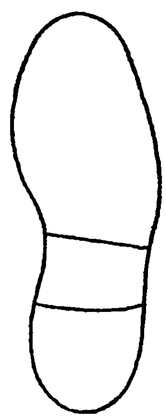
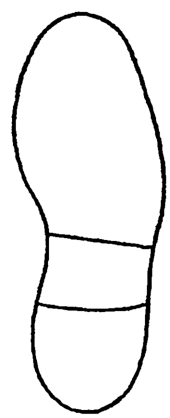
1	2	3	4
			
	Reason for variation ------------------------	Reason for variation ------------------------	Reason for variation ------------------------

Hallux Rigidus

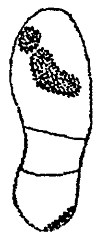
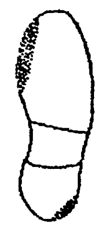
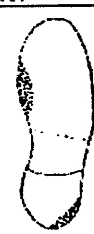
1	2	3	4
			
	Reason for variation ------------------------	Reason for variation ------------------------	Reason for variation ------------------------

APPENDIX 13 – contd.

2nd SWaMP Questionnaire (contd.)

2nd SWaMP Questionnaire (contd.) Rearfoot Varus			
1 	2 	3 	4 
	Reason for variation ------------------------	Reason for variation ------------------------	Reason for variation ------------------------
Pes Cavus			
1 	2 	3 	4 
	Reason for variation ------------------------	Reason for variation ------------------------	Reason for variation ------------------------

APPENDIX 14 Example of inductive analysis of wear patterns by pathology and pattern form

Patterns given				
I/D HR 11/2 Sub Theme Supination FPCode 1/6/13/18/19 	I/D HR 16/1 Sub Theme None FPCode 1/14/15/20 	I/D HR 20/1 Sub Theme None FPCode 1/14/15/20 	I/D HR 2/1 Sub Theme None FPCode 1/17/20 	I/D HR 3/1 Sub Theme None FPCode 1/17/20 
I/D Pron 11/2 Sub Theme Rearfoot Valgus FPCode 4/16/17 	I/D Pron 20/3 Sub Theme Forefoot Varus FPCode 4/16/17 	I/D Pron 34/4 Sub Theme Fully comp. FPCode 1/16/17 	I/D Pron 5/2 Sub Theme Rearfoot Valgus FPCode 4/16/17 	I/D Pron 7/1 Sub Theme None FPCode 1/16/17 

Division of patterns by category

Pattern reference	1. Pathology categories	2. Focal code predominance categories	3. Detailed focal code categories	4. Variable given
Pron 34/4	Pronation	16/17	1/16/17	Fully compensated
Pron 7/1			1/16/17	-----------------------
Pron 5/2			4/16/17	Rearfoot Valgus
Pron 11/2			4/16/17	Rearfoot Valgus
Pron 20/3			4/16/17	Forefoot Varus
HR 2/1	Hallux Rigidus	17/20	1/17/20	-----------------------
HR 3/1			1/17/20	-----------------------
HR 11/2		13/18/19	1/6/13/18/19	Supination
HR 16/1		14/15/20	1/14/15/20	-----------------------
HR 20/1			1/14/15/20	-----------------------

APPENDIX 15 Sample of pattern sub-categories based on focal code descriptions

From the category of patterns exhibiting 'localised central metatarso-phalangeal joint wear' (33 Patterns), the following sub-categories were derived:

1. Localised central metatarso-phalangeal joint wear with posterior/ posterior-lateral heel wear'	
Pathology	**Pattern Reference**
Pronation	42/2, 8/2, 16/3, 32/1, 22/2, 5/3, 32/4
Hallux rigidus	32/2, 50/2
Pes cavus	22/2, 6/2, 24/1, 1/1, 8/2, 42/3
Rearfoot varus	23/1, 18/3, 22/2, 9/1, 16/1, 23/3, 29/1

2. Localised central metatarso-phalangeal joint wear with no heel wear'	
Pathology	**Pattern Reference**
Pronation	32/1, 22/2, 5/3, 32/4
Hallux rigidus	32/2
Pes cavus	22/2
Rearfoot varus	22/2

3. Localised central metatarso-phalangeal joint wear with 1^{st}/ tip of 1^{st} wear'	
Pathology	**Pattern Reference**
Pronation	35/2, 37/2, 43/1, 11/3
Hallux rigidus	23/1, 40/1, 29/1, 23/2, 50/2
Pes cavus	8/3
Rearfoot varus	29/1

4. Localised central metatarso-phalangeal joint wear with medial heel wear	
Pathology	**Pattern Reference**
Pronation	25/3, 13/2, 3/1,26/1
Hallux rigidus	26/1

APPENDIX 15 – contd.

From the above categories, the following focal code sub-categories were derived:

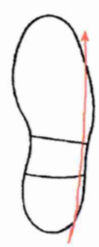
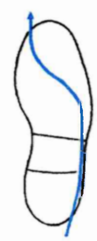
Focal code sub-categories for 'central metatarsal wear with posterior/ posterior-lateral heel wear'	
Focal Code	**Pattern Reference**
1/15	PRON - 42/2, 8/2, 16/3
	RFV – 16/1, 9/1, 18/3, 23/1
	PC – 1/1, 6/2, 8/2
2/15	PC – 24/1, 42/3
1/14	RFV – 23/3

Focal code sub-categories for 'central metatarsal wear with no heel wear'	
Focal Code	**Pattern Reference**
15	PRON – 32/1, 22/2, 5/3, 32/4
	RFV – 22/2
	PC – 22/2
	HR – 32/2

Focal code sub-categories for 'central metatarsal.wear with 1st/ tip of 1st wear	
Focal Code	**Pattern Reference**
1/15/20	PRON – 35/2, 37/2, 43/1, 11/3
	HR – 40/1, 29/1
6/15/20	PC - 8/3
15/20	HR – 23/1, 23/2
15/17	HR – 50/2
1/3/15/18/20	RFV – 29/1

Focal code sub-categories for 'central metatarsal wear with medial heel wear'	
Focal Code	**Pattern Reference**
1/3/15/20	HR – 26/1
1/4/15/20	PRON – 26/1
4/15/20	PRON – 3/1
2/3/4/9/14	PRON – 25/3
4/9/15	PRON – 13/2

APPENDIX 16 Illustration of hermeneutic circle traced in wear pattern analysis

Wear pattern I/D HR 11/2 Sub Theme Supination FPCode 1/6/13/18/19 	⇒	**Focal code** **1/6/13/18/19**	⇓
⇑	**"Leap of hermeneutic understanding"** Hallux rigidus suggests that the usual foot/ground contact cannot be expected due to the stiff 1st toe . Supination suggests a turning inwards of the foot. The focal code describes wear of the lateral outsole border suggesting that the normal force pathway has not been followed with a more lateral pathway avoiding the 1st toe stiffness. Foot anatomy suggests the lateral aspects of the foot contacting the ground 		**Normal force pathway** 
Supination Inversion (turning in along an axis running from front to back) of the foot			⇓
⇑	**Hallux Rigidus** 1st toe is fixed and does not dorsiflex (bend upwards) at the 1st metatarso-phalangeal joint	⇐	**Foot anatomy normally in ground contact while walking** 

APPENDIX 17 Patterns suggesting more than one function

Pronation patterns		
Pattern reference	Focal code	Suggested functions
PRON 1/1	1/9/15/16/17/20	1. Foot contacts normally with mid stance pronation and no attempt to recover 2. Abducted foot
PRON 7/1	1/16/17	1. Foot contacts normally with mid stance pronation and no attempt to recover 2. Abducted foot
PRON 7/2	1/9/16/17	1. Foot contacts normally with mid stance pronation and no attempt to recover 2. Abducted foot
PRON 8/1	1/17/20	1. Foot contacts normally with later pronation and attempt to stabilise via functional hallux limitus 2. Abducted foot
PRON 11/1	1/16/17	1. Foot contacts normally with mid stance pronation and no attempt to recover 2. Abducted foot
PRON 11/3	1/15/20	1. Foot contacts normally with later pronation and attempt to stabilise via functional hallux limitus 2. Abductory twist 3. Abducted foot
PRON 14/1	1/16/17/20	1. Foot contacts normally with mid stance pronation and no attempt to recover 2. Abducted foot
PRON 15/1	1/9/20	1. Foot contacts normally with later pronation and attempt to stabilise via functional hallux limitus 2. Abducted foot
PRON 16/1	1/15/16/17	1. Foot contacts normally with mid stance pronation and no attempt to recover 2. Abductory twist
PRON 17/1	1/15/16/17	1. Foot contacts normally with mid stance pronation and no attempt to recover 2. Abductory twist
PRON 20/2	1/14/15/20	1. Foot contacts normally with later pronation and attempt to stabilise via functional hallux limitus 2. Abductory twist
PRON 21/1	1/13/14/15/16/17	1. Foot contacts normally with late pronation 2. Abductory twist
PRON 21/4	1/13/15/16/17	1. Foot contacts normally with late pronation 2. Abductory twist
PRON 22/1	6/17/20	1. Foot lands in inversion to compensate for pronation, then later pronates fully 2. Abducted foot
PRON 23/1	1/16/17	1. Foot contacts normally with mid stance pronation and no attempt to recover 2. Abducted foot
PRON 24/2	2/14/15/20	1. Foot contacts normally with later pronation and attempt to stabilise via functional hallux limitus 2. Abductory twist
PRON 26/3	1/2/3/13/15/20	1. Foot pronates rapidly on contact and attempts to recover through supination 2. Abductory twist

APPENDIX 17 - contd.

Pattern reference	Focal code	Suggested functions
PRON 29/1	1/15/16/17	1. Foot contacts normally with mid stance pronation and no attempt to recover 2. Abductory twist
PRON 30/1	1/16/17	1. Foot contacts normally with mid stance pronation and no attempt to recover 2. Abducted foot
PRON 31/2	1/14/15/20	1. Foot contacts normally with later pronation and attempt to stabilise via functional hallux limitus 2. Abductory twist
PRON 33/2	1/15/16/17/20/21	1. Abductory twist 2. Abducted foot
PRON 34/4	1/16/17	1. Foot contacts normally with mid stance pronation and no attempt to recover 2. Abducted foot
PRON 35/1	1/20	1. Foot contacts normally with later pronation and attempt to stabilise via functional hallux limitus 2. Abducted foot
PRON 35/2	1/15/20	1. Foot contacts normally with later pronation and attempt to stabilise via functional hallux limitus 2. Abductory twist 3. Abducted foot
PRON 35/3	1/20	1. Foot contacts normally with later pronation and attempt to stabilise via functional hallux limitus 2. Abducted foot
PRON 36/1	1/16/17/20	1. Foot contacts normally with mid stance pronation and no attempt to recover 2. Abducted foot
PRON 37/1	1/20	1. Foot contacts normally with later pronation and attempt to stabilise via functional hallux limitus 2. Abducted foot
PRON 37/2	1/15/20	1. Foot contacts normally with later pronation and attempt to stabilise via functional hallux limitus 2. Abductory twist 3. Abducted foot
PRON 40/1	1/10/16/17/20	1. Foot lands in inversion to compensate for pronation, then later pronates fully 2. Abducted foot
PRON 43/1	1/15/20	1. Foot contacts normally with later pronation and attempt to stabilise via functional hallux limitus 2. Abductory twist 3. Abducted foot
PRON 43/2	1/2/6/15/16/17	1. Foot lands in inversion to compensate for pronation, then later pronates fully 2. Abductory twist
PRON 44/1	1/16/17	1. Foot contacts normally with mid stance pronation and no attempt to recover 2. Abducted foot
PRON 50/1	1/6/7/9/10/16/17/20	1. Foot lands in inversion to compensate for pronation, then later pronates fully 2. Abducted foot

APPENDIX 17 - contd.

Pattern reference	Focal code	Suggested functions
PRON 50/3	1/6/10/15/16/17	1. Foot lands in inversion to compensate for pronation, then later pronates fully 2. Abductory twist 3. Abducted foot
PRON 51/1	6/16	1. Foot lands in inversion to compensate for pronation, then later pronates fully 2. Abducted foot
PRON 51/3	6/15/16/17	1. Foot lands in inver/sion to compensate for pronation, then later pronates fully 2. Abductory twist
PRON 52/2	1/16/17/20	1. Foot contacts normally with mid stance pronation and no attempt to recover 2. Abducted foot
PRON 54/2	1/14/15/16/20	1. Foot contacts normally with later pronation and attempt to stabilise via functional hallux limitus 2. Abducted foot
PRON 55/2	1/16/17/21	1. Foot contacts normally with mid stance pronation and no attempt to recover 2. Foot contacts normally with later pronation and attempt to stabilise via functional hallux limitus
Hallux rigidus patterns		
Pattern reference	Focal code	Suggested functions
HR 12/2	17/20	1. Abducted gait 2. Pronation with abducted gait
HR 14/2	16/20/21	1. No medial or lateral deviation from normal gait pathway 2. Adductory twist
HR 21/1	1/12/13/14/15/20	1. Classic hallux rigidus function 2. Forefoot inversion
HR 23/2	15/20	1. Classic hallux rigidus function 2. Abductory twist
HR 25/2	13/20	1. Classic hallux rigidus function 2. Forefoot inversion
HR 26/1	1/3/15/20	1. Classic hallux rigidus function 2. Abductory twist
HR 28/1	1/13/20	1. Classic hallux rigidus function 2. Forefoot inversion
HR 29/1	1/15/20	1. Classic hallux rigidus function 2. Abductory twist
HR 31/3	13/16/18	1. Forefoot inversion 2. Adductory twist
HR 32/4	1	1. Calcaneal gait 2. Walking predominantly on heels
HR 33/1	1/6/13/17/18/20/21	1. Classic hallux rigidus function 2. Compensatory supination/inversion of the foot
HR 34/1	1/13/20	1. Classic hallux rigidus function 2. Forefoot inversion
HR 42/2	1/12/13/20	1. Classic hallux rigidus function 2. Forefoot inversion
HR 46/1	13/16/18	1. Adducted gait 2. Adductory twist

APPENDIX 17 - contd.

Pattern reference	Focal code	Suggested functions
HR 47/1	14/15	1. Abductory twist 2. Stamping gait 3. Vertical toe off
HR 48/3	1/9/16/17/20	1. Abducted gait 2. Pronation with abducted gait
HR 49/1	1/16/20/21	1. No medial or lateral deviation from normal gait pathway 2. Adductory twist
HR 51/1	15/16/17	1. Abducted gait 2. Abductory twist
HR 54/1	6/7/18/19/21	1. Compensatory supination/inversion of the foot 2. Compensatory supination/inversion of the foot 3. Forefoot inversion
HR 55/2	1/13/16/20	1. No medial or lateral deviation from normal gait pathway 2. Adductory twist
Pes Cavus patterns		
Pattern reference	Focal code	Suggested functions
PC 12/2	1/16	1. Normal or inverted heel, everted forefoot 2. Feet abducted
PC 28/1	1/13/16/17	1. Normal or inverted heel, everted forefoot 2. Feet abducted
PC 28/2	6/7/13/18/19/21	1. Foot inverted throughout 2. Foot inverted and abducted throughout
PC 31/1	6/7/12/13/18/19/21	1. Foot inverted throughout 2. Foot inverted and abducted throughout
PC 32/1	1/16/17	1. Normal or inverted heel, everted forefoot 2. Feet abducted
PC 34/2	6/13/16/18	1. Foot inverted throughout 2. Foot inverted and abducted throughout
PC 35/1	3/13/14/15/16/21	1. Everted heel 2. Feet abducted
PC 39/1	1/16	1. Normal or inverted heel, everted forefoot 2. Feet abducted
PC 47/3	16	1. No heel strike due to dropped forefoot of pes cavus and everted forefoot 2. Abductory twist
PC 47/4	15/16	1. No heel strike due to dropped forefoot of pes cavus and everted forefoot 2. Abductory twist
PC 48/4	1/13/15/16/17/20	1. Normal or inverted heel, everted forefoot 2. Feet abducted
Rearfoot varus patterns		
Pattern reference	Focal code	Suggested functions
RFV 1/3	1/13/18	1. Foot is inverted on heel strike and remains inverted throughout 2. Foot is inverted throughout with abduction 3. Foot is inverted throughout with adduction
RFV 2/2	1/13/14/18	1. Foot is inverted on heel strike and remains inverted throughout 2. Foot is inverted throughout with abduction

APPENDIX 17 - contd.

Pattern reference	Focal code	Suggested functions
RFV 5/4	6/13/20	1. Foot is inverted on heel strike and remains inverted throughout 2. Foot is inverted throughout with abduction
RFV 6/2	13/15/20/21	1. Forefoot supination 2. Adductory twist
RFV 8/1	1/13	1. Foot is inverted on heel strike and remains inverted throughout 2. Foot is inverted throughout with abduction 3. Foot is inverted throughout with adduction
RFV 11/1	1/13/14/15/17	1. Forefoot supination 2. Adductory twist
RFV 12/2	1/12/13/14/15	1. Foot is inverted on heel strike and remains inverted throughout 2. Foot is inverted throughout with abduction
RFV 15/1	1/13/18/20	1. Foot is inverted on heel strike and remains inverted throughout 2. Foot is inverted throughout with abduction
RFV 18/1	6/13/20	1. Foot is inverted on heel strike and remains inverted throughout 2. Foot is inverted throughout with abduction
RFV 20/3	1/12/13/14/15/18/19	1. Foot is inverted on heel strike and remains inverted throughout 2. Foot is inverted throughout with abduction
RFV 21/1	1/12/13/18/20	1. Foot is inverted on heel strike and remains inverted throughout 2. Foot is inverted throughout with abduction
RFV 22/1	6/13	1. Foot is inverted on heel strike and remains inverted throughout 2. Foot is inverted throughout with abduction 3. Foot is inverted throughout with adduction
RFV 23/2	1/13	1. Foot is inverted on heel strike and remains inverted throughout 2. Foot is inverted throughout with abduction 3. Foot is inverted throughout with adduction
RFV 26/2	1/13	1. Foot is inverted on heel strike and remains inverted throughout 2. Foot is inverted throughout with abduction 3. Foot is inverted throughout with adduction
RFV 28/2	1/6/7/13/14/15/18/19	1. Foot is inverted on heel strike and remains inverted throughout 2. Foot is inverted throughout with abduction
RFV 29/2	6/7/18/19/21	1. Foot is inverted on heel strike and remains inverted throughout 2. Foot is inverted throughout with adduction
RFV 33/2	1/6/7/12/13/18/19	1. Foot is inverted on heel strike and remains inverted throughout 2. Foot is inverted throughout with abduction 3. Foot is inverted throughout with adduction
RFV 34/2	1/13	1. Foot is inverted on heel strike and remains inverted throughout 2. Foot is inverted throughout with abduction

APPENDIX 17 - contd.

Pattern reference	Focal code	Suggested functions
RFV 35/2	6/13/20	1. Foot is inverted on heel strike and remains inverted throughout 2. Foot is inverted throughout with abduction
RFV 37/2	1/13/18	1. Foot is inverted on heel strike and remains inverted throughout 2. Foot is inverted throughout with abduction 3. Foot is inverted throughout with adduction
RFV 39/1	1/19/20/21	1. Foot is inverted on heel strike and remains inverted throughout 2. Forefoot supination 3. Adductory twist
RFV 42/1	1/12/13	1. Foot is inverted on heel strike and remains inverted throughout 2. Foot is inverted throughout with abduction 3. Foot is inverted throughout with adduction
RFV 48/1	1/13/14/15/18	1. Foot is inverted on heel strike and remains inverted throughout 2. Foot is inverted throughout with abduction
RFV 52/1	1/13/18	1. Foot is inverted on heel strike and remains inverted throughout 2. Foot is inverted throughout with abduction 3. Foot is inverted throughout with adduction
RFV 52/3	1/13/14/15/18	1. Foot is inverted on heel strike and remains inverted throughout 2. Foot is inverted throughout with abduction
RFV 52/4	6/13	1. Foot is inverted on heel strike and remains inverted throughout 2. Foot is inverted throughout with abduction 3. Foot is inverted throughout with adduction
RFV 53/2	1/13/14/15/20	1. Foot is inverted on heel strike and remains inverted throughout 2. Foot is inverted throughout with abduction
RFV 53/4	1/13/21	1. Foot is inverted on heel strike and remains inverted throughout 2. Foot is inverted throughout with abduction
RFV 54/2	1/13/18	1. Foot is inverted on heel strike and remains inverted throughout 2. Foot is inverted throughout with abduction 3. Foot is inverted throughout with adduction
RFV 55/3	6/7/12/13/17	1. Foot is inverted on heel strike and remains inverted throughout 2. Foot is inverted throughout with abduction

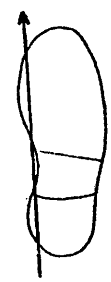
APPENDIX 18 Patterns repeated across pathology categories

Focal code	No. Pathologies affected	Pattern references
1/15	Pronation - 3	PRON - 42/2, 8/2, 16/3
	Rearfoot varus - 4	RFV – 16/1, 9/1, 18/3, 23/1
	Pes cavus - 3	PC – 1/1, 6/2, 8/2
15	Pronation - 4	PRON – 32/1, 22/2, 5/3, 32/4
	Rearfoot varus - 1	RFV – 22/2
	Pes cavus - 1	PC – 22/2
	Hallux rigidus - 1	HR – 32/2
1/15/20	Pronation - 4	PRON – 35/2, 37/2, 43/1, 11/3
	Hallux rigidus - 2	HR – 40/1, 29/1
14/15	Rearfoot varus - 1	RFV – 32/2
	Hallux rigidus - 1	HR – 47/1
1/14/15	Rearfoot varus - 3	RFV – 53/1, 20/1, 54/3
	Pronation - 1	PRON – 20/1
1/2/3/4/9/14/15	Rearfoot varus - 1	RFV – 31/1
	Pronation - 1	PRON – 31/1
1/13/14/15/16	Pes cavus - 8	PC – 13/2, 17/1, 36/1, 11/1, 44/1, 48/3, 41/1, 37/1
	Rearfoot varus - 2	RFV – 44/1, 42/2
2/13/14/15/16/17/20	Pronation - 1	PRON – 28/3
	Rearfoot varus - 2	RFV –28/1, 28/3
1/13/14/15/16/17	Pes cavus - 2	PC – 28/3, 48/2
	Pronation - 1	PRON – 21/1
6/13/14/15/16/17	Pes cavus - 1	PC – 48/1
	Hallux rigidus - 1	HR – 48/2
1/13/14/15	Rearfoot varus - 2	RFV – 13/1, 16/2
	Pes cavus - 1	PC – 24/3
	Hallux rigidus - 1	HR – 53/2
4/13/14/15/20/21	Pronation - 1	PRON – 31/3
	Rearfoot varus - 1	RFV – 31/3
1/13/18	Pronation - 1	PRON – 30/2
	Rearfoot varus - 4	RFV – 52/1, 37/2, 1/3, 54/2
	Pes cavus - 1	PC – 49/1
12/13	Pes cavus - 1	PC – 32/2
	Hallux rigidus - 1	HR – 32/3
1/14/15/20	Pronation - 2	PRON – 20/2, 31/2
	Rearfoot varus - 2	RFV – 20/2, 35/3
	Hallux rigidus - 6	HR 6/1, 20/1, 8/1, 16/2, 16/1, 4/1
1/13/14/15/17	Rearfoot varus - 1	RFV – 11/1
	Hallux rigidus - 1	HR –42/1
1/13/15/20	Pes cavus - 1	PC – 8/1
	Hallux rigidus - 1	HR – 55/1
13/15/20	Hallux rigidus - 1	HR – 26/2
	Hallux rigidus - 1	HR – 29/2
1/13/20	Pronation - 1	PRON – 11/4
	Hallux rigidus - 3	HR – 34/1, 28/1, 45/1
1/13/16	Rearfoot varus - 2	RFV 53/3, 26/3
	Pronation - 2	PRON 34/3, 50/4
	Pes cavus - 6	PC 53/1. 43/1, 23/1, 13/1, 26/1, 45/1
1/16	Pronation - 1	PRON 12/1
	Rearfoot varus - 4	RFV 18/2, 4/1, 38/1, 12/1
	Pes cavus - 2	PC 12/2, 39/1

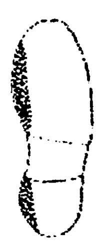
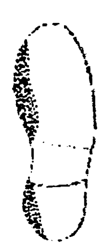
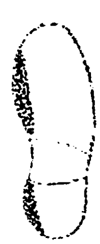
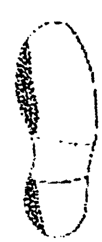
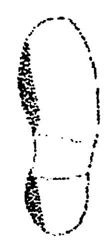
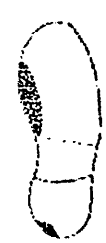
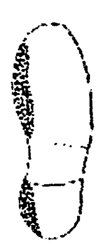
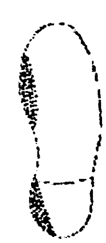
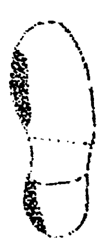
APPENDIX 18 – contd.

Focal code	No. Pathologies affected	Pattern references
6	Pronation - 2	PRON 45/1, 17/3
	Pes cavus - 1	PC 47/3
	Hallux rigidus - 2	HR 36/1, 46/2
1/16/17	Pronation - 6	PRON 44/1, 7/1, 23/1,11/1, 30/1, 18/1
	Rearfoot varus - 4	RFV 30/1, 14/1, 11/2, 34/3
	Pes cavus - 1	PC 32/1
	Hallux rigidus - 1	HR 11/1
4/9/16/17	Pronation - 3	PRON 5/2, 6/2, 20/3
	Rearfoot varus - 1	RFV 7/2
2/3/4/9/16/17	Pronation - 1	PRON 19/1
	Hallux rigidus - 1	HR 19/1
4/16/17/20	Pronation - 4	PRON 53/3, 28/2, 49/1, 29/2
	Hallux rigidus - 1	HR 28/2
2/15/16/17	Pronation - 2	PRON 44/2, 53/4
	Rearfoot varus - 1	RFV 2/1
1/15/16/17/20/21	Pronation - 2	PRON 33/2, 4/1
	Hallux rigidus - 1	HR 31/1
17	Hallux rigidus - 1	HR – 7/1
	Pronation - 1	PRON – 32/2
1/20	Pronation - 3	PRON – 35/1, 35/3, 37/1
	Rearfoot varus - 1	RFV – 35/1
	Hallux rigidus - 5	HR – 17/1, 8/2, 11/3, 18/1, 53/1
20	Pronation - 1	PRON – 46/2
	Hallux rigidus - 4	HR – 10/1, 14/1, 25/1, 32/1
1/17/20	Pronation - 1	PRON – 8/1
	Rearfoot varus - 1	RFV – 36/1
	Hallux rigidus - 4	HR – 41/1, 3/1, 2/1, 50/1
6/17/20	Rearfoot varus - 1	RFV – 40/1
	Pronation - 1	PRON 22/1
6/7/18/19/21	Rearfoot varus - 1	RFV – 29/2
	Hallux rigidus - 1	HR – 54/1
9	Pronation - 1	PRON – 32/3
	Rearfoot varus - 1	RFV – 32/3
1	Pes cavus - 1	PC – 39/2
	Hallux rigidus - 1	HR – 32/4
1/2/6	Pronation - 1	PRON – 28/1
	Rearfoot varus - 1	RFV – 19/1
6/7	Rearfoot varus - 1	RFV – 25/1
	Pronation - 1	PRON – 25/2

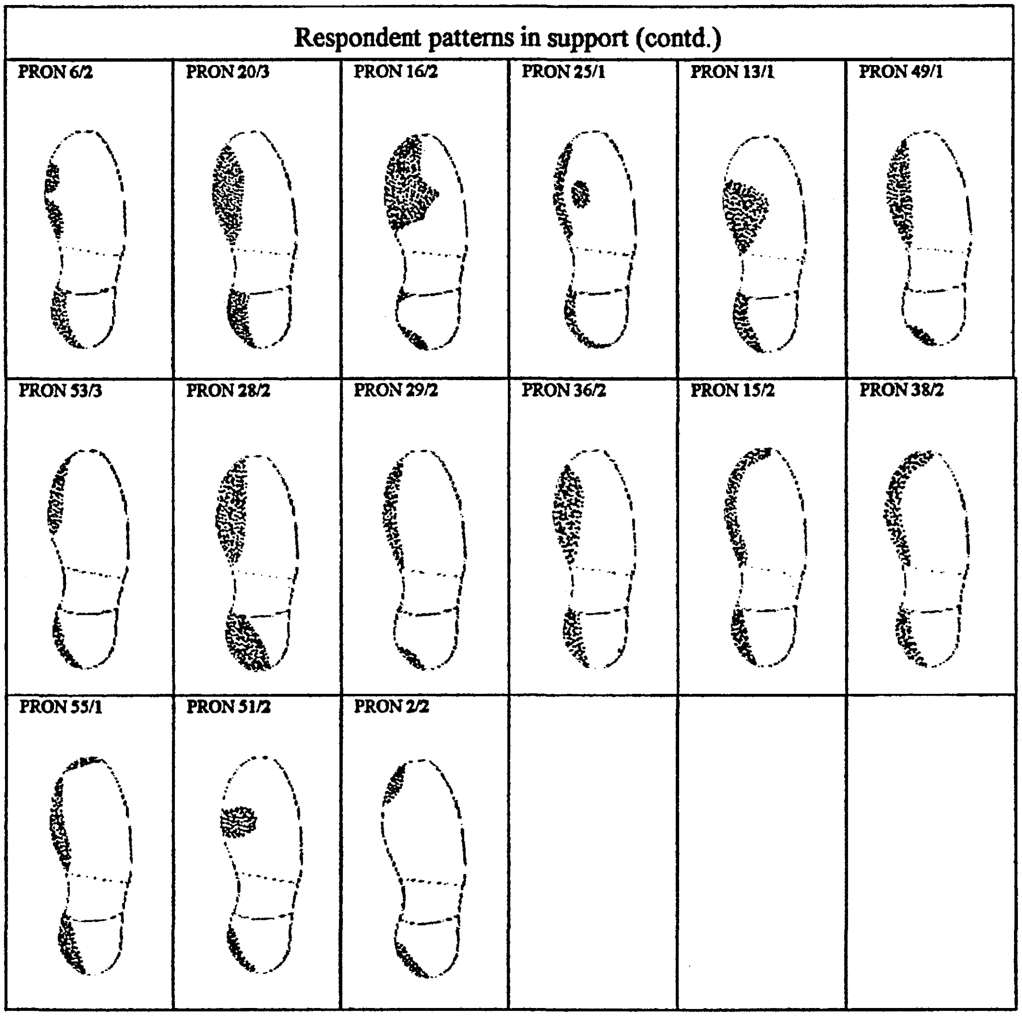
APPENDIX 19.1 Functions suggested by patterns with pronation

Function and description	Previously suggested by
<u>Foot pronated prior to heel strike and throughout stance</u> *Foot is fixed in pronation before heel strikes, therefore striking medially with the force pathway remaining medial as pronation remains*	Root, Orien and Weed (p303) Neale (p44)
Theoretical movements in the sagittal plane	**Force pathway**
Not applicable	

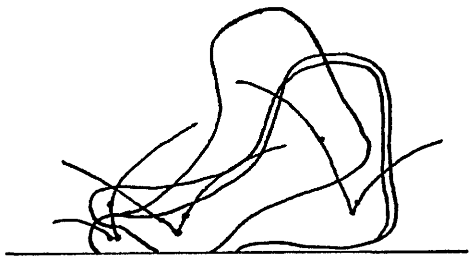
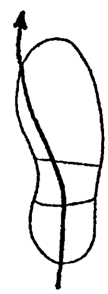
Respondent patterns in support

PRON 34/1 	PRON 23/2 	PRON 50/2 	PRON 48/2 	PRON 47/1 	PRON 51/4 
PRON 18/3 	PRON 14/2 	PRON 8/3 	PRON 17/2 	PRON 11/2 	PRON 5/2 

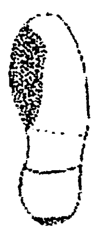
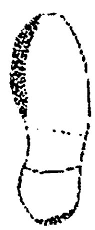
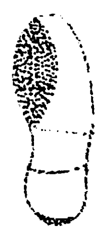
APPENDIX 19.1 – contd.



