An Investigation into Football-Specific Dynamic Balance Measures

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Candidate Declaration

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2. None of the material contained in the thesis has been used in any other submIssueion for an academic award.

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For Keavy Mae and Aria Rose

For always giving me a reason to persevere

Abstract

Dynamic balance is a key component required to be successful in many sports yet the importance of dynamic balance in elite level sports has not been identified. The aim of this programme of doctoral study was to determine whether sport specific measures of dynamic balance could differentiate for skill level in footballers.

Initially a literature review was performed to identify any gaps in the literature and to inform the research. A scoping review was then performed to provide an in-depth investigation into the understanding of the term dynamic balance and associated terms. More encompassing definitions of dynamic balance, postural control and postural stability were developed as well as a taxonomy to classify movements and existing balance tests. Following this, an investigation into important movements in football was conducted and those movements identified as important were classified using the taxonomy and aligned with existing dynamic balance tests to provide specificity. Finally, sport-specific measures of dynamic balance, along with a common balance measure used in football, were investigated to identify whether they had the ability to differentiate for skill level in footballers.

Definitions of dynamic balance and related terms demonstrated disparity, overlap and they fail to cover the full range of dynamic balance situations. There are numerous dynamic balance tests available, they lack specificity, and test selection is difficult due to the complex and multi-factorial nature of balance. The taxonomy provided an approach for differentiating dynamic balance components, comprehensive profile of existing dynamic balance tests and a tool to identify strengths and limitations of existing tests and identify sport specific tests. Important movements in football were identified as shielding the ball, a shoulder barge whilst running, jostling to win the ball and shielding the ball whilst jostling, accelerating and braking, and a single leg kick or standing volley. Investigations identified that no existing dynamic balance tests aligned with the important movements in football. The external forces test shows promise at being a measure that can differentiate for skill level in football. Time to stabilisation was lowest for elite players (1.33 s) followed by recreational players (1.91). A large effect size was observed between elite and recreational players ($g = -1.3$) and recreational and non-

football players (g = 0.82). There was a small effect size between elite and non-football players (g = -0.43). The mSEBT, kicking task and deceleration task were not considered a good measure of performance nor are they able to differentiate for skill level in football.

This programme of research identifies that previous research has not identified the components of balance that should be tested for in football, and previous research has not made use of sport specific tests to assess dynamic balance in football. It is recommended that future research in this field refers to the newly proposed definitions. Additionally, further work should investigate other outcome measures of dynamic balance and whether they provide a better indication of dynamic postural control strategies. Finally, future directions could focus on whether participant variability exists at different skill levels.

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Abbreviations

3D	Three Dimensional
ANOVA	Analysis of variance
AP	Anterior-posterior
BoS	Base of support
BBS	Berg Balance Scale
CoM	Centre of mass
CoP	Centre of pressure
DPSI	Dynamic postural stability index
FIFA	Fédération Internationale de Football Association
%FL	Percentage foot length
FRT	Functional Reach Test
ISB	International Society of Biomechanics
ML	Medio-lateral
mSEBT	Modified Star Excursion Balance Test
PL	Post-lateral
PM	Post-medial
SD	Standard deviation
SEBT	Star Excursion Balance Test
TtB	Time to boundary
TTS	Time to stabilisation
TuG	Timed up and Go
YBT	Y-Balance Test

Chapter 1 Introduction

1.1 Introduction

This thesis outlines a research programme investigating football specific dynamic balance measures. Within this programme of research, the different studies firstly focus on bringing dynamic balance and associated terms into concordance. Then using a newly developed tool to classify movements and identify sport specific tests studies, determine whether sport specific measures of dynamic balance can differentiate for skill level in footballers. This chapter firstly provides the motivation for the work, it further identifies the aims and objectives of the research and, finally, presents the thesis structure.

1.2 Motivation for the research

Association football is widely acknowledged to be the world's most popular single sport (Ritzer, 2012). An estimation by The Fédération Internationale de Football Association (FIFA) is that there are over 240 million active players in 204 countries with 1% participation at professional level (Stamm & Lamprecht, 2001). In the UK, it is the most popular sport to watch and participate in with more than two million people playing at least twice per month (Lange, 2020). Due to the popularity of the sport, studies investigating the fundamental skills required to play are numerous. The capacity of a player to perform actions which can have a major influence on match performance include sprinting, jumping, kicking and changing direction (Stolen et al., 2005). Over time the game has become progressively more athletic requiring varied forceful and explosive actions which are crucial in many game situations (Manolopoulos et al., 2016; Ramírez-Campillo et al., 2015). Performance on the pitch of elements such as passes, aerial duels, dribbling, feigns, receiving the ball from a player of the same team, interception of the opposition pass, and shots on goal demonstrate extremely high technical abilities. The performance of these actions is often at high speed and include opposition pressure, ball path flight changes and surface instability (Gerbino et al., 2007). There is considerable interest in the literature of these actions and constraints being better performed in the presence of well-developed body control, balance and in particular dynamic balance of players.

Dynamic balance is a key component required to be successful in many sports. The use of the term is widespread, however there is not an accepted definition (Pollock et al., 2000). It generally refers to an ability to maintain balance in the presence of varying challenges to posture. The production and use of a universally acceptable definition is essential to accurately report dynamic balance research. A definition that encompasses all the different components of dynamic balance will enable further research in terms of the importance of dynamic balance in sport, dynamic balance ability and training of dynamic balance.

Existing tests of dynamic balance in football are static in nature, have predictable environments and inadequately represent postural control demands in football specific situations involving complex and dynamically changing environments. They provide a single performance measure and do not provide detail pertaining to the control of the movement or the strategy involved in achieving, maintaining, or regaining balance. As it is purported that higher level athletes have better dynamic balance ability than lower level athletes and non-athletes (Hrysomallis, 2011), it is of interest to determine what these strategies are and how they differ in the most skilled athletes in comparison to lower level athletes. Differences in dynamic balance at different skill levels and across sports has been suggested to be due to training effects and movements that are specific to the sport population of interest (Hrysomallis, 2011). Additionally, dynamic balance has been related to injury risk and those with poor balance tend to suffer more injuries (Hrysomallis, 2007; McGuine & Keene, 2006). To the author's knowledge a comprehensive tool does not exist to support the identification of important movements for success in sport nor a method to determine suitable and sport-specific tests for assessing dynamic balance. Such a method would identify the important components of dynamic balance for a given population and provide a tool to obtain a detailed and comprehensive profile of all existing dynamic balance tests. Additionally, it would provide a tool whereby strengths and limitations of existing tests could be determined, aiding in the specificity of balance tests for the population of interest.

1.2 Aims and Objectives

The aim of this research was to provide an encompassing definition of dynamic balance and determine the extent to which dynamic balance differentiates skill level in football.

The objectives of this programme of research are as follows:

1. To provide a critical review of literature in dynamic balance, establishing current knowledge and identifying gaps that require further research.

2. To understand and provide an encompassing definition of dynamic balance and associated terms.

3. To identify the important dimensions of dynamic balance in football and to identify sport specific measures of dynamic balance in football.

4. To investigate the extent to which dynamic balance ability differentiates between skill levels in football and whether differences exist between limbs.

1.4 Thesis Structure

The chapters of this programme of research will be structured as follows:

Chapter two provides a critical review of the literature. It introduces balance and outlines the difficulties around current definitions, measurement techniques, balance research in sport, balance ability in sport and taxonomies used to classify balance.

Chapter three discusses the results of a scoping review of dynamic balance and associated terms.

Chapter four extends existing definitions to provide more encompassing definitions of dynamic balance and associated terms. Followed by the development of a new taxonomy that provides a tool to identify components of balance within human movement and a method to appraise and identify sport specific measures of dynamic balance.

Chapter five presents the identification of movements considered important for success of the game in football and identifies their alignment with exiting dynamic balance measures to provide specificity. This chapter concludes with a summary of the findings and identification of the most suitable measurement method for subsequent investigations.

Chapter six develops new sport specific measures of dynamic balance and uses these to investigate their ability to differentiate for skill level in football. A further focus is on a popular method of assessing dynamic balance in football and its ability to differentiate for skill level by providing detail of technique. Finally, differences in dynamic balance between limbs at different skill levels is presented.

Chapter seven presents an overview of this programme of research and final conclusions. The limitations and implications of this programme of research will be discussed and recommendations will be given for further research.

Chapter 2 - Literature Review

2.1 Introduction

The aim of this doctoral programme of study was to provide an encompassing definition of dynamic balance and determine the extent to which dynamic balance testing can differentiate for skill level in football players. To achieve this, the first objective was to understand and provide a comprehensive definition of dynamic balance. This chapter reviews the relevant literature in four sections.

1. An evaluation of general balance research is presented including an introduction to static and dynamic balance, and identification of difficulties arising from terms used synonymously and the concept of dynamic balance being multi-component.
2. Identification and evaluation of measurement techniques in dynamic balance research.
3. An evaluation of balance research in sport covering balance ability in athletes, balance ability at different competition levels, dynamic balance in football and dynamic balance components.
4. An evaluation of taxonomies used to classify item content of dynamic balance tests.

The chapter summary reviews the findings of the literature review and identifies the need for further research.

2.2 Balance

2.2.1 Human balance

Balance is a critical component of successful human activity across the lifespan: vital to the performance of activities of daily living and therefore essential for functional competence (Ragnarsdottir, 1996). It affects functional mobility and safety in the elderly, the development of postural control, and motor skills in children (Assaiante et al., 2005; Hatzitaki et al., 2002; Shumway-Cook & Woollacott, 1985). Balance is also vital to the performance of fundamental motor skills such as hopping, skipping, jumping, throwing, striking, and kicking and therefore essential for the performance of activities relating to sport.

The term ‘balance’ has no universally accepted definition (Berg, 1989; Ekdahl et al., 1989). As a mechanical term it can be defined using Newton’s First Law as the state of an object when the resultant load actions acting on it are zero (Hall, 1999). Human balance is considered a multidimensional concept, referring to the ability of a person not to fall (Berg, 1989; Winter, 1995b). It has been defined as maintaining steadiness on a fixed, firm, unmoving base of support (Riemann et al., 1999), as well as the ability to maintain equilibrium by positioning our centre of gravity (COG) over our base of support (Browne & O’Hare, 2001). Balance has additionally been categorised as static or dynamic and is often used alongside terms such as postural control and postural stability.

Static balance is generally understood as balance when not moving and is measured in a static condition i.e., stance however, this can be deemed imprecise as it does not take into account normal postural sway, considered part of standing balance (Ekdahl et al., 1989). Definitions for postural control and postural stability vary and will be explored in more detail later in the thesis.

A key piece of literature about the definitions of balance is that of Pollock and co-workers (Pollock et al., 2000) which argued that although the term balance was widely used and understood intuitively, there was no universally accepted definition. They suggested a clear definition was essential to clinical practice and, consequently, published a widely cited paper entitled “What is balance?” (Pollock et al., 2000) in which several definitions of key balance terms were provided. For ease of reference, their key definitions are listed in Table 2.1.

Table 2.1 Definitions of balance terms from Pollock et al. (2000)

Term	Definition
Balance	The state of an object when the resultant force acting upon it is zero.
Human balance	A multidimensional concept, referring to the ability of a person not to fall.
Stability	The inherent ability of an object to remain in or return to a specific state of balance and not to fall. The inherent ability referring to the physical properties of that object
Human stability	The inherent ability of a person to maintain, achieve or restore a specific state of balance and not to fall. The inherent ability referring to the motor and sensory systems and to the physical properties of the person.
Postural control	The act of maintaining, achieving or restoring a state of balance during any posture or activity.

Although the attempt to standardise the usage of balance-related terms is laudable, the definitions listed in Table 1 are limited in so far as they refer to a relatively narrow range of balance activities: those in which the body or support surface is not accelerating, and where the goal is merely not to fall. Many real-world balance activities require the body to accelerate, and thus require unbalanced forces. Such activities include those involving voluntary accelerations (such as sports or dancing), or involuntary accelerations such as travelling inside vehicles. More complex balance goals may involve maintenance of specific postures (such as standing on one leg) or progressing through a series of postures as in walking, dancing or tai-chi movement sequences. Perturbations to balance may occur from externally applied or removed forces, or from internal forces and torques generated by rapid limb movements. These types of activity have been termed ‘dynamic balance’; a term used as early as 1939 by Bass (1939) who defined it as:

> “The type of balance concerned in keeping one’s equilibrium while in motion, or while changing from one balanced position to another. Dynamic balance then pertains to the equilibrium evidenced through a series of changing positions taken successively”.

2.2.2 Dynamic balance

Literature evidence indicates a wide variety of definitions in use for the term dynamic balance which infer: the movement must conclude as a static state (Distefano et al., 2009) or the support surface (Shultz et al., 2000), and the centre of mass (CoM) must remain within the base of support (BoS) (Guskiewicz & Perrin, 1996). As identified in Section 2.2.1, dynamic balance can involve more complex demands on balance. As such, these definitions do not account for instances where the CoM is within the BoS and the velocity is directed outward, or where the CoM is outside of the BoS and the velocity is directed towards it (Hof et al., 2005), which is often the case in sport related movements; a sprint start or a football kick, for example. Additionally, the CoM lies outside the BoS for 80 % of the gait cycle during walking (Winter, 1995a). Even as early as 1989 it was considered that the term dynamic balance covers a “broad spectrum of situations”, and therefore is too broad a term (Berg, 1989, pp241). Yet, these limited definitions are still in use and the term dynamic balance is used synonymously with the terms dynamic postural control and dynamic postural stability. This presents problems relating to disparity between terms, identifying appropriate tests and providing a coherent research base on the topic of dynamic balance.

2.2.3 Synonymous terms

The definitions in use are inconsistent. For example, dynamic postural control has been defined as maintaining a stable base of support or centre of mass (CoM) during a movement (Winter et al., 1990), the ability to control body position to maintain whole body stability and orientation (Falk et al., 2014), and performing a functional task without compromising any part of the supporting leg (Wikstrom et al., 2004). Dynamic stability has been defined as the ability to maintain balance while transitioning from a dynamic movement to a static state over the base of support (Goldie et al., 1989; Gribble & Robinson, 2009; Wikstrom et al., 2005). Despite identification for the need of more encompassing definitions that account for the different scenarios of dynamic balance, current research fails to adopt previously proposed terms and to maintain or even provide consistent definitions of balance terms, in particular dynamic balance.

Within the literature, there are papers using the terms dynamic balance, stability and control without defining them, making it difficult to identify whether these terms are considered by different authors to mean the same thing or refer to different concepts. By stating a definition or using a specific test, authors have clarified their use of the concept; however, the literature is still lacking a generally accepted definition that encompasses all scenarios.

The lack of accepted definitions, synonymous use of terms and inability to identify what concept a paper refers to emphasises the need to explore the literature in depth to identify a root definition for each of the terms, to investigate the extent to which these terms are related and to gain an understanding of how this affects research around balance. A scoping review is presented in Chapter 3 which addresses these problems, identifying how these terms have been used in the literature and providing more encompassing definitions.

2.2.4 Dynamic balance components

There is opinion that balance is not a single construct but is made up of multi-components influenced by the task, the individual and the environment (Horak et al., 2009). This is based on Newell's model of constraints (Figure 1) which have been classified into three distinct categories: organismic, environment and task (Newell et al., 1989). Organismic constraints are those that refer to characteristics of a person such as genes, height, weight, muscle-fat ratio, cognitions, motivation and emotion. Environment constraints refer to global, physical variables in nature, such as ambient light, temperature, or altitude. Task constraint is more specific to performance such as task goal, specific rules associated with an activity, activity-related implement or tools and surfaces (Davids et al., 2008; 2013).

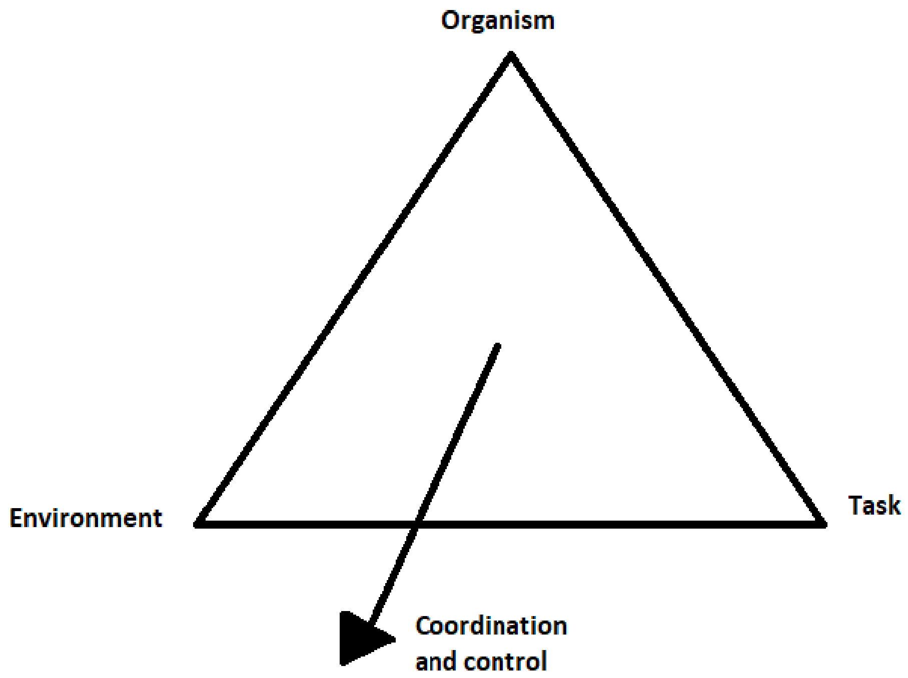

Figure 2.1 Newell's model of constraints, identifying the sources of constraints: the environment, the organism and the task. Recreated from (Newell et al., 1989)

Horak (Horak et al., 2009) developed a clinical test battery, the BESTest, to target six different balance control systems so that specific rehabilitation approaches could be designed for different balance deficits. The BESTest showed that participants with balance deficiencies in one category do not necessarily show deficits in other categories. This suggests that the tests measured specific sensorimotor skills rather than a general ability. Balance training research has also shown task specific training effects (Donath et al., 2017; Ogaya et al., 2011; Yaggie & Campbell, 2006). There were strong improvements in the trained balance task but minimal or no transfer to non-trained balance tasks.

These studies did not use participants with a sporting background so it is unknown whether this population would show improvements. Ringhof & Stein (2018) investigated whether dynamic balance tests (i) measure the same construct and (ii) can differentiate between artistic gymnasts and swimmers competing at regional level. Their results identified that there were no significant associations between a single leg jump landing, Posturomed[1] perturbation, simulated fall and single leg stance. Additionally, only single leg jump landing was able to differentiate between the two groups. They concluded that each of the dynamic balance tests measured task specific skills and not the same construct. Furthermore, they suggest that environmental, temporal and subject-specific constraints influence task specific skills of balance. Therefore, there are multiple internal and external conditions that are associated with a participant's experiences which will trigger the task-specific motor commands to achieve the desired effect (Ringhof & Stein, 2018). Davlin (2004) and Kioumourtzoglou et al. (1997) have found that gymnasts have outperformed other high-level athletes in similar tasks however, methodological differences may account for these differences. The differences in performance identified in the work of Ringhof & Stein (2018) is contradictory to the view that balance is a general ability. Their work strengthens the view that dynamic balance measures are not interchangeable and highlights the importance of selecting appropriate balance tests.

2.3 Measurement techniques

Numerous techniques have been employed to assess balance both statically and dynamically using functional tests and laboratory-based measures. The choice of balance measurement can depend on factors such as the population and/or the purpose of the measurement i.e., rehabilitation, injury risk, falls risk.

2.3.1 Functional tests

Dynamic balance has most commonly been assessed through functional tests, which traditionally have some subjective elements, for example in the Berg Balance Scale, a score is reported. Table 2.2 provides brief details of commonly used functional tests in the literature.

[1] The Posturomed is a platform suspended on an oscillation frame enabling the application of perturbations through variably adjusted oscillation amplitudes and oscillation.

Table 2.2 Commonly used functional balance tests in dynamic balance literature

Balance test	Reference	Method of assessment	Use
Timed up and go	(Mathias et al., 1986)	Uses the time that a person takes to rise from a chair, walk three meters, turn around, walk back to the chair, and sit down	Developed to predict falls, mostly used in older adult populations
Functional Reach Test	(Duncan et al., 1990)	Measures the maximal distance one can reach forward beyond arm's length while maintaining feet planted in a standing position	Developed to predict fall risk, mostly used in older adult and stroke populations
Berg Balance Scale	(Berg et al., 1995)	Determines the ability (or inability) to safely balance during a series of predetermined tasks (sitting, standing and postural transitions) using subjective scoring	Used in elderly and stroke populations
Star Excursion Balance Test	(Kinzey & Armstrong, 1998)	Measures single leg stance maximal reach distance in multiple directions	Used to assess physical performance, screen balance deficits, identify injury risk, and as a rehabilitation tool in sports populations
Single leg stance	(Fregly & Graybiel, 1968)	Uses the time that one can stand unaided in single leg stance	Used in a range of populations

2.2.1.1 The Timed Up and Go Test (TUG)

The TUG is a short and simple test that can be performed easily in clinical settings with the capability of predicting falls risk in the elderly (Shumway-Cook & Woollacott, 2000; Whitney et al., 2004). The test involves linking mobility skills involved in activities of daily living, sit to stand and turning, which require a control of balance and gait. The outcome measure of time taken to perform the test does not provide any details on balance strategies and it is not possible to identify and separate out how balance differs between the different components of the test. 3D kinematic analysis of the TUG performed by stroke patients and healthy subjects has shown that balance related parameters explain performance of the turn sub-task but not the gait sub-task (Bonnyaud et al., 2016).

2.2.1.2 The Functional Reach Test (FRT)

The FRT evaluates the limits of stability whilst in stance. As a subjective tool measuring reach distance of the arm, the test represents how far the participant can move their centre of mass (CoM) over their base of support (BoS) and has been shown to predict falls risk (Behrman et al., 2002). Although described as a test representing the movement of the centre of mass, traditionally there is no data collected that quantifies the CoM movement. Without any information pertaining to the movement of the centre of mass such as that of the CoM within the BoS and the minimum distance of the CoM from the edge of the BoS at any point in the movement, the test does not provide rich descriptions of the movement. Without this information, it is also impossible to identify strategies employed by participants in maintaining or restoring balance and how this differs between participants and populations. Laboratory measures incorporating three dimensional (3D) whole body kinematics and kinetics have been used to explore the correlation of CoM displacement with functional reach distance. It has been shown that functional reach is a weak measure of the stability limits as there is a low correlation ($r = 0.38$) between reach distance and displacement of centre of pressure (CoP) and a moderate correlation ($r = 0.68$) between forward rotation of the trunk and reach distance (Jonsson et al., 2002). Further, movement during the functional reach was observed to involve a large flexion of the trunk with small dorsiflexion at the ankle, which constrains the forward displacement of the CoP (Jonsson et al., 2002).

2.2.1.3 Berg Balance Scale (BBS)

The BBS is another test that has predominantly been used in older populations. This test has a subjective element to it. The scoring involves the administrator of the test to subjectively provide a number on a five-point ordinal scale, ranging from 0-4. Where “0” indicates the lowest level of function and “4” the highest level of function. The test does not provide any details on the balance strategies used within components of this test.

Kinematic and kinetic analysis of the BBS has identified that the dynamic stability margin does not correlate with the BBS score (van Meulen et al., 2016). Further to this, Vistamehr et al. (2016) found that laboratory-based measures of dynamic balance such as margin of stability only correlated with BBS in the paretic foot of stroke patients.

2.2.1.4 Star Excursion Balance Test (SEBT)

Traditionally the SEBT has been performed in single leg stance whilst reaching the other limb in eight predetermined directions. Its outcome measure is reach distance. It was found that reach distance was significantly influenced by leg length and so the accepted outcome variable is now normalised to leg length (Gribble & Hertel, 2003). As the SEBT does not involve any movement of the support limb, it could be considered as a static test of balance with a challenging element being movement of the non-supporting limb. The CoM always stays within the base of support when the test is performed successfully because the supporting limb remains static, and the reaching limb must not apply force to the ground. If the CoM were to move beyond the BoS, the participant would need to make an adjustment, such as putting their non-stance leg down to maintain balance, rendering it an unsuccessful trial. There is a possibility that one's centre of mass could move outside the BoS due to loading of the reaching limb, without it being an unsuccessful trial, which presents a difficulty of the test. Instructions for performing the SEBT include: make a reach with your other leg as far as possible and make a light tap on the measuring tape. Without pushing off the ground with your reaching leg, return it back to the centre of the testing grid (Gribble et al., 2013). The interpretation of "light tap" is likely to differ amongst participants and allows the participant to be supported by the floor for that moment. Without quantitative measurement of the light tap, it is difficult to quantify and control how much pressure is allowed through the foot. There is the additional difficulty of not being able to observe any shifting of weight to the reaching leg especially when focusing on reading the reach distance on the measuring tape. Therefore, it is difficult to determine how much of the light tap has contributed to the maintenance of balance. Additional difficulty related to the reliability of the results is the measurement error associated with reading the scale on the measuring tape to determine the reach distance. The interrater reliability of the SEBT is high with intraclass correlation coefficients (1,1) ranging from 0.86 to 0.92 (Gribble et al., 2013). However, this is due to raters having been provided with expert training. Often instructional documents and expert training are not provided (Gribble et al., 2013). It is not known how the reliability of the SEBT is affected when delivered by an inexperienced rater (Gribble et al., 2013). The SEBT involves flexion of the knee, and eccentric control of the knee extensors of the support leg. Previous studies have found relationships between greater eccentric strength of knee extensors and reach distance (Booysen et al., 2015; Lockie et al., 2013) and a significant relationship between knee flexion angles and reach distance (Robinson & Gribble, 2008), reduced eccentric strength and control of the knee extensors and a reduced ability to flex the knee due to over-activation would attenuate dynamic balance performance. Finally, the test should be carried out with four practice trials and three test trials, with eight directions that is 112 excursions, which can prove time consuming (Coughlan et al., 2012).

More recently, laboratory measures using 3D kinematics and/or kinetics have been used to provide insight into the movement patterns associated with the reach distances of the SEBT. This provides a more objective measure of the reach distance, increasing accuracy and avoiding experimenter dependence (Doherty et al., 2015; Doherty et al., 2016; Keith et al., 2016; Pionnier et al., 2016). The measurement error associated with the reach distance has been attenuated by determining reach distance from markers on the heel and toe of contralateral limbs, providing a more objective measure of reach distance (Pionnier et al., 2016). However, there is only one study to date that has employed this method and there has been no study that has investigated the reliability of this method. CoP variables have been used to identify how the body exploits its supporting environment in maintaining balance and specifically the complexity of the path of the CoP using fractal dimension (Doherty et al., 2015; 2016). Findings have identified that impaired performance in the SEBT results from changes in temporal and kinematic measures as well as reduced ability to effectively use the available base of support. This provides the ability to identify differences in movement patterns missing from the SEBT in its traditional approach. Nevertheless, the small number of studies using a laboratory-based approach and the different methodologies present difficulties when comparing results.

Although the analysis of the SEBT has been modified from a functional measure with summary values in its traditional form to one with the ability to identify differences in movement patterns and the ability to detect small changes, the test still involves the use of a static base of support. As such, it may be considered pseudo-static. Additionally, it is not representative of most movements that occur during sporting activities. As most of the literature for the SEBT focuses on injured populations, namely ankle injuries, there is a lack of evidence that identifies different balance strategies of non-injured populations and whether control strategies differ in athletes of different skill levels.

2.2.1.5 Single leg stance

The oldest reported test of balance is single leg stance (Fregly & Graybiel, 1968; Fregly et al., 1973). Often conducted with eyes closed to add difficulty for those without a balance disorder, it uses the time the participant remains in balance before having to make a postural adjustment, for example putting the non-stance leg to the ground, as an outcome measure with specified criteria to stop the test. It has been justified as a method of assessing balance in football because it replicates the unipedal posture used for sport specific technical movements such as passing and shooting (Paillard & Noe, 2006). However, within sport a single leg stance is never an isolated movement and is always preceded and most often followed by additional movement.

Using the amount of time a participant remains in balance as an outcome measure for single leg stance provides no quality of information relating to balance strategy. Second to this, when using single leg stance to evaluate change in performance it is important to note that Goldberg et al., (2011) found that this test is unlikely to be sensitive to change in performance in geriatric clinical settings and research studies.

Within the literature there is evidence of tests involving double and single leg stance with an additional challenge of an unstable surface that have been referred to as dynamic balance tests (Hrysomallis, 2007). Examples of unstable surfaces include the use of foam balance mats (Carolyn et al., 2005), and wobble and tilt boards (Hrysomallis, 2007). These methods provide destabilising challenges from the surface interaction by increasing the degrees of freedom of movement, decreasing the size of the base of support and reducing somatosensory information. However, these tests still involve a static base of support in the sense that the stance leg is in contact with the same surface throughout the test and the participant's centre of mass remains within the base of support unless there is a loss of balance. As such, these tests should be classified as static balance tests with challenging conditions. Additionally, the traditional use of time on balance within these tests as an outcome measure does not provide rich and meaningful information on balance strategies employed.

The aforementioned tests are useful as screening tools (Browne & O'Hare, 2001) however, as there are no rich descriptions of the movements providing details of any strategies employed by participants in maintaining or regaining balance, they cannot be used to quantify balance ability. Without valid kinematic and or kinetic measures, any small changes in a person's ability to balance or differences between populations would be difficult to detect. The lack of correlation between traditional scoring and laboratory-based measurements of the tests also calls into question the use and interpretation of these tests. It may be that some tests and sub-components of tests measure different constructs of dynamic balance, which will be discussed later in this chapter. It is also evident that many of these tests have been developed for older populations and determining risks associated with strokes and falls (Table 2.2). To the author's knowledge these tests, except for single leg stance and SEBT have not been used in sports populations. It is unknown whether these tests can differentiate between balance ability in populations other than those they have been used for. Additionally, their ability to differentiate between skill level of athletes would need to be investigated.

2.3.2 Laboratory based assessments

There are a range of laboratory-based methods available for assessing dynamic balance. Force plates and 3D motion capture are often used in balance assessment. Systems where results can be accessed quickly exist such as NeuroCom SMART Equitest system, Chattecx Balance System, Neurocom Pro and Smart Balance Master, and Biodex Stability System (Guskiewicz & Perrin, 1996). These systems can measure balance dynamically by altering the stance of the participant or provide rotational and translatory capabilities to provide the option of an unstable support surface. They can also monitor CoP and ground reaction force (GRF) for those that have force plates built in.

2.2.2.1 Force plates and 3D motion capture

Force plates have been used in balance research where postural sway has been an external criterion of balance. Measurements of the excursions of CoP can be recorded from force plates (Berg, 1989). CoP represents the centre of distribution of the total force applied to the supporting surface, and it varies according to both the movement of the centre of gravity and the distribution of the muscle forces required to control or produce the movement. Kinematics collected using 3D motion capture can provide information regarding the strategies of the motor system, and the motion of the limbs and trunk in maintaining or regaining balance, that cannot be determined from a score or time on balance. Although, in the tests discussed above, trunk and limb movements can be inspected visually, they are subjective interpretations. The use of 3D motion capture provides rich objective information that can be reviewed if necessary, to provide quantitative analysis. As detailed above, the SEBT has been assessed using 3D motion capture and force plates. This method of measurement allows a more detailed description of the movement to be analysed. Information is provided on strategies relating to the movement of the CoP and CoM in maintaining and regaining balance. Information is also provided relating to techniques employed by participants and can be related to their reach distance during the task, which provides more information than reach distance alone. Difficulties with the use of 3D motion capture and force plates are that they are relatively expensive, and their use is often confined to a laboratory. They also require calibration and post processing techniques before any valuable information can be extracted.

2.2.2.2 Clinical measurement tools

There are a variety of clinical tools known as dynamic posturography systems which objectively quantify balance using external perturbations, and/or visual conditions (Bloem et al., 2009). These devices include: The Neurocom SMART Equitest, the Chattecx Balance System, the Neurocom Pro & Smart Balance Master which record a participant's response to the external stimulus (Guskiewicz & Perrin, 1996). The Sensory Organisation test is a popular test for which the Neurocom SMART Equitest is used as a measuring tool, and can evaluate sensory contributions to balance control (Mancini & Horak, 2010). The Biodex Balance System is different in that it is a dynamic multiaxial tilting platform that measures the participant's ability to control the platform's angle of tilt, testing internal control mechanisms as opposed to reactions to perturbations. Tilt is quantified as a variance from centre, as well as degrees of deflection over time, at various stability levels. A large variance indicates poor muscle response (Guskiewicz & Perrin, 1996).