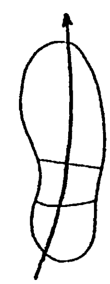
APPENDIX 19.2 Functions suggested by patterns with pronation

Function and description	Previously suggested by
Heel equinus causing centralised heel contact and later pronation to compensate *A heel equinus results in a central heel strike and an central force pathway. As restricted dorsiflexion is encountered, the foot pronates to accommodate this, redirecting the force pathway medially*	Root, Orien and Weed (p174) Neale (p47)
Theoretical movements in the sagittal plane	**Force pathway**
	

Respondent patterns in support

PRON 18/2	PRON 2/1	PRON 43/3	PRON 39/1	PRON 44/2	PRON 53/4
					
PRON 28/3	PRON 24/1				
					

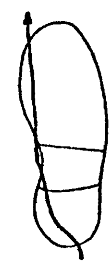
APPENDIX 19.3 Functions suggested by patterns with pronation

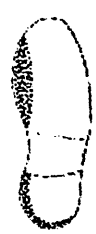
Function and description	Previously suggested by
Foot pronated prior to heel strike with attempt to recover via supination *As the foot lands in pronation, an attempted recovery through supination directs the force pathway more laterally*	Root, Orien and Weed (p120) Neale (p38)
Theoretical movements in the sagittal plane	**Force pathway**
Not applicable	

Respondent patterns in support

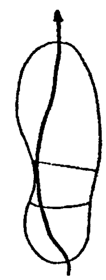
PRON 13/2	PRON 3/1	PRON 21/2	PRON 21/3	PRON 31/3	
					

APPENDIX 19.4 Functions suggested by patterns with pronation

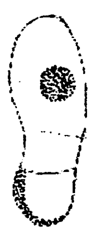
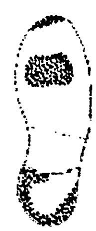
Function and description	Previously suggested by
<u>Foot pronates rapidly on contact and remains pronated throughout stance</u> *Foot is not in fixed pronation, but pronates on heel strike, directing the force pathway medially. The force pathway remains medially as it progresses anteriorly*	Neale (p44)
Theoretical movements in the sagittal plane	Force pathway
Not applicable	

Respondent patterns in support					
PRON 19/1 	PRON 52/1 	PRON 54/4 	PRON 48/1 	PRON 54/3 	

APPENDIX 19.5 Functions suggested by patterns with pronation

Function and description	Previously suggested by
<u>Foot pronates rapidly on contact and attempts to recover via forefoot supination</u> *Foot is not in fixed pronation, but pronates on heel strike, directing the force pathway medially. An attempted recovery through supination directs the force pathway more laterally*	Root, Orien and Weed (p174)
Theoretical movements in the sagittal plane	**Force pathway**
Not applicable	

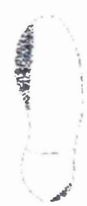
Respondent patterns in support

PRON 26/1	PRON 25/3	PRON 26/2	PRON 31/1	PRON 26/3	
					

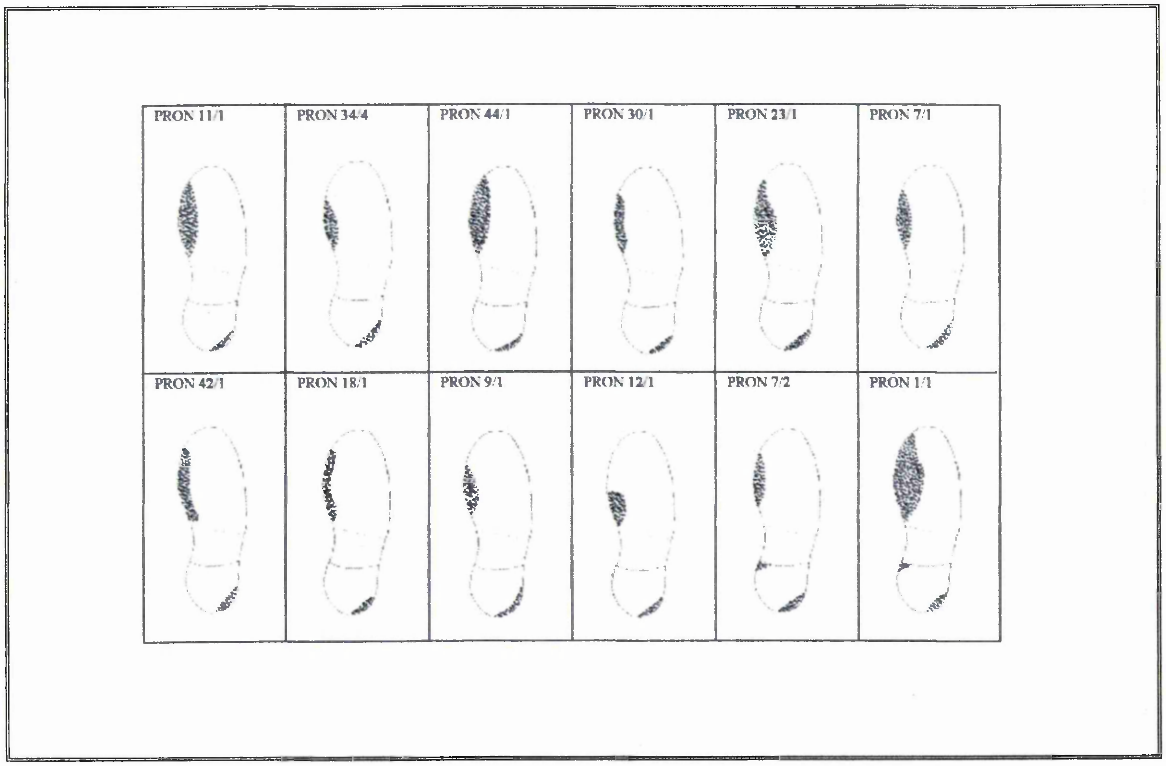
APPENDIX 19.6 Functions suggested by patterns with pronation

Function and description	Previously suggested by
<u>Foot contacts normally with mid-stance pronation and no attempt to recover</u> *After normal heel strike, the pronates at the subtalar joint, redirecting the force pathway medially*	Neale (p47)
Theoretical movements in the sagittal plane	**Force pathway**
Not applicable	

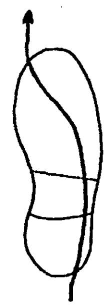
Respondent patterns in support

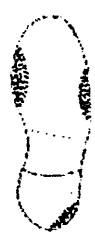
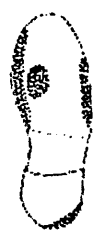
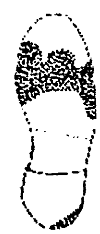
PRON 41/1	PRON 54/1	PRON 29/1	PRON 38/1	PRON 55/3	PRON 16/1
					
PRON 17/1	PRON 47/4	PRON 14/1	PRON 36/1	PRON 52/2	PRON 55/2
					

APPENDIX 19.6 – contd.

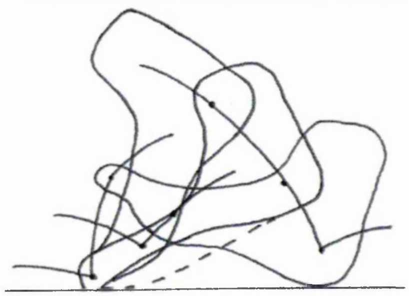
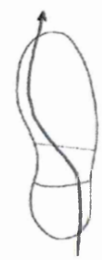


APPENDIX 19.7 Functions suggested by patterns with pronation

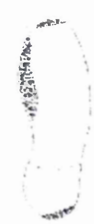
Function and description	Previously suggested by
Foot contacts normally with late pronation *Following a normal heel strike, the foot follows a normal force pathway, but pronates rapidly towards the end of stance, with the force pathway directed medially at a late stage*	Not previously suggested in association with pronation
Theoretical movements in the sagittal plane	**Force pathway**
Not applicable	

Respondent patterns in support					
PRON 34/3 	PRON 50/4 	PRON 21/4 	PRON 21/1 		

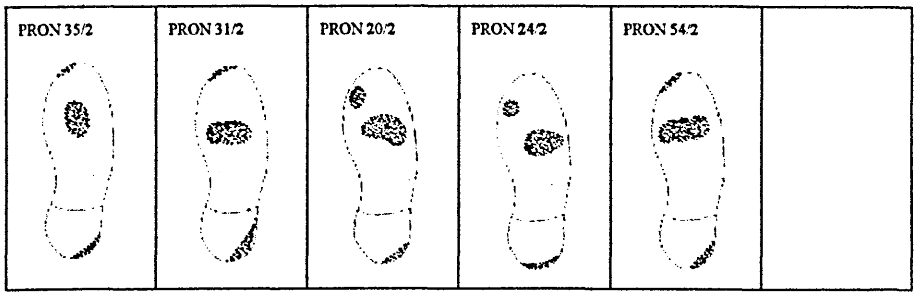
APPENDIX 19.8 Functions suggested by patterns with pronation

Function and description	Previously suggested by
Foot contacts normally with later pronation and attempt to stabilise via functional hallux limitus *Normal heel strike occurs, with later pronation occurring via the subtalar joint, directing the force pathway medially. Attempted stabilisation through functional hallux limitus prevents further medial deviation*	Not previously suggested in association with pronation
Theoretical movements in the sagittal plane	Force pathway
	

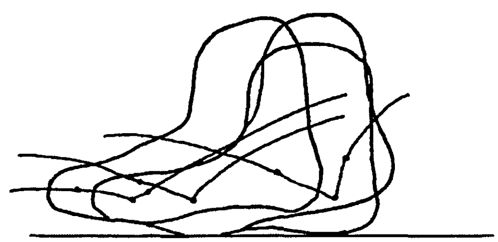
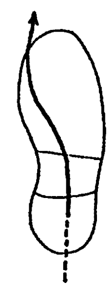
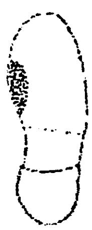
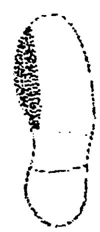
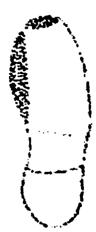
Respondent patterns in support

PRON 10/1	PRON 37/1	PRON 35/1	PRON 32/2	PRON 8/1	PRON 46/2
					
PRON 15/1	PRON 11/4	PRON 55/2	PRON 43/1	PRON 37/2	PRON 11/3
					

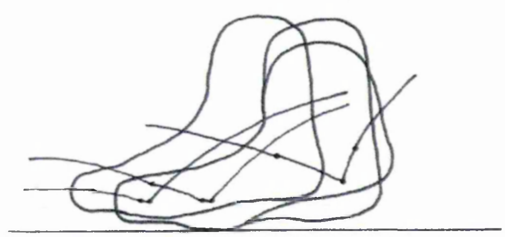
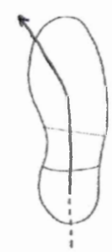
APPENDIX 19.8



APPENDIX 19.9 Functions suggested by patterns with pronation

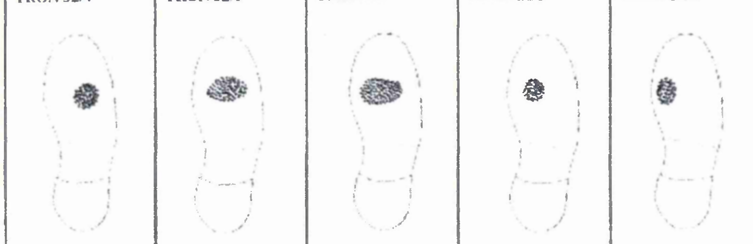
Function and description					Previously suggested by
Heel equinus causing no heel contact and later pronation to compensate *The restricted dorsiflexion of heel equinus results in a missed heel strike and a central force pathway. Due to this restricted dorsiflexion the foot pronates, redirecting the force pathway medially*					Not previously suggested in association with pronation
Theoretical movements in the sagittal plane					**Force pathway**
					
Respondent patterns in support					
PRON 45/1 	PRON 47/3 	PRON 5/1 	PRON 47/2 	PRON 32/3 	PRON 6/1 
PRON 12/2 					

APPENDIX 19.10 Functions suggested by patterns with pronation

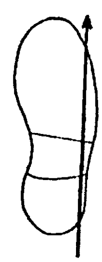
Function and description	Previously suggested by
<u>Heel equinus causing no heel contact and later abductory twist to compensate</u> *The restricted dorsiflexion of heel equinus results in a missed heel strike and a central force pathway. To accomodate this restricted dorsiflexion the foot undertakes an abductory twist , redirecting the force pathway medially*	Not previously suggested in association with pronation
Theoretical movements in the sagittal plane	Force pathway
	

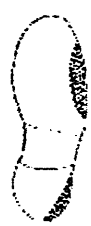
Respondent patterns in support

PRON 32/4	PRON 32/1	PRON 5/3	PRON 22/2	PRON 17/3	



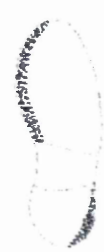
APPENDIX 19.11 Functions suggested by patterns with pronation

Function and description	Previously suggested by
<u>Foot lands in inversion to compensate for pronation and remains inverted throughout stance</u> *The foot attempts to resist the pronatory tendency by inverting before heel strike, remaining inverted throughout stance with the force pathway remaining lateral*	Not previously suggested in association with pronation
Theoretical movements in the sagittal plane	**Force pathway**
Not applicable	

Respondent patterns in support					
PRON 30/2 	PRON 34/2 				

APPENDIX 9.12 Functions suggested by patterns with pronation

Function and description	Previously suggested by
The foot lands in inversion to compensate for pronation, then later pronates fully *a) The foot attempts to resist the pronatory tendency by inverting before heel strike, with lateral force pathway. The foot later succumbs to the pronatory tendency with the force pathway being directed medially (Or b) vice versa – pronates to compensate for the inversion)*	b) Root, Orien and Weed (p174) Neale (p44)
Theoretical movements in the sagittal plane	**Force pathway**
Not applicable	

Respondent patterns in support					
PRON 51/1 	PRON 22/1 	PRON 51/3 	PRON 43/2 	PRON 50/3 	PRON 40/1 
PRON 50/1 	PRON 33/1 				

APPENDIX 19.13 Functions suggested by patterns with pronation

<table>
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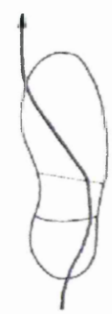
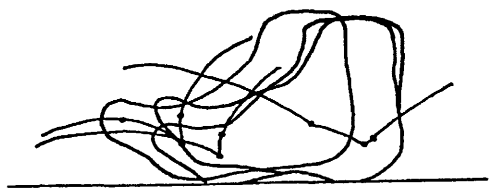
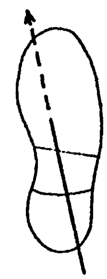
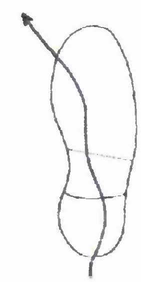
<tr><td colspan="4"><u>The foot inverts on heel strike, then later pronates fully</u>
Following a normal heel strike, the foot attempts to resist the pronatory tendency by inverting, with the force pathway being directed laterally. The foot later succumbs to the pronatory tendency with the force pathway being directed medially</td><td colspan="2">Root, Orien and Weed (p174)
Neale (p44)</td></tr>
<tr><td colspan="4">Theoretical movements in the sagittal plane</td><td colspan="2">Force pathway</td></tr>
<tr><td colspan="4">Not applicable</td><td colspan="2"></td></tr>
<tr><td colspan="6">Respondent patterns in support</td></tr>
<tr><td>PRON 53/1
</td><td>PRON 28/4
</td><td></td><td></td><td></td><td></td></tr>
</table>

APPENDIX 19.14 Functions suggested by patterns with pronation

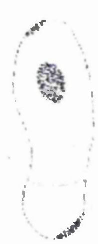
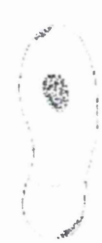
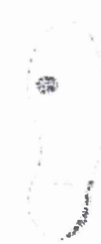
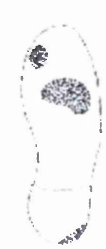
Function and description	Previously suggested by
<u>Foot in fixed pronation and walking on heels in abduction with early lift</u> *Due to a fixed, severe pronation, heel strike takes place with the foot abducted and the medial forefoot dorsiflexed. This directs the force pathway medially, but the foot is lifted early due to medial forefoot incompetence*	Neale (p51)
Theoretical movements in the sagittal plane	Force pathway
	

Respondent patterns in support					
PRON 25/2 	PRON 28/1 				

APPENDIX 19.15 Functions suggested by patterns with pronation

Function and description	Previously suggested by
Abductory twist *Following heel strike, the foot proceeds into pronation and as the force pathway reaches the met. area, an abductory twist places the forefoot into an abducted position with subsequent rolling over the medial side of the 1st to improve the efficiency of toe-off, medially redirecting the force pathway*	Neale (p47)
Theoretical movements in the sagittal plane	**Force pathway**
Not applicable	

Respondent patterns in support

PRON 42/2 	PRON 8/2 	PRON 16/3 	PRON 35/2 	PRON 43/1 	PRON 37/2 
PRON 11/3 	PRON 46/1 	PRON 53/2 	PRON 20/2 	PRON 31/2 	PRON 24/2 

APPENDIX 19.16 Functions suggested by patterns with pronation

<table>
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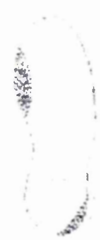
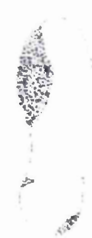
<tr><td colspan="4">Foot abducted A marked degree of abduction accompanies pronation of the foot, with the force pathway being directed from a marked lateral heel strike, medially across the foot to a medial toe off position</td><td colspan="2">Root, Orien and Weed (p422)
Neale (p47)</td></tr>
<tr><td colspan="4">Theoretical movements in the sagittal plane</td><td colspan="2">Force pathway</td></tr>
<tr><td colspan="4">Not applicable</td><td colspan="2"></td></tr>
<tr><td colspan="6">Respondent patterns in support</td></tr>
<tr><td>PRON 11/1
</td><td>PRON 34/4
</td><td>PRON 7/1
</td><td>PRON 23/1
</td><td>PRON 30/1
</td><td>PRON 44/1
</td></tr>
<tr><td>PRON 9/1
</td><td>PRON 52/2
</td><td>PRON 14/1
</td><td>PRON 36/1
</td><td>PRON 7/2
</td><td>PRON 1/1
</td></tr>
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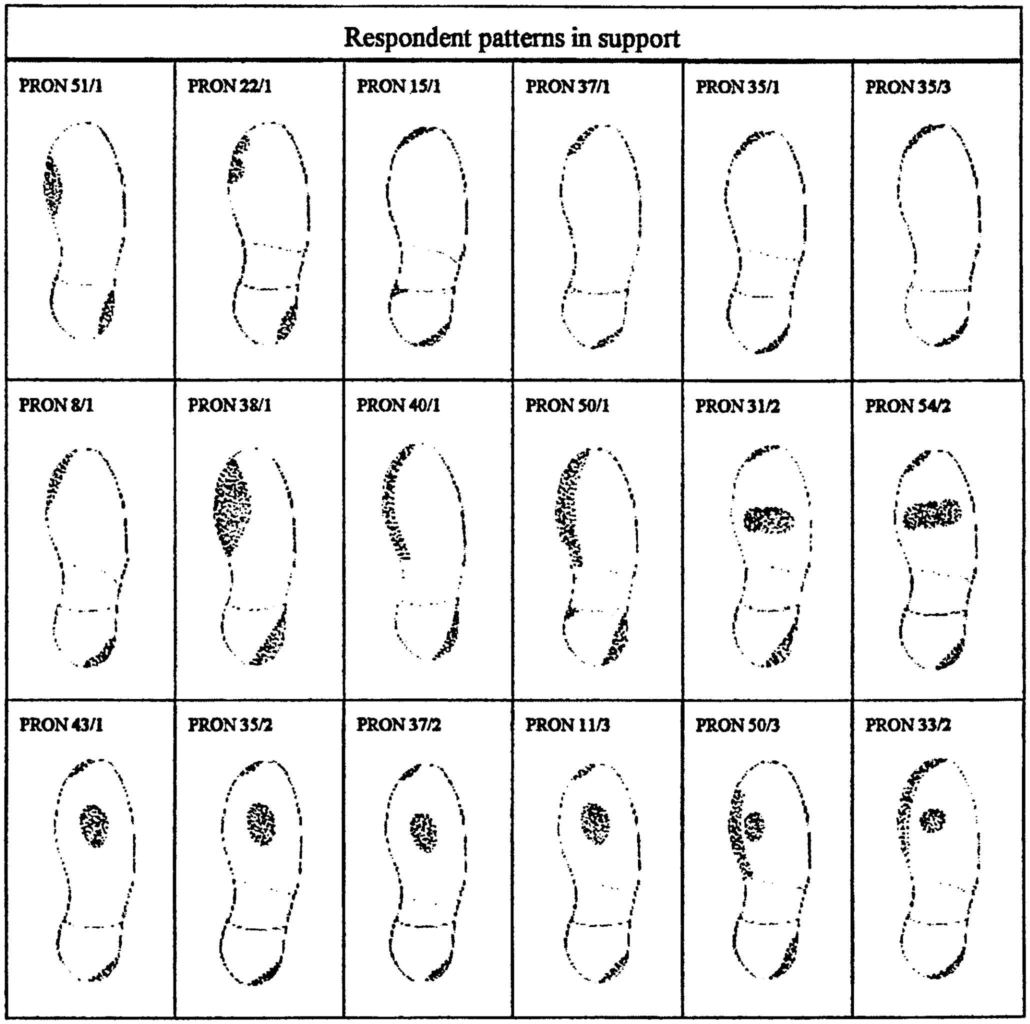
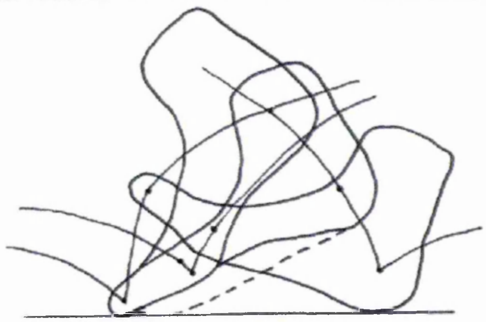
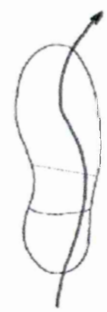
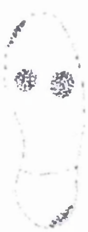
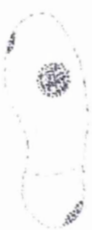
APPENDIX 19.16 – contd.



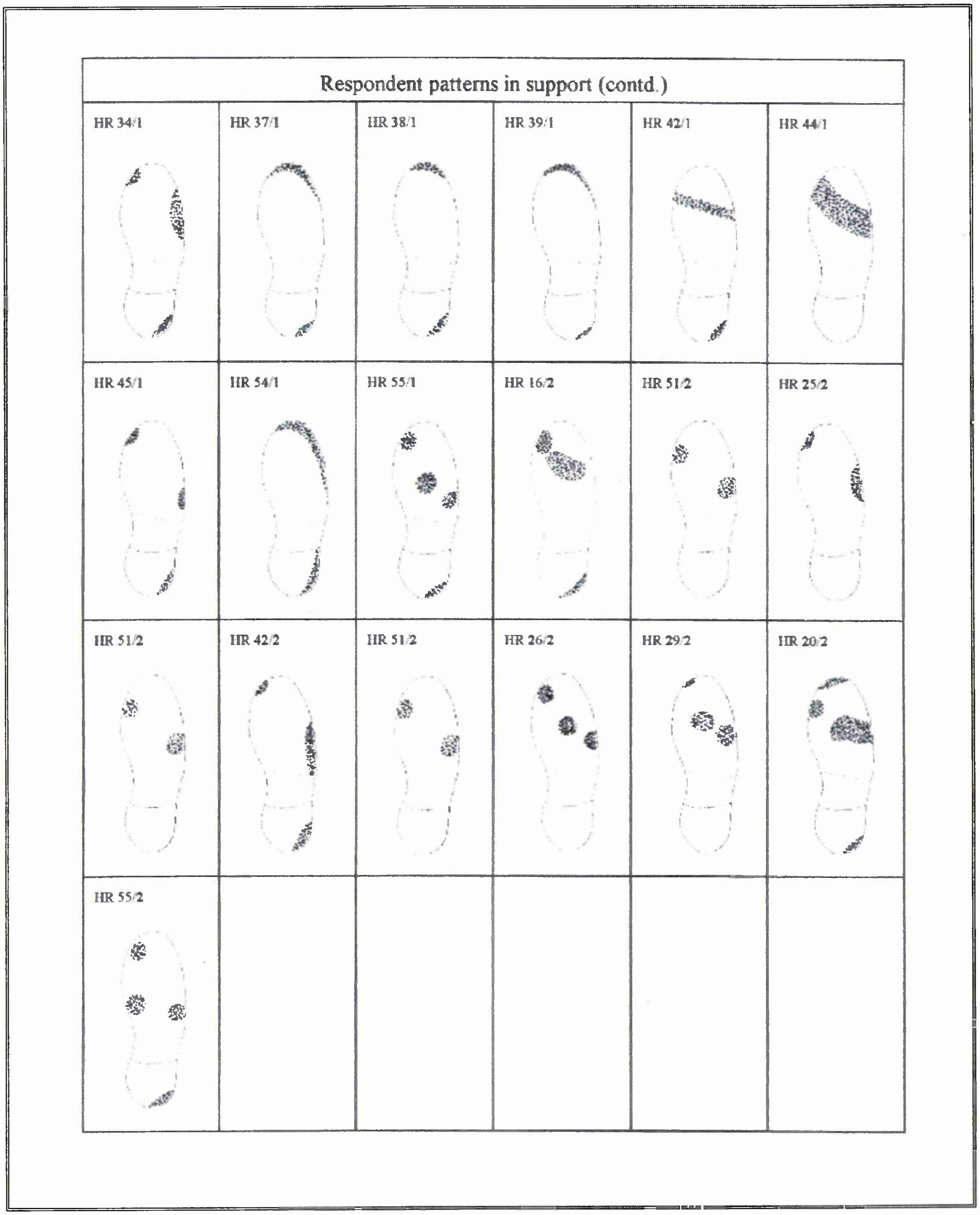
APPENDIX 20.1 Functions suggested by patterns with hallux rigidus

Function and description	Previously suggested by
Classic hallux rigidus function *5th MP.Jt and distal aspect of 1st toe form axis as lack of movement in the 1st MP.Jt prevents 1st toe from dorsiflexing. This directs the pathway laterally. The force pathway therefore meets and is diverted laterally by the H. Rig. pathology.*	Charlesworth (p597) Hanby and Walker (p159) Lucock
Theoretical movements in the sagittal plane	Force pathway
	

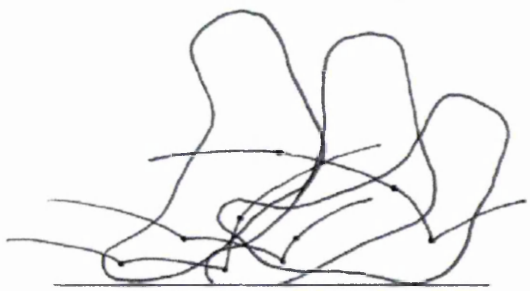
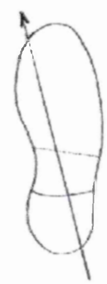
Respondent patterns in support

HR 4/1	HR 6/1	HR 8/1	HR 12/1	HR 16/1	HR 20/1
					
HR 24/1	HR 26/1	HR 27/1	HR 28/1	HR 29/1	HR 33/1
					

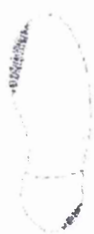
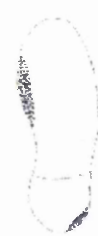
APPENDIX 20.1 – contd.



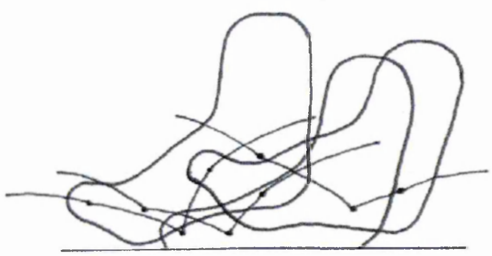
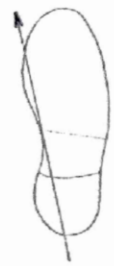
APPENDIX 20.2 Functions suggested by patterns with hallux rigidus

Function and description	Previously suggested by
Abducted gait *As the feet are directed out, the force pathway passes medially over the 1st MPJt with the 1st therefore not requiring dorsiflexing due to foot "rolling" off the medial side of the 1st toe and MPJt instead.*	Rzonka Sherman
Theoretical movements in the sagittal plane	Force pathway
	

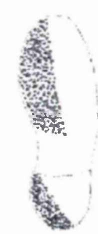
Respondent patterns in support

HR 2/1 	HR 3/1 	HR 11/1 	HR 13/1 	HR 22/1 	HR 31/1 
HR 41/1 	HR 48/1 	HR 50/1 	HR 51/1 	HR 32/4 	

APPENDIX 20.3 Functions suggested by patterns with hallux rigidus

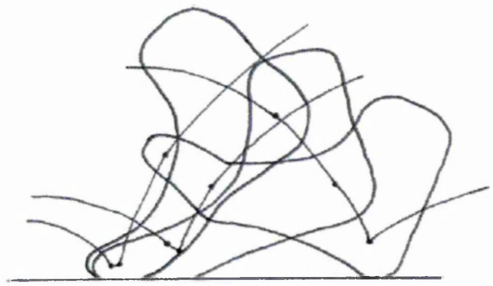
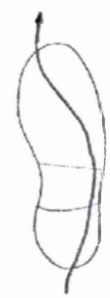
Function and description	Previously suggested by
Pronation with abducted gait *Heel strike may be on medial heel aspect. As with abducted gait, with the feet being directed out, the force pathway passes medially over the 1st MPJt with the 1st therefore not requiring dorsiflexing due to the foot "rolling" off the medial side of the 1st toe and MPJt instead.*	Dananberg (refers to pronation but not abduction) Sherman
Theoretical movements in the sagittal plane	Force pathway
	

Respondent patterns in support

HR 14/3	HR 17/2	HR 19/1	HR 48/3	HR 12/2	HR 31/2
					

APPENDIX 20.4 Functions suggested by patterns with hallux rigidus

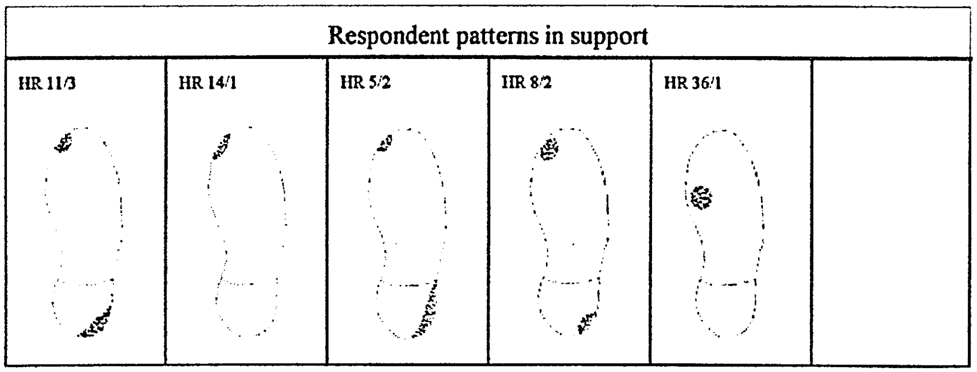
Function and description	Previously suggested by
<u>No medial or lateral deviation from normal gait pathway (with or without hyperextension of 1st MPJt)</u> *Lack of medial/lateral deviation gives normally appearing force pathway when viewed from above, but deviating pathway when viewed horizontally. Hyperextended distal phalanx of 1st toe will be present.*	Rzonka Root, Orien and Weed (p369)

Theoretical movements in the sagittal plane	Force pathway
	

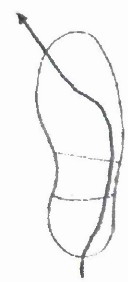
Respondent patterns in support

HR 7/1	HR 9/1	HR 10/1	HR 17/1	HR 18/1	HR 25/1
					
HR 30/1	HR 32/1	HR 40/1	HR 49/1	HR 53/1	HR 14/2
					

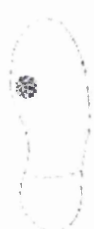
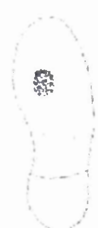
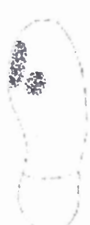
APPENDIX 20.4 - contd.