These systems provide data relating to the forward-backward sway and are considered a gold standard in measuring motor and sensory contributions to balance control. (Bloem et al., 2009). They are predominantly used in populations with falls risk or vestibular disorders (Guskiewicz & Perrin, 1996). However, the Pro and Smart Balance Master systems are most useful for assessing and rehabilitating orthopaedic injuries (Guskiewicz & Perrin, 1996). An important limitation to their use is that they are costly, in the region of 70,000 USD. Additionally, training is required to use them, testing is time consuming and the equipment requires space (Mancini & Horak, 2010). They require the participant to be in a stance phase and so only test visual perception and destabilising challenges that involve a deviation of the reference surface such as an imposed acceleration of the support surface or an inclination of the support surface. Therefore, are limited in their capability to provide information during dynamic activities for example gait and postural transitions.

Two previous literature reviews (Hrysomallis et al., 2006; Sell, 2012) have identified that when choosing a dynamic balance test, it is more favourable to use those with the ability to detect small changes in ability. Additionally, they identify that static balance performance is not reflective of dynamic balance performance. Further to this, Pollock identified that there are different components of balance and that selection of clinical balance tests should be related to the component of balance to be tested. In addition, factors with the potential to influence balance such as age, gender, leg dominance, height, weight, foot size, footwear, previous injury, sport participation level, sport participation specificity, visual feedback, learning effects and fatigue should be considered when assessing dynamic balance (Emery, 2003). There is evidence that activity levels and specificity are important considerations as well as a need for assessing dynamic balance, which are discussed later. When assessing a person's balance ability and identifying how this relates to skill level in a specific sport it may be more appropriate to use dynamic measures of balance that are specific to the movements performed by that individual. Additionally, many clinical balance tools which have been developed for use in the elderly and neurologically impaired populations are not appropriate for use in a healthy active population as they are not challenging enough, or they are predominantly static balance measures.

2.4 Balance in sport

Balance has been widely acknowledged as a key component for success in sport (Booysen et al., 2015; Chew-Bullock et al., 2012; Hrysomallis, 2011; Hrysomallis, 2007; Vuillerme & Nougier, 2004). Research in the field of balance and sport ranges from injury prevention/treatment[2], balance training[3], performance level assessments and skill profiling[4], association with skill level[5], intervention studies[6] and in the assessment of sport-related concussion (Catena et al., 2011).

Static balance is essential in sports such as shooting and archery (Ball et al., 2013; Mononen et al., 2007; Sattlecker et al., 2014). The important role of dynamic balance is apparent in the performance of freestyle sports such as snowboarding, skateboarding and windsurfing (Klos et al., 2019; Mkaouer et al., 2017; Staniszewski, 2019). In activities such as karate-kata, tai-chi, yoga, ballet or gymnastics, the goal is to control balance in sports specific positions, which can vary in difficulty depending on specialisation. In

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[2] Butler et al., 2013; Crockett & Sandrey, 2015; Dallinga et al., 2016; De Lima et al., 2015; Delahunt et al., 2013; Gorman et al., 2012,

[3] Akbari et al., 2016; Al-Khlaifat et al., 2016; Anoop et al., 2010

[4] Amiri-Khorasani, 2015; Ates, 2017; Balint & Spulber, 2017; Bhat & Moiz, 2013; Booysen et al., 2015; Bressel et al., 2007a; Butler et al., 2013; Butler et al., 2012; Chtara et al., 2018; Chtara et al., 2016; Davlin, 2004; Emirzeoğlu & Ülger, 2020; Fotios et al., 2013; Gkrilias et al., 2018; Guillou et al., 2007; Jadczak et al., 2019; Khuman et al., 2014; Matsuda et al., 2008; Onofrei et al., 2019; RouIssuei et al., 2018

[5] Butler et al., 2012; Davlin, 2004; Jadczak et al., 2019; Noe & Paillard, 2005; Paillard & Noe, 2006; Pau et al., 2015, 2019; Teixeira et al., 2011

[6] Akinci et al., 2019; Asadi & Arazi, 2012; Daneshjoo et al., 2012; Dunsky et al., 2017; Emery & MeeuwIssuee, 2010; Filipa, Byrnes, Paterno, Myer, & Hewett, 2010; Greig & Walker-Johnson, 2007; Jlid et al., 2019; Kunugi et al., 2020; Navarro-Santana et al., 2020; Paul et al., 2019)

sports where the support surface may be challenging or changing such as climbing, mountaineering, figure-skating and ice-hockey, the control of the centre of mass is important so as not to fall. Balance requirements in sports that require a seated pose such as rowing, canoeing, equestrian and cycling will be different to those requiring whole body movements. Movements that involve rotational exercises such as diving, dance and gymnastics will require a regulation of the centre of mass. Sports that involve combat and the application of force from an opponent such as fencing, boxing, karate, Tae-kwon-do, judo, wrestling, football and rugby will require different ways of controlling the centre of mass and dynamic balance (Zemkova, 2011). Despite this indication that there are different dynamic balance requirements in different sports, the following section identifies that static balance tests are still used to assess dynamic balance, and tests used lack the specificity required for the individual requirements of different sports.

2.4.1 Sports related balance measurement

Within balance research in sport, tests that are most commonly used include unipedal or bipedal stance using a stabilometer with the capacity to provide an unstable support surface (Davlin, 2004; Kioumourtzoglou et al., 1997), the SEBT and the Y-balance Test (YBT) (Bressel et al., 2007a; Butler et al., 2012). Tests involving single and unipedal stance in athlete populations are the same as those discussed earlier. They involve a stabilometer and use outcome variables such as time on balance and CoP measures. The difficulties associated with these tests are the same as those discussed earlier.

The two tests that are most common within the literature in sport are: the SEBT and the Y-balance Test (YBT) (Bressel et al., 2007; Butler et al., 2012). The SEBT has been described earlier. The YBT is a modified version of the SEBT using commercially available apparatus, designed to improve repeatability and standardize test procedures (Plisky et al., 2009). Like the SEBT, the YBT involves single leg stance whilst reaching the contralateral limb in the anterior, post-lateral (PL) and post-medial (PM) directions along a moveable slider. The tests are very similar in nature; however, the associated neuromuscular demands of each test are different. It has been shown that reach distances and kinematic profiles in healthy populations differ between the two tests which suggests the values should not be used interchangeably between the tests (Coughlan et al., 2012; Fullam et al., 2014). A difficulty with the YBT is that whilst the foot is pushing the slider forward it restricts the variability of the movement of the reaching leg in attaining the maximum distance possible for an individual because the foot must remain in contact with the slider for the entirety of the forward reach. An additional problem of the YBT is that it is considered as a dynamic balance measuring tool, yet like the SEBT, the stance leg remains stationary, and the CoM remains within the BoS, so should be considered a challenging static balance test. In addition to the popularity of these tests within the literature, anecdotal evidence suggests that these tests are most often used in football within the medical department when assessing dynamic balance of players. The justification of the use of these tests being specific to football is that the movement involved is indicative of those used within the game for example the single leg stance involved in kicking a ball. However, kicking a ball is always preceded and followed by other movements and so is never an isolated single leg stance event that occurs at a speed as slow as when performing the SEBT or YBT. Effectively the tests are evaluating the ability of the athletes to balance during a slow steady state movement as opposed to the quick movements and reactions required in the sport. The evaluation of dynamic balance ability in this static condition may not be challenging enough to elicit balance deficiencies in athletes (Emery, 2003).

Using the SEBT and YBT methods of assessing dynamic balance do not provide an accurate representation of control mechanisms required to maintain or regain dynamic balance and they are not sport specific. Measurement tools such as a stabilometer provide information regarding control mechanisms; however, they should be classed as a static balance test with a challenging condition. Dynamic balance tests where the supporting limb(s) is not fixed in position may be more specific to sport and situations that arise in the field. The previously discussed tests only test one component of balance, the ability to maintain balance in single leg stance whilst performing a destabilising movement. Dynamic balance testing in sport should involve testing all components specific to that sport and thus it is likely that a single dynamic balance assessment technique will not be appropriate. Instead, a battery of tests to assess different components as well as provide specificity to the sport relating to the participant will be required.

2.4.2 Balance ability in athletes of different sports

Previous research has found that athletes generally have superior static and dynamic balance ability when compared with control subjects (Davlin, 2004; Kioumourtzoglou et al., 1997; Perrin et al., 2002; Teixiera et al., 2011; Thorpe & Ebersole, 2008) and athletes of other sports (Bhat & Moiz, 2013; Bressel et al., 2007; Davlin, 2004; Gerbino et al., 2007; Perrin et al., 2002). Additionally, higher level athletes show better balance performance than lower-level athletes (Butler et al., 2012; Jadczak et al., 2019; Paillard & Noe, 2006; Paillard et al., 2006). Dynamic balance has been tested in these populations using stabilometry (Davlin, 2004; Kioumourtzoglou et al., 1997), the SEBT (Bressel et al., 2007; Thorpe & Ebersole, 2008), perturbations of the support surface (Perrin et al., 2002) landing from a jump and landing from a weight shift (Gerbino et al., 2007). Reasons for the better performance by athletes over controls and certain athletes over other athletes has been suggested to be due to training experience (Davlin, 2004; Kioumourtzoglou et al., 1997).

It has been proposed that gymnasts perform better than controls and other athletes in stabilometry tests as they have experience in co-ordinating body parts effectively, holding specific static positions as well as receiving specific training to maintain, recover and regain balance (Davlin, 2004; Kioumourtzoglou et al., 1997). Footballers have performed better than controls when tested with the SEBT and has been explained as being related to the type of training footballers experience, the amount of single leg tasks encountered during training and game play such as kicking a ball and reaching for a ball (Thorpe & Ebersole, 2008). Elite judoists have performed better than controls and ballet dancers in tests with a perturbed support surface. This has been explained through specificity of training and practice as they have to exploit their CoM to influence their opponent (Perrin et al., 2002). Whilst Gerbino et al. (2007) observed better performance of dancers in a jump landing in one outcome measure (sway index), there were no differences between dancers and footballers in another outcome measure, centre acquisition time. The centre acquisition time is a measure of how well a subject can attain a quiet, balanced state following perturbation. Gerbino et al. (2007) postulated that differences between these participant groups are down to the nature of their movements. In football, movements are defined by sprinting, cutting side-to-side, pivoting, and sudden stops and starts. There is also the involvement of physical contact:

pushing, pulling with other players and kicking a ball. Some of these movements can be unpredictable in occurrence. Whereas in dance, movements are choreographed and rehearsed, so a dancer is more in control of where they position themselves following a jump or movement. Davlin (2004) observed that gymnasts had superior dynamic balance to all other participants, and all athletes had better dynamic balance than the control group, but there was no difference between swimmers and football players during stabilometry testing. Footballers and swimmers do not have specific requirements within their respected activities to maintain a position as in gymnastics therefore; gymnasts would be expected to perform better. Bhat & Moiz (2013) found no differences between field hockey players' and footballers' performance in a SEBT. If you were to consider specificity of task, one might expect footballers to perform better as field hockey players are not required to stand on one leg and reach with the other during the game. The lack of difference might be attributed to the single leg stance not being an isolated event during play for footballers, and therefore, does not represent specificity of task for this group either. Further to this, testing with a SEBT has found no differences between gymnasts and footballers, but found footballers were superior to basketball players (Bressel et al., 2007). Gymnasts use cues from changes in joint position and acceleration through practice of balance skills for example on the balance beam. Footballers will experience passing, receiving and shooting during their training and therefore, experience single leg stance whilst performing additional tasks. Basketball players do not experience single leg stance and therefore are unlikely to have developed the specific requirements to perform well within that task.

Whilst it is plausible that the specificity of training may explain the enhanced performance of the certain athletes over others and/or when compared to non-athletes, there are additional points that have not been addressed. Bipedal stance tested in stabilometry, the SEBT and perturbations of the support surface should be considered tests of static balance with a challenging condition. They are often used and referred to as dynamic balance tests within the literature but do not involve a moving base of support. Aside from in gymnastics, single leg stance and jump landings never happen in isolation within the sports discussed above. They are always preceded and followed by other movements. Testing these in isolation is not specific of the experiences of these athletes in training or game play. Further to this, there are elements of the above test that are subjective or do not provide balance strategy information. For example, subjective elements of the SEBT do not provide any information pertaining to balance strategies involved and how these differ between participant groups. Further to this, studies have suggested that the measures used may not be sensitive enough to detect any differences between the participant groups (Bressel et al., 2007; Gerbino et al., 2007).

There is evidence to suggest that repetitive training experiences that influence motor responses result in experienced athletes having superior balance (Balter et al., 2004). There is also the argument that training experiences influence how proprioceptive and visual cues are handled by the participant producing superior balance (Ashton-Miller et al., 2001). Therefore, it is likely that the environmental constraints specific to individual sports influence dynamic balance ability and are likely different between different sports. The differences found between dynamic balance ability and type of sport played may be related to the type of balance test used as indicated in the above studies. Some dynamic balance tests may reproduce similar skills performed by an athlete in one sport but not an athlete in a different sport. There will be different skill requirements and environmental demands in each different sport, which are likely to challenge each athlete differently, influencing their dynamic balance ability. Further research is required to be able to identify the different components of dynamic balance required for each sport and to provide a dynamic balance test that challenges that component or a combination of components.

2.4.3 Balance ability and competition level

Previous research has compared dynamic balance between athletes at different competition levels to identify postural performance and strategy at different levels of expertise. Noe & Paillard (2005) tested the dynamic balance of alpine skiers at different competitive levels. They used a seesaw device on top of a force plate and compared CoP measures between groups. Similar performances were observed between groups when wearing ski boots but, surprisingly results showed that lower-level skiers presented with superior dynamic balance when barefoot. This impairment of the performance of high-level skiers was attributed to a long-term effect of repetitive wearing of ski boots. The unexpected results could be attributed to not measuring a component of dynamic balance that is important in skiing. It is unlikely when skiing that such a small area of the ski would be in contact with the ground and allow for a see-saw type movement, thus rendering the test non-specific to skiing. Additionally, there may have been an incorrect interpretation of the CoP variability. Elite level skiers showed significantly greater surface area of the CoP in standing posture without boots, which was interpreted as indicative of postural ability. Alternatively, the increased variability in higher-level skiers could be interpreted as functional and indicative of a releasing of degrees of freedom possibly due to their increased skill level.

Higher level footballers have better static balance than lower-level footballers in tests of single leg quiet stance (Paillard & Noe, 2006) and static posturography (Paillard et al., 2006) tests with higher level footballers displaying a significantly smaller CoP area and velocity than lower level footballers. Contrary to these findings, Pau et al. (2015, 2019) found no differences between higher level and lower level footballers during a static postural sway test. Researchers have identified that static balance ability is not reflective of dynamic balance ability (Hrysomallis et al., 2006; Pau et al., 2015; Sell, 2012) therefore tests involving single leg stance and static balance are not appropriate for determining dynamic balance ability.

Better performance of higher level footballers in comparison to lower level footballers or controls has been identified in tests of dynamic posturography (Paillard et al., 2006), an unstable surface (Jadczak et al., 2019) repetitive hip flexion-extension movements of the swinging leg (Teixeira et al., 2018), the YBT (Butler et al., 2012), and landing tasks (Pau et al., 2015, 2019). Within these studies measures with low values of CoP area (Paillard et al., 2006; Pau et al., 2015; Teixeira et al., 2018), CoP velocity (Paillard et al., 2006), deviations in the axis of the platform (Jadczak et al., 2019), vertical time to stabilisation (Pau et al., 2015, 2019), and dynamic postural stability index (DPSI) (Pau et al., 2019) are indicative of better performance. Butler et al. (2012) associate higher reach distances as representing better balance ability. Interestingly not all of the measures showed this trend. Butler et al. (2012) found that lower-level footballers performed significantly better on the anterior reach direction of the YBT and Paillard et al. (2006) demonstrated that anterior posterior (AP) total spectral energy of CoP between skill levels is not significantly different (Paillard et al., 2006). It is not known why lower level footballers reached further in the anterior direction of the YBT, nor why there were unexpected differences in spectral energies between groups reported by Paillard et al. (2006). Both outcomes were suggested to be due to different postural strategies between groups.

Paillard et al. (2006) suggests that the results of their study suggest when balance is evaluated with a sport specific task the level of performance can be discriminated. Additionally, other authors have justified their tests as being sport specific. However, one would argue that tasks involving single leg stance are very limited in their application to football tasks. It is rare that a footballer would remain in single leg stance for as extended a period of time as during the test. Additionally, single leg stance would not be an isolated movement within football. It has been argued that the better performance of higher-level footballers is due to a higher training load developing these skills (Paillard et al., 2006). The work of Pau et al. (2019) provides evidence that the use of a more sport specific test of dynamic balance is preferable and provides evidence that the use of sport specific measures of balance can differentiate for skill level. However, the test used only represents one component of dynamic balance. The authors also surmise that a forward jump landing is the most common movement in an actual match. There is no evidence presented to substantiate that claim, nor that it is an important movement and/or component of dynamic balance related to success of the game or injury risk and thus this statement warrants investigation.

Several factors may contribute to the superior balance of elite athletes. The training experience of athletes will be different to that of a novice, improving co-ordination, strength and range of motion. The repetitive experience of the skills involved may influence motor responses and an athlete’s ability to respond to proprioceptive and visual cues (Bressel et al., 2007). As higher-level athletes train more often, it is unknown whether the better performance can be attributed to intrinsic qualities i.e., natural predispositions or the amount high quantity of training which could improve specific postural adaptations. There is also no indication as to whether higher-level athletes possess better innate balance ability, which is potentially of interest for talent identification programmes. It is of interest to determine which components of balance are important in football and whether sport specific measures relating to these components of dynamic balance show the ability to differentiate skill level.

2.4.4 Dynamic balance in football

As discussed earlier in this chapter, there is a lack of consensus on the definition of balance terms, which is also evident in the dynamic balance research in football. In football specific literature, many articles have not provided a definition of dynamic balance. Where definitions have been provided the term has been defined in different ways:

- maintaining equilibrium during motion or re-establishing equilibrium through rapid and successively changing positions (Davlin, 2004)
- the ability of an individual to maintain stability of the centre of mass during movement (Butler et al., 2012; Chtara et al., 2018; Gkrilias et al., 2018; Halabchi, et al., 2020; RouIssuei et al., 2018)
- an ability to maintain the line of gravity of a body within the base of support and minimal postural sway (Paul et al., 2019)
- the ability of an individual to maintain the centre of mass within the body´s base whilst performing single leg movement (Lopez-Valenciano et al., 2019)
- the ability to perform an action while maintaining or restoring a stable position (Onofrei et al., 2019)

Regardless of the work of Pollock et al. (2000), there is no consensus on the definition of dynamic balance. It is of interest to determine the root of these definitions and to understand how the term and associated terms are used in the literature.

Literature relating specifically to dynamic balance in football ranges from identifying whether dynamic balance is associated with skill level[7], intervention studies relating to

[7] Davlin et al., 2004; Pailliard et al., 2006; Teixiera et al., 2011; Butler et al., 2012; Pau et al., 2015; Jadczak et al., 2019; Pau et al., 2019

improved performance[8], intervention studies aimed at injury prevention[9], injury risk (Butler et al., 2012), comparisons with participants of other sports[10], relationship with other performance measures[11], comparisons between player position[12], correlations with other balance measures (Meiners & Loudon, 2020) and player profiling[13].

The SEBT, modified SEBT (mSEBT) and the YBT are the most common tests when assessing dynamic balance in football. The mSEBT focuses on just three reach directions: anterior, postero-lateral (PL) and postero-medial (PM). It has been identified to capture the least redundant information and can be used to simplify the test's performance Hertel et al. (2011). The only difference between the YBT and the mSEBT is the instrumentation of the YBT. Of the above studies that have used one of the aforementioned tests, all have used reach distance (corrected for limb length and expressed as a percentage), with some also using a composite score for all reaches. The methodological issues with these tests have been discussed in Section 2.2.1.4.

Dynamic balance ability has been found to differ between football players and other sports athletes and controls when assessed with the SEBT (Bressel et al., 2007; Khuman et al., 2014), single leg stance (Davlin, 2004; Matsuda et al., 2017), and mobilisation tasks (Teixeira et al., 2011). Footballers have performed significantly better than basketball players (Bressel et al., 2007), volleyball players and cricket players (Khuman et al., 2014) in composite SEBT reach distance. Football players have demonstrated lower AP than medio-lateral (ML) sway in single leg stabilometry than swimmers, basketball players and controls (Matsuda et al., 2017). Additionally footballers have demonstrated smaller CoP sway area than non-football players during single leg stance (Teixeira et al., 2011). This suggests that differences exist in dynamic balance performance between sports. However, footballers have shown no significant differences in SEBT reach distance with gymnasts (Bressel et al., 2007), yet Davlin (2004) found footballers to have inferior

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[8] Filipa, 2010; Acinci et al., 2019; Jlid et al., 2019; López-Valenciano et al., 2019; Navarro-Santana et al., 2020

[9] Daneshjoo et al., 2004; Emery, 2010; Greig et al., 2007; Dunsky, 2017; Nagaraj & Solomon, 2019; Kunugi et al, 2020

[10] Bressel et al., 2007; Guillou et al., 2007; Matsuda et al., 2008; Khuman et al., 2014; Jadczaket al., 2019; Halabchi et al., 2020

[11] Chtara et al., 2016; RouIssuei et al., 2017; Chtara et al., 2018

[12] Ates, 2019; Emirzeoğlu & Ulger, 2020

[13] Gkrilias et al., 2018; Onofrei et al., 2019

dynamic balance to gymnasts in bipedal stabilometry, yet similarly to swimmers and controls. Matsuda et al. (2017) has found no significant differences in sway velocity during single leg stabilometry of athletes versus non-athletes. These differences may be attributed to the different dynamic balance tests employed and different components of balance being tested which may be more important for performance in different sports. The differences might also be attributed to a variation of the populations used in testing i.e., different skill levels and different playing styles.

There is evidence to suggest that differences exist in dynamic balance performance between skill level in football and playing position. Butler et al. (2012) identified that higher skilled players exhibited greater dynamic balance in the YBT than lower skilled players. However, they also found that less skilled football players reached further than higher skilled players during the anterior reach of the YBT. The difference in reach distance in the anterior direction of the SEBT was attributed to the effect of prior ankle injury on reach performance and ankle injuries being one of the most common injuries in football. Collection of data that provides information regarding the movement strategy using 3D kinematic and kinetic analysis, might help to explain differences between these groups. Ates (2017) and Emirzeoğlu & Ülger (2020) have found no differences in reach differences between football playing position, yet Akinci et al. (2019) found significant differences in PM reach distance between midfielders and wing backs. It is unknown what balance strategies relate to these differences in performance.

The dynamic balance tests above involve a static base of support and as discussed in Section 2.3.2 these tests cannot be considered sport specific. As previous literature has identified that static balance ability is not reflective of dynamic balance ability (Hrysomallis, 2011) it is uncertain whether athletes of different sports and higher skilled players would show the same differences in tests that provide sport specificity. In tests where better balance ability has been associated with lower CoP sway, it is unknown whether the same relationship would be replicated using sport specific tests. Additionally, Matsuda et al. (2017) found no significant differences between sway velocity in athletes versus non-athletes. It is not known whether higher skilled athletes would demonstrate better dynamic balance ability.

Furthermore, there is evidence that performance of the SEBT and YBT is not solely influenced by balance ability but also by limb strength and flexibility (Akinci et al., 2019; Chtara et al., 2016; John et al., 2018). It has been reported that stability in the PL reach direction is accomplished by the increased role of the hip flexors of the supporting leg, and the hip internal rotators in stabilising the pelvis in lateral movement (Neptune et al., 1999). Chtara et al. (2016) have identified significant positive relationships between isometric strength tests and directional reaching of the YBT. They found that the contribution of isometric strength depends on the angle of reach and the supporting limb. With the combination of methodological issues, lack of sport specificity and correlation of strength and reach distance, the SEBT may not be an appropriate method of determining dynamic balance ability in football. There is a need to identify alternative methods of assessing dynamic balance that are sensitive enough to identify differences and differentiate for skill level without being affected by the participant's strength or flexibility.

Recent research has adopted metrics such as time to stabilisation (TTS) using tests such as landing a jump or hop (Pau et al., 2015; Kunug et al., 2020; Jadczak et al., 2019; Pau et al., 2019; Navarro-Santana et al., 2020). TTS is associated with the participant's ability to stabilise the body following a jump landing. These measures are more sport specific but may be considered more laboratory based due to the use of force platforms. However, with the use of portable force plates these tests can be taken outside of laboratory conditions. One could argue that in a game of football the number of times a player lands from a jump in single leg stance is considerably less than they would experience running, dribbling, kicking, and destabilising forces due to an uneven surface or from opposition. A jump landing is also irrelevant to the game outcome, as the ball will be delivered elsewhere. Players are only likely to land in single leg stance from a jump to receive a ball on the chest or head, or to compete for a ball in the air. In doing so, they are never likely to land and hold that position for a period of time. For this reason, landing tasks may not be sport specific where they are not preceded or followed by additional movement. Additionally, landings are only relevant to jumping and so only describe abilities that are useful to that task in actual game situations. There are other balance challenging aspects of the game and there is no evidence to suggest that only single leg stance and landing strategy are the most important components of dynamic balance in football.

Apart from a jump landing, the remaining dynamic balance termed tests used in the aforementioned research could be considered as extensions of static balance tests. There is questionable specificity and representativeness of individual sport requirements. Different sports are likely to have different dynamic balance requirement therefore, we cannot be confident that the results of previous research can be considered to demonstrate that higher-level athletes possess better dynamic balance ability. It is important to find a dynamic balance test or battery of dynamic balance tests, which can differentiate for skill level, as the relationship between balance ability and the demands of the sport show a functional degree of specificity (Chew-Bullock et al., 2012). Poor dynamic balance ability could impact on acquisition and performance of other sport specific skills (Vuillerme & Nougier, 2004). If a link could be identified between better balance ability and skill level using sports specific measures and testing components of balance relevant to an individual sport, it would provide a strong argument for incorporating dynamic balance training into the training schedules of lower-level athletes to improve their performance. Further research would need to be conducted to determine whether these aspects are trainable.

2.5 Classification Systems

As dynamic balance covers a broad spectrum of situations, Berg (1989) suggested that dimensions of balance should be delineated into functionally significant headings: maintenance of a position, postural adjustments to voluntary movements, and reaction to external disturbances. These would provide a framework from which the degrees of difficulty of a task could be considered. These varying difficulties could be explained through basic mechanics applied to the human body. Identifying dimensions of balance and providing a framework to categorise difficulty would provide a functional interpretation of the concept of balance (Berg, 1989). This is not only useful in falls research but its application to all balance scenarios and measures would provide a method by which the strengths and limitations of measures can be assessed and lead to more appropriate and sport specific measures of balance to be chosen. Only two classification systems have attempted to assess balance measures. Both systems have drawn on Gentile’s taxonomy of tasks; a framework for analysing movement and action based on task and environmental complexity (Gentile, 1987).

Huxham et al. (2001) used a model to evaluate clinical balance assessment methods and the interpretation of test results. They considered that the difficulty of a balance component may increase or decrease due to the characteristics of a task (Huxham et al., 2001). Equally, there is a constraint on the way a task is performed due to the environment in which it is performed. Task and environmental constraints affect motor performance in two ways (Gentile, 1987): altering the biomechanical features of the activity; and affecting the amount of information that must be processed in order to achieve both balance and the motor goal, therefore altering balance demands (Huxham et al., 2001). Huxham et al. (2001) used the framework of the taxonomy of tasks (Gentile, 1987) to examine common balance tests by differentiating by biomechanical challenge (Table 2.3). The model firstly categorises the BoS as stationary or moving and secondly sub-divides tasks superimposed on the body. The use of this model identified biomechanical differences assessed by tests and thus which were involved in balance control. However, some tests such as those with multiple components (BBS and Performance-Oriented Assessment) fall into more than one class. This classification model fails to recognise that the environmental context of a task influences the biomechanical parameters and therefore has significant limitations. The role played by the amount of information processed from the task and its environmental context is also neglected (Huxham et al., 2001).

Table 2.3 Classification of some clinical balance tests according to biomechanical demands reproduced from (Huxham et al., 2001)

	Stationary Base of Support	Moving Base of Support
Unperturbed	Timed standing Steadiness in standing	10m walk, whether times or qualitative
Self-generated perturbations	Performance-Oriented Assessment – balance (most items) Berg Balance Scale (most items) Step test Functional Reach Reach test	Performance-Oriented Assessment – mobility Times up and Go Dynamic Gait Index Performance-Oriented Assessment – balance (turn item) Performance-Oriented Mobility Assessment Instrument Functional Obstacle Course
External perturbation	Performance-Oriented Assessment – balance (sternal thrust item) Postural Stress Test Shoulder Tap Test Clinical Test of Sensory Integration and Balance	
Sensory manipulation or perturbation		Performance-Oriented Mobility Assessment Instrument

Although Huxham et al. (2001) provided a way of classifying balance measures, they only applied it to a sample of clinical tests related to falling. Pardasaney et al. (2013) is the first and only study known to date which has performed a systematic item-level content analysis of balance measures. The method focuses on balance measures used for community-dwelling elderly people with the aim of developing profiles of balance measures describing the extent to which different aspects of the task and environment are represented within their items. This method allows content comparison across balance measures, to guide the selection of the most appropriate measure for a given purpose. In development of their classification system Pardasaney et al. (2013) modified Gentile's definitions of task role and motion in the environment for applicability to postural control. They did not include Gentile's concept of inter-trial variability due to its relevance to practise and skill acquisition. Figure 2.2 presents the classification criteria extracted from their literature review. They used seven factors related to task and environment that can influence balance performance and be systematically varied for balance assessment. Their results identified that most of the balance measures used in the community-dwelling elderly population failed to incorporate important task and environmental variations. It is possible that ceiling effects and reduced sensitivity to change of balance measures in this population are due to these content gaps (Huxham et al., 2001).

Role of Task*	Environmental Variation	Object Interaction*	Obstacle Negotiation	External Forces	Dual-Tasking	Moving People/Objects*
Static body stability	No variation	Present	Present	Present	Present	Present
Dynamic body stability	Variation of support surfaces	Absent	Absent	Absent	Absent	Absent
Transfers	Variation of visual conditions					
Gait	Variation of support surfaces and visual conditions					
Transfers and gait						

[a] Each item was coded on each of the 7 classification criteria listed. Asterisk indicates item was adapted from: Gentile AM. Skill acquisition: action, movement, and neuromotor processes. In: Carr J, Shepherd R, eds. *Movement Science: Foundations for Physical Therapy in Rehabilitation.* 2nd ed. Gaithersburg, MD: Aspen Publishers Inc; 2000.

Figure 2.2 Classification criteria from Pardasanay et al. (2013)

To the author's knowledge, there is no evidence within the literature that either of these tools have been used to determine important components of balance for their test population. The use of a classification tool would provide a framework to be able to identify whether a balance measure selected test components of balance that are specific to that population. It would also enable identification of whether the balance measure involves task and environmental influences that represent the range of task and environment components important for balance assessment. The model presented by Huxham et al. (2001) had a physiotherapy focus only assessing clinical tests; identifying balance deficits associated with falls. Pardasaney et al. (2013) only assessed balance measures commonly used to assess community dwelling older people. It is, therefore, unknown if these classification systems are valuable as tools for assessing balance measures for other populations and more specifically for sport. The Bloomfield Movement Classification (BMC has been used for classifying movements in sport (Bloomfield et al., 2004) most notably for analysing the agility demands of soccer (Bloomfield et al., 2007) and netball (Hale & O'Donoghue, 2007), and injury risk in netball (Williams & O'Donoghue, 2005). Despite the BMC not being a tool to assess balance measures, it may be beneficial in the context of football, to aid as an identifier of movements involved to help determine tasks and components of balance.

2.6 Chapter Summary

This review has identified that the literature concerning dynamic balance in terms of its definition is ambiguous. Many definitions exist in the literature for dynamic balance and the associated terms dynamic postural control and dynamic postural stability. These terms and definitions are often interchanged or used synonymously within the literature. Often definitions are not provided, so as a reader it can be difficult to understand and establish what the focus of the research is.

The importance of dynamic balance in elite level sports has not been identified. Balance is multidimensional in nature, dependent on the coordinated function of several body systems including vision, proprioception, vestibular information, muscular function, and energy systems. Environmental, temporal and subject-specific constraints influence task specific skills of balance. However, these are only aspects of balance. People can become unstable in different task and environmental conditions, so one's ability to balance is context dependent and depends on the particular body systems impaired (Horak, 2006). Evidence shows that in some sports, higher-level athletes have better balance skill, and athletes in some sports have better balance than in other sports. However, the balance measures used within sport and in particular football, underrepresent the demands placed on the postural control system and therefore, are not representative of sport requirements. Additionally, different sports are likely to have different balance requirements. Thus, different and relevant components of balance should be identified and assessed, providing sport specificity. The literature, as yet, has not provided an effective framework whereby important components of balance can be identified for individual sports, allowing tests and measures to be used specific to that sport. The literature has also identified that there are numerous balance tests available and there is a need for more sport specific measures.

A more appropriate and accurate method of determining dynamic balance and all its different components is required to complement a definition encompassing all scenarios of dynamic balance. The dynamic balance tests should be sensitive enough to be able to differentiate between skill levels across different sports and be more specific to sports situations.