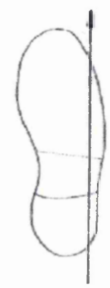
APPENDIX 20.5 Functions suggested by patterns with hallux rigidus

Function and description	Previously suggested by
Abductory twist *As the force pathway reaches the met. area, an abductory twist places the forefoot into an abducted position with subsequent rolling over the medial side of the 1st preventing the need for the 1st to dorsiflex.*	Not previously suggested in association with hallux rigidus
Theoretical movements in the sagittal plane	**Force pathway**
Not applicable	

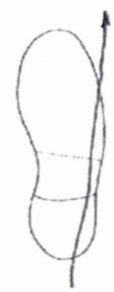
Respondent patterns in support

HR 36/1 	HR 51/1 	HR 52/1 	HR 23/1 	HR 32/2 	HR 46/2 
HR 50/2 					

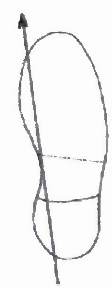
APPENDIX 20.6 Functions suggested by patterns with hallux rigidus

<table>
<tr><th colspan="4">Function and description</th><th colspan="2">Previously suggested by</th></tr>
<tr><td colspan="4">Compensatory supination/inversion of the foot Uncompensated calcaneal inversion keeps the force pathway lateral therefore avoiding the limitation in dorsiflexion of the 1st caused by the H. Rig.</td><td colspan="2">Neale (p64)
Turchin
Rzonka
Sherman</td></tr>
<tr><th colspan="4">Theoretical movements in the sagittal plane</th><th colspan="2">Force pathway</th></tr>
<tr><td colspan="4">Not applicable</td><td colspan="2"></td></tr>
<tr><th colspan="6">Respondent patterns in support</th></tr>
<tr><td>HR 33/1
</td><td>HR 54/1
</td><td>HR 5/3
</td><td>HR 11/2
</td><td>HR 53/2
</td><td>HR 31/3
</td></tr>
</table>

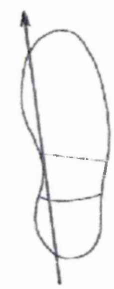
APPENDIX 20.7 Functions suggested by patterns with hallux rigidus

<table>
<tr><td colspan="6">Function and description</td><td>Previously suggested by</td></tr>
<tr><td colspan="6"><u>Forefoot inversion</u> Normal heel strike occurs. As inverted forefoot is met, the force pathway remains lateral, therefore avoiding the limitations in dorsiflexion of the 1st caused by the H. Rig.</td><td>Dananberg
Rzonka</td></tr>
<tr><td colspan="6">Theoretical movements in the sagittal plane</td><td>Force pathway</td></tr>
<tr><td colspan="6">Not applicable</td><td></td></tr>
<tr><td colspan="7">Respondent patterns in support</td></tr>
<tr><td>HR 21/1
</td><td>HR 32/3
</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

APPENDIX 20.8 Functions suggested by patterns with hallux rigidus

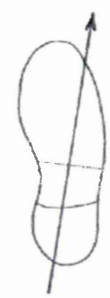
<table>
<tr><td colspan="6">Function and description</td><td>Previously suggested by</td></tr>
<tr><td colspan="6">Abducted gait with eversion Everted calc. plus abducted foot results in medial heel strike from which propulsion is gained with only slight assistance from 1st toe, avoiding limitation in dorsiflexion of the 1st caused by the H. Rig. through medial pathway.</td><td>Not previously suggested in association with hallux rigidus.</td></tr>
<tr><td colspan="6">Theoretical movements in the sagittal plane</td><td>Force pathway</td></tr>
<tr><td colspan="6">Not applicable</td><td></td></tr>
<tr><td colspan="7">Respondent patterns in support</td></tr>
<tr><td>HR 17/2
</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

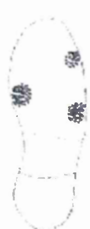
APPENDIX 20.9 Functions suggested by patterns with hallux rigidus

Function and description	Previously suggested by
<u>Abducted gait with eversion</u> *Everted calc. plus abducted foot results in medial heel strike from which propulsion is gained with only slight assistance from 1st toe, avoiding limitation in dorsiflexion of the 1st caused by the H. Rig. through medial pathway.*	Not previously suggested in association with hallux rigidus.
Theoretical movements in the sagittal plane	Force pathway
Not applicable	

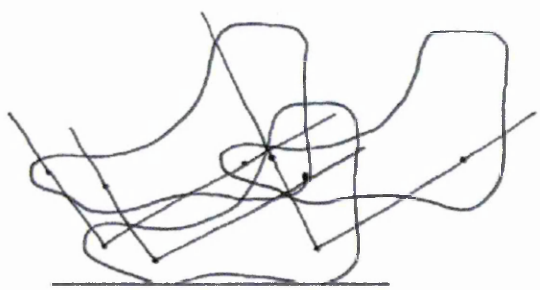
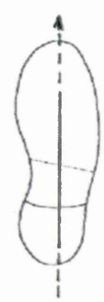
Respondent patterns in support					
HR 17/2 					

APPENDIX 20.10 Functions suggested by patterns with hallux rigidus

Function and description	Previously suggested by
Adducted gait *Medial heel strike, possibly with calcaneo-valgus results in force pathway passing laterally across the foot avoiding for need for the 1st to dorsiflex through this lateral deviation with resultant toe off from lateral aspect of the forefoot.*	Not previously suggested in association with hallux rigidus
Theoretical movements in the sagittal plane	**Force pathway**
Not applicable	

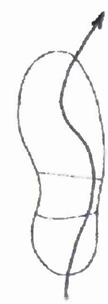
Respondent patterns in support					
HR 46/1 	HR 48/4 				

APPENDIX 20.11 Functions suggested by patterns with hallux rigidus

Function and description	Previously suggested by
Stamping gait *The foot "stamps" down and vertically lifts, therefore eliminating the need for dorsiflexion of the 1st toe.*	Not previously suggested in association with hallux rigidus
Theoretical movements in the sagittal plane	Force pathway
	

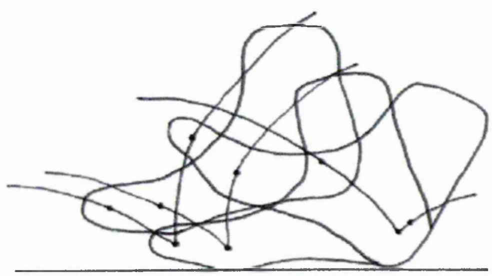
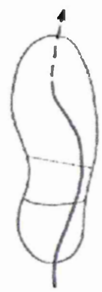
Respondent patterns in support					
HR 47/1 					

APPENDIX 20.12 Functions suggested by patterns with hallux rigidus

<table>
<tr><td colspan="6">Function and description</td><td>Previously suggested by</td></tr>
<tr><td colspan="6">Adductory twist As the pathway reaches the met. area, an adductory twist places the forefoot into the adducted position with subsequent lateral progress of the force pathway, preventing the need for the 1st to dorsiflex through this lateral deviation with resultant toe off from lateral aspect of the forefoot.</td><td>Not previously suggested in association with hallux rigidus</td></tr>
<tr><td colspan="6">Theoretical movements in the sagittal plane</td><td>Force pathway</td></tr>
<tr><td colspan="6">Not applicable</td><td></td></tr>
<tr><td colspan="7">Respondent patterns in support</td></tr>
<tr><td>HR 55/2
</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

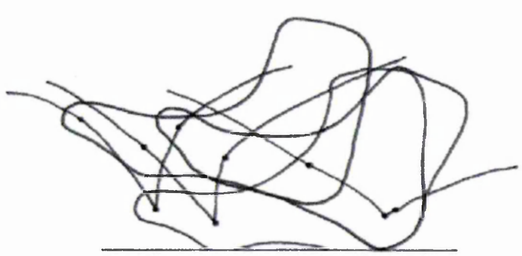
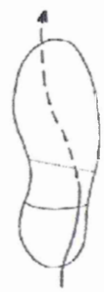
APPENDIX 20.13 Functions suggested by patterns with hallux rigidus

Function and description	Previously suggested by
Calcaneal gait *Through a lax tendo-achilles, dorsiflexion is taken up by the ankle. This may subsequently lead to vertical toe off, possibly with scuffing of the toes.*	Not previously suggested in association with hallux rigidus

Theoretical movements in the sagittal plane	Force pathway
	

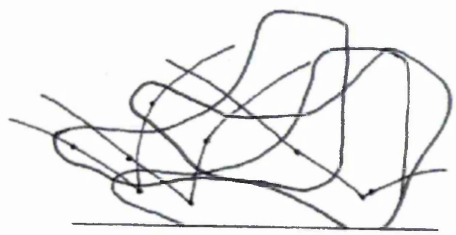
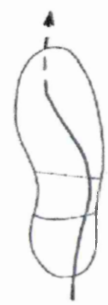
Respondent patterns in support					
HR 32/4 					

APPENDIX 20.14 Functions suggested by patterns with hallux rigidus

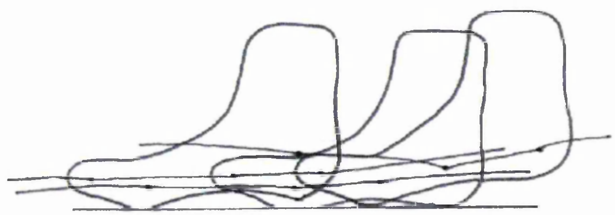
Function and description	Previously suggested by
Walking predominately on heels *Similar to calcaneal gait, but without excess ankle dorsiflexion. Weight bearing is on the heels with minimal or no forefoot contact and vertical lift off prevents the need for 1st dorsiflexion.*	Not previously suggested in conjunction with hallux rigidus
Theoretical movements in the sagittal plane	Force pathway
	

Respondent patterns in support					
HR 32/4 					

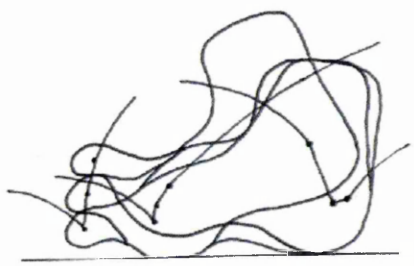
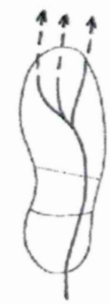
APPENDIX 20.15 Functions suggested by patterns with hallux rigidus

<table>
<tr><th colspan="5">Function and description</th><th>Previously suggested by</th></tr>
<tr><td colspan="5"><u>Vertical toe-off</u> Normal gait cycle until 1st MPJt restriction is encountered, when the foot lifts vertically.</td><td>Dananberg
Rzonka
Root, Orien and Weed (p367)</td></tr>
<tr><th colspan="5">Theoretical movements in the sagittal plane</th><th>Force pathway</th></tr>
<tr><td colspan="5"></td><td></td></tr>
<tr><th colspan="6">Respondent patterns in support</th></tr>
<tr><td>HR 47/1
</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

APPENDIX 20.16 Functions suggested by patterns with hallux rigidus

<table>
<tr><th colspan="6">Function and description</th><th>Previously suggested by</th></tr>
<tr><td colspan="6"><u>Shuffling gait</u> Feet strike ground in predominately horizontally directed movement, abrading as they strike. This extreme inhibition of vertical movement eliminates the need for the 1st to dorsiflex.</td><td>Not previously suggested in association with hallux rigidus</td></tr>
<tr><th colspan="6">Theoretical movements in the sagittal plane</th><th>Force pathway</th></tr>
<tr><td colspan="6"></td><td></td></tr>
<tr><th colspan="7">Respondent patterns in support</th></tr>
<tr><td>Not observed in returned patterns</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

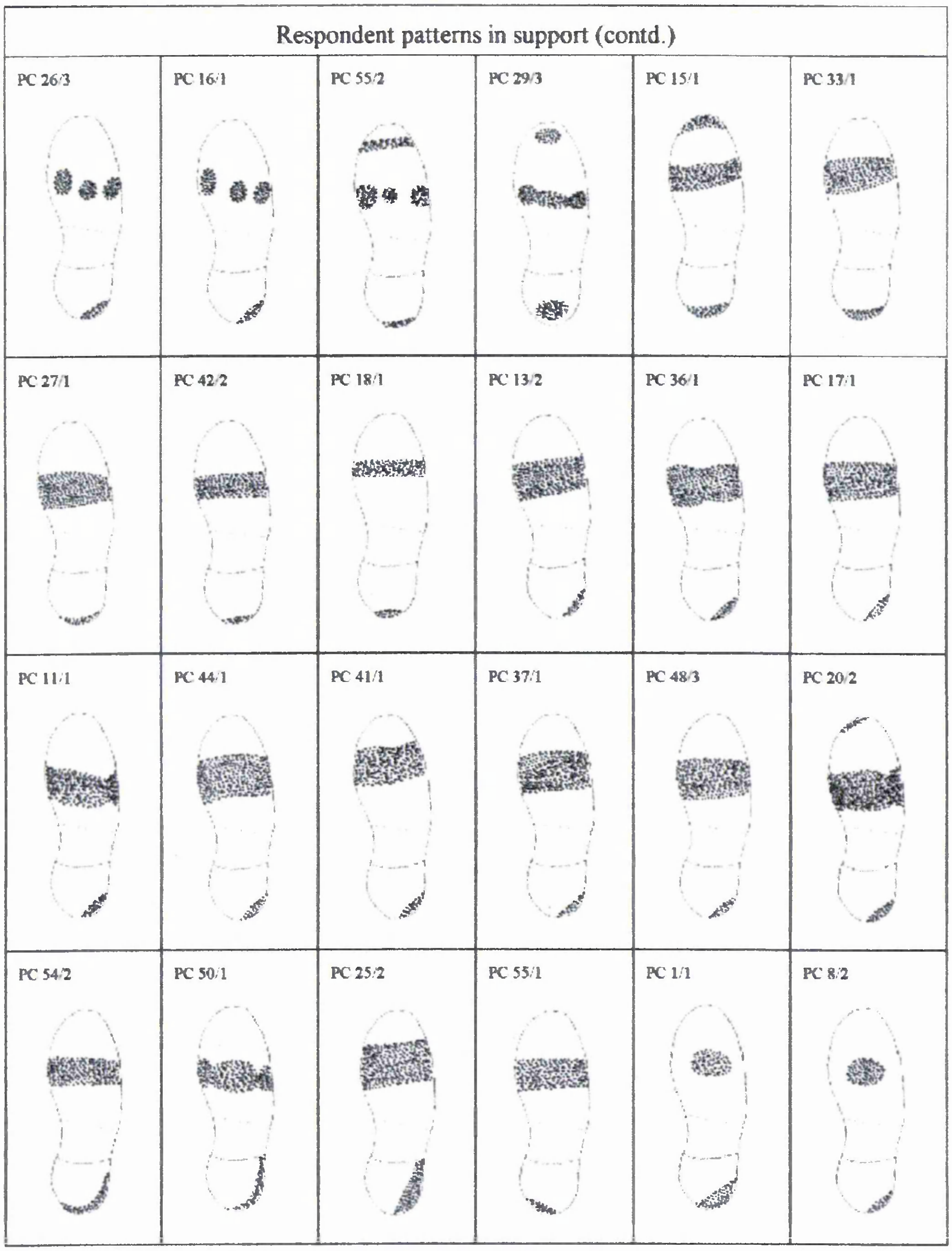
APPENDIX 21.1 Functions suggested by patterns with pes cavus

Function and description	Previously suggested by
<u>Normal force pathway with increased forefoot loading and no toe-off propulsion due to pes cavus</u> *Normal heel strike and normally directed force pathway with weight-bearing dissipated at the forefoot and without toe-off due to retracted toes.*	Neale (p53)
Theoretical movements in the sagittal plane	Force pathway
	

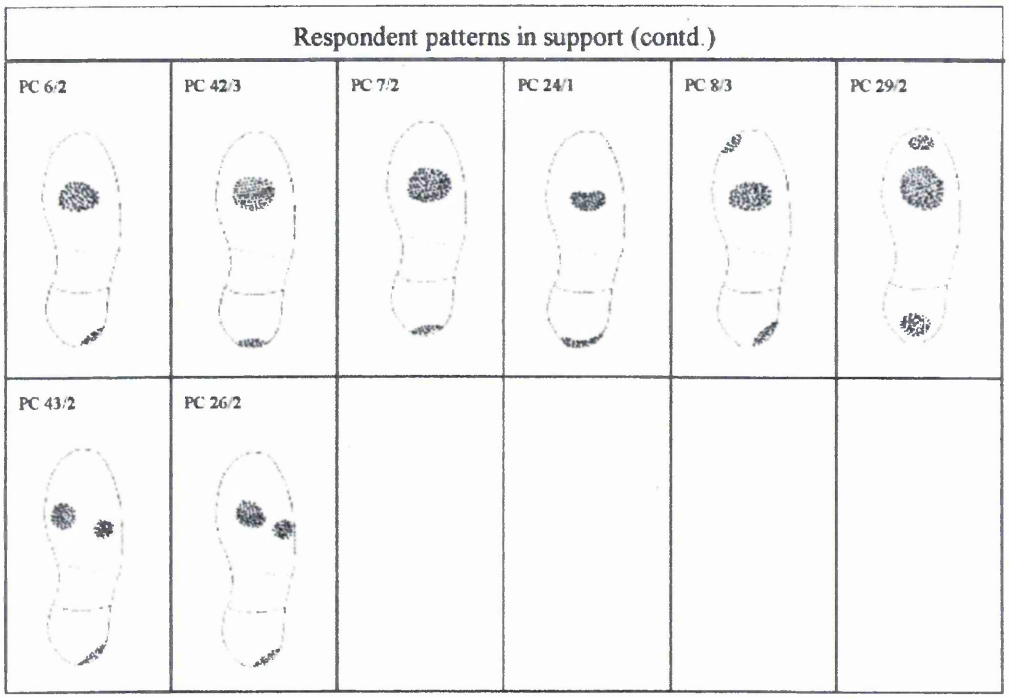
Respondent patterns in support

PC 45/1	PC 26/1	PC 13/1	PC 23/1	PC 43/1	PC 53/1
					
PC 18/2	PC 24/2	PC 42/1	PC 19/1	PC 51/2	PC 2/2
					

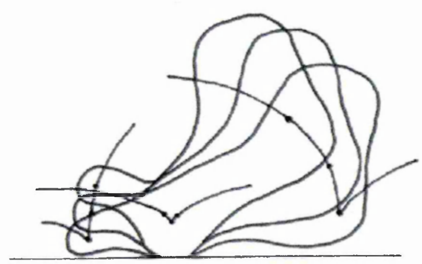
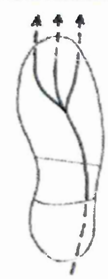
APPENDIX 21.1 – contd.



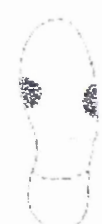
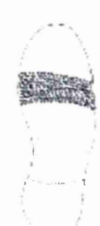
APPENDIX 21.1 – contd.



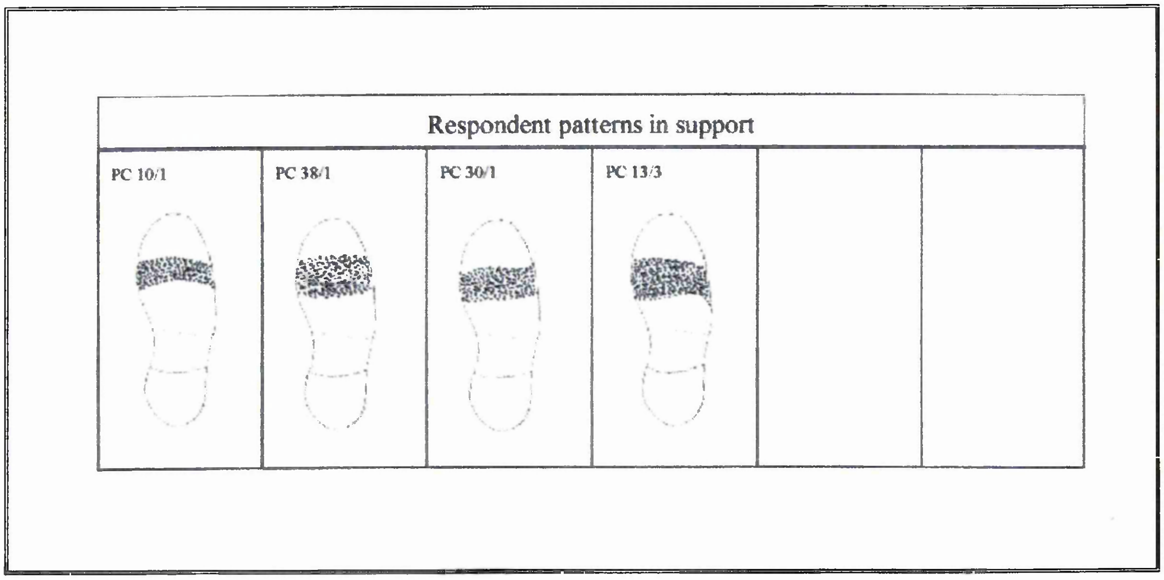
APPENDIX 21.2 Functions suggested by patterns with pes cavus

Function and description	Previously suggested by
Normal force pathway with forefoot loading and no toe-off propulsion due to pes cavus and without heel strike due to dropped forefoot *No heel strike due to position of heel in relation to forefoot and normally directed force pathway with weight-bearing dissipated at the forefoot and without toe-off due to retracted toes.*	Not previously suggested in association with pes cavus
Theoretical movements in the sagittal plane	Force pathway
	

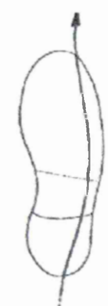
Respondent patterns in support

PC 46/2	PC 7/1	PC 14/1	PC 5/1	PC 5/2	PC 22/1
					
PC 46/1	PC 54/3	PC 5/3	PC 14/2	PC 1/3	PC 27/2
					

APPENDIX 21.2 – contd.

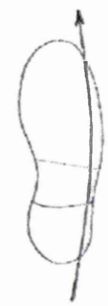


APPENDIX 21.3 Functions suggested by patterns with pes cavus

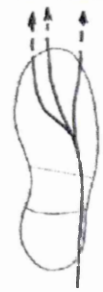
Function and description	Previously suggested by
Foot inverted throughout stance *Lateral heel strike due to inversion of the foot, maintained throughout stance hence with laterally positioned force pathway*	Not previously suggested in association with pes cavus
Theoretical movements in the sagittal plane	Force pathway
Not applicable	

Respondent patterns in support					
PC 34/2	PC 52/1	PC 51/4	PC 28/2	PC 31/1	
					

APPENDIX 21.4 Functions suggested by patterns with pronation

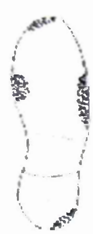
<table>
<tr><th colspan="3">Function and description</th><th colspan="3">Previously suggested by</th></tr>
<tr><td colspan="3"><u>Foot inverted and abducted throughout stance</u> Lateral heel strike, accentuated through concurrent abduction of the foot maintained throughout stance hence with laterally positioned force pathway</td><td colspan="3">Not previously suggested in association with pes cavus</td></tr>
<tr><th colspan="3">Theoretical movements in the sagittal plane</th><th colspan="3">Force pathway</th></tr>
<tr><td colspan="3">Not applicable</td><td colspan="3"></td></tr>
<tr><th colspan="6">Respondent patterns in support</th></tr>
<tr><td>PC 34/2
</td><td>PC 52/1
</td><td>PC 51/4
</td><td>PC 28/2
</td><td>PC 31/1
</td><td></td></tr>
</table>

APPENDIX 21.5 Functions suggested by patterns with pes cavus

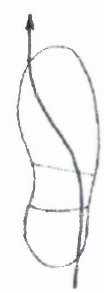
<table>
<tr><th colspan="4">Function and description</th><th colspan="2">Previously suggested by</th></tr>
<tr><td colspan="4"><u>Foot inverted on heel strike, normal force pathway at forefoot</u>
Lateral heel strike due to inversion of the heel with lateral force pathway which shifts centrally to assume normal inclination of forefoot.</td><td colspan="2">(Neale p. 51)</td></tr>
<tr><th colspan="4">Theoretical movements in the sagittal plane</th><th colspan="2">Force pathway</th></tr>
<tr><td colspan="4">Not applicable</td><td colspan="2"></td></tr>
<tr><th colspan="6">Respondent patterns in support</th></tr>
<tr><td>PC 6/1
</td><td>PC 25/1
</td><td>PC 33/2
</td><td>PC 4/1
</td><td></td><td></td></tr>
</table>

APPENDIX 21.6 Functions suggested by patterns with pes cavus

Function and description	Previously suggested by
Normal heel strike, inverted forefoot *From normal heel strike, the foot inverts with the force pathway passing laterally*	Root, Orien and Weed (p263) Neale (p37)
Theoretical movements in the sagittal plane	**Force pathway**
Not applicable	

Respondent patterns in support					
PC 49/1 	PC 21/1 	PC 31/3 	PC 15/2 	PC 8/1 	PC 24/3 
PC 20/1 					

APPENDIX 21.7 Functions suggested by patterns with pes cavus

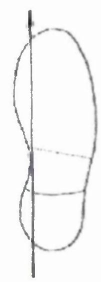
Function and description	Previously suggested by
Normal or inverted heel, everted forefoot *Normal or slightly inverted heel strike occurs. As functionally everted forefoot is met, the force pathway passes medially*	Neale (p37, p51)
Theoretical movements in the sagittal plane	**Force pathway**
Not applicable	

Respondent patterns in support					
PC 12/2 	PC 39/1 	PC 1/2 	PC 32/1 	PC 3/1 	PC 54/1 
PC 28/3 	PC 48/2 	PC 48/1 	PC 2/1 	PC 48/4 	PC 28/1 

APPENDIX 21.7 – contd.

Respondent patterns in support					
PC 34/1 	PC 9/1 				

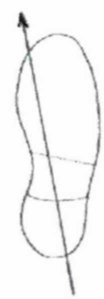
APPENDIX 21.8 Functions suggested by patterns with pes cavus

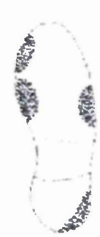
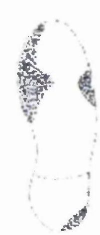
<table>
<tr><th colspan="5">Function and description</th><th>Previously suggested by</th></tr>
<tr><td colspan="5"><u>Everted heel and forefoot</u> *Eversion of the heel results in medially inclined heel strike maintained into the forefoot with medial force pathway throughout.*</td><td>Neale (p37).</td></tr>
<tr><th colspan="5">Theoretical movements in the sagittal plane</th><th>Force pathway</th></tr>
<tr><td colspan="5">Not applicable</td><td></td></tr>
<tr><th colspan="6">Respondent patterns in support</th></tr>
<tr><td>PC 12/3
</td><td>PC 51/3
</td><td></td><td></td><td></td><td></td></tr>
</table>

APPENDIX 21.9 Functions suggested by patterns with pes cavus

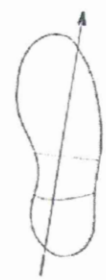
<table>
<tr><th colspan="5">Function and description</th><th>Previously suggested by</th></tr>
<tr><td colspan="5">Everted heel, inverted forefoot Medial heel strike from the everted heel results in force pathway passing laterally across the foot where it is counteracted by the inverted forefoot</td><td></td></tr>
<tr><th colspan="5">Theoretical movements in the sagittal plane</th><th>Force pathway</th></tr>
<tr><td colspan="5">Not applicable</td><td></td></tr>
<tr><th colspan="6">Respondent patterns in support</th></tr>
<tr><td>PC 35/1
</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

APPENDIX 21.10 Functions suggested by patterns with pes cavus

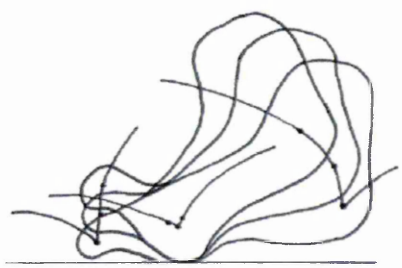
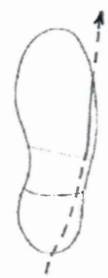
Function and description	Previously suggested by
<u>Feet abducted</u> *Abduction of the foot leads to lateral heel strike, with force pathway passing medially across prominent 1st MPJt area*	Not previously suggested in association with pes cavus
Theoretical movements in the sagittal plane	Force pathway
Not applicable	

Respondent patterns in support					
PC 12/2 	PC 39/1 	PC 32/1 	PC 28/1 	PC 48/4 	

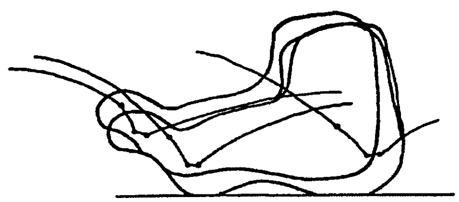
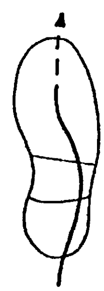
APPENDIX 21.11 Functions suggested by patterns with pes cavus

<table>
<tr><th colspan="4">Function and description</th><th colspan="2">Previously suggested by</th></tr>
<tr><td colspan="4"><u>Feet Adducted</u> Medial heel strike due to adducted position of footb with force pathway passing laterally across prominent 5th MPJt area</td><td colspan="2">Not previously suggested in association with pes cavus</td></tr>
<tr><th colspan="4">Theoretical movements in the sagittal plane</th><th colspan="2">Force pathway</th></tr>
<tr><td colspan="4">Not applicable</td><td colspan="2"></td></tr>
<tr><th colspan="6">Respondent patterns in support</th></tr>
<tr><td>PC 35/1
</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

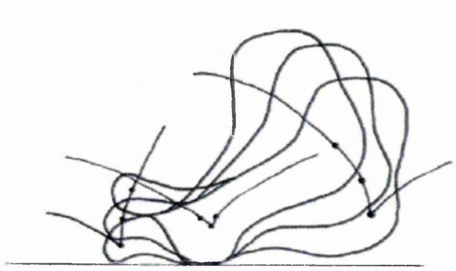
APPENDIX 21.12 Functions suggested by patterns with pes cavus

<table>
<tr><th colspan="6">Function and description</th><th colspan="6">Previously suggested by</th></tr>
<tr><td colspan="6"><u>No heel strike due to dropped forefoot and inverted forefoot</u>
Prominent inverted forefoot with limited dorsiflexion restricts heel strike and inversion of forefoot gives laterally inclined force pathway</td><td colspan="6">Not previously suggested in association with pes cavus</td></tr>
<tr><th colspan="6">Theoretical movements in the sagittal plane</th><th colspan="6">Force pathway</th></tr>
<tr><td colspan="6"></td><td colspan="6"></td></tr>
<tr><th colspan="12">Respondent patterns in support</th></tr>
<tr><td colspan="2">PC 32/2
</td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
</table>

APPENDIX 21.13 Functions suggested by patterns with pes cavus

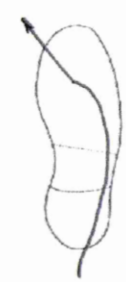
<table>
<tr><th colspan="4">Function and description</th><th colspan="2">Previously suggested by</th></tr>
<tr><td colspan="4"><u>Dorsiflexion of foot with load bearing (heavily) on heel</u> Foot dorsiflexed at heel strike with force pathway avoiding prominent MPJt area and foot lifted vertically avoiding toe off</td><td colspan="2">Neale (p36)</td></tr>
<tr><th colspan="4">Theoretical movements in the sagittal plane</th><th colspan="2">Force pathway</th></tr>
<tr><td colspan="4"></td><td colspan="2"></td></tr>
<tr><th colspan="6">Respondent patterns in support</th></tr>
<tr><td>PC 39/2
</td><td>PC 40/1
</td><td></td><td></td><td></td><td></td></tr>
</table>

APPENDIX 21.14 Functions suggested by patterns with pes cavus

Function and description	Previously suggested by
No heel strike due to dropped forefoot and everted forefoot *Prominent inverted forefoot with limited dorsiflexion restricts heel strike and eversion of forefoot gives medially inclined force pathway*	Not previously suggested in association with pes cavus
Theoretical movements in the sagittal plane	**Force pathway**
	

Respondent patterns in support					
PC 47/3 	PC 47/4 	PC 51/1 			

APPENDIX 21.15 Functions suggested by patterns with pes cavus

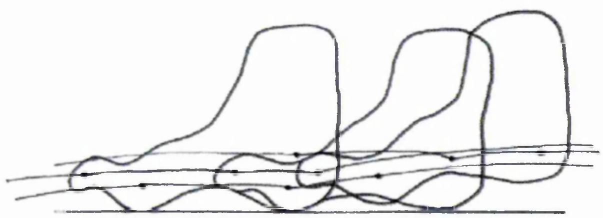
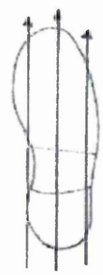
Function and description	Previously suggested by
Abductory twist *Normal force pathway until prominent met. area is reached, then abductory twist directs pathway medially.*	Not previously suggested in association with pes cavus
Theoretical movements in the sagittal plane	Force pathway
Not applicable	

Respondent patterns in support					
PC 47/3 	PC 47/4 	PC 22/2 			

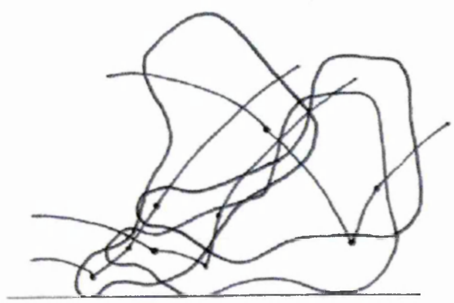
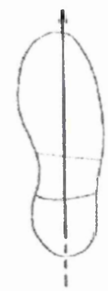
APPENDIX 21.16 Functions suggested by patterns with pes cavus

<table>
<tr><th colspan="5">Function and description</th><th>Previously suggested by</th></tr>
<tr><td colspan="5">Adductory twist Normal force pathway until prominent met. area is reached, then adductory twist directs pathway laterally.</td><td>Not previously suggested in association with Hallux Rigidus</td></tr>
<tr><th colspan="5">Theoretical movements in the sagittal plane</th><th>Force pathway</th></tr>
<tr><td colspan="5">Not applicable</td><td></td></tr>
<tr><th colspan="6">Respondent patterns in support</th></tr>
<tr><td>PC 53/2
</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

APPENDIX 21.17 Functions suggested by patterns with pes cavus

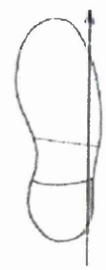
<table>
<tr><th colspan="4">Function and description</th><th colspan="2">Previously suggested by</th></tr>
<tr><td colspan="4"><u>Shuffling Gait</u> Foot strikes ground in predominately horizontally directed movement, abrading the outsole with this strike.</td><td colspan="2">Not previously suggested in association with pes cavus</td></tr>
<tr><th colspan="4">Theoretical movements in the sagittal plane</th><th colspan="2">Force pathway</th></tr>
<tr><td colspan="4"></td><td colspan="2"></td></tr>
<tr><th colspan="6">Respondent patterns in support</th></tr>
<tr><td>PC 31/2
</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

APPENDIX 21.18 Functions suggested by patterns with pes cavus

Function and description	Previously suggested by
Foot placed down and lifted vertically with dragging of toes at toe-off due to retraction *Foot placed and lifted vertically with careful ground contact, but dragging of tip at vertical lift*	Neale (p37)
Theoretical movements in the sagittal plane	Force pathway
	

Respondent patterns in support					
PC 47/2 					

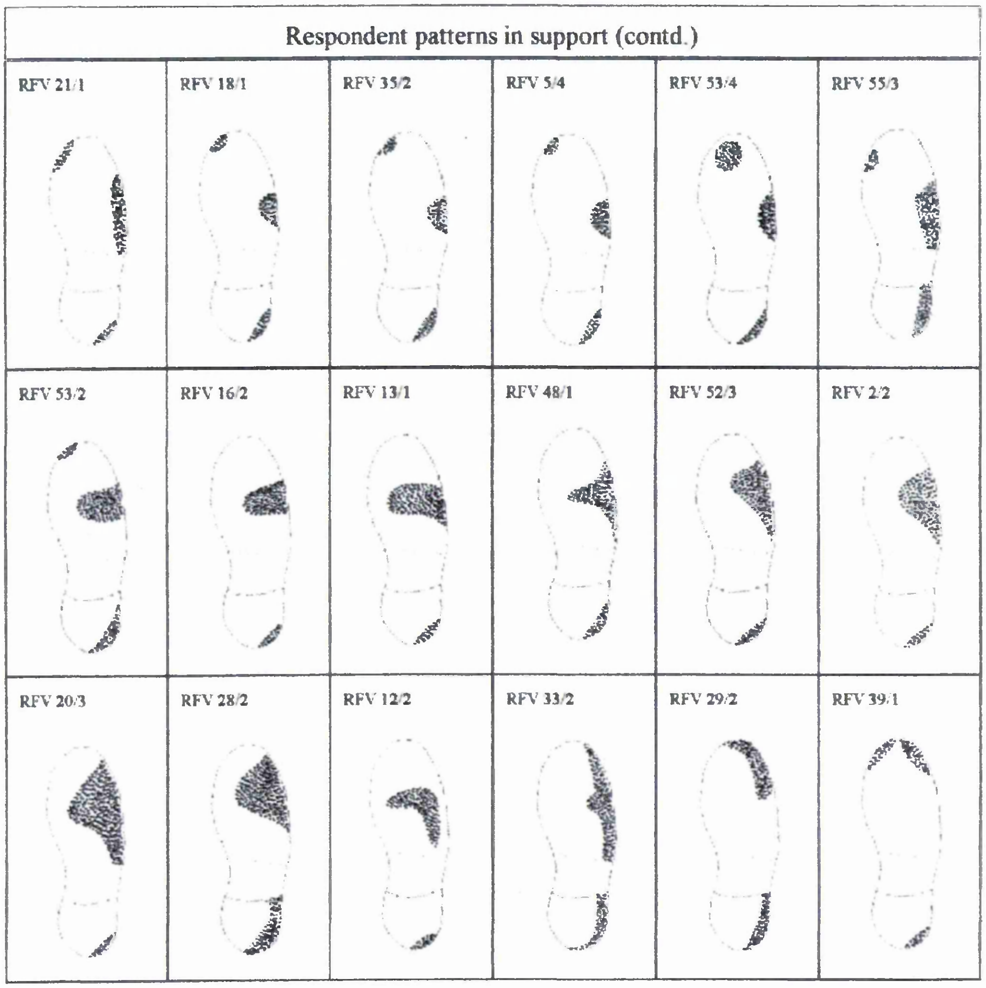
APPENDIX 22.1 Functions suggested by patterns with rearfoot varus

Function and description	Previously suggested by
Foot inverted on heel strike, remaining inverted throughout stance *Foot lands in inversion due to rearfoot varus, remaining inverted in the forefoot with the force pathway remaining lateral.*	Root, Orien and Weed (p436-437) Neale (p47)
Theoretical movements in the sagittal plane	**Force pathway**
Not applicable	

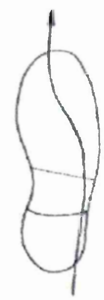
Respondent patterns in support

RFV 24/2	RFV 23/2	RFV 8/1	RFV 26/2	RFV 22/1	RFV 52/4
					
RFV 42/1	RFV 37/2	RFV 52/1	RFV 54/2	RFV 1/3	RFV 15/1
					

APPENDIX 22.1 – contd.



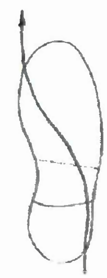
APPENDIX 22.2 Functions suggested by patterns with rearfoot varus

Function and description	Previously suggested by
Foot inverted on heel strike, reverting to normal inclination at forefoot *Foot in inversion at heel strike due to rearfoot varus, correcting to normal inclination at forefoot, with the force pathway changing from initial lateral position, to more normal central position*	Root, Orien and Weed (p327) Neale p47
Theoretical movements in the sagittal plane	**Force pathway**
Not applicable	

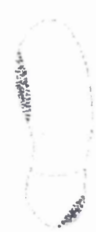
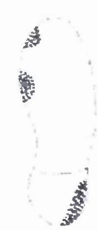
Respondent patterns in support

RFV 53/3 	RFV 26/3 	RFV 24/2 	RFV 2/3 	RFV 34/3 	RFV 1/1 
RFV 44/1 	RFV 42/2 	RFV 24/1 			

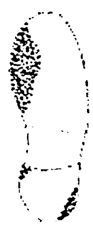
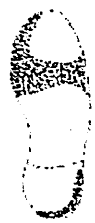
APPENDIX 22.3 Functions suggested by patterns with rearfoot varus

Function and description	Previously suggested by
Foot inverted on heel strike, followed by pronation *Foot either attempts to compensate for pronation through inversion at heel strike, later succumbing to pronation, or has a rearfoot varus resulting in lateral heel strike, which is over-corrected through excessive pronation. In both cases, initial laterally-inclined force pathway moves medially in the forefoot*	Root, Orien and Weed (p298) Neale (p37)
Theoretical movements in the sagittal plane	**Force pathway**
Not applicable	

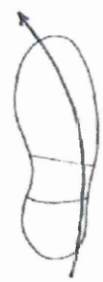
Respondent patterns in support

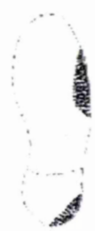
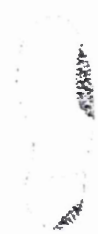
RFV 12/1 	RFV 38/1 	RFV 4/1 	RFV 18/2 	RFV 30/1 	RFV 14/1 
RFV 34/4 	RFV 11/2 	RFV 1/2 	RFV 5/2 	RFV 3/1 	RFV 54/1 

APPENDIX 22.3 – contd.

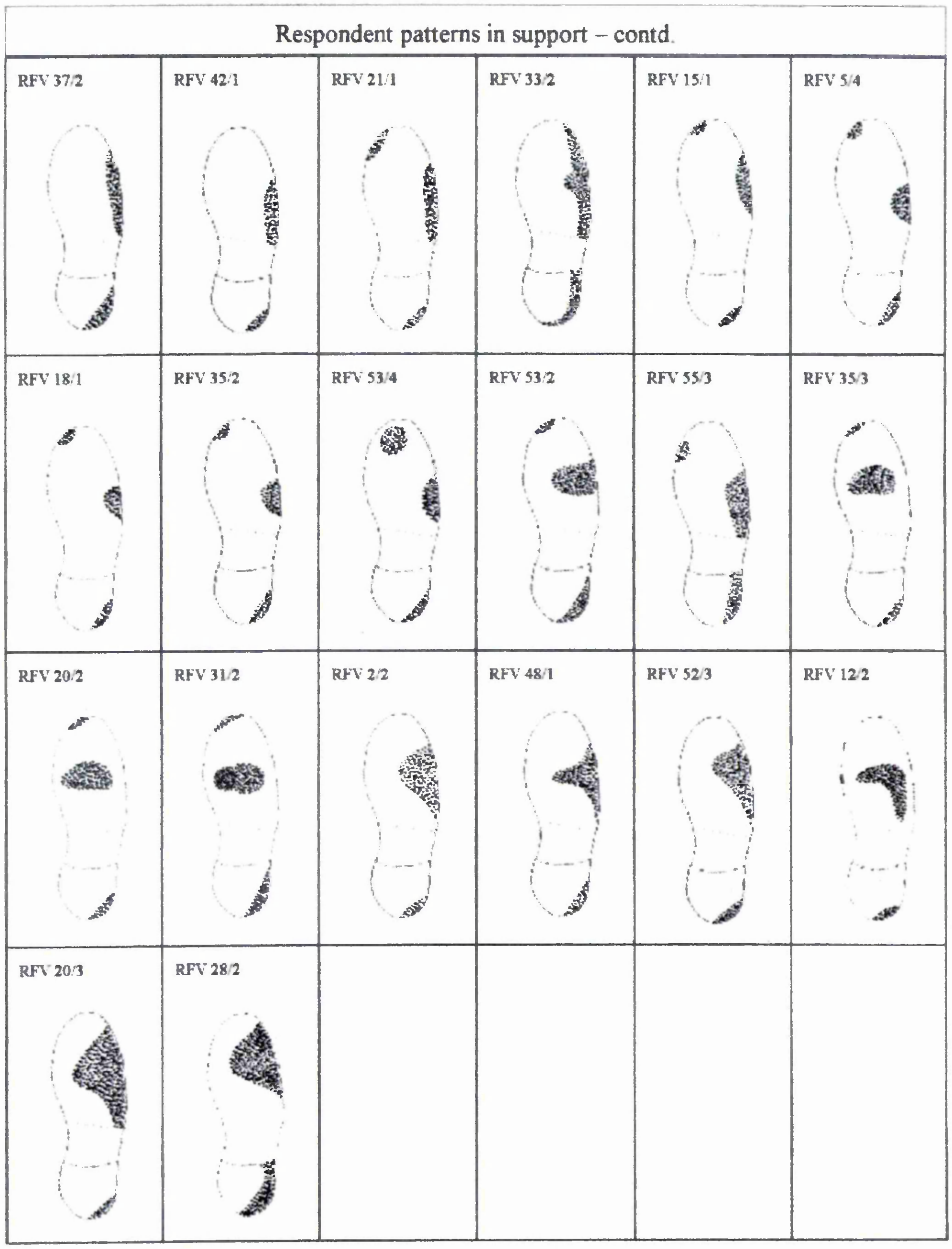
Respondent patterns in support					
RFV 51/2 	RFV 52/2 	RFV 50/1 			

APPENDIX 22.4 Functions suggested by patterns with rearfoot varus

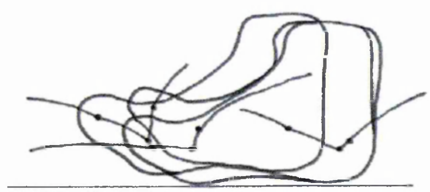
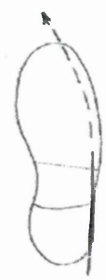
Function and description	Previously suggested by
Foot inverted throughout with abduction *Foot lands in inversion with marked abduction due to rearfoot varus, remaining inverted in the forefoot with the force pathway moving from an initial posterior lateral position, directly across the foot to a medial anterior toe-off position.*	Neale (p37)
Theoretical movements in the sagittal plane	**Force pathway**
Not applicable	

Respondent patterns in support					
RFV 35/1 	RFV 36/1 	RFV 40/1 	RFV 8/1 	RFV 23/2 	RFV 26/2 
RFV 34/2 	RFV 22/1 	RFV 52/4 	RFV 1/3 	RFV 54/2 	RFV 52/1 

APPENDIX 22.4 – contd.

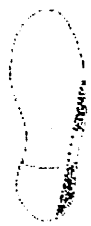


APPENDIX 22.5 Functions suggested by patterns with rearfoot varus

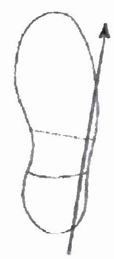
Function and description	Previously suggested by
Foot inverted throughout stance with abduction and walking on heels *Foot lands in inversion with marked abduction due to rearfoot varus, remaining inverted with weight bearing concentrated on the heels and no toe-off. The force pathway moves from an initial posterior lateral position in a medial anterior direction, but lifts prior to toe-off.*	Not previously suggested in association with rearfoot varus
Theoretical movements in the sagittal plane	Force pathway
	

Respondent patterns in support					
RFV 43/1 	RFV 32/1 	RFV 37/1 	RFV 46/1 	RFV 41/1 	RFV 45/1 
RFV 5/1 	RFV 26/1 	RFV 17/1 	RFV 8/2 	RFV 19/1 	RFV 25/1 

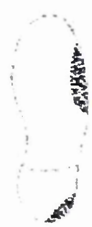
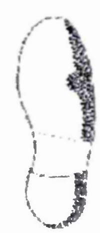
APPENDIX 22.5 – contd.

Respondent patterns in support – contd.					
RFV 40/2 					

APPENDIX 22.6 Functions suggested by patterns with rearfoot varus

Function and description	Previously suggested by
<u>Foot inverted throughout with adduction (intoing)</u> *Foot lands in inversion and adduction with weight bearing and the force pathway remaining on the extreme lateral aspect of the foot throughout stance*	Root, Orien and Weed (p158) Neale (p47)
Theoretical movements in the sagittal plane	**Force pathway**
Not applicable	

Respondent patterns in support

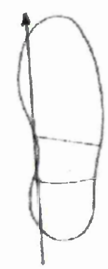
RFV 8/1	RFV 23/2	RFV 26/2	RFV 34/2	RFV 22/1	RFV 52/4
					
RFV 1/3	RFV 54/2	RFV 52/1	RFV 37/2	RFV 42/1	RFV 33/2
					

APPENDIX 22.6 – contd.

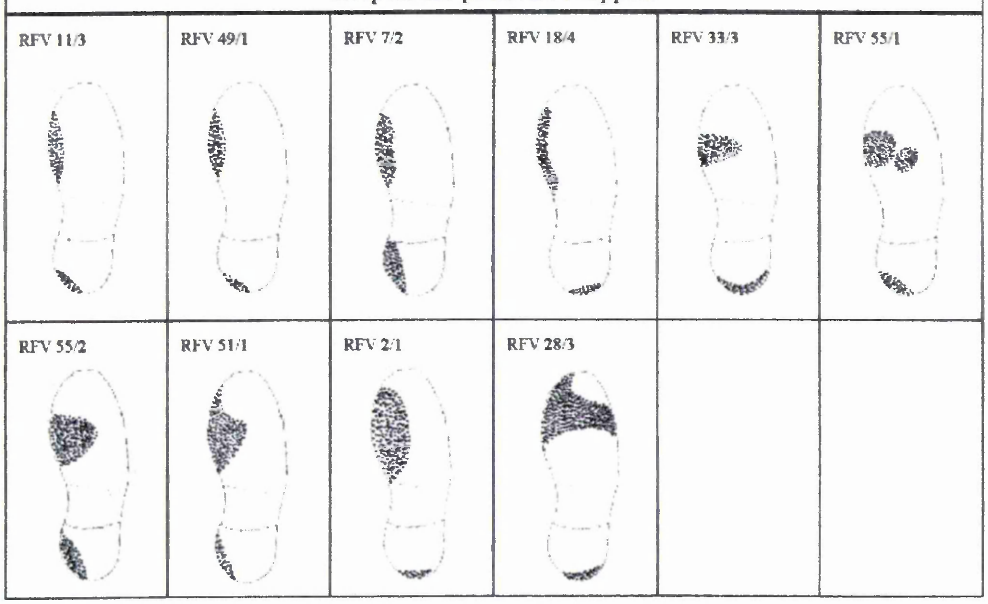
Respondent patterns in support – contd.					
RFV 29/2 					

APPENDIX 22.7 Functions suggested by patterns with rearfoot varus

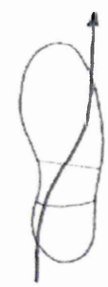
Function and description	Previously suggested by
<u>Foot pronated prior to heel strike and throughout stance</u> *Foot moves into pronated position prior to heel strike to compensate for rearfoot varus and remains pronated throughout stance with medial force pathway throughout*	Not previously suggested in association with rearfoot varus

Theoretical movements in the sagittal plane	Force pathway
Not applicable	

Respondent patterns in support

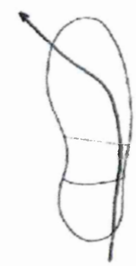


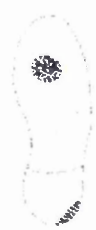
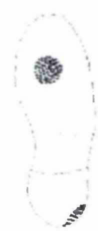
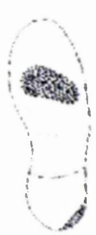
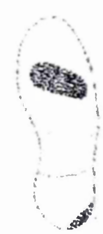
APPENDIX 22.8 Functions suggested by patterns with rearfoot varus

Function and description	Previously suggested by
<u>Foot lands in pronation then transfers to inversion to compensate</u> *Medial strike due to pronated position, with force pathway transferring laterally as foot inverts to compensate*	Root, Orien and Weed (p120)
Theoretical movements in the sagittal plane	**Force pathway**
Not applicable	

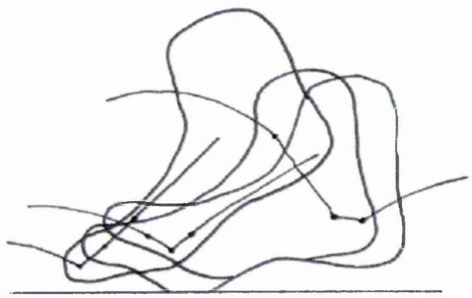
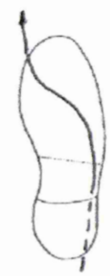
Respondent patterns in support					
RFV 51/3 	RFV 31/3 	RFV 29/1 			

APPENDIX 22.9 Functions suggested by patterns with rearfoot varus

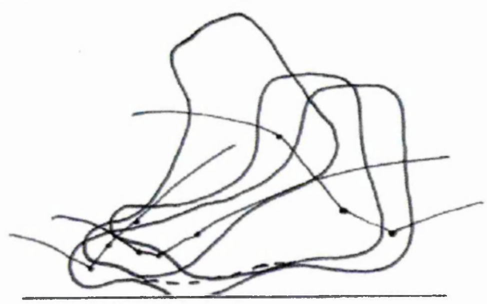
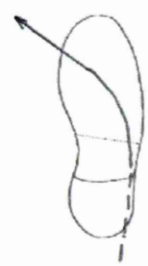
Function and description	Previously suggested by
Foot lands in inversion, then pronates with abductory twist to compensate *Foot lands in inversion, with lateral force pathway. Foot then pronates to compensate for inversion with abductory twist resulting in force pathway transferring medially, markedly so when abductory twist occurs*	Not previously suggested in association with rearfoot varus
Theoretical movements in the sagittal plane	**Force pathway**
Not applicable	

Respondent patterns in support					
RFV 23/1 	RFV 18/3 	RFV 9/1 	RFV 18/3 	RFV 23/3 	RFV 54/3 
RFV 53/1 	RFV 20/1 	RFV 13/2 	RFV 5/3 	RFV 31/1 	

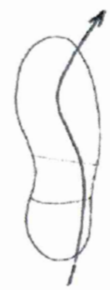
APPENDIX 22.10 Functions suggested by patterns with rearfoot varus

<table>
<tr><th colspan="3">Function and description</th><th colspan="3">Previously suggested by</th></tr>
<tr><td colspan="3"><u>Inversion with heel equinus leading to no heel strike and pronation</u> Restricted dorsiflexion occurs with the inversion, markedly limiting heel strike. Ground contact occurs mid-foot and accompanying pronation to compensate for heel inversion transfers the force pathway medially</td><td colspan="3">Root, Orien and Weed (p174)
Neale (p47)</td></tr>
<tr><th colspan="3">Theoretical movements in the sagittal plane</th><th colspan="3">Force pathway</th></tr>
<tr><td colspan="3"></td><td colspan="3"></td></tr>
<tr><th colspan="6">Respondent patterns in support</th></tr>
<tr><td>RFV 6/1
</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

APPENDIX 22.11 Functions suggested by patterns with rearfoot varus

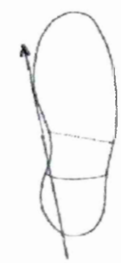
<table>
<tr><th colspan="4">Function and description</th><th colspan="2">Previously suggested by</th></tr>
<tr><td colspan="4"><u>Inversion with heel equinus leading to no heel strike and compensation via abductory twist</u> Restricted dorsiflexion occurs with the inversion, markedly limiting heel strike. Ground contact occurs mid-foot and accompanying pronation with abductory twist to compensate for heel inversion transfers the force pathway medially, markedly when abductory twist occurs</td><td colspan="2">Not previously suggested in association with rearfoot varus</td></tr>
<tr><th colspan="4">Theoretical movements in the sagittal plane</th><th colspan="2">Force pathway</th></tr>
<tr><td colspan="4"></td><td colspan="2"></td></tr>
<tr><th colspan="6">Respondent patterns in support</th></tr>
<tr><td>RFV 22/2
</td><td>RFV 32/2
</td><td></td><td></td><td></td><td></td></tr>
</table>

APPENDIX 22.12 Functions suggested by patterns with rearfoot varus

Function and description	Previously suggested by
Forefoot supination (or adductory twist) *Inversion occurs when mid-stance phase is encountered with force pathway transferring from normal to lateral position. Alternately, adductory twist takes place at mid stance, with same force pathway effect*	Not previously suggested in association with rearfoot varus
Theoretical movements in the sagittal plane	Force pathway
Not applicable	

Respondent patterns in support					
RFV 39/1 	RFV 11/1 	RFV 6/2 			

APPENDIX 22.13 Functions suggested by patterns with rearfoot varus

Function and description	Previously suggested by
Compensatory eversion with abduction *Foot everts to compensate for rearfoot varus resulting in medial strike. Accompanying abduction of the foot results in an extreme medial force pathway avoiding full forefoot weight bearing*	Root, Orien and Weed (p297) Neale (p47)
Theoretical movements in the sagittal plane	**Force pathway**
Not applicable	

Respondent patterns in support					
RFV 7/1 	RFV 10/1 	RFV 33/1 	RFV 32/3 		

APPENDIX 23 Summary of "named variable" analysis

Named variable	No. times named with main conditions					Wear associations	Strength of wear assoc.	Notes
	Total	Pron.	HR	PC	RFV			
Equinus	11	3	1	7	0	Wear across MPJt area	Strong	
						No heel wear	Strong	
Rearfoot valgus	3	3	0	0	0	Ant. med. segment wear	Strong	
						Med. heel wear	Strong	
Forefoot inv./ varus	7	2	3	2	0	Med. heel wear	Strong	With Pron. only
						Ant. med. segment wear	Strong	With Pron. only
						5th MPJt wear	Strong	With HR and PC only
						Ant. med. segment wear	Strong	With HR only
Pl.fl. 1st ray	14	4	1	3	6	1st MPJt wear	Strong	
						Post./lat. heel wear	Moderate	
						5th MPJt wear	Strong	With RFV and RFV+HR only
Abd. Twist	15	8	4	2	1	Localised central met. wear	V. strong	
						Localised 1st MPJt wear	1 only	
						Post./lat. heel wear	Moderate	With Pron. only
						Ant./med. segment wear	Strong	
Abducted gait	6	1	2	1	2	Post./lat. heel wear	Strong	
						Central met. wear	Strong	
						Ant./med. segment wear	Strong	
Adducted gait	3	1	2	0	0	Ant./med. segment wear	Strong	
						Central/lat. central wear	Moderate	With HR only
O'loaded 2nd MPJt	2		1	0	1	2nd/3rd MPJt wear	Strong	
HAV	2	1	1	0	0	Med. forefoot wear	Strong	
Arthritis	2	1	1	0	0	Post./lat. heel wear	Strong	
						Tip of 1st wear	Strong	
						Absent met. area wear	Strong	
Calc. Varus/inversion	4	2	0	2	0	Lat. heel wear	Strong	
						5th MPJt wear	Strong	
						Ant. med. segment wear	Strong	
						Central MPJt. wear	Moderate	
Comp. Pes cavus	3	0	0	3	0	Central MJt wear	Strong	With PC only
Comp. pronation	3	3	0	0	0	Ant. med. segment wear	Moderate	With Pron. only

APPENDIX 23 Summary of "named variable" analysis

Named variable	No. times named with main conditions					Wear associations	Strength of wear assoc.	Notes
Comp. rearfoot varus	21	3	0	0	18	Post/lat. heel wear	Moderate	
						1^{st} toe area wear	Moderate	
D'flexed 1^{st}+5^{th} mets	2	1	0	1	0	Post/lat. heel wear	Strong	
						Central MPJt. wear	Strong	
Fixed/severe pronation	21	19	1	0	1	Med. heel wear	Strong	
						Ant. med. segment wear	Strong	
H. Limitus	2	2	0	0	0	1^{st} toe area wear	Strong	With Pron. only
H'mob. 1^{st} ray	3	3	0	0	0	Central MPJt. wear	Strong	With Pron. only
H'mob. Pronation	3	3	0	0	0	Post/lat. heel wear	Strong	With Pron. only
						Ant. med. segment wear	Strong	
IPJt extn.	2	0	2	0	0	1^{st} toe area wear	Strong	With HR only
Mobile Pes cavus	3	0	0	3	0	Central MPJt. wear	Strong	With PC only
Painful hallux	3	0	3	0	0	Post/lat. heel wear	Strong	With HR only
						5th MPJt. wear	Strong	
						Central MPJt. wear	Strong	
						1^{st} toe area wear	Strong	
Part. comp. pronation	3	3	0	0	0	Post/lat. heel wear	Strong	With Pron. only
						5th MPJt. wear	Strong	
						1st MPJt. wear	Strong	
Part. comp. rearfoot varus	15	0	0	0	15	Post/lat. heel wear	Strong	With RFV only
						5th MPJt. wear	Strong	
						1^{st} toe area wear	Strong	
Rigid pes cavus	6	0	0	6	0	1st MPJt. wear	V.Strong	With PC only
						5th MPJt. wear	V.Strong	
						Central heel wear	Moderate	
Rigid pl. fl. 1^{st}+5^{th} MPJts	3	0	0	3	0	1st MPJt. wear	V.Strong	With PC only
						5th MPJt. wear	V.Strong	
						Central heel wear	Moderate	

APPENDIX 24 Questionnaire to determine criteria to be used as definitions for the inter-observer reliability trial

Explanatory notes

The questionnaire consists of 4 sections :

- Section 1 definitions/criteria for the visual recognition of pathologies
- Section 2 definitions/criteria for the visual recognition of gait types
- Section 3 definitions/criteria for the visual recognition of described ranges of movement
- Section 4 definitions/criteria for the visual recognition of footwear variables

In each section are given lists of conditions or states which may act as variable factors in the production of shoe wear patterns.

Each named condition or state requires a short definition which would allow you to state how you recognised it, or what factors would need to be present in order to trigger a conclusion that the state or condition was present without the availability of specialised measuring instruments.

The definition given should be a working definition, easily understood by other podiatrists and which, if accepted would allow two podiatrists using that definition to agree as to whether an observed patient was exhibiting that condition or not.

The definition should be based on the considerations that you would have given before writing a diagnosis or observed state on a clinical record card.

If you believe that some of the condition or states included in the questionnaire would be unlikely to influence shoe wear patterns, please mark these with a cross.

If you cannot answer any of the questions, please leave those sections blank, though an attempt to answer all of the questions is preferable.

When completing the questionnaire, you may be in the same room as other participants. It is important that your response is kept anonymous from the other participants and that you don't openly discuss your responses with the others at any stage of the procedure.

There is no time limit allocated to completion of the questionnaire.

You may be asked to participate in subsequent rounds of the questionnaire. In this case, all the responses received in the first round will be summarised and presented to you along with the proportions of participants who had given each response. You would then consider these responses and indicate which you would agree with. In any subsequent rounds, you may change your response from that given previously in light of viewing the responses as a whole. You may also agree with more than one response if you wish.

Questionnaire section 1

Thank you for agreeing to participate in this phase of my research project. You are asked to consider the three sections presented in this questionnaire and provide a simple definition or simple criteria for the **visual recognition** of each given condition or state. If there are any conditions which you feel would be irrelevant to a project investigating shoe wear patterns, please mark these with a cross (X). Two examples for hallux rigidus and hallux valgus are already given in section one. When you have completed all three sections, please hand the questionnaire in. Thank you.

Section 1 Definitions/criteria for the visual recognition of pathologies

Name of condition	My definition of this condition is :
ABDUCTION	
ABDUCTION AND EVERSION	
ADDUCTION	
ADDUCTION AND EVERSION	
ANKLE EQUINUS	
BOW LEGS	
CALCANEAL APOPHYSITIS	
CALCANEAL BURSITIS	
CALCANEAL EVERSION	
CALCANEAL SPUR	
CALCANEO-CAVUS	
CALCANEO-VALGUS	
CALCANEO-VARUS	
CALCANEO-VARUS (COMPENSATED)	
CHARCOT JOINTS	

APPENDIX 24 - contd.

Name of condition	My definition of this condition is :
CHOREA	
CLAW TOES	
DIGITI QUINTI VARUS	
DROP FOOT	
EQUINO-CAVUS	
EQUINO-VARUS	
EVERTED FOOT	
EXCESSIVE ANKLE DORSIFLEXION	
FOOT STRAIN	
FOREFOOT VALGUS	
FOREFOOT VARUS	
FREIBERG'S INFRACTION	
GENU VALGUM	
GENU VARUM	
HALLUX FLEXUS	
HALLUX RIGIDUS	Fused 1st MJt and $< 15^0$ lat. deviation
HALLUX VALGUS	$> 15^0$ lat. deviation
HAMMERED 2ND TOE	
HEMIPLEGIC GAIT	
HINDFOOT VALGUS	
HINDFOOT VARUS	
HYPERMOBILE 1ST AND 5TH MPJtS	
HYPERMOBILE FOOT	
INFLARED FOOT	

APPENDIX 24 - contd.

Name of condition	My definition of this condition is :
INVERTED FOOT	
KOHLERS DISEASE	
LOWER MOTOR NEURONE WEAKNESS	
METATARSUS ADDUCTUS	
METATARSUS PRIMUS ELEVATUS	
METATARSUS PRIMUS VARUS	
OUT-TOED GAIT	
OVERLOADED 2ND MET.	
PAINFUL NAIL DISORDERS OF THE 1ST TOE	
PARAPARESIS	
PES CAVUS	
PES PLANO-VALGUS	
PLANTAR DIGITAL NEURITIS (MORTON'S TOE)	
PLANTAR FASCIITIS	
PLANTAR FLEXED 1ST AND 5TH TOES	
PLANTAR FLEXED TOES	
POST-OPERATIVE STATES	
PRONATED FOOT	

APPENDIX 24 - contd.

Name of condition	My definition of this condition is :
PYRAMIDAL NEUROLOGICAL DISORDERS	
REDUCTION OF LONGITUDINAL AND TRANSVERSE ARCHES	
RETRACTED TOES	
RETRO-CALCANEAL BURSITIS	
SEVERS DISEASE	
SHORT 1ST METATARSAL	
SHORT 5TH METATARSAL	
SPLAYING OF THE METATARSALS	
TAYLORS BUNION	
TALIPES CALCANEO VALGUS	
TALIPES CALCANEO VARUS	
TALIPES EQUINO VALGUS	
TALIPES EQUINO VARUS	
TARSAL ARTHRITIS	
VERTICAL TALUS	

If you feel that any other conditions should have been given in the list above, please name these below and provide a short definition of each one.