Chapter 3 Investigation of the use of dynamic balance terminology and tests

3.1 Introduction

Chapter two provided an overview of the literature on balance. The term static balance is inadequate when used in reference to the human body. The body is never in a fixed or stationary condition as the somatosensory, visual, and vestibular systems are constantly interacting to make minor automatic adjustments to maintain body position in upright stance. Additionally, dynamic balance is not clearly defined. It has different and interchangeable definitions and has been used synonymously with the terms dynamic postural control and dynamic postural stability. There are many different tests available which all purport to measure dynamic balance yet there is no indication of their appropriateness. The evidence in Chapter two proposes that tests need to be sport specific and sensitive enough to differentiate skill level within and between individuals and within and across sports. Yet a lack of evidence and methodology to support choosing tests and measures, makes test choice difficult. Berg (1989) suggested that there are different dimensions of dynamic balance which should be defined according to headings: maintenance of a position, postural adjustment to voluntary movements, and reaction to external disturbances. These dimensions would then provide a framework from which the skill level within each category can be assessed.

It has been shown that static balance performance is not reflective of dynamic balance, (Muehlbauer et al., 2012; Pau et al., 2015; Sell, 2012) and that dynamic balance measures are better than static measures at differentiating previously injured from uninjured individuals (Ross & Guskiewicz, 2004). There is growing evidence that balance ability is highly task specific implying it has multiple constructs or dimensions (Giboin et al., 2015; Kümmel et al., 2016). As most falls occur in dynamic conditions (Shimada et al., 2003) and the ability to perform in destabilising situations is a requirement of many sporting and recreational activities, it follows that balance training and assessment is important in health and sporting contexts, and should be appropriate and specific to the task and population being studied. It is important to define dynamic balance in a general enough sense to encapsulate all possible situations requiring dynamic balance skill. Pollock et al. (2000) stated that:

> "The valid definition of clinical terminology is fundamental to the formation of evidence-based practice and to the provision of optimal patient care."

Therefore, the balance literature was investigated to ascertain whether there were suitably comprehensive and widely accepted definitions of the terms: "dynamic balance", "dynamic postural control" and "dynamic postural stability".

This chapter details an in-depth investigation into the understanding of the term dynamic balance and associated terms. The objectives were to:

- Identify how the terms dynamic balance, dynamic postural control and dynamic postural stability have been defined.
- Critically evaluate the literature to determine how these terms are understood.
- Identify the different test measures that exist and understand their relationship with the above terms.

3.2 Methods

A scoping review is a thorough approach used for identifying gaps in existing literature using a narrative or descriptive approach. Arksey and O'Malley's (Arskey & O'Malley, 2005) 5-stage framework was adopted to perform a scoping review investigating how the terms "dynamic balance", "dynamic postural control" and "dynamic postural stability" have been used in the literature; particularly focussing on their formal definitions and balance tests used.

3.2.1 Data Sources

The protocol for this scoping review had four steps: the search strategy was determined, then a literature search was performed, followed by a selection process for relevant articles and finally data were extracted for analysis. Figure 1 illustrates the search and selection process. A systematic search of literature was conducted to identify original research that included one or more of the terms "dynamic balance", "dynamic postural control", and "dynamic postural stability" in the title only. The search was limited to these terms in the title to constrain the number of articles generated. The search was conducted on literature published up to the end of 2017 using the computerised databases SPORTDiscus; CINAHL; MEDLINE; Scopus; PubMed; Web of Science and Science Direct.

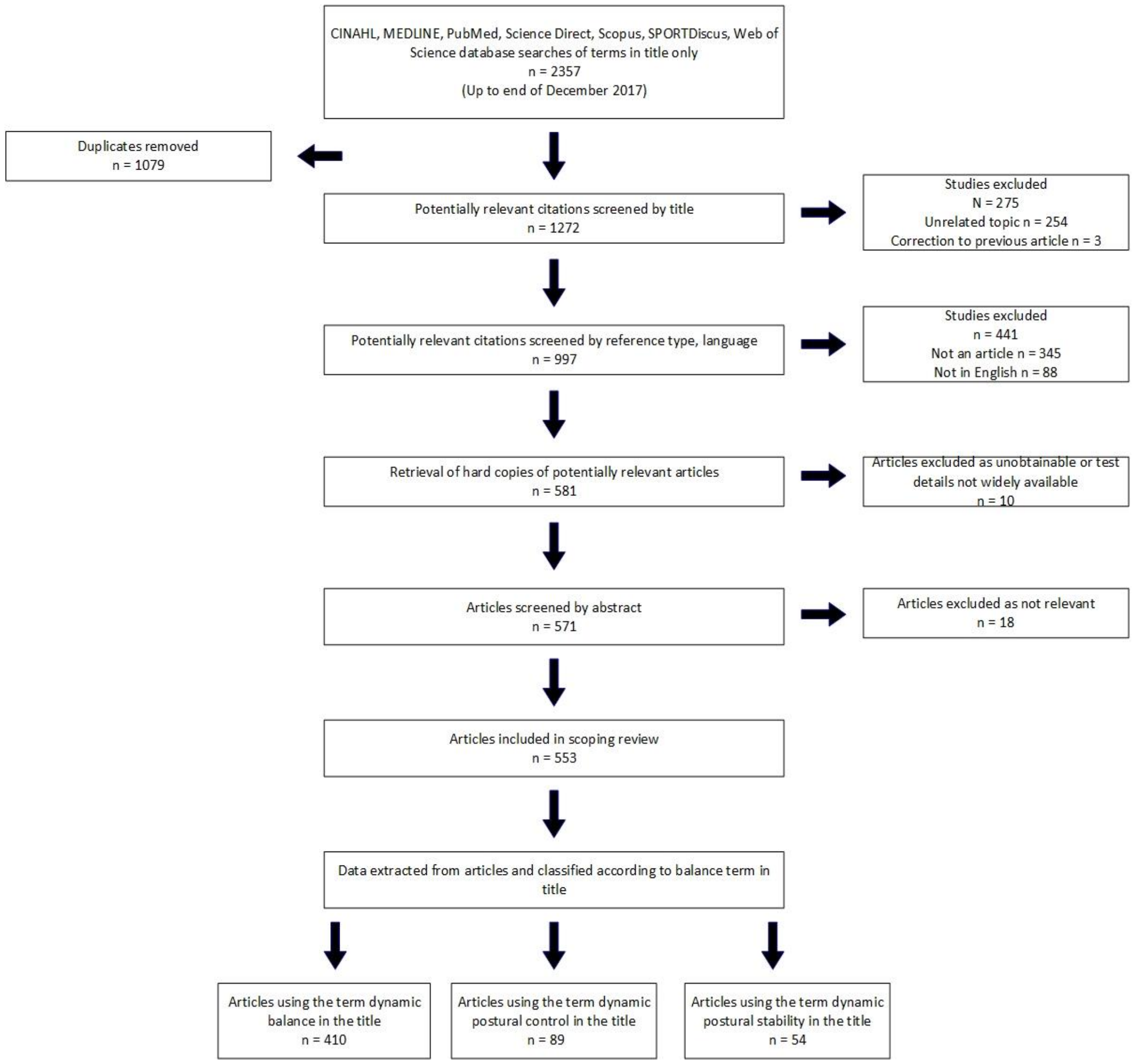


Figure 3.1 Flow diagram of literature selection and reviewing process

3.2.2 Reviewing Methods

Figure 3.1 shows the process used to select and review literature. Articles were excluded articles if they were not in peer reviewed journals, or if the language was not English. Exclusions included unpublished articles; books; book sections; conference abstracts; monographs; and dissertation theses. Following this process, retrieval of article hard copies was conducted. Any articles that were not readily available through institutional library subscriptions were requested through the British Library Document Supply Service. Any articles unobtainable at this point were excluded. Article titles were removed if they concerned an unrelated topic or a correction to a previous article. Following this, articles were discarded after screening by their abstract and, if necessary, full text. An additional reviewer checked 10% of exclusions to assess any rater-bias.

The following information was extracted from the title, introduction and methods of each remaining article:

- The balance term used in the title
- The definition of the term used, if any
- The source of the definition
- Evidence of synonymous use of the terms
- The type of study used in the research
- The participant information in each study
- The balance test used in the study
- The outcome measures used in the study
- The balance device employed in the study

Papers were classified according to which balance term was used in the title. Sources provided as balance term definitions were retrieved and read, with a record made of any definition used and whether any additional sources for the definition were cited. Definitions were categorised by term and then into themes by task goals and constraint(s). The 'goal' was the desired outcome, for example to maintain stability, locomote, or to manipulate an object. The 'constraints' were the additional challenges, and according to Newell's Constraints Model (Glazier, 2017) may arise within the organism (physical, physiological, morphological, or psychological), external to the organism (spatial and temporal layout of environment and applied forces) or may be inherent to the task (the task rules and goals).

3.3 Results

3.3.1 Incidence of terms

After the search and selection process 553 articles (Appendix A) were included in the scoping review. 410 were classified by their title as dynamic balance, 90 as dynamic postural control and 54 as dynamic postural stability. Figure 2 shows the incidence of the terms by the year they arise in a publication.

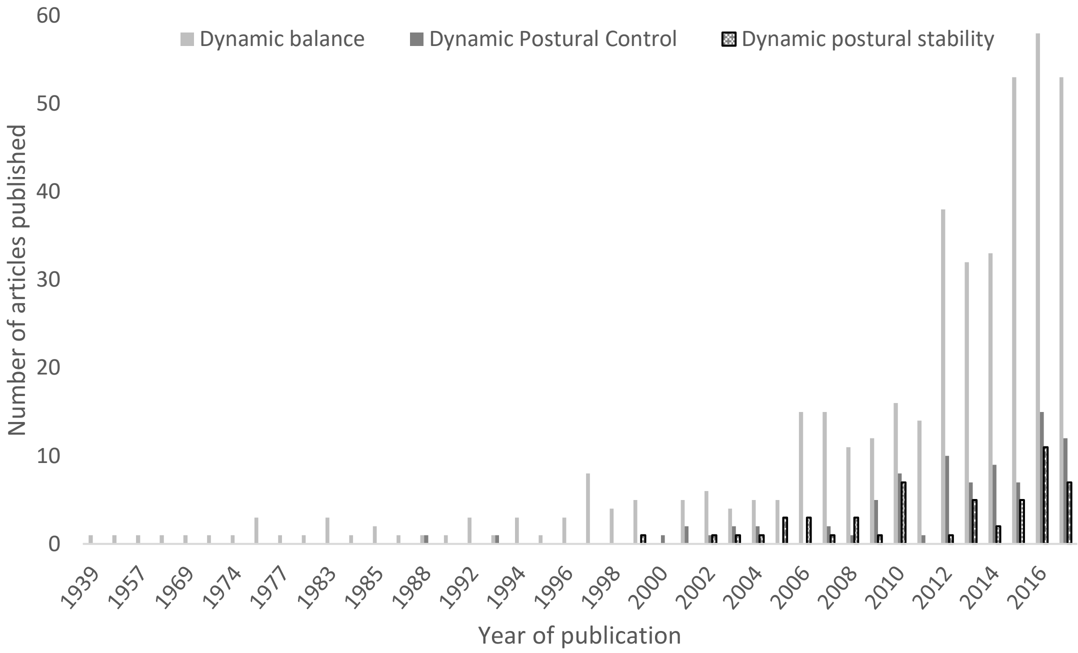


Figure 3.2. Number of articles published per year with the terms “dynamic balance”, “dynamic postural control” or “dynamic postural stability” in the title.

3.3.2 Definitions

Eighty-four articles provided a definition of the term they used. These consisted of 58 dynamic balance articles, 13 dynamic postural control articles and 13 dynamic postural stability articles. Sources for these definitions originated from 38 articles for dynamic balance, 12 for dynamic postural control and all 13 for dynamic postural stability.

Several sources were cited as definitions of terms, which upon inspection had not used the term or had not defined it within the article. The same source (Goldie et al., 1989) was cited as the earliest definition of both terms dynamic postural control and dynamic postural stability. Some articles neither provided a source for their definition nor made it explicit that they formulated their own definitions. A table of all articles with sources of definitions are presented in Appendix B.

There were 33 differently worded definitions found for dynamic balance, 13 for dynamic postural control, and five for dynamic postural stability. Some definitions were repeated both within terms and across two or more of the terms. Table 3.1 groups the different definitions into themes divided into tasks and constraints. Reference numbers are presented in Appendix C with the appropriate reference.

Table 3.1 Definitions of balance terms categorised by task goal and constraints. References are presented in Appendix C

Balance Term	Task goal	Constraints	References
Dynamic balance	maintain balance/ equilibrium/orientation	moving: during rapid changes of the individual's kinetic condition, while moving, during motion, while changing positions, while making postural adjustments, from one balanced position to another, during centre of gravity shifts, during control of body position in space shifts, during control of body position in space	1, 2-6
		during a transition from a dynamic to a static state/steady situation	17-20
		on an unstable support/on a moving surface	8, 21
		on a single limb and manipulate other limb	22
		With no constraint	23
	maintain stability/ stable/ steady position/ posture/ postural control	moving: while performing a task, during dynamic tasks, movement, while sitting, while standing, while walking, during expected and/or unexpected movements, against forces exerted by movement of a part of the body or movement of the whole body.	24-35
		during a perturbation	36
		during a transition from a dynamic to a static state	37, 38
		while anticipating changes in balance and coordinate muscle activity	28
		while shifting the centre of gravity (COG) on a moving base of support	38
		with no constraint	39

Balance Term	Task goal	Constraints	References
	maintain stable base of support/do not compromise base of support	while performing a movement/task	22, 40-44
	maintain centre of gravity/centre of mass over/within base of support/stability of centre of mass	while performing a movement/task	9, 45-48
		while standing, walking, or performing another skill	7, 49
		With no constraint	50
		While performing a prescribed movement	7, 22
	predict postural changes during movement	To give appropriate responses to changes in balance	51
Dynamic postural control	maintain stable base of support	While completing a prescribed movement perform a (functional) task	52-55
	maintain balance	during a transition from a dynamic to a static state	56
		while moving	57
	control/maintain COM	while moving/within BOS	58, 59
		while the body is subjected to internal or external perturbations that are anticipated or not	59
	regulate/control body position	while moving	60, 61
	not compromising supporting leg	during a functional task	62

Balance Term	Task goal	Constraints	References
Dynamic postural stability	balance/stabilise	while transitioning from a dynamic to a static state	63-69
	transfer and control centre of mass over base of support	while transitioning from a dynamic to a static state	70
		With no constraint	71
		while performing a task	72
		while body parts are in motion	73
		with respect to the centre of mass	74

3.3.4 Synonymous use of terms

Of the total articles in this study, 21% (118/561) used two or more of the terms synonymously (i.e., they used different terms within the article to refer to the same concept). Of papers that provided a definition of a term and a source of that definition, two of these sources (Gallahue, 1987; Wikstrom et al., 2005) were cited for both dynamic balance and dynamic postural control, one (Hof et al., 2005) was cited as a source for both dynamic balance and dynamic postural stability, one (Shumway-Cook & Woollacott, 1995) was cited a source for both dynamic postural control and dynamic postural stability and one paper (Winter et al., 1990) was cited as a source for all three terms.

3.3.5 Tests

Test were recorded as they were referred to in the text of each academic paper. 189 differently named tests were identified in the literature across all balance terms. Table 3.2 displays the frequency of tests identified for each balance term individually and the frequency of tests used for one or more balance terms. Table 3.3 displays the highest occurring tests identified in the scoping review.

Table 3.2 Frequency of balance tests identified within the literature of the scoping review for each of the individual balance terms and combined balance terms: dynamic balance, dynamic postural control, and dynamic postural stability.

Balance term	**Number of tests identified**
Dynamic balance	121
Dynamic postural control	42
Dynamic postural stability	26
Dynamic balance and dynamic postural control	11
Dynamic balance and dynamic postural stability	3
Dynamic postural control and dynamic postural stability	3
All three balance terms	12

Table 3.3 Most frequently identified tests within the literature of the scoping review

Balance test	Frequency
Perturbed stance	122
SEBT	81
SEBT combined with mSEBT	105
Walking gait	40
TUG	39
YBT	33
Limits of stability	28
BBS	23
Jump landings	23
Functional Reach	20
Moving the CoP to a target	10
Walking gait on a balance beam	10
All other tests	< 10

There were 12 instances where tests were referred to with the same name but had methodological differences (balance beam gait, drop landing, functional reach, gait initiation, jump landing task, limits of stability, moving CoP to a target, obstacle crossing, perturbed stance, single leg hop, weight shift, walking gait). There were also tests that had different names but methodological similarities (drop jump vs drop landing, mSEBT vs LQ-YBT, rhythmic weight shift vs rhythm-direction control of movement).