Name of condition	My definition of this condition is :

Questionnaire section 2

Section 2 Criteria for the visual recognition of gait types	
Gait type	**My criteria for the recognition of this gait is :**
ABDUCTED GAIT	
GAIT WITH ABDUCTORY TWIST	
GAIT WITH ADDUCTORY TWIST	
ADDUCTED GAIT	
ATAXIC GAIT	
BOW LEGGED GAIT	
CALCANEAL GAIT	
GAIT WITH CLASSIC HALLUX RIGIDUS FOOT FUNCTIONING	
DROP FOOT GAIT	
HEMIPLEGIC GAIT	
HIGH STEPPING GAIT	
NORMAL GAIT	
INTOED GAIT	
OUT-TOED GAIT	
PARAPLEGIC GAIT	
PRONATING GAIT	
SHUFFLING GAIT IN PARKINSONISM	
SUPINATING GAIT	
WADDLING GAIT	
If you feel that any other gait types should have been given in the list above, please name these below and provide a short definition of each one.	
Gait type	**My criteria for recognising this gait type is :**

Questionnaire Section 3

Section 3 Criteria/definitions for the visual recognition of described ranges of movement	
Described range of movement	**My definition of this described range of movement is :**
Restricted ankle movement	
Normal ankle movement	
Excessive ankle movement	
Excessive forefoot inversion	
Normal forefoot movement	
Excessive forefoot eversion	
Excessive rearfoot inversion	
Normal rearfoot movement	
Excessive rearfoot eversion	
Restricted toe movement	
Normal toe movement	
Excessive toe movement	
Restricted overall foot mobility	
Normal overall foot mobility	
Hypermobile foot	
If you feel that any other described ranges of movement should have been given in the list above, please name these below and provide a short definition of each one.	
Described range of movement	**My definition of this described range of movement is :**

Questionnaire section 4

Section 4 Criteria/definitions for the visual recognition of footwear variables	
Described footwear variable	**My definition of this described variable is :**
Low heel height	
Medium heel height	
High heel height	
Thin sole	
Medium sole	
Thick sole	
New shoe condition	
Used shoe condition	
Poor shoe condition	
Shallow toe box	
Normal depth toe box	
Deep toe box	
Sole unworn	
Light wear on sole	
Average wear on sole	
Heavy wear on sole	
Shoe length short	
Shoe length acceptable	
Shoe length excessive	
Shoe width tight	
Shoe width acceptable	
Shoe width excessive	
Overall shoe depth shallow	

APPENDIX 24 - contd.

Described footwear variable	**My definition of this described variable is :**
Overall shoe depth acceptable	
Overall shoe depth excessive	
Heel fit of shoe tight	
Heel fit of shoe acceptable	
Heel fit of shoe loose	
Toe box too tight	
Toe box of shoe acceptable	
Toe box of shoe too broad	

If you feel that any other footwear variables should have been given in the list above, please name these below and provide a short definition of each one.

Described footwear variable	**My definition of this described variable is :**

Thank you for completing this questionnaire. Please hand this in when completed.

Wesley Vernon
SWaMP Project Research Student
Sheffield Hallam University

APPENDIX 25 Comparison of agreements achieved in round 6 with previous opinion

Section 1 Definitions/criteria produced for the visual recognition of pathologies		
Condition	**Round 1 definitions given**	**Compatible with previous opinion (✓/✖)**
Abduction	A motion away outward from the mid-line of the body in the transverse plane.	✓ (1)
Abduction and eversion	A motion away outward from the mid-line of the body in the transverse plane, eversion is a motion outward from the mid-line in the frontal plane	✓ (1)(3)
Adduction	Foot diverted towards the midline of the body in the transverse plane	✓(1)
	A motion inward from the mid-line of the body in the transverse plane	✓(1)
Adduction and eversion	A motion inward from the mid-line of the body in the transverse plane. Add is an inward motion in the trans. Eversion outward motion in the frontal plane	✓(1)(3)
Ankle equinus	Restriction of ankle joint dorsiflexion less than 10^0 dorsiflexion=Ankle Equinus	✓(2)(3)
Bow legs	Outward curvature of the legs whereby the gap between the knees is greatest	✓(1)
Calcaneal apophysitis	Where the insertion of ligament/tendon is partly pulled away from the bone-usually gives point tenderness - Stone Bruise-will show as a hot spot on CT scan.	✓(2)
Calcaneal bursitis	Inflamed bursa, painful on direct pressure directly under calc	✓(2)
Calcaneal eversion	Where the calc everts i.e. moves away from the midline in frontal plane	✓(2)
Calcaneal spur	Bony exostosis on calc-step usually horizontal-shows on X ray	✓(2)
	Bony prominence on the calc resembling a coat hook at the insertion of the tendon	✓(2)
Calcaneo-valgus	Everted calc – weightbearing	✓(2)(3)
Calcaneo-varus	Inverted calc - weightbearing	✓(2)(3)
Calcaneo-varus (Comp.)	Talus inverted to attain ground contact in above	✖ (2)(3) (A)
Charcot joints	Destruction of joints with neurological damage leading to collapse of the structure and flat foot	✓(1)(2)(3)
Chorea	St Vitus dance - shaking partly uncontrolled movements	✓(1)(2)
Claw toes	Where proximal IPJs are df and toes plantarflex getting below level of mets	✓(2)(3)

APPENDIX 25 -contd.

Condition	Round 1 definitions given	Compatible with previous opinion (✓/✖)
Digiti quinti varus	Fifth digit inverted	✓(2)(3)
	Inverted 5^{th} toe	✓(2)(3)
	Rolling in of the 5^{th} toes towards the centre line of the foot	✓(2)(3)
Drop foot	Flaccid muscles/poor muscle tone preventing control of dorsi/plantar flexion	✖ (3)[(B)]
Equino-cavus	Plantar flexed foot position-with high arch	✓(2)
Equino-varus	Plantar flexed foot position-with inverted foot/heel position	---------------
Everted foot	Markedly pronated foot	---------------
Excessive ankle d'flexion	Flat foot with compression of the medial longitudinal arch and rolling out of the foot	---------------
	More than 50^0 ankle movement (towards tibia)	---------------
Footstrain	Being able to move the ankle in a dorsal direction to a point more than a third of the way between the ground and the leg	---------------
	Generalised term for foot ache soft tissue in nature	✖ (2)[(C)]
Forefoot valgus	5th MPJt elevated from ground-MPJts not at same level	✓(2)(3)
Forefoot varus	1st MPJt elevated	✓(2)(3)
Freiberg's infraction	Stress fracture of the metatarsal (second)	✖ (2)[(D)]
Genu valgum	Knees together, ankles more than 2cm apart	✓(1)
Genu varum	Knees apart more than 2cm with ankles together	✓(1)
Hallux flexus	Hyperextended 1^{st} – elevated from ground	?(1)(2)[(E)]
Hallux rigidus	Fused 1st MPJt and $< 15^0$ Lat. Deviation	✓(1)(2)(3)
Hallux valgus	$> 15^o$ Lat. Deviation	✓(1)(2)(3)
Hammered 2^{nd} toe	= Plantarflexed metatarsal with df of the proximal phalanx of the 2^{nd} toe	✓(2)?(1)[(F)] (3)[(G)]
Hemiplegic gait	A gait. One side is affected by paralysis i.e. from stroke-gives asymmetrical gait	✓(1)?(2)[(H)]
Hindfoot valgus	Everted rear of foot	✓(2)(3)
	The rearfoot is in a position where it is rolling away from the body line	✓(2)(3)
Hindfoot varus	Inverted rear of foot	✓(2)(3)
	The rearfoot is in a position where it is rolling into the body line	✓(2)(3)
Hypermobile 1st and 5th MPJts	Excessive movement of 1st and 5th MPJts-can move independently of other MPJts	✓(3)
Hypermobile foot	Where motion is in excess to normal ranges	?(3)[(I)]
	All joints of the foot move beyond the required range of motion	?(3)[(J)]
Inverted foot	Plantar of foot facing towards the midline of the body	✓(1)

APPENDIX 25 -contd.

Condition	Round 1 definitions given	Compatible with previous opinion (✔/✖)
Kohlers disease	Navicular-pathology with ossification?	✔(1)(2)
Lower motor neurone weakness	Poor muscle control and strength with loss of tone/bulk	✔(1)(3)
Metatarsus adductus	Met facing towards the midline of body	✔(1)(2)
Metatarsus primus elevatus	Raising of the first met in a non-weightbearing position	✔(2)(3)
Metatarsus primus varus	Rolling in of the first met in a non-weightbearing position	✔(2)(3)
Out-toed gait	Walking with the toes pointing to a 10 to 2 position or greater	✔(2)(3)
	Gait where the toes are pointing away from the centre of the body	✔(2)(3)
Overloaded 2nd met.	Plantar 2nd MPJt-HD or callosity	✔(2)(3)
	Excessive weightbearing over the head of the 2nd met	✔(2)(3)
Painful nail disorders of the 1st toe	Conditions whereby the patient suffers discomfort as a result of damage or related conditions affecting the nail	✔(2)
Paraparesis	No sensation or control of movement	✖ (1)[(K)]
Pes cavus	High arched foot	✔(1)(2)
Pes plano-valgus	Flat foot	✔(1)(2)
Plantar digital neuritis (Morton's toe)	Pain between 3-4 mets. Compress ff and palpate if painful click = Morton's	✔(1)(2)
	Pain at the 3rd and 4th MPJ. On movement a clicking sound may be audible	✔(1)(2)
Plantar fasciitis	Plantar aspect painful to weightbear-may be tight and inflamed	✔(1)(2)
	Inflammation of the P.F. and itσ perifascial tissues	✔(1)(2)
	Inflammation of the plantar fascia causing discomfort on weightbearing on the plantar area	✔(1)(2)
	Inflammation of fascia in the foot	✔(1)(2)
Plantar flexed 1st and 5th toes	Where these sit below the level of the other metatarsals *(NB replies refer to mets. and not toes)*	✔(2)
Plantar flexed toes	All toes are in a position where they are in a lower plane than the norm when non-weightbearing	--------------
Post-operative states	Following surgery with evidence of inflammation/trauma	✔(1)
Pronated foot	A foot comprising eversion, abduction and plantarflexion leading to flat foot and flattened arch on weightbearing	✔(1)(2)(3)
Pyramidal neurological disorders	No fine movement control	?(2)[(L)]

APPENDIX 25 -contd.

Condition	Round 1 definitions given	Compatible with previous opinion (✓/✖)
Reduction of longitudinal and transverse arches	Flattened arches	--------------
	Flattening of the arches of the foot on weightbearing	--------------
Retracted toes	Extensor tendons pulling toes into clawed position	?(1)[(M)]
	Toes curling upwards into a non-weightbearing position	✓(2)
Retro-calcaneal bursitis	Post calc inflamed bursa over Haglands bump	✓(1)(2)(3)
	Soft tissue swelling that displaces on the back of the heel at the insertion of A.T.	✓(1)(2)(3)
Short 1st metatarsal	Reduced length of the 1st met	✓(2)(3)
Short 5th metatarsal	5th appears shorter than other digits, but phalanx normal	--------------
Splaying of the metatarsals	Gradual widening of the gap between the metatarsals from the base to apex beyond the norm leading to an excessively broad forefoot	✓(2)(3)
Tailors bunion	Lateral deviation and subluxation and bony exostosis of the 5th met head	✓(2)?(3)[(N)]
Talipes calcaneo valgus	-Congenital deformity. Where calc slips back off talus	✓(1)(2)
Talipes calcaneo varus	- congenital. Where heel is inverted. Tilt inward on the frontal plane	✓(2)
Talipes equine varus	Ankle fixed in inverted position	✖ (1)[(O)](2)[(P)]
Tarsal arthritis	Pain and stiffness ankle-crepitus palpated	✓(2)
	Destruction of the joints of the midfoot leading to loss of range of motion and bony prominences	✓(2)
Vertical talus	Talus in straight position	✖ (2)[(Q)]

APPENDIX 25 -contd.

Section 2 Criteria for the visual recognition of Gait types

Gait type	Round 1 definitions given	Compatible with previous opinion (✓/✖)
Abducted gait	Walking with feet positioned pointing away from midline of body	✓(2)(3)
Gait with abductory twist	When heel lifts heel flicks inward from the back in the transverse plane	--------------
Gait with adductory twist	When the heel lifts heel flicks outward from the back in the transverse plane	--------------
Adducted gait	Walking with feet positioned pointing towards midline	✓(2)(3)
	The feet point towards one another, or in that direction, on walking	✓(2)(3)
	Gait where foot is facing towards the midline of the body	✓(2)(3)
Ataxic gait	Unsteady, jerky gait style	✓(1)(2)
Bow legged gait	Walking with the knees being the furthest pont apart and the feet loading laterally	--------------
Calcaneal gait	Walking with great emphasis on the heel. Walk on the heel	✓(2)
Gait with classic hallux rigidus foot functioning	Toe off from medial border of foot	✖ (2)(R)(3)(S)
Drop foot gait	Forefoot slaps to floor after heel contact – no control	✓(2)(3)
	Forefoot strike with rock back on to heel	✓(2)(3)
Hemiplegic gait	Half of body circumducting during swing phase	✓(2)
High stepping gait	Excessive clearing of foot from ground during swing phase	?(2)(T)(3)(U)
	Gait with very high steps	?(2)(T)(3)(U)
Normal gait	Slightly inverted on heel strike, moving to neutral on lift off and rolling off forefoot centrally	✓(2)(3)
Intoed gait	Toes pointing towards midline of body throughout cycle	✓(1)(2)(3)
	Walking with the toes pointing closer to the body line than directly ahead	✓(1)(2)(3)
	Walking with the toe pointing inwards	✓(1)(2)(3)
Out-toed gait	Toes pointing away from midline of body through cycle	✓(2)(3)
	Walking with the toes pointing away from the body line 10 to 2 or more	✓(2) ✖ (3)(V)
	Walking with the toe pointing outwards	✓(2)(3)
P'plegic gait	Poor ground clearance abducted gait with dragging of the feet	✓(2)
Pronating gait	Abduction of the foot, rolling in and flattening of the arches and inefficient propulsion	✓(1)(2)(3)
Shuffling gait in Parkinsons	Dragging of the feet with no ground clearance	✓(2)
	Gait where subject does not lift foot off the ground. Shuffles	✓(2)

APPENDIX 25 -contd.

Gait type	Round 1 definitions given	Compatible with previous opinion (✓/✖)
S'pinating gait	Inverted foot dorsiflexed throughout gait	✓(3)
Waddling gait	Side to side lateral motion	✓(1)(2)
Circumducted gait	During swing phase leg laterally moves in a circular motion to clear ground	✓(1)(2)
Uncomp. equinus	No heel strike	✓(2)
Partially comp. equinus	Heel lift early	✓(2)(3)

Section 3 Criteria/definitions for the visual recognition of described ranges of movement		
Range of movement	**Round 1 definitions given**	**Compatible with previous opinion (✓/✖)**
Restricted ankle movement	Less than 10^0 of dorsiflexion	✓(3)
Normal ankle movement	More than 10^0 of dorsiflexion	✓(3)
Excessive ankle movement	XS of df 30^0	--------------
Excessive forefoot inversion	Walking on lateral border/sole wear on lateral border	✖ (3)$^{(W)}$
Normal forefoot movement	15^0-20^0 roughly	✖ (3)$^{(X)}$
Excessive forefoot eversion	In XS of 15^0-20^0	✓(3)$^{(Y)}$
Excessive rearfoot inversion	Sole wear lat heel border excessive and call.	✓(2)(3)
Normal rearfoot movement	Wear post-lat border heel-calc	---------------
Excessive rearfoot eversion	Medial calc call. sole wear in conjunction with movement away from body line of more than 1/3 of travel to 90^0	✓(2)?(3)$^{(Z)}$

APPENDIX 25 -contd.

Range of movement	Round 1 definitions given	Compatible with previous opinion (✓/✖)
Restricted toe movement	1^{st} MTPJ = <65^0 df <20^0 pf 2-5 MTPJ = <30^0 df <15^0 pf	✖ (3)(AA)
Normal toe movement	1^{st} MTPJ = <65^0 df <20^0 pf 2-5 MTPJ = <30-70^0 df <15-20^0 pf	✖ (3)(BB)
Excessive toe movement	More than 90^0 dorsal and 30^0 plantar movement	✖ (3)(CC)
Restricted overall foot mobility	Being able to move the joints of the foot less than the required range of motion for normal gait	--------------
Normal overall foot mobility	Meeting the required range of motion for normal gait	✓(3)
Hypermobile foot	Majority of motions being in excess of normal values	✖ (3)(DD)

Section 4 Criteria/definitions for the visual recognition of footwear variables

Footwear variable	Round 1 definitions given	Compatible with previous opinion (✓/✖)
Low heel height	2cm or less	--------------
Medium heel height	4cm	--------------
High heel height	Over 4cm	--------------
Thin sole	less than 5mm	--------------
Medium sole	1-2cm	
Thick sole	2+ cm	--------------
New shoe condition	No creases, even uppers, even tread	--------------
Used shoe condition	Creased uppers, worn tread	--------------
	-worn upper, indentations inside shoe, wear marks on sole	--------------
	Some wearing of sole pattern and scuffing of upper. Heel worn.	--------------
Poor shoe condition	Sole worn with holes, overhanging uppers	--------------
	Extensive wearing of sole and distortion of the shoe body	--------------
Shallow toe box	Able to see toe imprints on uppers - shallower on digits	--------------
	Too little room in toe box resulting in dorsal compression of toes	--------------
Normal depth toe box	Creased, no indentations from digits	--------------
Deep toe box	Deeper than digits	--------------

APPENDIX 25 -contd.

Footwear variable	Round 1 definitions given	Compatible with previous opinion (✓/✗)
Sole unworn	No markings. If leather, no colour change	--------------
	No diminution of sole pattern or wearing of heel	--------------
	Sole with clear tread mark	--------------
Light wear on sole	Part of tread abrased	--------------
	Some diminution of sole pattern but still visible	--------------
	Tread mark clear with slight scuffing	--------------
Average wear on sole	Distinct lessening of sole pattern in obvious areas and some heel wear	--------------
Heavy wear on sole	No tread-possible holes-(or nearly!)	--------------
	-marked breakdowns of leather worn through - marked worn rubber - distinct areas of wear	--------------
	Extensive lessening/absence of sole pattern to point of affecting function	--------------
Shoe length short	Length of shoe too little to accommodate foot ° impingement on apices of toes	--------------
Shoe length acceptable	Digits palpated within 1cm of end of shoes	--------------
Shoe length excessive	Digits palpated 2cm or more from end of shoe	--------------
	More than 1/2" of room such that the foot can move excessively within the shoe	--------------
Shoe width tight	Marked indentations from foot structures	--------------
Shoe width acceptable	Creases but not indentations on uppers	--------------
Shoe width excessive	Uppers baggy or overhanging	--------------
Overall shoe depth shallow	-bulging upper - indentations. - loose lace markings - narrow gap	--------------
Overall shoe depth acceptable	Contact on the dorsum of midfoot but not with excessive pressure and 1/2" room around forefoot	--------------
Overall shoe depth excessive	Excessive room around dorsum of foot and leading to the foot moving excessively in the shoe	--------------
Heel fit of shoe tight	Broken upper at heel - top worn. Stains (blood) on upper	--------------
Heel fit of shoe acceptable	Doesn't slip or rub. Room for movement	--------------
Heel fit of shoe loose	Too much room around heel allowing the heel to move within the heel cup	--------------
Toe box tootight	Too little room leading to compression of the toes laterally and dorsally	--------------
Toe box of shoe acceptable	1/2" of room around the toes laterally and dorsally	--------------

APPENDIX 25 -contd.

Footwear variable	Round 1 definitions given	Compatible with previous opinion (✓/✖)
Toe box of shoe too broad	More then 1/2" of room allowing the foot to move excessively within the shoe	--------------

Key

(1) Osol A., Ed. Blakiston's Pocket Medical Dictionary 3rd Edition, (New York: McGraw-Hill Book Co.), 1973.
(2) Neale D., Common foot disorders: diagnosis and management, (Churchill Livingstone: Edinburgh, London, Melbourne, New York), 1981.
(3) Root M.L., Orien W.P., Weed J.H., Normal and abnormal function of the foot, (Clinical Biomechanics Corporation: Los Angeles, California), 1977.

✖ No conflict with previous published views expressed in texts given.

? Insufficient information provided to compare with previous views.

✓ Conflict with previous published views expressed in texts given.

-------------- No previous opinion expressed.

Blue text = Consensus in excess of 70% achieved.

Notes on conflicts/ potential conflicts

(A)Conflict with both Neale (1981) and Root Orien and Weed (1977) who suggest that compensation in Calc. Varus is achieved by pronation at the subtalar joint and not inversion of the talus.
(B) Conflict in suggesting that there is poor control of plantarflexion. No conflict with regard to poor control of dorsiflexion.
(C) Conflict with acute foot strain but not with chronic foot strain.
(D) Conflict in that Neale (1981) states that this is a fracture of the 2nd metatarsal head specifically.
(E) Possible conflict in that the brevity of the wording used by participants could also to be interpreted to mean the opposite of Hallux Flexus in that the parts of anatomy described to be hyperextended and elevated need to be specified more accurately.
(F) Possible conflict in that Blakiston's (Osol, 1973) specifically mentions flexion of both distal phalanges in conjunction with the extended (dorsiflexed) toe.
(G)Possible conflict in that Root, Orien and Weed (1977) specifically mention flexion of the distal phalanges in conjunction with the extended (dorsiflexed) toe. They also mention the plantar flexion of the metatarsal as a possible cause.
(H)Although there is no conflict with Neale (1981), in describing an asymmetrical gait, he also specifies that this is with an arc-like dragging movement, with the foot plantarflexed and inverted and the heel being the secondary weightbearing area without primary heel strike. It may therefore be that these are the important factors of recognition, with the definition given not being specific enough.
(I)Possible conflict in that the brevity of the wording used by participants does not specify movement contrary to the normal plane of joint motion as suggested by Root, Orien and Weed (1977).
(J) Possible conflict in that the brevity of the wording used by participants does not specify movement contrary to the normal plane of joint motion as suggested by Root, Orien and Weed (1977).
(K)Conflict with Medical dictionary which suggests that the affectation is partial only.
(L)There are several other symptoms of recognition given by Neale (1981), so while this definition given can be seen as one of those signs, it may not go far enough to facilitate recognition.
(M)This definition does not allow differentiation from claw toes.
(N)Neale (1981) and Root et al suggest that the inclusion of a bursa in addition to these symptoms is

necessary for the classification of Tailor's Bunion.
(O)Blackiston's suggests that this must also include plantarflexion.
(P)Neale (1981) suggests that this must also include plantarflexion.
(Q) Neale (1981) suggests that the talus tilts downward and medially in relation to the calc., with the head acting as a wedge between the calc. And the forefoot, the plantar surface having a convex "rocker bottom" appearance.
(R)Conflict with Neale (1981) who suggests that the lateral border of the foot is overloaded through supination.
(S)Conflict with Root, Orien and Weed (1977) who suggest that hyperextension of the distal phalanx of the 1st toe is the means of compensation during walking for the 1st stiffening of Hallux Rigidus and that at the Limitus stage, avoidance of the propulsive phase of gait through picking the foot up flatly rather than raising the heel is the typical method.
(T)While this does not conflict with Neale (1981), he suggests that this is essentially associated with drop foot and this is not mentioned.
(U) While this does not conflict with Root, Orien and Weed (1977), they suggest that this is essentially associated with drop foot and this is not mentioned.
(V) Root, Orien and Weed (1977) suggest that normal is up to 15^0 at heel strike which would make abnormal anything over this and therefore above the 5 to 1 position and not the 10 to 2 position.
(W)Neale (1981) suggests that this does not usually occur in locomotion, where the 1st met. Segment is required for propulsion and therefore the abnormal inversion/supination is compensated for by pronation of the hindfoot, bringing the medial border of the foot into ground contact.
(X) Root, Orien and Weed (1977) suggest that there is 20^0 of inversion and 10^0 of eversion available in the normal foot (i.e. a 30^0 range of movement in the frontal plane). As their measurements are taken at the calc., this implies that there would be at least this much movement available in the forefoot and not the 15^0 to 20^0 as agreed here).
(Y)Although Root, Orien and Weed (1977) don't give a range for forefoot movement, their range of movements suggested at the calc. Would appear to approximately conform with this agreement when the additional movement possible at the forefoot is taken into account.
(Z)While the statement can be seen as conforming with Neale (1981) and Root, Orien and Weed (1977), the wording used is ambiguous and could be subject to a number of different interpretations.
(AA)Conflict with Root, Orien and Weed (1977) who suggest that lesser toes as well as the Hallux should dorsiflex normally65^0, similar to the 1st MPJt.
(BB) Conflict with Root, Orien and Weed (1977) who suggest that lesser toes as well as the Hallux should dorsiflex normally65^0, similar to the 1st MPJt.
(CC) Conflict with Root, Orien and Weed (1977) who suggest that lesser toes as well as the Hallux should dorsiflex normally65^0, similar to the 1st MPJt.
(DD) Root, Orien and Weed (1977) suggest that hypermobility is only used as a descriptive term when the joints should be providing stability (therefore excessive ranges of motion would only be a factor where this lack of stability is evident).

APPENDIX 26 Forms used for inter observer reliability test

Please work through the following forms, completing each section as you do so. Observation number	
Your name	
Date, appointment time and clinic observation made in	
Subject assessment (Left foot)	
Lower limb pathologies present (Please list)	
Foot type/ pathology present (Please list)	
Localised foot pathologies of heel present (Please list)	
Localised foot pathologies of ILA present (Please list)	
Localised foot pathologies of forefoot area present (Please list)	
Localised foot pathologies of hallux present (Please list)	
Localised foot pathologies of lesser toes present (Please list)	
Gait abnormalities present (Please list)	

APPENDIX 26 – contd.

Conditions affecting the whole foot present (Please list)						
Conditions affecting the ankle present (Please list)						
Range of ankle movement (Please tick)	Restricted		Normal		Excessive	
Range of forefoot inversion (Please tick)	Restricted		Normal		Excessive	
Range of forefoot eversion (Please tick)	Restricted		Normal		Excessive	
Forefoot position (Please tick)	Inverted		Normal		Everted	
Movement in 2nd toe (Please tick)	Restricted		Normal		Excessive	
Movement in 3rd toe (Please tick)	Restricted		Normal		Excessive	
Movement in 4th toe (Please tick)	Restricted		Normal		Excessive	
Movement in 5th toe (Please tick)	Restricted		Normal		Excessive	
Overall foot mobility (Please tick)	Restricted		Normal		Excessive	
Subject assessment (Right foot)						
Lower limb pathologies present (Please list)						
Foot type/ pathology present (Please list)						
Localised foot pathologies of heel present (Please list)						
Localised foot pathologies of ILA present (Please list)						
Localised foot pathologies of forefoot area present (Please list)						

APPENDIX 26 – contd.

Localised foot pathologies of hallux present (Please list)	
Localised foot pathologies of lesser toes present (Please list)	
Gait abnormalities present (Please list)	
Conditions affecting the whole foot present (Please list)	
Conditions affecting the ankle present (Please list)	

Range of ankle movement (Please tick)	Restricted		Normal		Excessive	
Range of forefoot inversion (Please tick)	Restricted		Normal		Excessive	
Range of forefoot eversion (Please tick)	Restricted		Normal		Excessive	
Forefoot position (Please tick)	Inverted		Normal		Everted	
Movement in 2nd toe (Please tick)	Restricted		Normal		Excessive	
Movement in 3rd toe (Please tick)	Restricted		Normal		Excessive	
Movement in 4th toe (Please tick)	Restricted		Normal		Excessive	
Movement in 5th toe (Please tick)	Restricted		Normal		Excessive	
Overall foot mobility (Please tick)	Restricted		Normal		Excessive	
Footwear assessment - (Both shoes)						
Heel height (Please tick)	Low		Medium		High	
Sole thickness (Please tick)	Thin		Medium		Thick	
Depth of toe box (Please tick)	Shallow		Normal		Deep	

APPENDIX 26 – contd.

Left shoe							
Condition of shoe (Please tick)	New		Used		Poor		
Sites of heel/sole wear (Please describe)							
Amount of wear (Please tick)	Unworn		Some wear				
	Usual wear		Heavy wear				
Footwear fit - length (Please tick)	Tight		Acceptable		Over-size		
Footwear fit - width (Please tick)	Tight		Acceptable		Over-size		
Footwear fit - depth (Please tick)	Tight		Acceptable		Over-size		
Footwear fit - heel (Please tick)	Tight		Acceptable		Over-size		
Footwear fit - toe box (Please tick)	Tight		Acceptable		Over-size		
Footwear fit - other mismatches (Please describe)							
Right shoe							
Condition of shoe (Please tick)	New		Used		Poor		
Sites of heel/sole wear (Please describe)							
Amount of wear (Please tick)	Unworn		Some wear				
	Usual wear		Heavy wear				
Footwear fit - length (Please tick)	Tight		Acceptable		Oversize		
Footwear fit - width (Please tick)	Tight		Acceptable		Oversize		
Footwear fit - depth (Please tick)	Tight		Acceptable		Oversize		
Footwear fit - heel (Please tick)	Tight		Acceptable		Oversize		
Footwear fit - toe box (Please tick)	Tight		Acceptable		Oversize		
Footwear fit - other mismatches (Please describe)							

APPENDIX 27.1 Calculation of Cohen's Kappa to test inter-observer reliability – confusion matrix and method

Number of agreements found in the inter-observer reliability tests

	Agreements levels between pairs of Observers					
Condition/state	1 v 2	1 v 3	1 v 4	2 v 3	2 v 4	3 v 4
Lower limb pathologies	10/13 (37%)	7/12 (58%)	10/15 (66%)	5/12 (42%)	9/15 (60%)	8/18 (44%)
ILA pathologies	1/10 (10%)	5/12 (42%)	6/9 (66%)	2/11 (18%)	1/10 (10%)	6/11 (55%)
Foot type	6/14 (45%)	6/12 (50%)	8/10 (80%)	10/17 (59%)	8/15 (53%)	7/12 (58%)
Heel pathologies	0/13 (0%)	2/10 (20%)	2/11 (18%)	6/11 (55%)	8/10 (80%)	5/9 (56%)
Forefoot pathologies	6/11 (55%)	6/11 (55%)	7/13 (54%)	8/11 (73%)	9/12 (75%)	7/12 (58%)
Hallux pathologies	9/16 (56%)	9/17 (53%)	6/16 (38%)	8/11 (73%)	7/11 (64%)	6/12 (50%)
Lesser toe pathologies	8/13 (62%)	1/12 (8%)	2/2 (100%)	5/5 (100%)	2/2 (100%)	3/3 (100%)
Whole foot pathologies	7/7 (100%)	7/7 (100%)	11/11 (100%)	5/5 (100%)	8/8 (100%)	7/7 (100%)
Ankle pathologies	8/8 (100%)	9/9 (100%)	9/9 (100%)	10/10 (100%)	10/10 (100%)	10/10 (100%)
Gait pathologies	4/13 (31%)	5/5 (100%)	11/11 (100%)	7/7 (100%)	5/5 (100%)	5/5 (100%)
Range of jt movement	31/47 (66%)	38/46 (83%)	32/47 (68%)	32/45 (71%)	38/47 (81%)	33/46 (72%)
Shoe fit	32/50 (64%)	39/49 (80%)	29/49 (59%)	36/49 (73%)	40/55 (73%)	35/50 (70%)
Shoe dimensions	9/16 (56%)	9/16 (56%)	11/16 (69%)	10/16 (63%)	10/18 (56%)	11/17 (65%)
Shoe condition	5/11 (45%)	9/11 (82%)	5/11 (45%)	11/11 (100%)	11/11 (100%)	7/11 (64%)
Amount of shoe wear	6/6 (100%)	5/5 (100%)	5/5 (100%)	3/3 (100%)	4/4 (100%)	6/6 (100%)

To calculate the inter-observer agreements between each pair of observers for each condition/state, the method demonstrated by Robson (1993) was used, i.e.:

1. The confusion matrices are drawn up
2. The proportion of agreement (Po) is calculated as follows:

$$Po = \frac{\text{No. of agreements}}{\text{No. of agreements} + \text{No. of disagreements}}$$

(Expressed as a percentage as the index of agreement)

3. The proportion of agreement expected by chance (Pc) is calculated:

$$Pc = (P_{1A} \times P_{2A}) + (P_{1B} \times P_{2B}) + (P_{1C} \times P_{2C}) \text{ etc.}$$

(Where 1 = Observer 1
2 = Observer 2
A = Diagnosis 1
B = Diagnosis 2
C = Diagnosis 3 etc.)

4. Cohen's Kappa is calculated in order to correct for chance:

$$K = \frac{Po - Pc}{1 - Pc}$$

APPENDIX 27.2 Calculation of Cohen's Kappa to test inter-observer reliability – Kappa values with interpretation

The Kappa value is compared to the following scale in order to show how good the levels of agreement are. The interpretation used here is that advocated by Lowe (Lowe, 1993:126) :

Kappa	Interpretation
Below zero	Poor agreement
Zero to .20	Slight agreement
.21 to .40	Fair agreement
.41 to .60	Moderate agreement
.61 to .80	Substantial agreement
.81 plus	Almost perfect agreement

Kappa values obtained with interpretation

Diagnostic area	Observer pairing	Kappa value	Interpretation
Lower limb pathologies	1 v 2	.65	Substantial
	1 v 3	.35	Fair
	1 v 4	.53	Moderate
	2 v 3	.13	Slight
	2 v 4	.42	Moderate
	3 v 4	.28	Fair
Inner longitudinal arch pathologies	1 v 2	-.06	Poor (lower than that expected by chance)
	1 v 3	.19	Slight
	1 v 4	.43	Moderate
	2 v 3	.03	Slight
	2 v 4	-.06	Poor (lower than that expected by chance)
	3 v 4	.25	Fair
Foot type	1 v 2	.11	Slight
	1 v 3	-0.09	Poor (lower than that expected by chance)
	1 v 4	.52	Moderate
	2 v 3	.44	Moderate
	2 v 4	.37	Fair
	3 v 4	.25	Fair
Heel pathology	1 v 2	-.16	Poor (lower than that expected by chance)
	1 v 3	.09	Slight
	1 v 4	.06	Slight
	2 v 3	.15	Slight
	2 v 4	.64	Substantial
	3 v 4	.22	Fair
Forefoot pathology	1 v 2	.25	Fair
	1 v 3	.1	Slight
	1 v 4	.33	Fair
	2 v 3	.21	Fair
	2 v 4	.56	Moderate
	3 v 4	.07	Slight
Hallux pathology	1 v 2	.32	Fair
	1 v 3	.28	Fair
	1 v 4	.11	Slight
	2 v 3	.48	Moderate
	2 v 4	.46	Moderate
	3 v 4	.31	Fair
Lesser toe pathology	1 v 2	.27	Fair
	1 v 3	.06	Slight
	1 v 4	1.0	Perfect
	2 v 3	1.0	Perfect
	2 v 4	1.0	Perfect
	3 v 4	1.0	Perfect

APPENDIX 27.2 - contd.

Diagnostic area	Observer pairing	Kappa value	Interpretation
Whole foot pathology	1 v 2	1.0	Perfect
	1 v 3	1.0	Perfect
	1 v 4	1.0	Perfect
	2 v 3	1.0	Perfect
	2 v 4	1.0	Perfect
	3 v 4	1.0	Perfect
Ankle pathology	1 v 2	1.0	Perfect
	1 v 3	1.0	Perfect
	1 v 4	1.0	Perfect
	2 v 3	1.0	Perfect
	2 v 4	1.0	Perfect
	3 v 4	1.0	Perfect
Gait pathology	1 v 2	.19	Slight
	1 v 3	1.0	Perfect
	1 v 4	1.0	Perfect
	2 v 3	1.0	Perfect
	2 v 4	1.0	Perfect
	3 v 4	1.0	Perfect
Range of joint movement	1 v 2	.33	Fair
	1 v 3	.6	Moderate
	1 v 4	.37	Fair
	2 v 3	.44	Moderate
	2 v 4	.67	Substantial
	3 v 4	.44	Moderate
Shoe fit	1 v 2	.33	Poor
	1 v 3	.63	Substantial
	1 v 4	.27	Fair
	2 v 3	.51	Moderate
	2 v 4	.5	Moderate
	3 v 4	.43	Moderate
Shoe dimensions	1 v 2	.33	Fair
	1 v 3	.33	Fair
	1 v 4	.51	Moderate
	2 v 3	.43	Moderate
	2 v 4	.31	Fair
	3 v 4	.47	Moderate
Shoe condition	1 v 2	-.15	Poor (lower than that expected by chance)
	1 v 3	0	Slight (equal to that expected by chance)
	1 v 4	-.15	Poor (lower than that expected by chance)
	2 v 3	1.0	Perfect
	2 v 4	1.0	Perfect
	3 v 4	0	Slight (equal to that expected by chance)
Amount of shoe wear	1 v 2	1.0	Perfect
	1 v 3	1.0	Perfect
	1 v 4	1.0	Perfect
	2 v 3	1.0	Perfect
	2 v 4	0	Slight (equal to that expected by chance)
	3 v 4	1.0	Perfect

APPENDIX 28 Invitation to participate in the study

Letter Heading

Date

Address

Dear

I am a podiatrist undertaking a research project on shoe wear patterns at Sheffield Hallam University. In this project, I am studying the link between foot problems and patterns of wear (shoe wear patterns) seen in footprints left by shoes. I have chosen one condition in which there is a stiffening of the big toe, to study in detail.

I understand that you attend the podiatry/chiropody service for treatment and that you may be willing to help with this study. I am seeking volunteers who would be willing to attend Central clinic for a foot assessment and interview and would ask you to bring your footwear to this interview.

If you are willing to take part in my study, please complete and return the attached form in the stamped, addressed envelope provided. I will then contact you over the next few weeks to arrange a convenient appointment time.

Thank you

Yours sincerely

Wesley Vernon
SwaMP project research student, Sheffield Hallam University.

Enc

I am willing to take part in the shoe wear pattern study

Name:
....

Address:
....

....

Telephone number :
....

APPENDIX 29 Appointment letter

Letter Heading

Date

Address

Dear

Thank you for indicating your willingness to help with my research. I have arranged an appointment for you at (time) on (date) in the podiatry/chiropody department at Central health clinic and enclose a map showing how to get there. The examination and interview will last approximately 1½ hours and tea, coffee and biscuits will be available. If you are unable to attend, I would be grateful if you could telephone the above number to let me know.

Would you please bring all of your current footwear irrespective of condition and purpose to this appointment.

I also enclose an information sheet explaining what to expect at your appointment.

Thank you once again for your help

Yours sincerely

Wesley Vernon
SWaMP project research student
Sheffield Hallam University

Enc

APPENDIX 30 Information sheet

Information for participants in the shoe wear pattern study

What is this study about ?
The shoe wear pattern study is looking at the link between shoe wear and foot problems. If shoe wear is understood better, this may be helpful in diagnosing foot problems and in investigating footprints found at scenes of crime.

What will the study involve ?
When you attend for the appointment, it is important that you bring all of your current footwear with you. When you arrive, you will be weighed, your height measured and your feet will be examined and measured barefoot and when wearing shoes. You will also be video-recorded walking in your shoes. The footwear that you bring will be examined, measured and photographed separately. I will ask you some questions about your footwear and you will be asked to put items of footwear on and comment about their fit while standing and walking. The interview will be recorded on audio tape unless you object.

Will I be given any treatment at the appointment ?
No treatment will be given at the appointment, but if any problems are found that require immediate treatment, this will be arranged in an adjacent chiropody clinic.

Will the study be confidential ?
All information will be entirely confidential. The photographs and video-recordings made in the study are for record purposes only. They will only show your feet and legs, your face will be kept out of all pictures and you will not be able to be identified from them. All tapes will be kept confidential and anonymous to all others but the researcher and will be erased after use.

How long will it take ?
The whole process should take about 1½ hours.

What if I don't wish to take part ?
This will in no way affect the treatment you receive at the clinic.

What if I change my mind during the study ?
You have the right to withdraw from the study at any time without affecting your normal attendance at the clinic.

What if I have further questions ?
You should contact : Wesley Vernon, SWaMP project research student, on 0114 2716767

APPENDIX 31 Subject assessment form

Subject ref. no.		Name	dob / /
Address		Tel.	
Height		Weight	
H. Rig. assessment	Left	Right	
Joint movement			
Joint angle			
Standing assessment	Left	Right	
Foot length			
Foot width			
Lower limb pathologies present			
Foot type/ pathologies present			
Localized foot pathologies present			

APPENDIX 31 - contd.

<table>
<tr><th colspan="2">Sitting assessment</th><th>Left</th><th>Right</th></tr>
<tr><td colspan="2">Sites of foot pain</td><td></td><td></td></tr>
<tr><td rowspan="4">Range of ankle movement</td><td>Dorsal</td><td></td><td></td></tr>
<tr><td>Plantar</td><td></td><td></td></tr>
<tr><td>Inversion</td><td></td><td></td></tr>
<tr><td>Eversion</td><td></td><td></td></tr>
<tr><td colspan="2">Calc. position (Inv/Ev)</td><td></td><td></td></tr>
<tr><td rowspan="2">Range of forefoot movement</td><td>Inversion</td><td></td><td></td></tr>
<tr><td>Eversion</td><td></td><td></td></tr>
<tr><td colspan="2">F'foot position (Inv/Ev)</td><td></td><td></td></tr>
<tr><td colspan="2">Observed restricted movement in toes</td><td></td><td></td></tr>
<tr><td colspan="2">Overall mobility</td><td></td><td></td></tr>
<tr><td colspan="2">Callosities/ skin lesions present</td><td></td><td></td></tr>
<tr><th colspan="2">Walking assessment</th><th>Left</th><th>Right</th></tr>
<tr><td colspan="2">Abnormalities noted</td><td></td><td></td></tr>
<tr><td colspan="3">Video recording made (tick ✓ when completed)</td><td>☐</td></tr>
</table>

APPENDIX 31 - contd.

Subject ref. no.		Name	Footwear Ref. No.	

Footwear Description		
Materials		
Style		
Fastening device		
Heel height		
Sole thickness		
	Left	Right
Condition		
Marked length		
Sized length		
Marked width		
Sized width		
Depth (describe)		
Wear pattern observed (describe)		
Focal point codes		

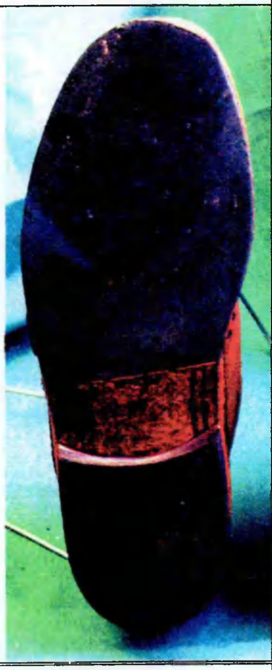
Footwear Fit (subjective assessment)			
Length		Width	
Depth		Heel fit	
Toe box fit		Other mismatches	

Shoe outsoles photographed (tick ✓ when completed)	☐

APPENDIX 32 Subject outsole wear patterns with focal codes

Subject 1			
1/1 (right)	1/1 (left)	1/2 (right)	1/2 (left)
1/13/14/15/20/21	1/13/14/15/16/20/21	Not discernible	Not discernible
			
1/3 (right)	1/3 (left)	1/4 (right)	1/4 (left)
1/3/13/14/15/20/21	1/3/13/14/15/16/20/21	1/13/14/15/18/19/21	1/13/14/15/16/20/21
			

APPENDIX 32 - contd.

Subject 2			
2/1 (right)	2/1 (left)	2/2 (right)	2/2 (left)
6/13/14/15/20/21	1/13/14/15/21	6/13/14/15/20/21	1/13/14/15/21
			
2/3 (right)	2/3 (left)	2/4 (right)	2/4 (left)
6/13/14/15/20/21	1/13/14/15/21	6/13/14/15/20/21	1/13/14/15/21
			

APPENDIX 32 - contd.

Subject 3			
3/1 (right)	3/1 (left)	3/2 (right)	3/2 (left)
6/7/14/15/16/21	6/9/15/16/21	6/7/14/15/16/21	6/9/15/16/21
			
3/3 (right)	3/3 (left)		
6/7/14/15/16/21	6/9/15/16/21		
			

APPENDIX 33 Observer questionnaire to validate video frame descriptions

Thank you for your earlier participation in the validation phase of the SWaMP project. The assessment of subjects' foot function while walking which you undertook has been collated and compared with a frame by frame examination of the video recording of that function. Various statements have been prepared to summarise the function which was believed to be shown by the video still frame sequence. You are asked to compare these statements with the relevant still frame sequences and indicate whether you agree/disagree/are unsure of each description. If you disagree with any statements given, please offer an alternative explanation of the function presented in the relevant still frame.

Thank you.

Subject one

Subject 1 – Left bare foot observations

Statement no.	Statement made on observed function	Agree (✓)/disagree (✖)/ unsure (?)
1.	Normal heel strike	
	(If disagreeing, please provide an alternative statement here) ……………………………………………………………………	
2.	Heel strike is followed by rapid heel eversion	
	(If disagreeing, please provide an alternative statement here) ……………………………………………………………………	
3.	Foot abducted	
	(If disagreeing, please provide an alternative statement here) ……………………………………………………………………	
4.	Hallux limitus restricts full foot pronation	
	(If disagreeing, please provide an alternative statement here) ……………………………………………………………………	
5.	No attempted recovery observed from pronation	
	(If disagreeing, please provide an alternative statement here) ……………………………………………………………………	
6.	Pronatory control is from the 1st toe restriction alone.	
	(If disagreeing, please provide an alternative statement here) ……………………………………………………………………	

APPENDIX 33 – contd.

Subject 1 – Right bare foot observations		
7.	Normal heel strike	
	(If <u>disagreeing</u>, please provide an alternative statement here) ………………………………………………………………………	
8.	Heel strike is followed by rapid heel eversion	
	(If <u>disagreeing</u>, please provide an alternative statement here) ………………………………………………………………………	
9.	Foot straight, not abducted throughout stance	
	(If <u>disagreeing</u>, please provide an alternative statement here) ………………………………………………………………………	
10.	Hallux limitus restricts full foot pronation later in stance	
	(If <u>disagreeing</u>, please provide an alternative statement here) ………………………………………………………………………	
11.	A "classic" hallux rigidus function occurred with inversion along the 5th MPJt., 1st toe axis	
	(If <u>disagreeing</u>, please provide an alternative statement here) ………………………………………………………………………	
12.	No abductory twist occurred	
	(If <u>disagreeing</u>, please provide an alternative statement here) ………………………………………………………………………	
Subject 1 – Right shod foot observations with footwear item 1-4 (R)		
13.	The foot was clearly shown inverting throughout stance, with no medial ground contact	
	(If <u>disagreeing</u>, please provide an alternative statement here) ………………………………………………………………………	
Subject 1 – Left shod foot observations with footwear item 1-4 (L)		
14.	With the shod foot, the function was not as detailed	
	(If <u>disagreeing</u>, please provide an alternative statement here) ………………………………………………………………………	
15.	A normal heel strike with rapid eversion was clearly seen,	
	(If <u>disagreeing</u>, please provide an alternative statement here) ………………………………………………………………………	
16.	Pronation was restricted due to the hallux limitus	
	(If <u>disagreeing</u>, please provide an alternative statement here) ………………………………………………………………………	

APPENDIX 33 – contd.

17.	The controlling orthotic effect of delayed eversion after heel strike could not be seen	
	(If disagreeing, please provide an alternative statement here) ………………………………………………………………	
Subject 2		
Subject 2 – Left bare foot observations		
18.	Foot abducted during stance	
	(If disagreeing, please provide an alternative statement here) ………………………………………………………………	
19.	Forefoot inverted	
	(If disagreeing, please provide an alternative statement here) ………………………………………………………………	
Subject 2 – Right bare foot observations		
20.	Foot abducted during stance	
	(If disagreeing, please provide an alternative statement here) ………………………………………………………………	
21.	With classic hallux rigidus function	
	(If disagreeing, please provide an alternative statement here) ………………………………………………………………	
Subject 3		
Subject 3 – Left bare foot observations		
22.	Both feet were seen abducting and pronating during function,	
	(If disagreeing, please provide an alternative statement here) ………………………………………………………………	
23.	With 1st ray incompetence leading to 2nd toe toe-off,	
	(If disagreeing, please provide an alternative statement here) ………………………………………………………………	
24.	Abductory twist was not seen in the video frames	
	(If disagreeing, please provide an alternative statement here) ………………………………………………………………	

APPENDIX 33 – contd.

Subject 3 – Right bare foot observations		
25.	Both feet were seen abducting and pronating during function,	
	(If disagreeing, please provide an alternative statement here) …………………………………………………………………………	
26.	with 1st ray incompetence leading to 2nd toe toe-off,	
	(If disagreeing, please provide an alternative statement here) …………………………………………………………………………	
27.	Abductory twist was not seen in the video frames	
	(If disagreeing, please provide an alternative statement here) …………………………………………………………………………	
General statements		
Statement no.	Statement made	Agree (✓)/disagree (✖)/ unsure (?)
28.	The freeze frame analysis showed aspects of function which could not be appreciated when viewing gait at normal speed	
	(If disagreeing, please provide an alternative statement here) …………………………………………………………………………	

Please state any further comments you may have below, continuing on a separate sheet in necessary.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

Thank you

D. W. Vernon

SWaMP project research student

Sheffield Hallam University

APPENDIX 34 Summary of observer comments on statements describing the video frame analysis

Re: Statement no. 4 – "Hallux limitus restricts full foot pronation"		
Observer no.	Disagrees/unsure	Comment
1	Unsure	Pronates (arch still lowering) into propulsive phase (after heel lift), so the q. is – would it continue to pronate at this late stage without (a H. limitus)?
2	Disagrees	Could contribute, but other structures may also have an equal role
Re: Statement no. 6 – "Hallux limitus restricts full foot pronation"		
Observer no.	Disagrees/unsure	Comment
1	Unsure	It could be 1st toe restriction, but factors have to be considered i.e. tension in the p.f. and in this case, when pronation is occurring so late i.e. after heel lift that the supinating effect of the swing limb is responsible
2	Disagrees	Could contribute, but other structures may also have an equal role
Re: Statement no. 16 – "Pronation was restricted due to the hallux limitus"		
Observer no.	Disagrees/unsure	Comment
1	Unsure	Effects of orthoses and limited data/info. to make such a statement
2	Disagrees	Orthotics must play a role as well as other foot structures

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REFERENCES

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o. ...oe Wear Marks

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Anne Parry[2]
Mike Potter[3]

Abstract: The value of shoe wear marks as footwear evidence has long been treated with skepticism, although podiatrists are known to interpret the meaning of such marks in clinical diagnosis. Prior to the carrying out of a major study using Delphi methodology, a first round questionnaire was devised to collate experienced podiatrists' knowledge of characteristic wear marks. The results did not appear to demonstrate the level of consensus expected. Closer examination, however, indicated that there may be agreement about the meaning of specific areas of wear in the overall wear pattern shown. Reasons for the lack of overall consensus are suggested and the need for caution in the use of wear marks is reinforced pending further investigation.

Introduction

Forensic scientists have been aware of shoe wear marks for a long time, yet there is doubt as to whether these marks can be of value as forensic evidence [1]. Consequently, although it is thought that these marks represent important information about the owner of a worn shoe [2], they are of limited use in forensic investigations. Conversely,

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nosis an ear y c iro. y an simi ar texts contain reference to wear mark interpretation, including diagrammatic representations of wear marks stated to be characteristically caused by named pathological conditions [3, 4, 5, 6].

In 1967, L. J. Lucock, an English chiropodist, published a paper on identification from footwear illustrated with wear marks related to given pathologies [7]. These published references, however, were based on clinical observation combined with experience, and it is assumed that podiatrists' clinical use of wear marks is founded on a knowledge base derived from personal experience. In common with other health professions, the knowledge base of podiatry is growing rapidly. Parry and Stone [8] pointed out that the characteristics of knowledge underpinning physiotherapy practice are unclear and the process whereby the knowledge of a practitioner is developed from the theoretical frameworks provided by scientific disciplines and from experience is not understood. Rules of thumb, reasoned guesses, insight, informed opinion and identification of exceptions to the rule all contribute to clinical expertise.

Knowledge is hidden in many ways and there is a need to retrieve informal knowledge about podiatry so that it can be transferred to students. Elicitations of knowledge about shoe wear marks will either confirm or deny that they can be used with a degree of certainty in clinical diagnoses and forensic investigations and should be taught to students. On this basis, a Delphi study was planned to collect experts' knowledge of characteristic shoe wear marks.

The Delphi technique

The Delphi technique is a method of obtaining the most reliable consensus of a group of experts via several rounds of questionnaires. It was devised by the Rand Corporation in the 1950s to predict effects of a nuclear war [9], but due to the secretive nature of this work, publication was delayed for ten years. The technique has become widely adopted by the health care professions since 1975 when it became widely used by the nursing profession. Of the many benefits derived from the use of the Delphi technique, the method was chosen for this study because:

- Experiences stated by those questioned have not been influenced by others;
- The technique allows access to large numbers of experts across widespread locations;
- Group consensus is possible;
- The technique is time efficient;
- All responses carry equal weighting;
- Overview is achieved after round one;
- Key issues are produced;
- The technique is simple to use;
- Participants' abilities are fully used;
- The technique usually produces good response rates.

The stages of the Delphi technique include devising the research question, choosing enough suitable participants to ensure study feasibility, noting and matching subsequent responses and final presentation, explanation and analysis of results.

As it was intended to include every U.K. National Health Services Trust with a Podiatry Department in the Delphi study, a pilot Delphi was seen to be essential in order to test the proposed method.

Aim

The aim of the pilot study was to test the suitability of the Delphi method for collecting expert knowledge on characteristic shoe wear marks in the form of a wide range of wear mark patterns together with their stated cause and to seek consensus over this knowledge.

Method

The Delphi Round 1 was devised to collect experts' knowledge gained through interpreting shoe wear patterns characteristically associated with named structural or functional disorders of the foot, lower limb, or type of gait.

Sample

Ten U.K. Health Trusts volunteered to assist with the Pilot Delphi with each Professional Head of Service nominating their most experienced podiatrist to take part in the study.

Questionnaire

The questionnaire itself asked respondents to mark on blank outsole outlines a maximum of 10 characteristic patterns with which they were familiar through experience and to name the condition associated with that pattern.

Procedure

The questionnaire was distributed to the participating Trusts together with several items of supportive information including a covering letter, explanatory notes, an example sheet and a comprehensive "prompt" list of possible pathologies. A feedback sheet and return envelope were also included.

Analysis

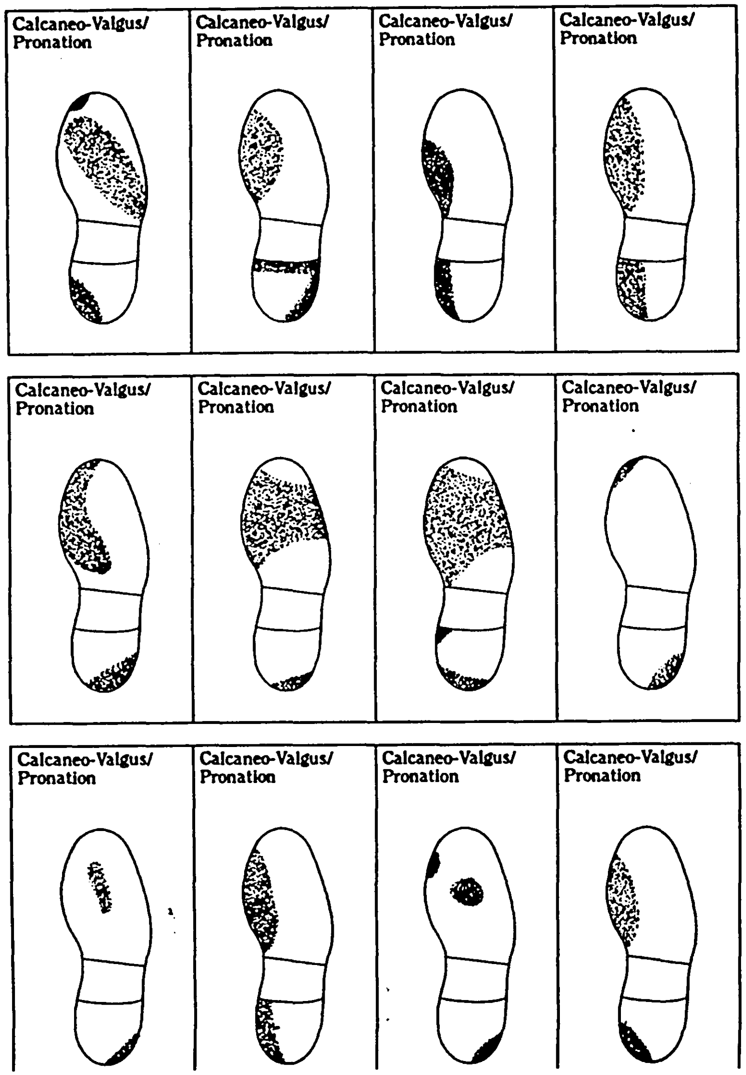
The returned wear mark patterns were initially collated and stored under pathology headings. Patterns given under each heading were scrutinized for similarities and agreements and common patterns under each heading were recorded diagrammatically and prepared for returning to participants in order to seek a future consensus agreement.

Results

There was a 70% response rate achieved in Round 1 of the Pilot Study. The returned information, however, yielded unexpected results. The given patterns related to a total of twenty nine different pathological states (Diagram 1). Wear patterns for thirteen of these pathologies were identified by more than one respondent and could therefore be examined for consensus. These patterns are depicted in figure 1. Twelve patterns were recorded for Calcaneo-Valgus/pronation (figure 1.1), five for Hallux Rigidus (figure 1.2), three for shuffling gait in

Figure 1 (1.1)

Shoe wear mark patterns depicted by podiatrists for conditions that received more than one response



ıgure

Shoe wear mark patterns depicted by podiatrists for conditions which received more than one response

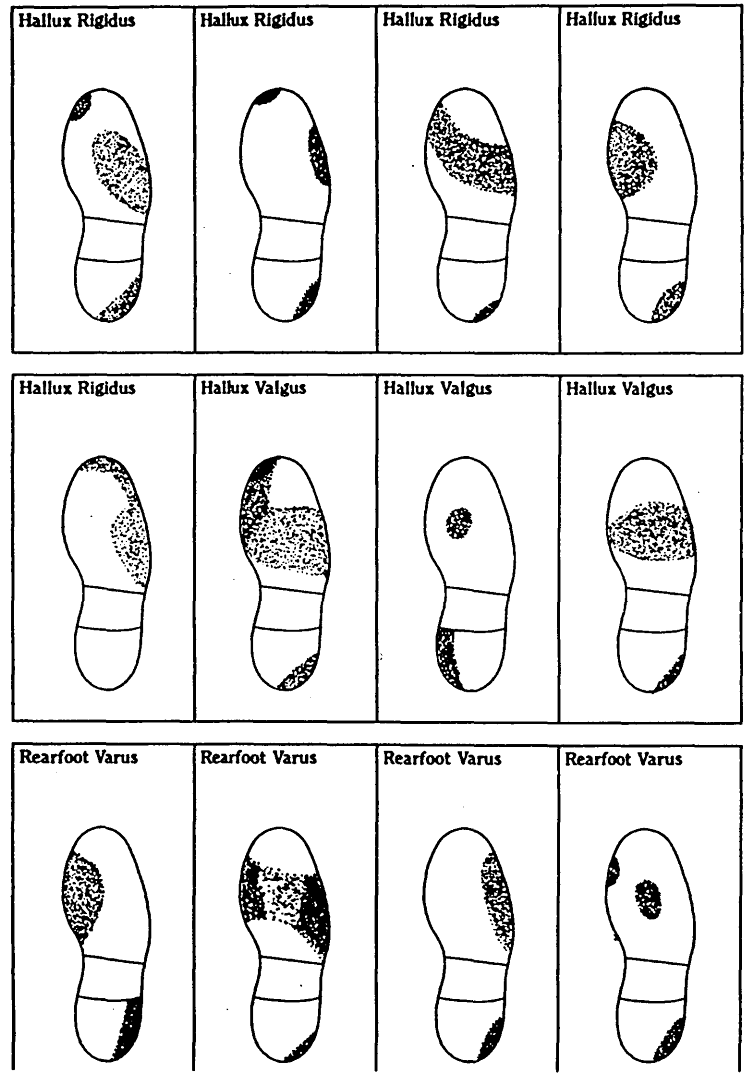
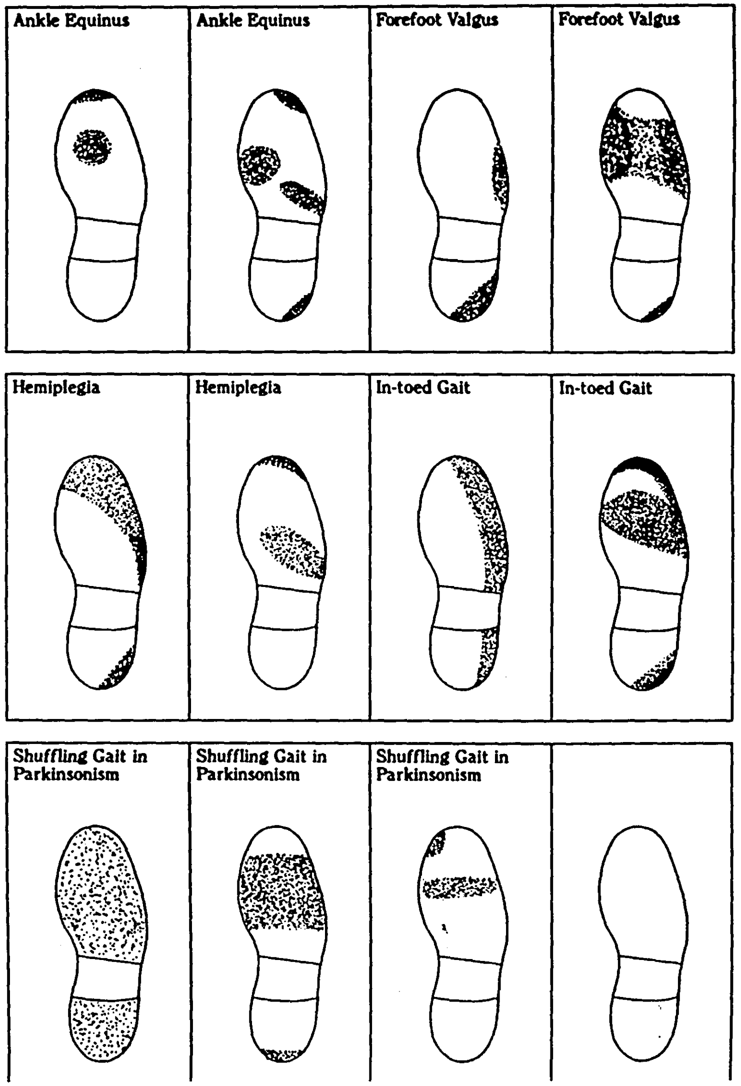
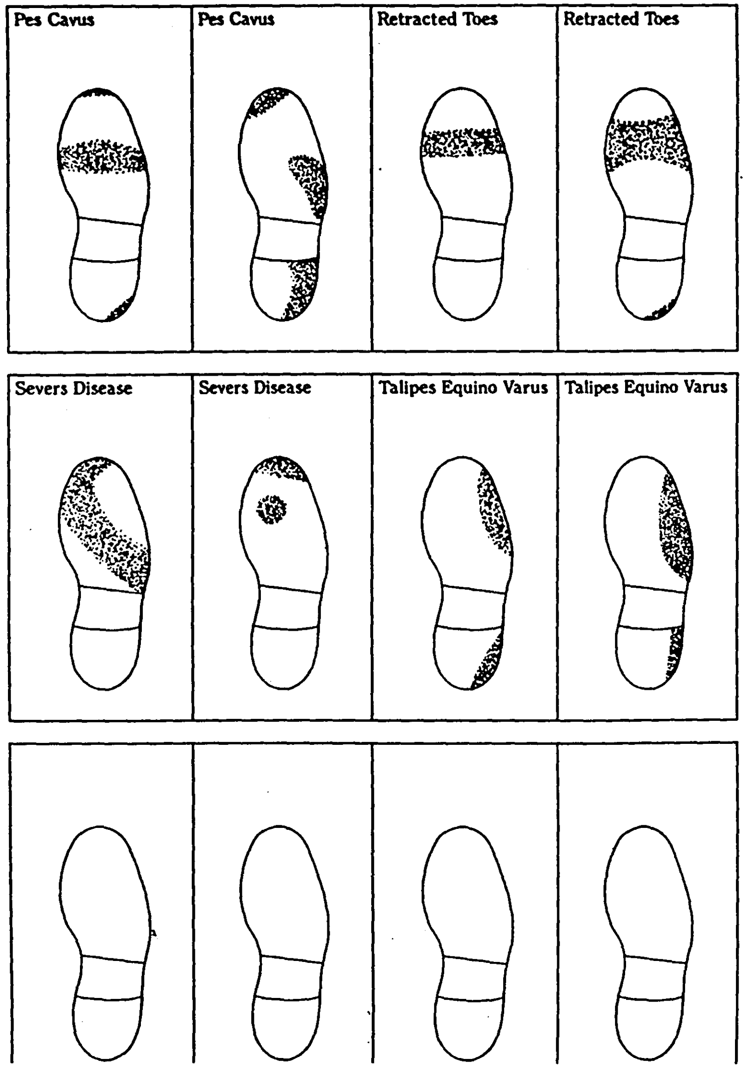


Figure 1 (1.3)

Shoe wear mark patterns depicted by podiatrists for conditions which received more than one response



Shoe wear mark patterns depicted by podiatrists for conditions which received more than one response



Parkinson's disease, and two each for ankle equinus, forefoot valgus, hemiplegia and in-toes gait (figure 1.3) and two each for pes cavus, retracted toes, Severs disease and talipes equino varus (figure 1.4).