3.4 Discussion

This study investigated articles using the terms "dynamic balance", "dynamic postural control" and "dynamic postural stability" in their titles. The results show that dynamic balance is the most common title term used in the literature followed by dynamic postural control and then dynamic postural stability. Definitions of these terms are varied, although some do have similarities and, in some cases, the same definition has been used for two or more terms with evidence of these terms being used synonymously. Additionally, there are many tests and a lack of consistency in their methodologies and in their use concerning what they claim to measure.

3.4.1 Definitions of terms

Overall, only 10% of dynamic balance articles defined their respective term; this suggests that the authors considered the terms they used to be intuitively clear. However, the variety and overlap of definitions of all 3 terms implies this is not the case. Table 2 shows that the definitions of “dynamic balance” are most varied. The keywords "balance", "stability" and "control of the COM within the BOS" are present across all three balance term definitions. The phrase "maintain posture" is present in the goal section of definitions of both “dynamic balance” and “dynamic postural control”, and there are similarities in the sections of the definitions: "maintain posture” and “retain poise or steadiness” that were found for dynamic balance and dynamic postural control. Constraints are most varied for dynamic balance; transitioning from a dynamic to a static state is present in definitions across all three terms. The constraints include: perturbations which can be internal (such as muscular and inertial forces, as in the movement of a limb) or external to the participant (a moving support/surface or a force applied directly to the participant), motion and moving from one balanced position to another.

The similar language used for the definitions - in terms of tasks and constraints - suggests that these three terms are defined in very similar ways, with overlapping meanings, which limits their utility as independent terms. At the same time, they do not account for all aspects of dynamic balance occurring in real-world movement contexts: non-steady state motions which include accelerations, externally applied forces, and/or sequences of postures.

3.4.2 Tests

Perturbed stance was the most commonly occurring test. This was one of the tests with the most methodological differences. 122 papers referred to a method that involved perturbed stance. Tests have been administered using a range of different types of equipment that use a moveable surface that can rotate through a specified angle along single or multiple axes or translate, such as: Biodex Balance System; Stabilometers; Prokin 5 balance platform; Equitest; SMARTwobbleboard; Radboud Falls Simulator; Balance Testing System Accusway; Stability Platform, force plate allowing a floor translation. There is no gold standard method identified in the literature for testing perturbed stance. The slightly different methodologies of these tests and the different outcome measures, which range from a score, pivot displacement, stability index, CoP trajectory, time the platform is held within a certain position and margin of stability make comparisons across tests difficult. Additionally, all three terms of balance have been used by research applying these tests. Where methodologies, balance devices and outcome measures are the same, authors have used different balance terms with no apparent distinction[14]. This shows the similarity between terms. Where methodologies and outcome measures are different, being able to make comparisons between studies becomes difficult. There is no accepted method to determine a suitable test and methodology and to which balance term it relates.

The TUG (39 instances) is a test predominantly used for populations such as older adults, those at risk of falls (Beauchet et al., 2011) and strokes (Alghadir et al., 2018), as it involves activities of daily living. The test involves rising from a chair, walking 3 m, turning though 180 degrees, walking back to the chair and sitting down. The outcome measure is the time it takes to complete the test. There are no detailed descriptions of the strategies involved, so it is difficult to determine whether different strategies are related to performance and whether the test can differentiate populations and skill level within and between populations. Furthermore, if it were used as a test for dynamic balance in sports populations it is unlikely to provide any specificity because the movements involved are not key movements within sport.

[14] Abdelghany et al., 2016; Akbari et al., 2016; Akhbari et al., 2015; Aydoğ et al., 2006b; Costa et al., 2009; Davlin-Pater, 2008; Douglas et al., 2013; Farajzadeh et al., 2017; Fatma et al., 2010; Fujisawa et al., 2005; Fujisawa et al., 2007; Gusi et al., 2010, 2012b; Koşullarda et al., 2014; Kovacevic et al., 2010; Kuo et al., 2010; Lee & Han, 2017; Mohammadi-Rad et al., 2016; Mohsen & Emara, 2015; Rowe et al., 1999b; Salavati et al., 2016; Salek et al., 2015b; Schmitz & Arnold, 1998; Sherafat et al., 2014; Trampas et al., 2015

The SEBT, mSEBT and LQ-YBT are similar tests but with both the mSEBT and LQ-YBT only using three reach directions and the LQ-YBT being instrumented. 219 papers used one of these tests. Whilst they are very popular methods of assessing dynamic balance, they have also been used to assess dynamic postural control and dynamic postural stability. The difficulties associated with these tests have been identified in Chapter 2. There are no methodological differences between administration of these tests nor a difference in outcome measures used to assess balance ability. When the test has been used for all three balance terms it is difficult to determine whether the authors are testing the same construct or intend to test different things.

Section 2.2.2 identified that there are multiple components to dynamic balance. One major issue within the literature is that where authors have used one test for dynamic balance, they have not acknowledged which component of dynamic balance they have tested not justified why that was the most important component to test. Similarly, where authors have used a battery of tests, they do not provide a method for identification of why those tests were chosen as being important for the population being tested. They have not considered the specificity of the test, making it difficult for researchers and clinical practitioners to determine the best method of assessing dynamic balance. A taxonomy of components of dynamic balance would provide a method of identifying important movements that relate to a population whist also providing a framework by which existing tests can be aligned.

The results of this study show that 52 tests involved a static base of support. Additionally, there were 20 multiple component tests where one or more of the tests involved a static base of support. As discussed in Sections 2.2 and 2.3, a static base of support should not be considered as representing dynamic balance but instead static balance with a challenging condition. Evidence has already shown that static balance performance is not reflective of dynamic balance performance (Hrysomallis, et al., 2006; Sell, 2012). The use of tests that involve a static base of support purporting to assess dynamic balance are unsuitable and should not be used as an assessment of dynamic balance individually or within a battery of tests.

These results support the literature in Section 2 in identifying that current tests to assess dynamic balance lack specificity. Where tests were referred to by the same name but had methodological differences, problems arise in making comparisons across studies as well as making an informed choice in choosing an appropriate test to be used in future research or assessment of dynamic balance. Additionally, there were instances where tests were referred to with the same name but had methodological differences. For example, Hoch et al. (2012a, 2012b) uses the SEBT in two different studies However, in one of the studies, the mSEBT is used.

Many tests exist where the outcome measures do not provide any rich descriptions of the movements involved or the strategies employed which relate to lower or higher dynamic balance ability. These include the use of a score, time, number of stands, number of steps, distance travelled, variation in direction of the dynamic balance board, velocity, reach distance, gait speed, reaction time, number of balance errors. It is difficult to identify what separates populations and individuals without movement strategy information. For example, how does the movement of the CoP or the CoM compare within and between individuals and within and across sports?

3.5 Limitations

There are limitations to this study: first, to keep the pool of articles manageable, only articles with one of the balance terms in the title were used. There are likely to be additional relevant papers that did not include the term in the title; however, sources of definitions were followed up, even if they did not have one of the terms in the title. Second, it is not possible to determine whether authors that have apparently used terms synonymously actually considered the terms to have different meanings but did not make this explicit. Third, this research only included articles that were in the English language. Those excluded for that reason may have reported different definitions or referred to a conceptual framework for the definition of these terms. Finally, it was not possible to access three of the articles found from the original search, however, the number of articles included in this study provides a clear pattern in the literature.

3.6 Conclusion

Dynamic balance is a term that has been used widely in the literature and is a research area that continues to grow in popularity. The related terms and their definitions demonstrate limitations including disparity amongst definitions of the same term, overlap amongst definitions of different terms, and no existing definitions covering the full range of dynamic balance situations.

The use of the terms to describe dynamic balance in the literature do not satisfy the aspirations stated by Pollock et al. (2000),

> "The production and use of universally accepted definitions of terms used within clinical practice is essential for the accurate and precise assessment, documentation and interpretation of patient problems."

The ambiguity in the use and definition of terms, together with the task specificity of dynamic balance are a barrier to development of a coherent research base in dynamic balance. Consequently, an extension of the definitions of Pollock et al. (2000) is required to cover the full range of dynamic balance circumstances. The evidence provides a clear need for dynamic balance, dynamic postural control, and dynamic stability to have distinct and precise meanings.

Many difficulties have been identified with the tests that currently exist for dynamic balance. Difficulties in the selection of a test are increased due to the complex and multi-factorial nature of balance. A taxonomy of the different components of dynamic balance is required, which would allow different components of dynamic balance to be associated with specific tests. This would provide a framework by which specificity of tests can be determined.

Chapter 4 Redefinition of dynamic balance and development of a classification tool

4.1 Introduction

The results of Chapter 3 identified that research in dynamic balance has been growing in frequency. Section 2.1.1 outlined the work of Pollock et al. (2000) in suggesting clear definitions that would standardise the use of the terms dynamic balance, dynamic postural control and dynamic postural stability. However, as identified in Chapter 3, inconsistency still exists between the definitions of the terms dynamic balance, dynamic postural control and dynamic postural stability. These terms are often used synonymously, which limits their use as independent terms. Additionally, it was identified in Section 2.1.1 that existing definitions and those proposed by Pollock et al. (2000) refer to a relatively narrow range of balance activities and do not account for many real-world balance scenarios.

Section 3.4.2 identified the problems that exist regarding dynamic balance tests. There are hundreds of tests to choose from and test selection is made difficult due to the complex and multifactorial nature of balance (Woollacott & Tang, 1997). There is no widely used method to be able to determine which components of dynamic balance are being tested in each test, and how they are appropriate for different populations. In the interests of this programme of research, a tool is required to be able to match important balance components of football with existing tests to provide specificity and to identify where new tests may be required. Section 2.4 identified two taxonomies that could be used to identify the components of balance for a particular population as well as assess balance measures for their task and environmental influences. However, they have seen little use within balance research and their use in fall risk and community dwelling older adult populations means their effectiveness as a tool for identifying balance components of a wider range of tests and appropriate tests for additional populations, and in particular sports applications, is unknown.

This chapter reports firstly, the development of new more encompassing definitions of dynamic balance, postural control and postural stability, and secondly, a taxonomy to classify movement identify appropriate tests. The objectives were to:

- Determine the most frequent definitions used for each term and identify any themes that emerge.
- Extend the definitions of Pollock et al. (2000) to create new definitions suitable for dynamic balance measurements.
- Determine the effectiveness of the two existing balance taxonomies for classifying all extracted balance tests from Chapter 3.
- Extend the existing balance taxonomies to cover a wider range of balance applications.

4.2 Definitions of dynamic balance and associated terms

Section 3.3 extracted definitions from the papers identified in the scoping review. The information was presented in Table 3.1, by categorising definitions by task goal and constraint. Using the information in this table, definitions with the same or similar language relating to task goals and constraints were identified and grouped. Using this information and Newell's model of constraints (Newell et al., 1989), a consultation process between four researchers was used to develop and agree on extended definitions by building on the definitions presented by Pollock et al. (2000).

4.2.1 Dynamic balance

For dynamic balance, there were 10 different task goals identified and 15 different constraints (Table 3.1, Section 3.3.2). Definitions centred on the identification of the involvement of a variety of task goals that needed to be achieved. The constraints referred to the involvement of internal or external forces and accelerations. For dynamic postural control there were three different task goals which had a focus on moving. The constraints focused on maintaining balance or BoS but there were also references to making postural adjustments to maintain balance. For dynamic postural stability there were two task goals and three constraints. Both task goals and constraints had also been used in the definitions for dynamic balance and dynamic postural control.

Dynamic balance was associated with more task goals and constraints than dynamic postural control and dynamic postural stability. There were many definitions where the language used was broad and unspecific, for example: perform a movement, a perturbation, maintain balance, and maintain equilibrium. However, in contrast, there were specific definitions in which the term dynamic balance was related to the experimental method presented in the paper, for example: “balance on a single limb while manipulating the other limb” (Anoop et al., 2010), and “involves achieving a compromise between the forward propulsion of the body and the need to maintain the lateral stability of the body” (Zech et al., 2012). This supports the view that dynamic balance is multi-factorial and has many components. Chapter 2 and the results of this study demonstrate that the limitation with existing definitions is their assertion that to maintain dynamic balance the body’s centre of mass needs to be maintained within the base of support, or that the body needs to remain stable. However, this is often not the case for many activities of daily living or sporting situations, which renders existing dynamic balance definitions using those terms insufficient. The aspirations of Pollock et al. (2000) were:

- The acknowledgement that postural control refers to the act of maintaining achieving and or restoring the line of gravity inside the BoS
- That there are different components of balance and assessment tools may test different aspects of postural control
- That the newly proposed definitions should be adopted within clinical and research settings.

Chapter 3 has identified that these aspirations have not been satisfied. Additionally, the definitions of the terms are insufficient in accounting for the unbalanced forces that are inherent in everyday movement. Pollock et al. (2000) proposed that dynamic balance is the ability of a person not to fall. However, if we are to consider the task and environmental constraints when competing in sport, the task goal of an athlete is rarely limited to not falling. Control of gravitational and acceleration forces is required to maintain posture and equilibrium in normal balance (Massion & Woollacott, 1996). Acceleration forces may be internal, when resulting from a voluntary movement, or external force as the consequence of a disturbance such as a push (Winter, 1995b). The environmental constraints for example may include the condition or type of support surface, which may be slippery or wet, or dealing with a physical challenge from an opponent whilst moving and quite possibly interacting with a ball or other object. Thus, the environmental constraints will involve non-static internal or external forces or accelerations. So, it is clear that not falling is one of many task goals in this scenario. An extended definition for dynamic balance is presented in Table 4.1 providing more coherence with a specific task goal and constraints.

4.2.2 Dynamic postural control

Pollock et al. (2000) consider dynamic postural control as "the act of maintaining, achieving or restoring a state of balance during any posture". This refers to how the outcome is achieved, where the outcome is the task goal. The definition is insufficient because there is a lack of detail of what is involved in maintaining, achieving or restoring the state of balance. In dynamic movements, control of moving body segments requires making continuous postural adjustments. Within one task, there may be multiple postures involved in maintaining, achieving or restoring a state of balance. Not only are there internal forces involved in making these postural adjustments, but external forces influence these adjustments as well as torques, position of the centre of mass and the size and shape of the base of support, all of which need to be considered. Disregarding definitions provided in Table 3.1, where definitions for dynamic balance and dynamic postural stability have been used synonymously, two definitions remain:

> 1: "the ability to alter the magnitude and patterns of segmental kinematics (e.g., trunk and limb movements) in order to direct body position in response to external mechanical demands imposed" (Song et al., 2012)
>
> 2: "the ability to control body position to maintain body stability and orientation" (Falk et al., 2014)

These are more in line with Pollock et al. (2000) definition of the non-dynamic case. If we consider the scenario of a footballer trying to evade a defender, the task goal is to evade the defender. The constraints will involve the footballer making postural adjustments to manipulate their internal forces which involves the control of the momentum of the body segments as well as external forces due to the support surface, or a collision with the defender to achieve that task goal. An extended dynamic postural control definition has been developed that considers the task goal and the constraints to provide a more precise definition and is presented in Table 4.1. The term dynamic postural control should be used in relation to balance strategies; how the person manipulated internal and external forces etc., through postural adjustments whilst maintaining, achieving or restoring dynamic balance.

4.2.3 Dynamic postural stability

All the dynamic postural stability definitions in the literature had been used synonymously with the other terms. There were no emerging themes that provided any additional information that would help in the development of a new definition. The extended definition for dynamic postural stability presented in Table 4.1 proposes a change to the language used to shift the focus to the organismic constraints that are related to the inherent ability. The organismic constraints are things such as the speed capability of the individual, or a person’s unique physical and mental characteristics (Glazier, 2017). The term dynamic postural stability should be used when discussing or testing the organismic constraints of the participant. For example, how the skill level, or physical characteristics of the person relates to their ability of maintaining, achieving or restoring dynamic balance.

Table 4.1 Extensions of definitions of static balance terms provided by Pollock et al. to encompass dynamic situations

Static case Term	Pollock definition	Dynamic case Term	Extension to definition
Balance	A multidimensional concept, referring to the ability of a person not to fall	Dynamic balance	A multidimensional concept, referring to the requirement to adapt posture effectively over time to achieve a task goal in the presence of non-static internal or external forces or accelerations.
Postural control	The act of maintaining, achieving or restoring a state of balance during any posture or activity	Dynamic postural control	The process of making postural adjustments to manipulate internal and external forces and torques, the centre of mass, or base of support to maintain, achieve or restore dynamic balance.
Stability	The inherent ability of a person to maintain, achieve or restore a specific state of balance and not to fall. The inherent ability referring to the motor and sensory systems and to the physical properties of the person	Dynamic postural stability	The inherent ability of a person to maintain, achieve or restore dynamic balance for a specific task. The inherent ability referring to the organismic constraints.

4.3 Analysis of existing taxonomies

In addition to the broad terms, the inherently task specific and multidimensional nature of dynamic balance suggested that further work was needed to determine whether previously identified taxonomies in Chapter 2 proposed by Huxham et al. (2001) and Pardasaney et al. (2013) were suitable as a classification system. All existing dynamic balance tests and individual balance items within each test were extracted from the papers identified in Section 3.3. When the test method was unobtainable from the original article, secondary sources were used. Where measure content could not be obtained, the measure was not included in the analysis (Pardasaney et al., 2013). Two existing taxonomies (Huxham et al., 2001; Pardasaney et al., 2013) presented in Table 4.2 and Figure 4.1 respectively, were used to classify existing balance tests to determine their suitability as a classification system (Appendices D and E).

4.3.1 Classification of tests through exiting taxonomies

Difficulties identified through the classification of existing tests using the taxonomies of Huxham et al. (2001) and Pardasaney et al. (2013) are presented below. When classifying the existing tests with the model set forth in Huxham et al. (2001) there was not enough separation of the individual items to differentiate between the individual and environmental constraints. For this reason, tests with very different balance demands were classified under the same category. Where tests had multiple components, the test could be classified in multiple categories. The model of Huxham et al. (2001) did not allow categorisation of interactions with equipment/other people.

Table 4.2 Classification of clinical balance tests according to biomechanical demands using the taxonomy proposed by Huxham et al. (2001).

	Stationary Base of Support	**Moving Base of Support**
Unperturbed	Timed standing Steadiness in standing	10m walk, whether times or qualitative
Self-generated perturbations	Performance-Oriented Assessment – balance (most items) Berg Balance Scale (most items) Step test Functional Reach Reach test	Performance-Oriented Assessment – mobility Times up and Go Dynamic Gait Index Performance-Oriented Assessment – balance (turn item) Performance-Oriented Mobility Assessment Instrument Functional Obstacle Course
External perturbation	Performance-Oriented Assessment – balance (sternal thrust item) Postural Stress Test Shoulder Tap Test Clinical Test of Sensory Integration and Balance	
Sensory manipulation or perturbation		Performance-Oriented Mobility Assessment Instrument

Role of Task*	Environmental Variation	Object Interaction*	Obstacle Negotiation	External Forces	Dual-Tasking	Moving People/Objects*
Static body stability	No variation	Present	Present	Present	Present	Present
Dynamic body stability	Variation of support surfaces	Absent	Absent	Absent	Absent	Absent
Transfers	Variation of visual conditions					
Gait	Variation of support surfaces and visual conditions					
Transfers and gait						

[a] Each item was coded on each of the 7 classification criteria listed. Asterisk indicates item was adapted from: Gentile AM. Skill acquisition: action, movement, and neuromotor processes. In: Carr J, Shepherd R, eds. *Movement Science: Foundations for Physical Therapy in Rehabilitation.* 2nd ed. Gaithersburg, MD: Aspen Publishers Inc; 2000.

Figure 4.1 Classification criteria presented by Pardasaney et al. (2013)

The taxonomy of Pardasaney et al. (2013) provided classification criteria which allowed better differentiation of individual and environmental constraints. There were also operational definitions provided to assist with interpretation of the criteria (figure 4.2). The taxonomy of Pardasaney et al. (2013) was developed from balance tests used on community-dwelling older adults and has to not been used to classify a large range of different balance tests. The wide range of dynamic balance tests extracted in Chapter 3 challenged this tool in that it failed to recognise or be able to differentiate several aspects. It was difficult to identify exactly which item within multi-component tests was classified in each category. For example, the Berg Balance scale includes both static body stability and dynamic body stability.

Criterion	Operational Definition
1. Role of task*	
Static body stability	Maintenance of a static posture with no concurrent active movement
Dynamic body stability	Maintenance of a posture while performing active movement
Transfers	Movement of the body from one position to another without taking steps, such as sit-stand
Gait	Movement of the body from one position to another by taking steps; may or may not end in the starting position
Transfers and gait	Tasks involving both transfers and gait as defined above
2. Environmental variation	
No variation	No variation of support surfaces or visual conditions as defined below
Variation of support surfaces	Any change in support surface, including type of surface, inclination of surface, movement of surface, or base of support, with the reference being a firm, flat, nonmoving surface and normal base of support
Variation of visual conditions	Any change in visual conditions including level of lighting, alteration of visual field, or movement of visual surround, with the reference being eyes open, well-lit environment, unaltered frontal visual field, and a nonmoving visual surround
Variation of support surfaces and visual conditions	Variation of both support surface and visual conditions as defined above
3. Object interaction*	Any physical interaction of a person with an external object
4. Obstacle negotiation	Negotiation of obstacles systematically placed in the environment
5. External forces	Application of, or sudden removal of, external forces
6. Dual-tasking	Performance of a secondary task, such as a manual or cognitive task, while performing a primary balance task
7. Moving people or objects*	Presence of moving people or objects in the environment

[a] Asterisk indicates item was adapted from: Gentile AM. Skill acquisition: action, movement, and neuromotor processes. In: Carr J, Shepherd R, eds. *Movement Science: Foundations for Physical Therapy in Rehabilitation*. 2nd ed. Gaithersburg, MD: Aspen Publishers Inc; 2000.

Figure 4.2 Operational definitions of classification criteria in the taxonomy set forth by Pardasaney et al., (2013).

Pardasaney et al. (2013) define static body stability within the role of the task as, "maintenance of a static posture with no concurrent active movement". This does not account for natural sway. Nor does it consider that static stance may involve different types or sizes of supports for example, biped stance or single leg stance, foot flat or tiptoes which are not environmental variations. Despite the operational definitions provided, it is difficult to interpret where some movements should be classified, for example, the classification of hops and jumps. In performing a jump posture changes with the phase of the jump so classifying under dynamic body stability would be difficult. The classification of gait does not provide a level of detail to be able to differentiate between items that may involve walking at different speeds, which is a more balance challenging activity involving larger internal accelerations of body segments. Nor does it provide the level of detail needed to classify tests that involve a turn within the motion such as in balance beam tests.

Within the environmental variations of the taxonomy of Pardasaney et al. (2013), more detail is needed to be able to differentiate the range of environmental constraints that were presented in the tests identified in Chapter 3. For example, there is no way of identifying the type of variation of the support surface. Pardasaney et al. (2013) define the variation of support surfaces to include the BoS. However, the BoS is not an environmental constraint. Any change in the BoS is related to postural equilibrium thus variations in the BoS should come under a separate classification. An example of this is the difficulty that arises when determining how to categorise the forward lunge test. The test starts and concludes in the same place so it does not include locomotion, yet there is a change in position and using the definitions provided by Pardasaney et al. (2013) it could be classified as gait. There is a change in the BoS similar to that which occurs in walking, moving from one support limp to two support limbs. Another example is the change in the BoS that occurs in the BESS which cannot be classified using the taxonomy of Pardasaney et al. (2013). Object interaction is an independent category within this tool, but one could argue that it is an environmental constraint and should be classified as such. Pardasaney et al. (2013) define external forces as the application of, or sudden removal of, external forces. There is some crossover with the environmental variation of support surfaces within this category: if for example, the external force is applied by a translating floor, which occurs in the Limits of Stability test. Furthermore, if external forces are being accounted for, it is also of interest to be able to classify internal forces as the proposed definitions of dynamic balance and dynamic postural control in Section 4.4.1 refer to internal forces. Pardasaney et al. (2013) definition of moving people and objects is the “presence of moving people or objects in the environment”. This category should specify whether these moving objects are or are not related to the support surface. Additionally, there can be moving objects that are not in the physical environment, for example, the use of tests that involve controlling the position of the CoP, which is displayed on a screen, and the use of virtual reality. Finally, there were no categories that allow classification of items that challenge perception or action for example the use of medication, neurostimulation, anaesthesia, and limb cooling.

4.4 Development of a new taxonomy

The difficulties identified with classifying tests in the existing two taxonomies established the need for the development of a new taxonomy. The BMC (Bloomfield et al., 2004) was used to identify all common movements that can occur in sport due to its use in football and netball. This was to ensure that the taxonomy would represent task and environmental constraints for football players. Additionally, consultation with researchers with expertise in running, gymnastics, cycling and capoeira were sought to ensure a comprehensive range of task and environmental constraints were considered for other sports and everyday tasks. A four-level taxonomy was produced in line with Gentile's taxonomy of tasks and Newell's Constraints model, building on the taxonomies of Huxham et al. (2001) and Pardasaney et al. (2013), with level headings:

- Postural equilibrium challenges
- Destabilising challenges (challenging posture)
- Challenging perception
- Challenging action.

Postural equilibrium challenges refers to self-initiated movements of constant velocity, repeatable patterns of motion or when the body is at rest. Destabilising challenges are internal and/or external accelerations, and object interactions that challenge the CoM of the body and are occurring in addition to the movement identified within the postural equilibrium challenge. Challenging perception relates to the introduction of visual, vestibular, proprioceptive and cognitive processing tasks. Challenging action refers to items that influence the performance of the action. The new taxonomy is presented in Figure 4.3. New classifications were created where the existing classification systems lacked appropriate categorisation. Each outcome at each level of the classification was given a code by which balance tests and movements could be classified. All existing dynamic balance tests were classified through the new taxonomy and assessed by another researcher for agreement (Appendix F). A glossary was produced to provide a reference for the terms used (Appendix G). For demonstrative purposes, the starting point and direction through the taxonomy, using a single leg hop (that commences and finishes on the same leg) as an example movement, is presented with red boxes and arrows. A single leg hop is classified as follows:

- Postural equilibrium challenges

PE11: A non-static base of support, with flight, no change in point of support, with one support in contact with the reference surface P11, D2, D5, P1 and A1

- Destabilising challenges

D2: Suprapostural acceleration of the whole body vertically

D5: Suprapostural acceleration of the whole body anteriorly

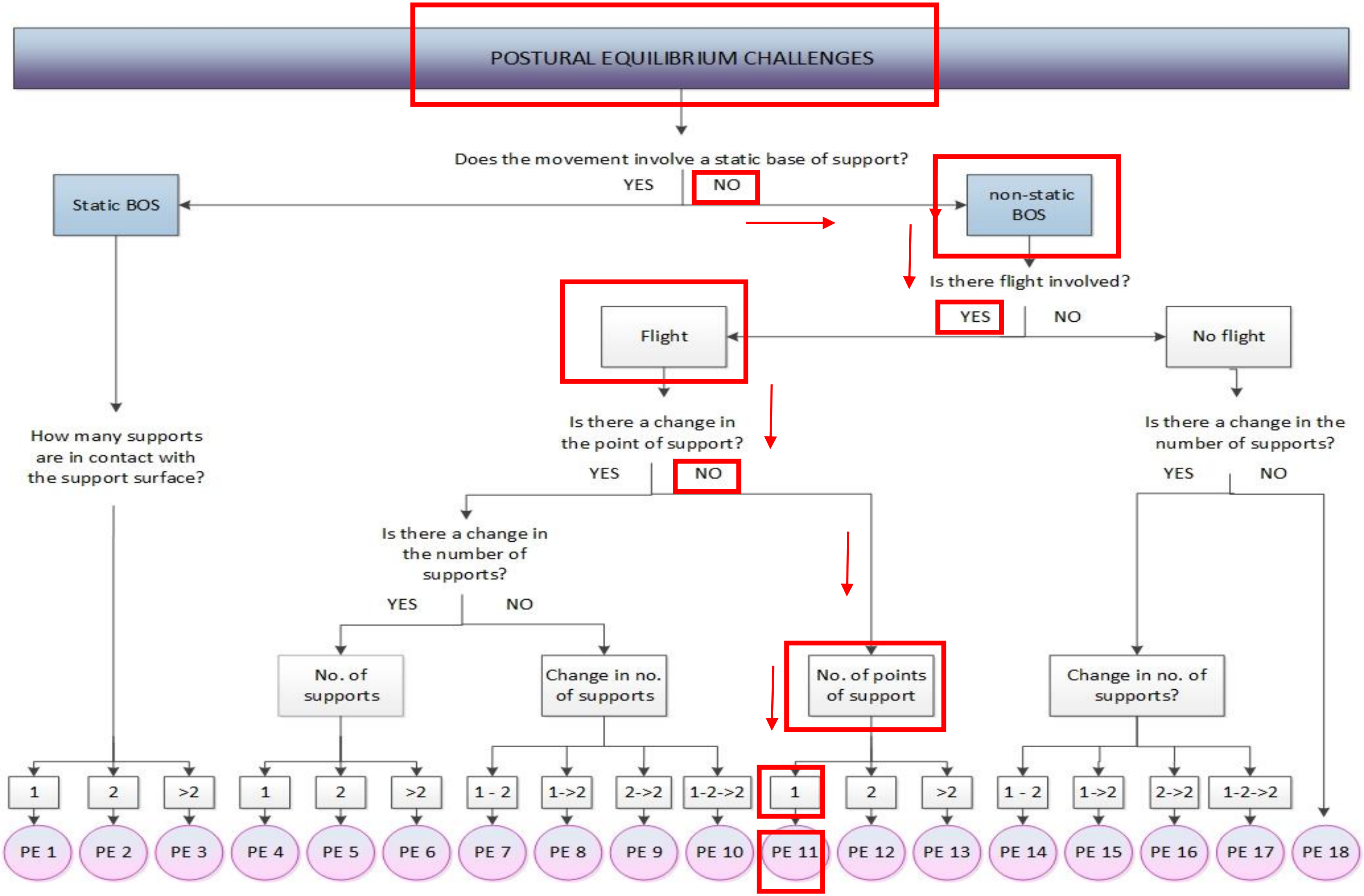
- Challenging perception

P1: None

- Challenging action

P1: None

a


POSTURAL EQUILIBRIUM CHALLENGES
Does the movement involve a static base of support?
YES
NO
Static BOS
non-static BOS
Is there flight involved?
YES
NO
Flight
No flight
How many supports are in contact with the support surface?
Is there a change in the point of support?
YES
NO
Is there a change in the number of supports?
YES
NO
Is there a change in the number of supports?
YES
NO
No. of supports
Change in no. of supports
No. of points of support
Change in no. of supports?
1
2
>2
1
2
>2
1 - 2
1->2
2->2
1-2->2
1
2
>2
1 - 2
1->2
2->2
1-2->2
PE 1
PE 2
PE 3
PE 4
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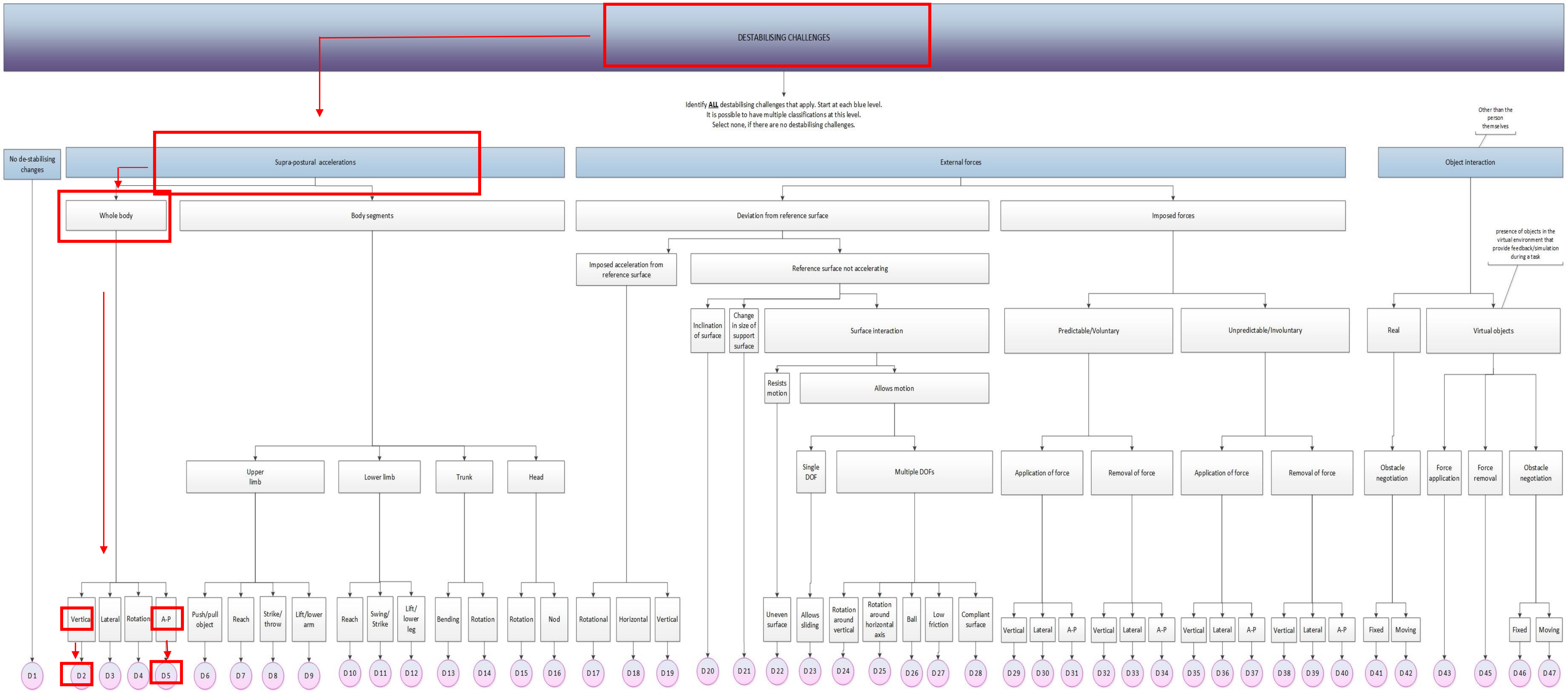
PE 13
PE 14
PE 15
PE 16
PE 17
PE 18