Initially it appeared that the majority of patterns stated under each pathology heading had no consensus whatsoever. Close scrutiny however indicated that there could indeed be a number of common wear areas suggested by respondents under each heading. These commonalities related to single aspects of the entire pattern shown. This is to say that although there was no consensus suggested with regard to the entire pattern, a consensus view existed over certain single aspects of the pattern. These common features are recorded in Diagram 2.

Discussion

The results themselves indicate six possible interpretations. While poor agreement over the totality of patterns was initially of concern, close scrutiny revealed consensus over specific areas of wear under stated headings. The six possible conclusions are:

- 1. The task was too difficult. That is, while we recognize patterns, we are unable to draw good likenesses of these patterns.

- 2. There was no consensus over patterns because the respondents did not possess the knowledge required.

- 3. There was no consensus over patterns because wear marks have no relationship to underlying states.

- 4. There was no consensus over patterns because even though wear marks could have a relationship to underlying states, there are too many variables present to be able to place a meaningful interpretation on these wear marks. Examples of such variables are shoe type, last type and shoe sole material.

- 5. There was no consensus over patterns because there are regional variations to be seen in wear mark patterns as related to defined states - i.e. the characteristic wear pattern will vary according to where an individual resides due to geographical, industrial, or socio-economic factors.

- . ere is potential for consensus shown in the results but this is related to specific areas of the pattern as opposed to the entire patterns. For example, although only 3 of the 12 patterns shown for Calcaneo Valgus appeared to be the same, eight respondents agreed that there would be wear along the entire medial sole area. This implies that some of the specific wear areas may relate to general function or secondary pathologies: In a total wear pattern some of the wear could be caused by the normal walking process, some could be characteristic of the pathological state of the foot and some could be due to secondary complications of that pathology. If this is the case, respondents could have misinterpreted the overall pattern while still identifying the specific wear area relating to a particular condition. This may also be related to hemispheric asymmetries in cognitive style. That is, the right cerebral hemisphere of the brain is more holistic and recognizes form and shape, whereas the left cerebral hemisphere is more sequentially analytical. Thus the right hemisphere recognizes a whole pattern and the left attends to the separate parts.

It is felt that lack of knowledge is not the reason for the differences because different patterns were presented even for very common, easily diagnosed conditions (e.g. Hallux Rigidus, Hallux Valgus). If further investigation still leaves this suggestion as a possibility, then a testing of knowledge may be required, possibly covering the currently known "experts" in this field.

With regard to the idea that wear marks have no relationship to underlying states, this is a highly unlikely conclusion. Studies using force plate technology have shown that characteristic motions and pressure patterns arise during gait cycles relating to specific states [10]. If characteristic force and pressure pathways exist it must necessarily follow that any interface (shoe sole) between the pressure source (foot) and the ground must be affected in a similar way on each occasion that this interface is subjected to a characteristic pressure pattern.

Wear marks are the product of usual, not variant footsteps. However, extraneous variables can have an effect on shoe wear patterns. Shoe soles can be manufactured from different materials which can wear at different rates and it is also conceivable that if the material is hard enough, foot function may be corrupted. The style of shoe may that allows full foot function may in turn allow a different characteristic representation of wear marks than a shoe which through different heel height, slip-on nature and forefoot and toe restriction may influence the foot function to an extent that the wear mark alters.

If a shoe is too small or too large, then this may also affect foot function. Different last types exist, such as straight last and curved lasts, upon which shoes are manufactured. It is therefore feasible that shoes manufactured on different lasts may exert control over foot function in different ways, therefore also affecting wear mark patterns. However, as shoes are "worn in", the usual footstep will begin to produce the characteristic patterns for that foot/shoe relationship.

Despite the possibility of these variables affecting foot function and shoe wear marks, this may not account for the lack of consensus observed. Information given was based on clinical experience. Despite the presence of possible confounding factors, experience would be based on repeated observations over several years. If the observations are repeated, they have been observed on many occasions irrespective of these factors which may not be known by the observers. Investigation into variable effects may however be required at some stage although the project is only attempting to determine whether there is broad pattern agreement.

Regional factors may certainly have a part to play in confounding consensus. This is a novel suggestion which may account for some of the disagreements currently in existence regarding bio-mechanical theory. This does not, however, take into account the fact that respondents may have worked and studied in several different areas and Schools of Podiatry and subjects alike may have exhibited varying degrees of mobility around the U.K. throughout life. If lack of consensus continues in later Delphi Rounds, this will be an area requiring further investigation, possibly by collecting data from defined areas by direct observation and recording methods.

The Round 1 Delphi Pilot results have raised a number of questions regarding the issue of wear marks. The limited number of consensual replies received was inevitable in a Pilot Test where free expression is given yet limited to a maximum of ten suggestions. The amount of commonality shown, however, has been adequate for the purpose of this Pilot Round which aimed to test the method for potential problems

objectives have been achieved.

An interesting point is that two respondents showed patterns for Severs disease, one respondent showed a pattern for Freibergs Infraction and one respondent showed a pattern for Charcot-Marie-Tooth disease. None of these conditions is common and would not have been expected in a list based on familiarity by experience. An influencing factor could have occurred, however, in that when an unusual feature is encountered clinically, the clinician may then retain far more detail about that condition than usual through greater interest being generated by such an interesting case. This influence would be helpful in the main data collection phase as it may pull in data otherwise overlooked. The minimal pattern consensus was not expected, but as stated, when the data is scrutinized in detail, consensus about specific areas in overall patterns can be seen. This possibility now requires further investigation.

Limitations of study

A number of minor administrative problems became apparent with the questionnaire which will be addressed before the main Delphi Round 1 is undertaken and feedback comments were very helpful in this respect.

Conclusion

A number of conclusions can be drawn from Delphi Pilot Round 1 as follows:

- The Pilot Round collected the information sought successfully. The information was not that which had been expected in that there initially appeared to be widespread lack of consensus. This will need to be investigated.

- The Delphi Pilot showed some sensitivity to capturing useful data on obscure conditions.

- The lack of apparent consensus appears to warrant investigation but it would be sensible first to investigate the possibility that there may be consensus relating to specific wear areas. If there still proves to be lack of consensus, then experts must be tested to see if any expertise exists in this field at all. If so, other influencing factors must be investigated.

- At some stage, investigation into variable effects of footwear styles, materials and occupational factors may be required.

Although preliminary, the results reinforce the view that care should be taken in using outsole wear marks in forensic investigations until more information becomes known through sound research.

It is therefore concluded that as a follow up to this Pilot Delphi Round 1, a Delphi Pilot Round 2 should be commenced, amending the format where necessary to take account of recommendations. This round should have the aim of determining consensus (if possible) over specific wear areas as opposed to seeking consensus over the broad patterns shown initially under each structural/functional heading. This round would therefore only involve states for which more than one pattern has been given in Round 1. If consensus is not ultimately found, then the suggested reasons for this must be investigated. If the series of preliminary studies suggests that consensus is indeed possible, then a major study across the U.K. on the same basis will be initiated.

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Diagram 2.

Pathology	No. of responses showing wear in each given area of the sole (shown in brackets as % of total patterns received for each pathology)														
	Toe areas				Metatarsal head areas				Heel areas						
	Apex of 1st	Apex of 2,3,4	1st	5th	1st	2nd/3rd	4th	5th	Anterior	Anterior medial	Anterior lateral	Posterior medial	Posterior lateral	Central	Posterior
Calcaneo-valgus/ Pronation	6 (50%)		8 (66%)		8 (66%)	5 (42%)	3 (25%)	3 (25%)	1 (8%)	5 (42%)		5 (42%)			3 (25%)
Hallux Rigidus	4 (80%)			2 (40%)	1 (20%)	3 (60%)	3 (60%)	4 (80%)					5 (100%)		
Rearfoot Varus			3 (75%)	2 (50%)	4 (100%)	3 (75%)	1 (25%)	2 (50%)			1 (25%)		4 (100%)		
Hallux Valgus	1 (33%)		1 (33%)	1 (33%)	2 (66%)	3 (100%)	2 (66%)	2 (66%)		1 (33%)		1 (33%)	2 (66%)		
Parkinsons (shuffling gait)	2 (66%)	1 (33%)	2 (66%)	2 (66%)	3 (100%)	3 (100%)	3 (100%)	3 (100%)	1 (33%)	1 (33%)	1 (33%)	1 (33%)	1 (33%)	1 (33%)	2 (66%)
Retracted toes					2 (100%)	2 (100%)	2 (100%)	2 (100%)					1 (50%)		
Ankle Equinus		2 (100%)				2 (100%)		1 (50%)					1 (50%)		

Diagram 1.

Condition/state	No. of responses	Condition/state	No. of responses
Calcaneo-valgus pronated foot	12	Charcot-Marie-Tooth disease	1
Hallux Rigidus	5	Claw toes	1
Rear Foot Varus	4	Foot drop	1
Hallux Valgus	3	Forefoot Varus	1
Parkinsonism	3	Freibergs infraction	1
Ankle Equinus	2	Genu Valgum	1
Forefoot Valgus	2	Genu Varum	1
Hemiplegia	2	Hammer 2nd toe	1
In-toed gait	2	High stepping gait	1
Pes Cavus	2	Hypermobile 1st and 5th metatarsals	1
Retracted Toes	2	Metatarsus Adductus	1
Severs disease	2	Out toed gait	1
Talipes Equino Varus	2	Rheumatoid arthritis	1
Ataxic Gait	1	Short 1st metatarsal	1
Charcot Joint	1		

Diagram 2 (contd.)

Pathology	No. of responses showing wear in each given area of the sole (shown in brackets as % of total patterns received for each pathology)														
	Toe areas				Metatarsal head areas				Heel areas						
	Apex of 1st	Apex of 2.3.4	1st	5th	1st	2nd/ 3rd	4th	5th	Anterior	Anterior medial	Anterior lateral	Posterior medial	Posterior lateral	Central	Posterior
Forefoot Valgus	1 (50%)		1 (50%)	1 (50%)	1 (50%)	1 (50%)	1 (50%)	1 (50%)					2 (100%)		
Intoed Gait		2 (100%)		1 (50%)		1 (50%)	1 (50%)	2 (100%)			1 (50%)		2 (100%)		
Talipes Equino Varus				2 (100%)		1 (50%)		2 (100%)			2 (100%)		1 (50%)		
Severs Disease	1 (50%)	2 (100%)	1 (50%)			2 (100%)	1 (50%)	1 (50%)							
Hemiplegia		2 (100%)		1 (50%)		1 (50%)	1 (50%)	2 (100%)					1 (50%)		
Pes Cavus	1 (50%)	2 (100%)			1 (50%)	1 (50%)	1 (50%)	2 (100%)			1 (50%)		2 (100%)		

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Moving Towards Consensus: The First Draft of an Evaluative Instrumental Grid to Interpret Shoe Wear Patterns

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Mike Potter[3]

Abstract: In a first round pilot Delphi study of podiatrists' experiences of shoe wear marks, considerable lack of agreement had been noted among participating podiatrists. A second Delphi round has now been carried out. This second Delphi round showed a moderate move towards consensus among participating podiatrists in the context of overall wear interpretation. When chosen wear patterns were examined more closely, however, hidden agreements were found with regard to specific areas of wear – the focal points from which the wear was spreading. These focal points can be diagrammatically represented on a drawing of a shoe outsole with identifying numbers ascribed to each such point. When this analytical grid was used on depictions of wear patterns chosen by second round respondents, the location codes were found to be specific for the conditions to which the wear related. This preliminary grid may form the basis of the first "measuring" device capable of translating and giving meaning to shoe wear marks.

Introduction

In a Delphi study of podiatrists' experience of shoe wear marks, unexpected lack of agreement had been observed in the first round [1]. The data provided by participating podiatrists had been based on their

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many clinical observations over a number of years and supported the current belief that wear marks are of doubtful value to forensic investigators due to the many variables acting on the shoe outsole.

As past errors have been made with regard to wear mark interpretation in forensic investigations [2], the findings had been considered to be sufficiently important to be submitted for early publication [1]. When the data in this Round 1 Delphi study was examined in greater depth however, the possibility of a hidden consensus had been noted. Where participating podiatrists were in general disagreement over the overall pattern relating to specific foot/gait conditions, there had appeared to be some agreement over specific components of wear relating to each condition.

It had also been noted in this study that podiatrists had shown that specific patterns could be caused by a number of different foot conditions. In order to explore this further and seek a basis for consensus, a follow-up Delphi round was planned. This would test participant's strength of belief over which conditions could be associated with specific wear patterns where multiple suggested causes had been made. It would also test the level of agreement over specific areas of wear within an overall pattern being common to a specific condition.

Method

Information received in Round 1 was presented again to participants as a Delphi Round 2 questionnaire. In this, the Podiatrists were asked to associate wear patterns and wear pattern components with named conditions which had arisen on Round 1. In doing this, consensual agreement was sought over two specific aspects of the Round 1 data for which two Round 2 questionnaire sections were planned.

Section 1

In this first section, those patterns which had been shown as having several different possible causes in Round 1 (diagram 1) were presented again and respondents asked which of the conditions named could lead to that pattern. The patterns involved were reproduced on the questionnaire sheet along with the conditions which had been named by respondents in Round 1 as being related to these patterns. Respondents were asked to indicate which of the possible conditions they believed would cause the wear patterns shown and they were advised that they were not

Diagram 1

Section 1 of the Delphí Round 2 Pilot Questionnaire

Wear patterns given in Round 1 under more than one 'pathology' heading. Please tick ✓relevant boxes.

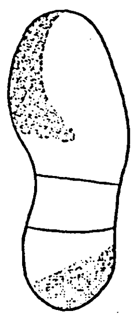
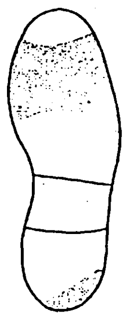
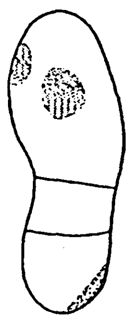
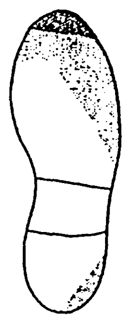
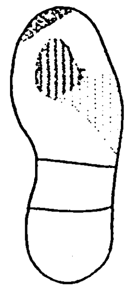
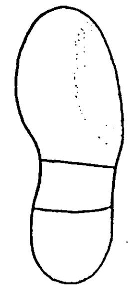
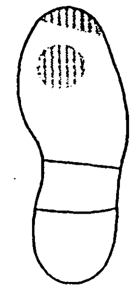
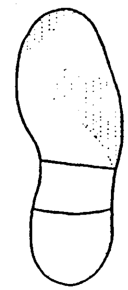
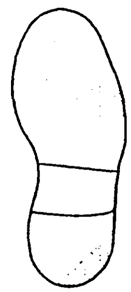
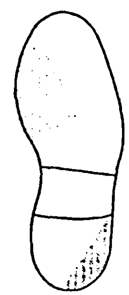
PATTERN 1.	PATTERN 2.	PATTERN 3.	PATTERN 4.
			
Pronated Foot ☐ Metatarsus Adductus ☐ Neither of these ☐ Other condition/s (please state) ☐	Pronated Foot ☐ Retracted Toes ☐ Forefoot Valgus ☐ None of these ☐ Other condition/s (please state) ☐	Pronated Foot ☐ Calc. Varus (compensated) ☐ Neither of these ☐ Other condition/s (please state) ☐	Forefoot Varus ☐ Freiberg's Infraction ☐ Hemiplegia ☐ None of these ☐ Other condition/s (please state) ☐ ....

Diagram 1 (continued)

PATTERN 5.	PATTERN 6.	PATTERN 7.	PATTERN 8.
			
Hammer 2nd toe ☐ Claw toes ☐ Neither of these ☐ Other condition/s (please state) ☐	Talipes Equino Varus ☐ Rearfoot Varus ☐ Neither of these ☐ Other condition/s (please state) ☐	Ankle Equinus ☐ Severs disease ☐ Neither of these ☐ Other condition/s (please state) ☐	Pes Cavus ☐ Hallux Rigidus ☐ Neither of these ☐ Other condition/s (please state) ☐ ....

PATTERN 9.	PATTERN 10.	PATTERN 11.	PATTERN 12.
			
Hallux Rigidus ☐ Short 1st Metatarsal ☐ Neither of these ☐ Other condition/s (please state) ☐	Hallux Rigidus ☐ Rearfoot Valgus ☐ Neither of these ☐ Other condition/s (please state) ☐	☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ....

restricted to a single response for each wear pattern. The need for the response to be based on knowledge and experience was emphasized to ensure that this was based on actual repeated observations and not personal theory.

Section 2

In Round 1, three conditions (Calcaneo Valgus/Pronation, Hallux Rigidus and Rearfoot Varus) had been shown by respondents as having several possible related wear patterns. In Section 2, the patterns depicted for these conditions were broken down and presented as wear pattern components. Of the three named conditions, fifteen possible pattern components were shown for Calcaneo Valgus/Pronation, six for Hallux Rigidus and four for Rearfoot Varus. Stated alongside each pattern component was the percentage of Round 1 respondents who had associated that component with the named condition (diagram 2). Respondents were invited to indicate with which of these components they were now in agreement in light of the consensual levels shown.

The questionnaires were sent directly to all eight Round 1 respondents who were asked to reply within three weeks of receipt.

Results

There was 100% response in Round 2 and all responses were received within four weeks of posting.

Section 1

In seven of the ten patterns presented to participants in Section 1, there was over 70% agreement that the pattern could have been caused by one of the possible conditions listed (graph 1), and overall, only one possible causative condition was rejected – that of Forefoot Valgus being associated with Pattern 4. For some patterns, a number of respondents had suggested additional causative conditions which had not been named in Round 1 (table 1).

In Section 1, respondents differed in their opinions as to which patterns were caused by each condition and some respondents indicated that they believed that some conditions could lead to more than one characteristic pattern (graph 2).

Diagram 2

Section 2 of the Delphi Round 2 Pilot Questionnaire

**Possible wear area components which make up a total characteristic wear pattern for named pathologies are indicated. Please tick those with which you are in agreement.
(See Key for explanation).**

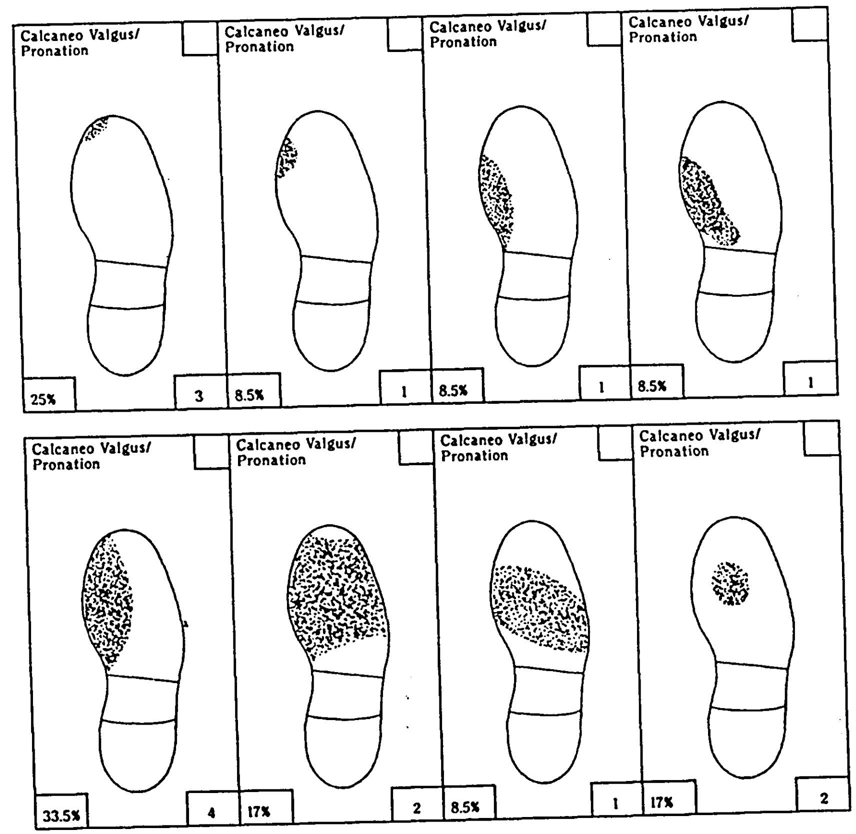


Diagram 2 (continued)

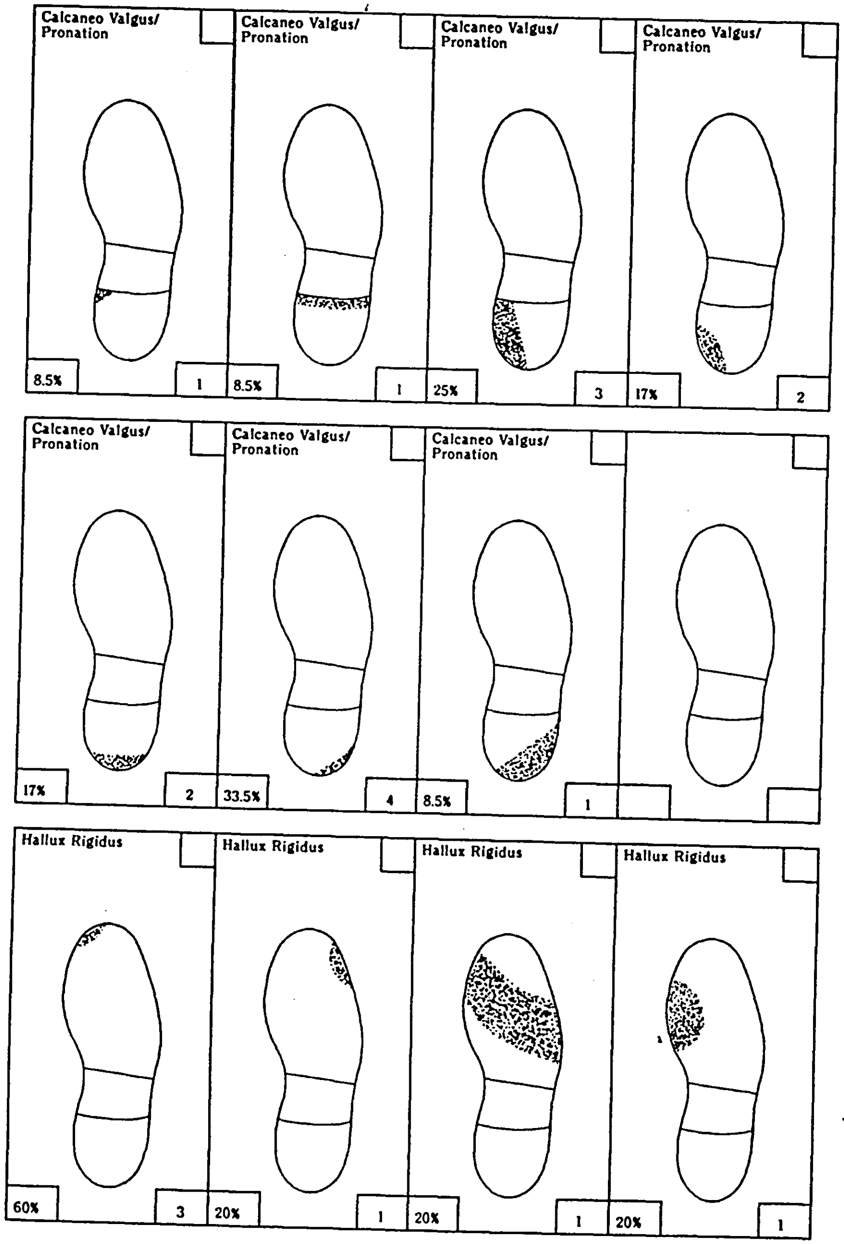


Diagram 2 (continued)

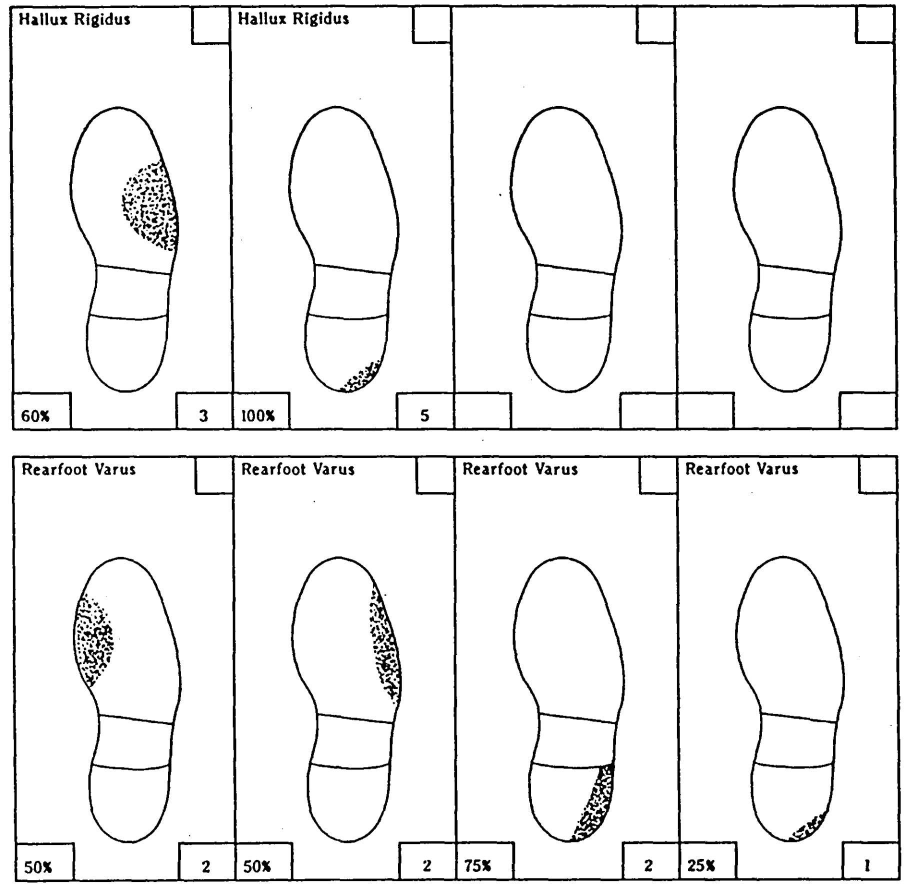
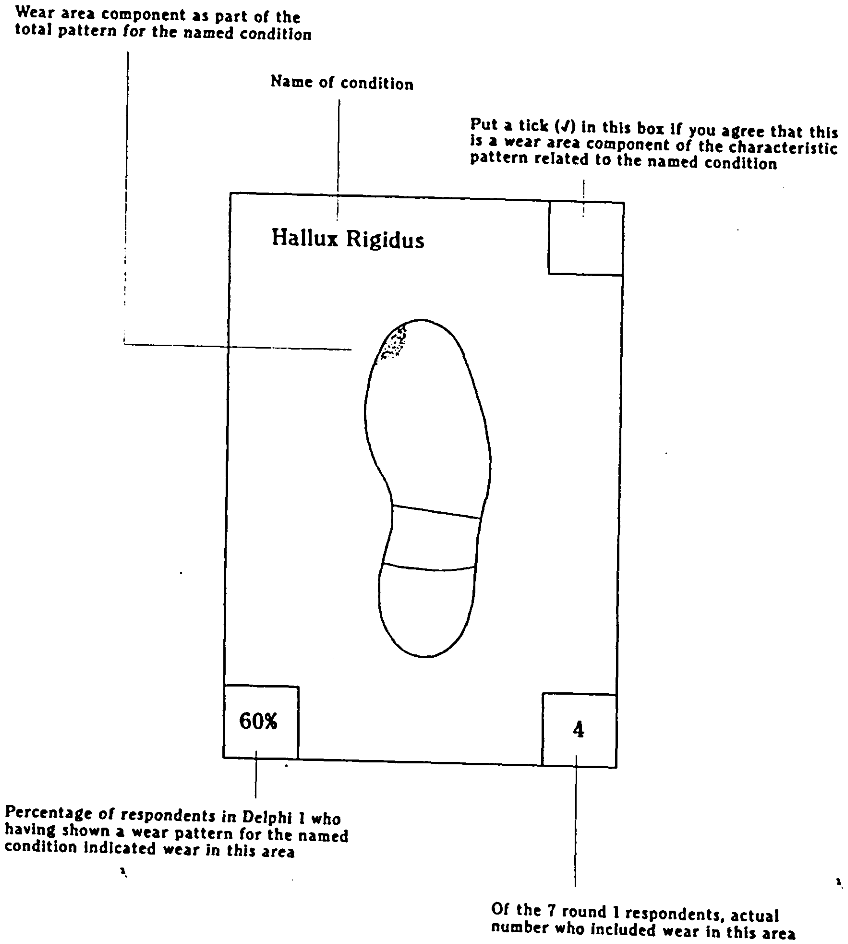


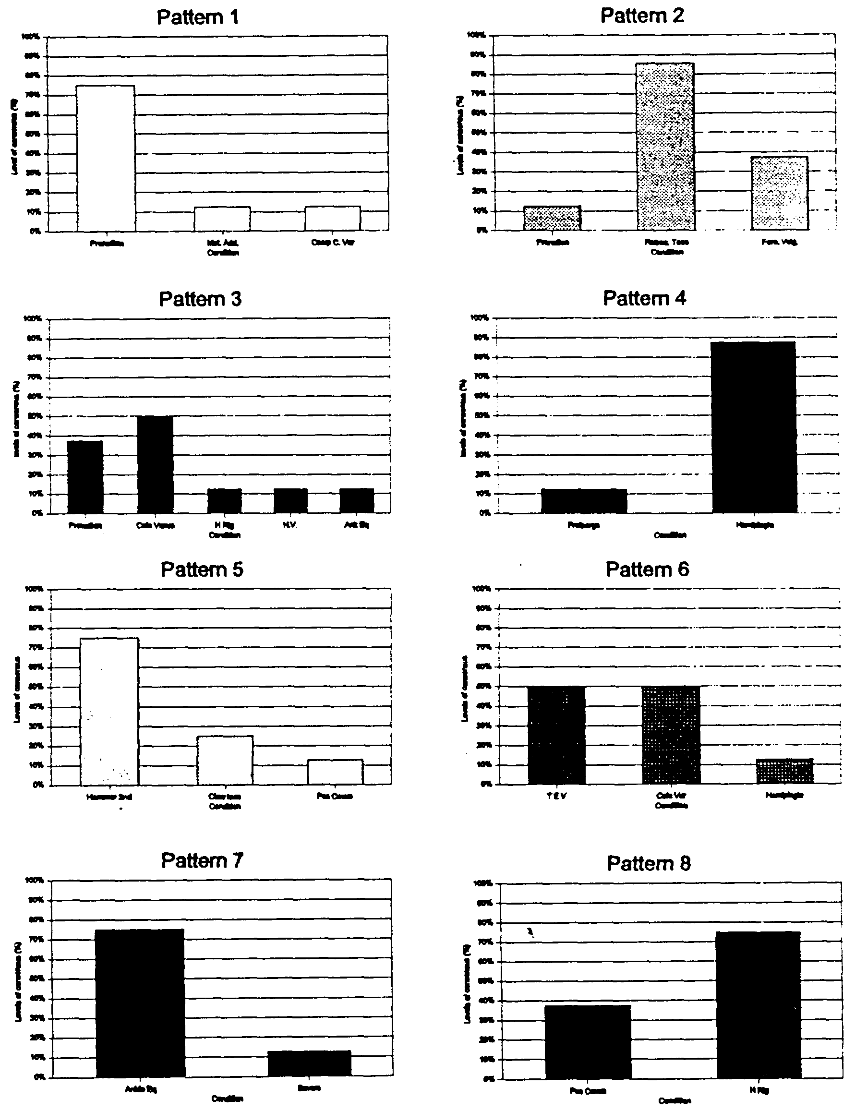
Diagram 2 (continued)

Key to Section 2



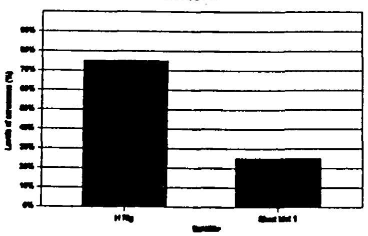
Graph 1

Levels of consensus in Section 1



Graph 1 (continued)

Pattern 8



Pattern 10

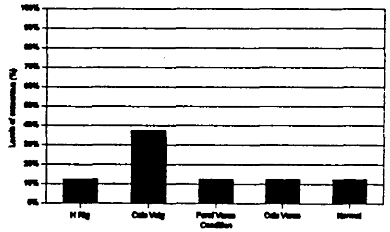
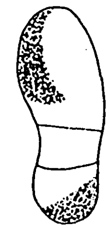
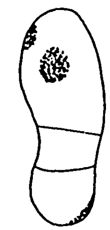
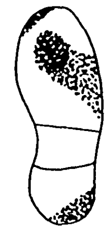
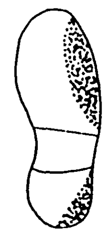
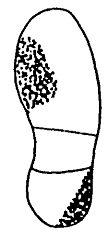


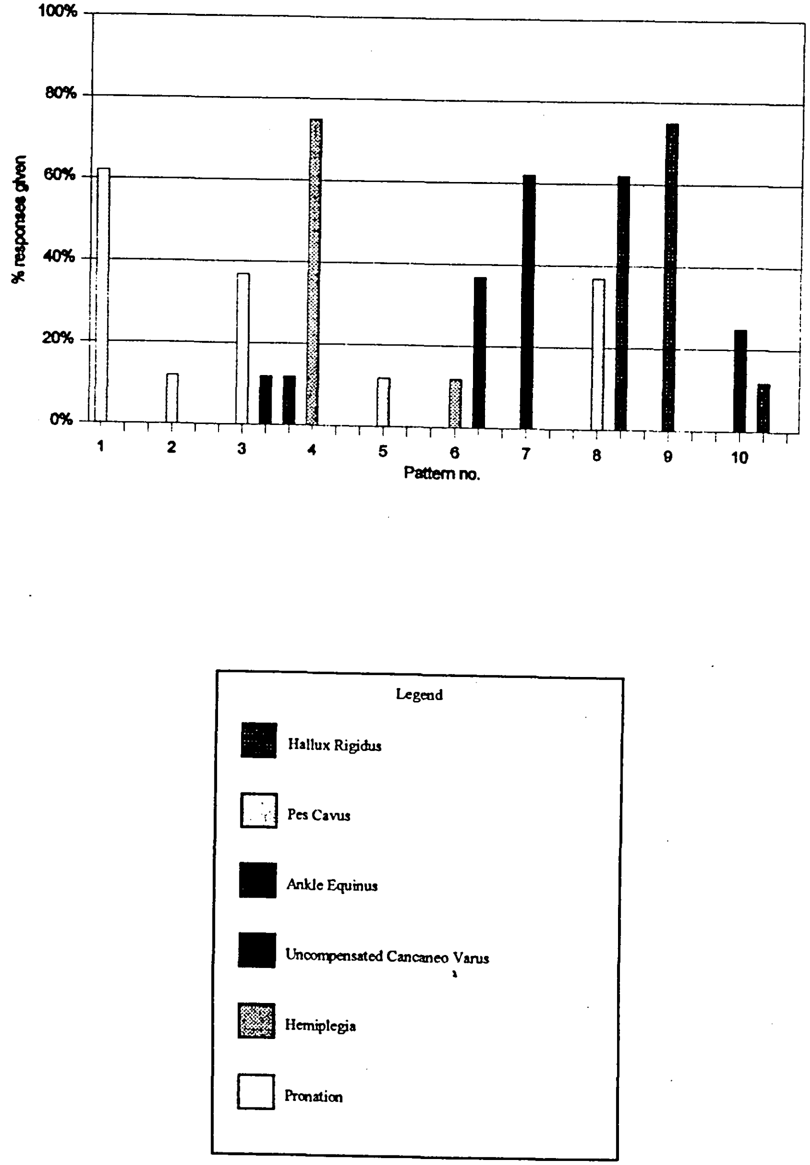
Table 1

Patterns for which additional causative conditions were suggested in Round 2

Pattern and number	Additional suggested causative conditions		Pattern and number	Additional suggested causative conditions
1 	Partially compensated Rearfoot Varus.		3 	Ankle Equinus Hallux Rigidus Hallux Abductor Valgus.
5 	Pes Cavus		6 	Hemiplegia
10 	Forefoot Varus Rearfoot Varus Normal Foot			

Graph 2

% response by condition and pattern



Section 2

There was 100% agreement that two of the separate pattern components shown for Calcaneo Valgus/Pronation and Rearfoot Varus were related to the associated condition and four of the depicted pattern components were not acknowledged by any of the participants (graph 3). Twelve of the pattern components had increased recognition from Round 1, five remained the same and seven had decreased.

Analysis

Although it had been noted in Round 1 that while different, the wear mark patterns offered by participants covered a number of common areas of the shoe sole, the consensual levels achieved in Round 2 Section 2 showing separate wear components were only moderate.

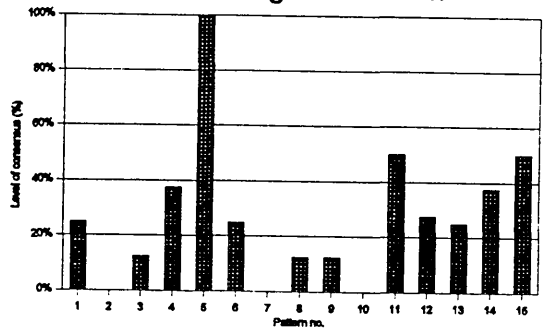
When the replies were studied in greater depth however, agreements emerged. The wear components offered in Section 2 were of diverse shape, but it was noted that very specific outsole locations were common to several of these components. These location points could be described verbally by relating them to the overlying foot anatomy (e.g., tip of 1st toe, 1st metatarso phalangeal joint, etc.) and reflected the areas from which wear would be spreading. A list of these points was drawn up and extended by drawing on clinical experience to include other possible locations of the outsole which could act as focal points of wear and an identifying code number was allocated to each point (table 2).

An analytical "grid" was drafted on the basis of these focal points (diagram 3). The less precise grid point representing the second/third metatarso-phalangeal joint area represents the difficulty in locating these specific anatomical points from the outsole. When this grid was applied to patterns and pattern components depicted in Round 2, those patterns could be represented by a grid code locating the grid points from which each area of wear in the patterns would be spreading.

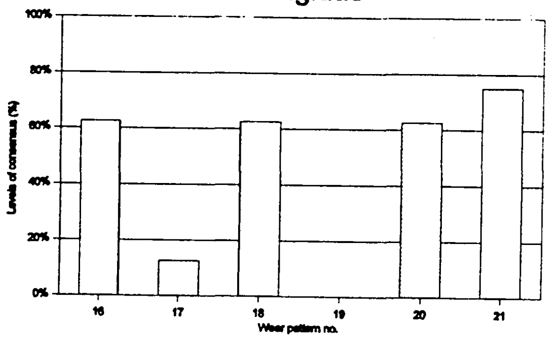
For example, in Pattern 7, wear was radiating from the 2nd/3rd metatarso phalangeal joint area (represented by Code 15) and from the tips of the 2nd, 3rd and 4th toes (represented by Code 21). Pattern 7 would therefore be represented by a grid code of 15/21 (diagram 4). The codes for all patterns in Section 1 and pattern components in Section 2 are given in tables 3 and 4. When this draft analytical grid was used to "measure" the depicted wear pattern components shown in raph 3

Levels of consensus in Section 2

Calcaneo Valgus/Pronation



Hallux Rigidus



Rearfoot Varus

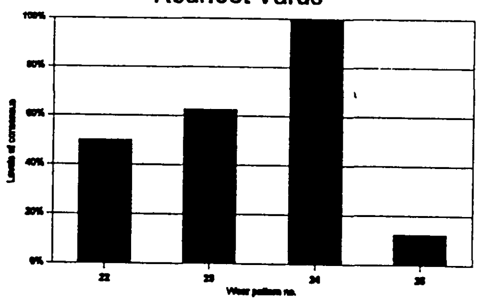


Table 2

Coded anatomical areas of the foot from which outsole wear would spread

Identifying code no.	Area of foot anatomy represented by code
1	Posterior Lateral Heel
2	Posterior Heel
3	Posterior Medial Heel
4	Medial Heel
5	Central Heel
6	Lateral Heel
7	Anterior Lateral Heel
8	Anterior Central Heel
9	Anterior Medial Heel
10	Anterior Inner Longitudinal Arch
11	Centre of foot
12	Base of 5th Metatarsal
13	5th Metatarso-phalangeal joint
14	4th Metatarso-phalangeal joint
15	2nd/3rd Metatarso-phalangeal joint
16	1st Metatarso-phalangeal joint
17	1st Toe
18	Tip of 5th Toe
19	Tip of 4th toe
20	Tip of 1st Toe
21	Tip of 2nd, 3rd and 4th Toes

Diagram 3

Draft instrumental grid for the interpretation of shoe wear marks

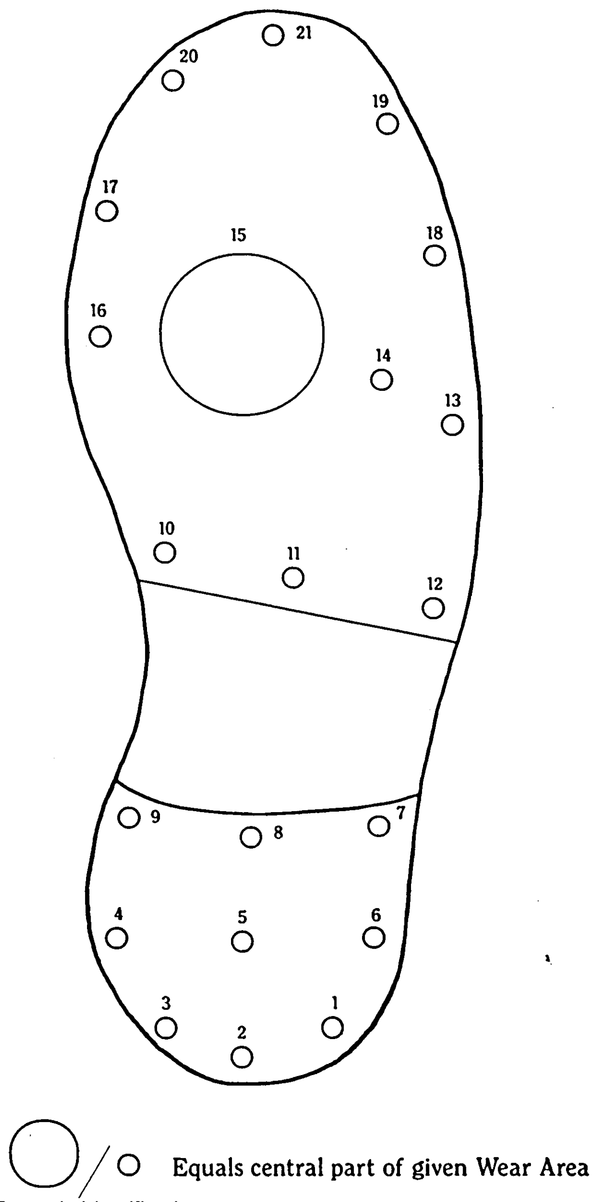


Diagram 4

Application of the instrumental grid

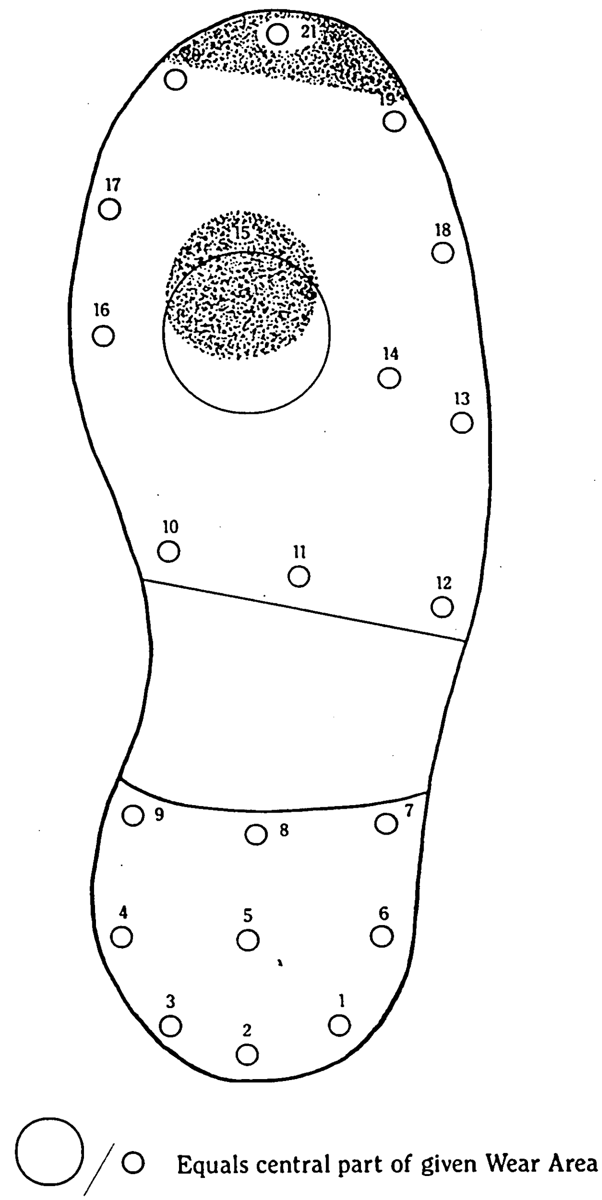


Table 3

Grid areas covered by Section 1 patterns

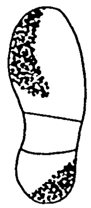
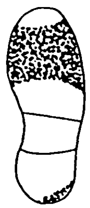
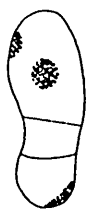
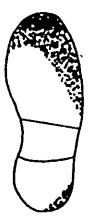
Pattern	Anatomical areas involved (with code)	Overall representative code
1 	Posterior/lateral heel area (1.) 1st Metatarso-phalangeal Joint (16.) 1st toe (17.) Tip of 1st toe (20.)	1/16/17/20
2 	Tip of 5th toe (18.) 1st toe (17.) 1st Metatarso-phalangeal joint (16.) 2nd/3rd Metatarso-phalangeal joint (15.) 4th Metatarso-phalangeal joint (14.) 5th Metatarso-phalangeal joint (13.) Posterior lateral heel area (1.)	1/13/14/15/16/17 18
3 	1st toe (17.) 2nd/3rd Metatarso-phalangeal joint (15.) Posterior lateral heel area (1.)	1/15/17
4 	Tip of 2nd, and 3rd toes (21.) Tip of 1st toe (20.) Tip of 4th toe (19.) Tip of 5th toe (18.) 5th Metatarso-phalangeal joint (13.) Posterior lateral heel area (1.)	1/13/18/19/20/21

Table 3 (continued)

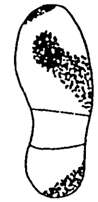
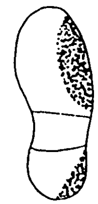
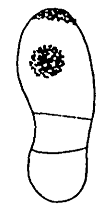
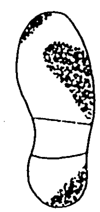
Pattern	Anatomical areas involved (with code)	Overall representative code
5 	Tip of 1st toe (20.) 2nd/3rd Metatarso-phalangeal joint (15.) 5th Metatarso-phalangeal joint (13.) Posterior lateral heel area (1.)	1/13/15/20
6 	Tip of 4th toe (19.) Tip of 5th toe (18.) 5th Metatarso-phalangeal joint (13.) Lateral heel area (6.)	6/13/18/19
7 	Tip of 2nd, and 3rd toes (21.) 2nd/3rd Metatarso-phalangeal joint (15.)	15/21
8 	Tip of 1st toe (17.) 2nd/3rd Metatarso-phalangeal joint (15.) 4th Metatarso-phalangeal joint (14.) 5th Metatarso-phalangeal joint (13.) Posterior-lateral heel area (1.)	1/13/14/15/17

Table 3 (continued)

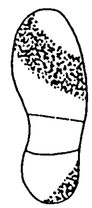
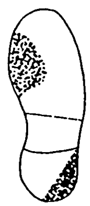
Pattern	Anatomical areas involved (with code)	Overall representative code
9 	Tip of 1st toe (20.) 1st toe (17.) 2nd/3rd Metatarso-phalangeal joint (15.) 4th Metatarso-phalangeal joint (14.) 5th Metatarso-phalangeal joint (13.) Posterior-lateral heel area (1.)	1/13/14/15/17/20
10 	1st toe (17.) 1st Metatarso-phalangeal joint (16.) 2nd/3rd Metatarso-phalangeal joint (15.) Lateral heel area (6.)	6/15/16/17

Table 4

Grid areas covered by Section 2 pattern components

Pattern component no.	Code		Pattern component no.	Code
1	20		14	1
2	17		15	1
3	16		16	20
4	16		17	19
5	16/17/20		18	13/14/15/17/20
6	13/14/15/16/17/18/19/20		19	16
7	13/14/15/16		20	13/14
8	15		21	1
9	9		22	16/17
10	7/8/9		23	13/18
11	4		24	6
12	3		25	1
13	2			

Section 2, the deeper hidden consensus with regard to these specific grid points became apparent.

Section 1

In using the instrumental grid to verify the level of hidden agreement in Section 1, it was noted that respondents had indicated that they believed some conditions to be responsible for causing a number of the patterns shown. As a number of grid points were repeated in these patterns, the grid points covered by that respondent were only counted once to avoid a bias favoring respondents who had given such multiple opinions (i.e., in effect, they were stating the same case several times). After taking account of this, it could be seen that a consensus of 70% or more had been achieved for several specific location points (graph 4).

Section 2

Section 2 had been devised to pursue hidden consensus for specific components of wear, but the true level of agreement only became apparent when the instrumental grid was applied to these components. As in Section 1 the same allowance was made for multiple code responses for single respondents and again, hidden levels of agreement represented a strong basis for consensus (graph 5).

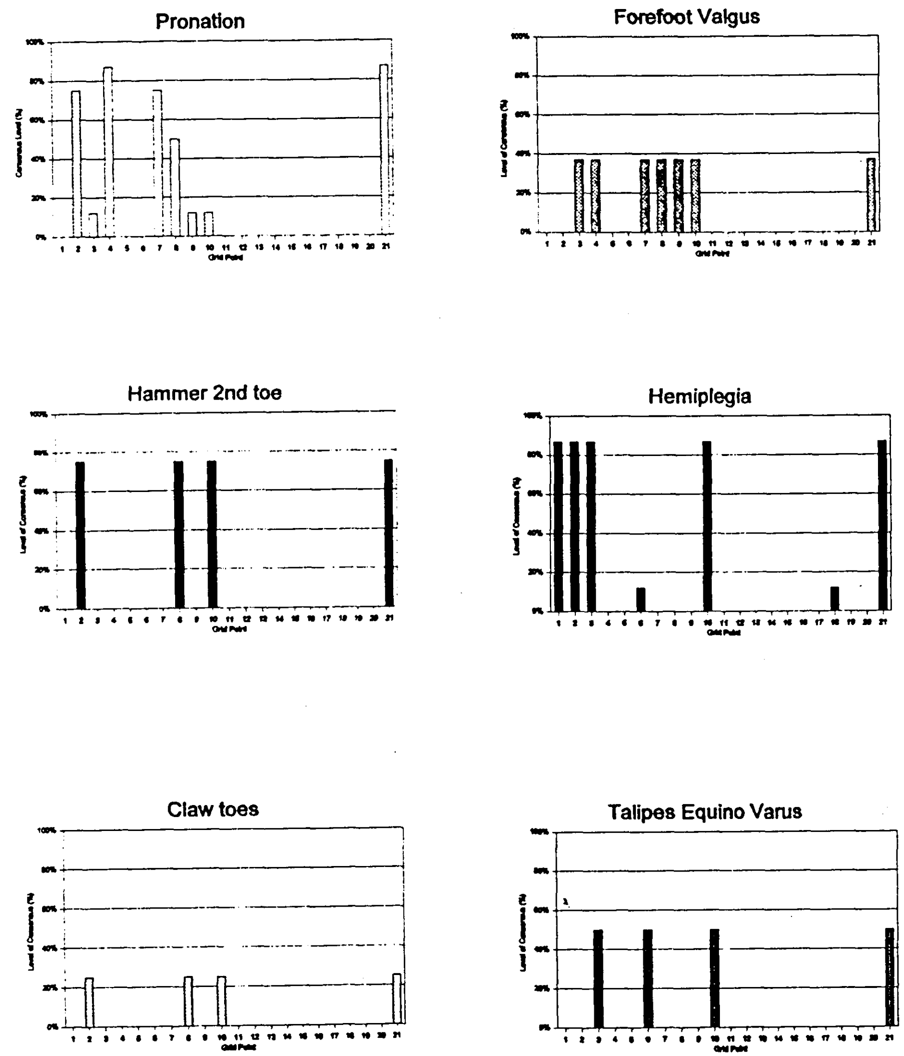
For Calcaneo Valgus/Pronation, the totality of patterns selected covered thirteen grid points. Of these thirteen points, 100% consensus had been achieved for three grid points (points 16, 17, 20). One grid point (point 1) had achieved 60%consensus and five grid points (points 9, 13, 14, 18, 19) had very low levels of agreement at 15%.

For Hallux Rigidus, the pattern components in total covered seven of the grid points. Of these seven grid points, 85% consensus had been achieved for four grid points (points 1, 13, 14, 20), two grid points (points 15, 17) had achieved 60% consensus and one grid point (point 19) had very low levels of agreement at 15%.

For Rearfoot Varus, the pattern components in total covered six of the grid points. Of these six grid points, 85% consensus was achieved on one grid point (point 6) and two grid points (points 13 and 18) had achieved 60% agreement.

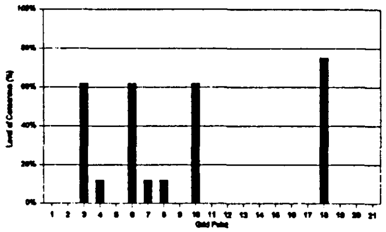
Graph 4

Hidden levels of consensus in Section 1 by grid points

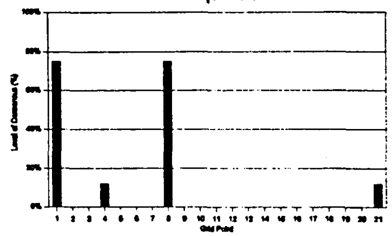


Graph 4 (continued)

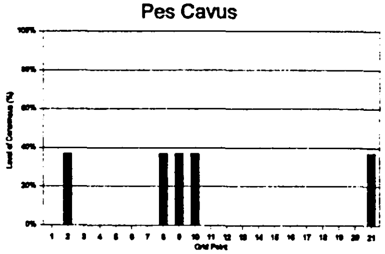
Calcaneo Varus



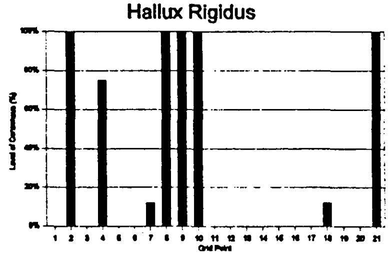
Ankle Equinus



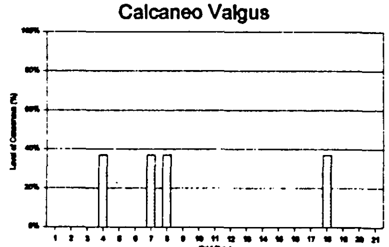
Pes Cavus



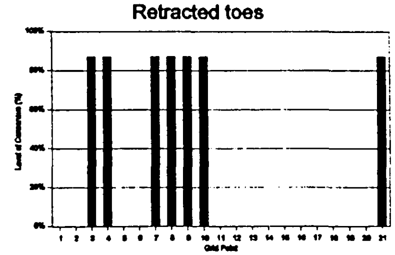
Hallux Rigidus



Calcaneo Valgus

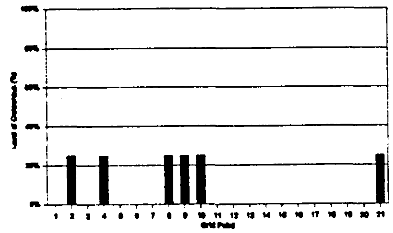


Retracted toes

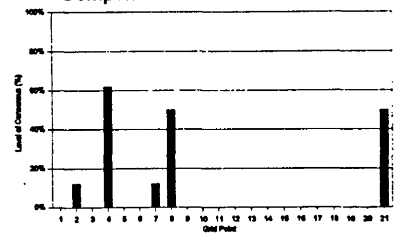


Graph 4 (continued)

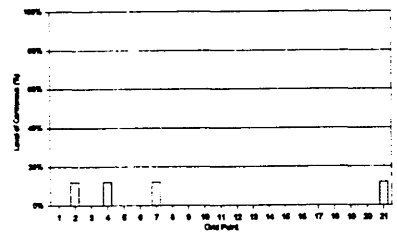
Short 1st Metatarsal



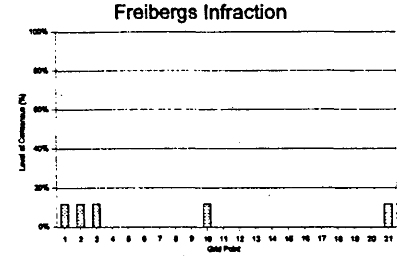
Compensated Calcaneo Varus



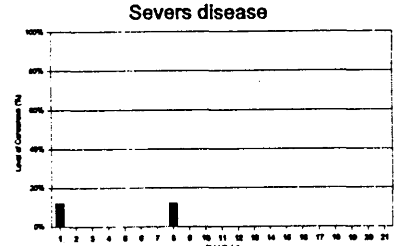
Metatarsus Adductus



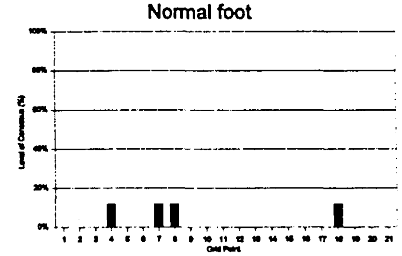
Freibergs Infraction



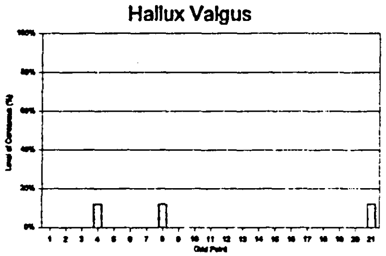
Severs disease

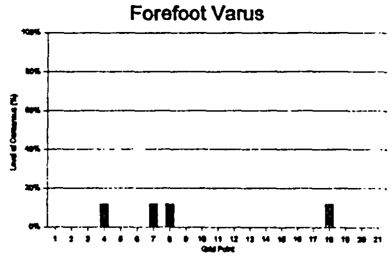


Normal foot



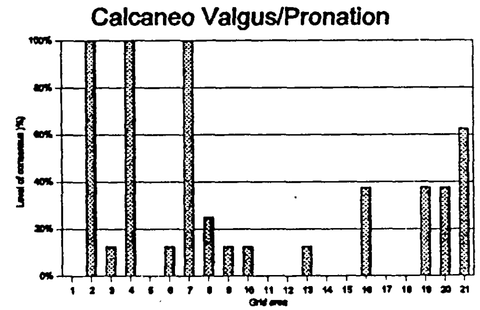
Graph 4 (continued)

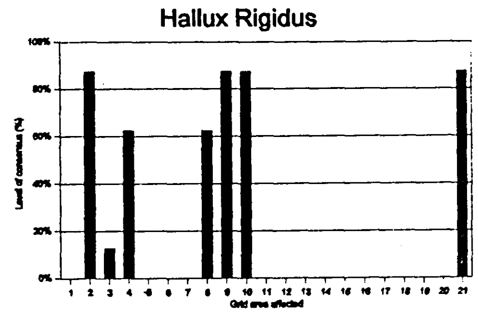


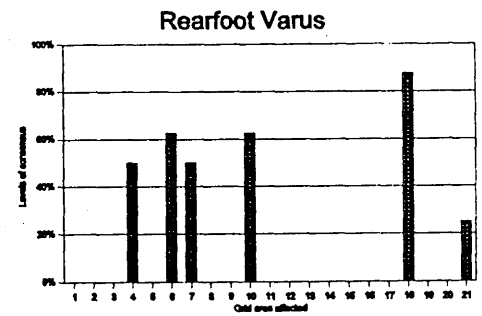


Graph 5

Hidden levels of consensus in Section 2 by grid points







Comparison of hidden consensus in Section 1 with Section 2

The three conditions being examined in Section 2 (Calcaneo Valgus/Pronation, Hallux Rigidus and Calcaneo Varus) also were chosen by respondents in Section 1 as being represented by some of the wear patterns shown. The hidden consensus in Section 1 was compared with that also observed in Section 2 for these conditions. Although the same respondents were involved in both sections, the context differed, so such a comparison would give an indication of the reliability of the responses. The consensual levels for the defined conditions in both sections compare closely. Graph 5 shows that the same specific grid points with strong and weak agreements occur in both Sections 1 and 2 and that these points differ between the three involved conditions. Only one grid point in Section 2 (point 17) had strong agreement yet had not been selected in Section 1.

Discussion

Although no categorical figure exists, a 70% level of agreement has been used in some Delphi studies [3, 4]. This level of consensus has therefore been achieved in recognition and interpretation of seven of the ten patterns shown in Section 1 and three of the twenty five pattern components shown in Section 2. This is a major shift from Round 1 where minimal consensus existed.

The higher level of consensus achieved in Section 1 over Round 1 of the Delphi study seems to demonstrate that when shown a characteristic pattern, podiatrists are capable of recognizing this and reaching high levels of agreement over interpretation. This is supported by the additional fact that nine alternative conditions not stated in Round 1 had been suggested for the same patterns presented again in Round 2.

This situation differs markedly from Round 1, when many different wear patterns had been suggested as being characteristic for a common condition. It appears that when asked to reproduce a characteristic wear pattern from memory alone, podiatrists have difficulty; however, when shown a pattern and asked for an interpretation, this is an easier task, especially when a limited list of possibilities is also available. Recall from memory has proved difficult, yet when faced with an image, memory recognition occurs. Similarly, most people have no difficulty in facial recognition, yet have considerable difficulty in reproducing the face by drawing from memory. This phenomena is well known and understood by psychologists and is explained by the difference between recall and recognition memories in a visual memory context [5]. The consensual failure observed in Round 1 [1] may therefore be due to memory failure alone.

Although a swing towards consensus had been observed with regard to gross patterns, there were still areas of disagreement between participants. Subsequent Delphi rounds should either confirm or remove these opinion differences when respondents would be asked to give an explanation in support of such differences.

Delphi Round 2 moved towards consensus at two levels. The gross picture (i.e., that of fully depicted wear) has moved towards agreement but differences of opinion are still present. The instrumental grid using focal points for comparison, however, demonstrates a hidden basis for agreement and in Section 2, the apparently low levels of consensus are seen to dramatically increase when the grid is applied. The focal points represent areas of the outsole which relate to the functioning of the foot during its contact with the ground and from which the wear spreads. This is a potentially useful and novel manner of looking at wear marks.

Concern has been expressed by forensic scientists over the number of variables involved in outsole wear. Both variability in shoe wear belonging to the same individual and similarity of wear in shoes belonging to different individuals has been noted, thus limiting the value of outsole wear in identification [6]. It has also been stated that the number of factors influencing wear characteristics is also small [6]. Using focal points of wear as the basis of a measurement grid would address these concerns. Where shoe variables exist (e.g., age of shoe, sole material, shoe style, etc.), these variabilities could be eliminated by focal point assessment – the focal point remaining the same irrespective of the amount of wear and peripheral pattern shape.

Focal grid points would only record the fundamental effects of causative foot/gait conditions which would remain irrespective of the spread and peripheral variability of wear. They would therefore be giving information about the condition present which led to the wear and not about the individual specifically. If, however, the individual has an unusual causative condition, the probability of a link with that individual would be increased. The availability of 21 grid points also increases the number of wear characteristic factors available for consideration and the high number of possible selections of grid points could in some cases provide the powerful individuality required in forensic science. Common conditions would exhibit a bias towards a greater frequency of occurrence thus limiting the value, but conversely, more unusual conditions of foot functioning may reflect a high level of individuality.

Round 2 analysis of grid point consensus shows that combinations of grid point codes for each condition appear to differ. The method of recording shoe wear by focal point code as represented by the measurement grid may therefore be useful in identification after further investigation through subsequent Delphi rounds and validation at all levels.

Conclusions

This 2nd Delphi Round has moved towards a basis for consensus at two levels. At an obvious level, there is a moderate consensus basis reflecting the difference between the recall memory utilized in Round 1 and the recognition memory required in this Round 2. When examined on a grid point basis, a stronger hidden consensus is observed relating specific combinations of points to named conditions.

Although involving the same participants, results in Section 1 correlated closely with Section 2 results indicating that repeatability should be expected. This focal point basis is a potentially useful method of looking at wear marks and if 100% consensus opinion can be achieved in subsequent rounds, this could form the basis for an analytical measurement grid. Using focal points of wear, variables relating to materials, style and age of footwear would be eliminated as the focal point would remain the same irrespective of wear amount.

A follow-up Delphi Round 3 is now required for all patterns/pattern components that have not yet achieved either 0% or 100% consensus. In this next round, respondents should indicate with which patterns they are in strong disagreement and also mark focal points of wear on the depicted patterns in addition to justifying the maintenance of a minority viewpoint. If the higher levels of consensus sought can be achieved, then the concept of an evaluative interpretation grid would gain greater strength and testing and validation of the grid would follow.

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