b


DESTABILISING CHALLENGES
Identify ALL destabilising challenges that apply. Start at each blue level.
It is possible to have multiple classifications at this level.
Select none, if there are no destabilising challenges.
No de-stabilising changes
Supra-postural accelerations
External forces
Object interaction
Other than the person themselves
Whole body
Body segments
Deviation from reference surface
Imposed forces
presence of objects in the virtual environment that provide feedback/simulation during a task
Imposed acceleration from reference surface
Reference surface not accelerating
Inclination of surface
Change in size of support surface
Surface interaction
Predictable/Voluntary
Unpredictable/Involuntary
Real
Virtual objects
Resists motion
Allows motion
Single DOF
Multiple DOFs
Upper limb
Lower limb
Trunk
Head
Application of force
Removal of force
Obstacle negotiation
Force application
Force removal
Vertical
Lateral
Rotation
A-P
Push/pull object
Reach
Strike/ throw
Lift/lower arm
Swing/ Strike
Lift/ lower leg
Bending
Nod
Rotational
Horizontal
Uneven surface
Allows sliding
Rotation around vertical
Rotation around horizontal axis
Ball
Low friction
Compliant surface
Fixed
Moving
D1
D2
D3
D4
D5
D6
D7
D8
D9
D10
D11
D12
D13
D14
D15
D16
D17
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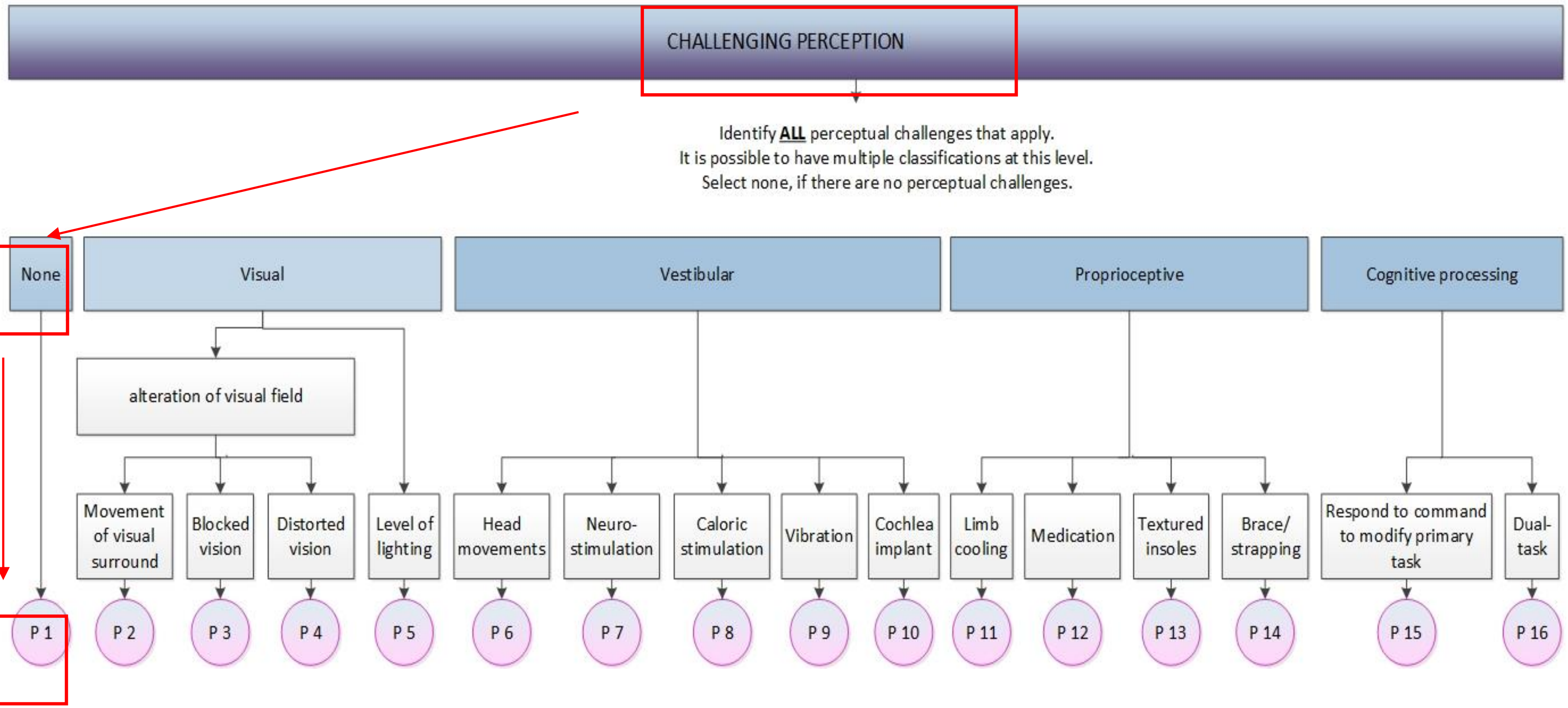
CHALLENGING PERCEPTION
Identify ALL perceptual challenges that apply.
It is possible to have multiple classifications at this level.
Select none, if there are no perceptual challenges.
None
Visual
Vestibular
Proprioceptive
Cognitive processing
alteration of visual field
Movement of visual surround
Blocked vision
Distorted vision
Level of lighting
Head movements
Neuro-stimulation
Caloric stimulation
Vibration
Cochlea implant
Limb cooling
Medication
Textured insoles
Brace/ strapping
Respond to command to modify primary task
Dual-task
P 1
P 2
P 3
P 4
P 5
P 6
P 7
P 8
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P 10
P 11
P 12
P 13
P 14
P 15
P 16

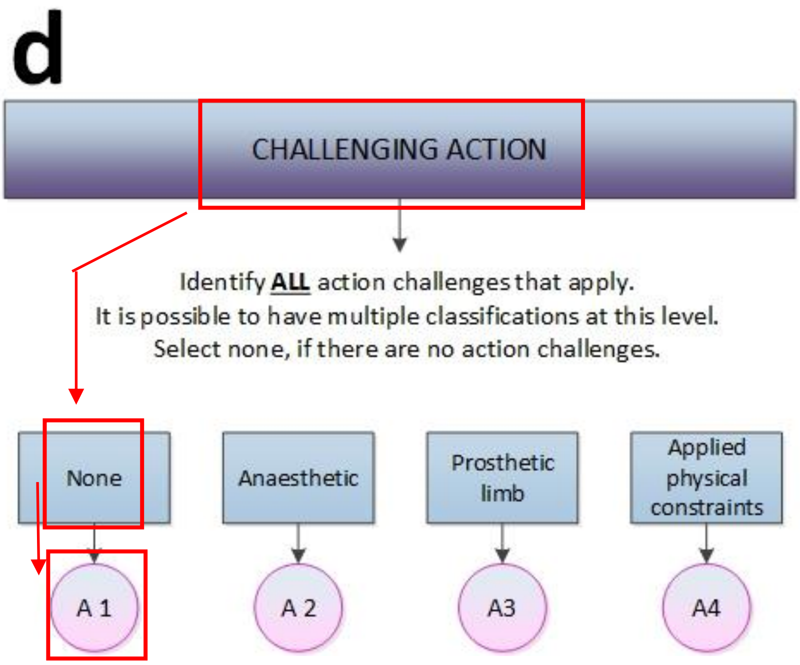

Figure 4.3 Four-level taxonomy for balance component analysis and identification of appropriate balance tests. a) Postural equilibrium challenges, b) Destabilising (challenging posture), c) challenging perception, d) challenging action. The red boxes and arrows refer to the path taken to classify

In the new taxonomy the first level, postural equilibrium challenges, refers to movements of the base of support challenging overall posture and has 18 classifications denoted by PE followed by a number. It is split into two levels, the first a static base of support and the second, a non-static BoS. Static BoS has one level, the number of supports: one, two or more than two, where more than two might be the use of another limb or a walking aid. The non-static BoS, is further refined into flight or no flight. Flight splits into two pathways. One pathway where the point of support changes during the movement, for example one leg to another, or two legs to two hands. This pathway further splits into two options of whether there is a change in the number of supports in contact with the support surface or not. The second pathway in the non-static BoS involving flight involves the point of support remaining the same during movement, for example, the same leg whilst hopping or the same two legs during jumping. No flight has two pathways: One involves a change in the number of supports in contact with the support surface and alternative does not involve a change in the number of supports. Table 4.2 provides examples of positions and/or movements that might occur at each level of the classification. The second level of the taxonomy, destabilising (challenging posture) has 47 classifications. External forces within this level do not include those that come from a change in the support surface. Virtual objects are the presence of objects in the virtual environment that provide feedback and/or stimulation during a task. Table 4.3 provides examples of destabilising challenges for each classification. The third level, challenging perception, has 15 classifications and includes classifications that change the way we perceive the environment, where the ability of the visual and vestibular systems, proprioceptive and cognitive processing are categorised. Table 4.4 provides examples of perceptual challenges. The fourth level, challenging action, has four classifications and categorises items that influence the perception of the environment and therefore affect the ability to perform a task.

All individual items within balance tests were successfully classified at all levels. At the postural equilibrium level individual items were uniquely classified as they represent the task constraint. At the other levels, it was possible for individual items within each test to be classified multiple times as these were the environmental constraints. There were some classifications for which no dynamic balance conditions were coded for because they did not present in any of the existing tests.

Table 4.2 Examples of postural equilibrium positions and movements

Classification Code	Classification	Example
PE 1	Static, unipedal BoS	Single leg stance
PE 2	Static, bipedal BoS	Double support stance
PE 3	Static, multiple support BoS	More than two body parts providing support on the support surface or two limbs and an assistive device such as a walking stick
PE 4	Non-static BoS involving flight with one support making contact with the support surface, where the support changes from limb to limb	Running
PE 5	Non-static BoS involving flight with two supports making contact with the support surface, where the supports change from limb to limb	Flick-Flack
PE 6	Non-static BoS involving flight with more than two supports making contact with the support surface, where these supports change with each contact with the support surface	Jump with walking poles
PE 7	Non-static BoS involving flight where the point of support in contact with the support surface changes during the movement from 1-2 supports	Hopscotch
PE 8	Non-static BoS involving flight where the point of support in contact with the support surface changes during the movement from 1->2 supports	Hop onto surface and land on all fours
PE 9	Non-static BoS involving flight where the point of support changes in contact with the support surface changes during the movement from 2->2 supports	Frog jump
PE 10	Non-static BoS involving flight where the point of support changes in contact with the support surface changes during the movement from 1-2->2 supports	Running with poles

Classification Code	Classification	Example
PE 11	Non-static BoS involving flight with the same uniped point of support making contact with the support surface	Hops
PE 12	Non-static BoS involving flight with the same biped points of support making contact with the support surface	Jumps
PE 13	Non-static BoS involving flight with the same multiple points of support making contact with the support surface	Frogs
PE 14	Non-static BoS, no flight, where the number of supports in contact with the support surface change from 1-2.	Walk/cartwheel
PE 15	Non-static BoS, no flight, where the number of supports in contact with the support surface change from 1->2.	Walking with crutch
PE 16	Non-static BoS, no flight, where the number of supports in contact with the support surface change from 2->2.	Jumping with frame
PE 17	Non-static BoS, no flight, where the number of supports in contact with the support surface change from 1-2->2.	Walking with a frame
PE 18	Non-static BoS, no flight, where the number of supports in contact with the support surface do not change.	Rolling

Table 4.3 Examples of destabilising challenges

Classification code	Classification	Example
D 1	No destabilising challenges present	None
D 2	A vertical supra-postural acceleration of the whole body	Squat
D 3	A lateral supra-postural acceleration of the whole body	Side lunge
D 4	A rotational supra-postural acceleration of the whole body	Pirouette
D 5	An anterior-posterior supra-postural acceleration of the whole body	Lunge
D 6	A supra-postural acceleration resulting from a push/pull movement of the upper limb	Opening a door
D 7	A supra-postural acceleration resulting from a reaching movement of the upper limb	Reaching for an object
D 8	A supra-postural acceleration resulting from a strike/throw movement of the upper limb	Throwing a ball
D 9	A supra-postural acceleration resulting from a lifting or lowering movement of the upper limb	Lifting arms above head
D 10	A supra-postural acceleration resulting from a reaching movement of the lower limb	Reaching for a ball
D 11	A supra-postural acceleration resulting from a swing/strike movement of the lower limb	Swinging the leg prior to kicking a ball
D 12	A supra-postural acceleration resulting from a lifting/lowering movement of the upper limb	Lifting leg before stepping up
D 13	A supra-postural acceleration resulting from a bending of the trunk	Bending down
D 14	A supra-postural acceleration resulting from a rotation of the trunk	Rotation during a golf swing

Classification code	Classification	Example
D 15	A supra-postural acceleration resulting from a head rotation	Turning to change angle of view
D 16	A supra-postural acceleration resulting from a head nod	Movement to change angle of view
D 17	An external force due to a deviation of the reference surface involving a rotational imposed acceleration	Neurocom SMART Equitest system
D 18	An external force due to a deviation of the reference surface involving a horizontal imposed acceleration	Chattecx Balance System
D 19	An external force due to a deviation of the reference surface involving a vertical imposed acceleration	Vertically raising platform/elevator
D 21	An external force due to a deviation of the reference surface involving an inclination of the support surface without an imposed acceleration	Ramp
D 22	An external force due to a deviation of the reference surface involving a reduced size of support surface without an imposed acceleration	Beam
D 23	An external force due to a deviation of the reference surface where the surface interaction resists motion and is uneven	Grass
D 24	An external force due to a deviation of the reference surface where the surface interaction allows a sliding motion in a single degree of freedom	Ice in a single direction
D 25	An external force due to a deviation of the reference surface where the surface interaction allows a rotation around the vertical axis	Playground round-about
D 26	An external force due to a deviation of the reference surface where the surface interaction allows a rotation around the horizontal axis	Rotation around a bar
D 27	An external force due to a deviation of the reference surface where the surface interaction allows movement in multiple degrees of freedom	Gym exercise ball

Classification code	Classification	Example
D 28	An external force due to a deviation of the reference surface where a low friction surface allows movement in multiple degrees of freedom	Highly glossed support surface
D 29	An external force due to a deviation of the reference surface where low friction surface allows movement in multiple degrees of freedom	Foam surface
D 30	The application of a vertical predictable/voluntary imposed external force	Releasing from suspension
D 31	The application of a lateral predictable/voluntary imposed external force	Inside a vehicle going around a bend
D 32	The application of an anterior-posterior predictable/voluntary imposed external force	Inside a vehicle accelerating
D 33	The removal of a vertical predictable/voluntary imposed external force	Releasing from suspension
D 34	The removal of a lateral predictable/voluntary imposed external force	Inside vehicle coming out of a bend
D 35	The removal of an anterior-posterior predictable/voluntary imposed external force	Inside a vehicle decelerating
D 36	The application of a vertical imposed external force	Releasing from suspension
D 37	The application of a lateral unpredictable/involuntary imposed external force	Inside a vehicle going around a bend
D 38	The application of an anterior-posterior unpredictable/involuntary imposed external force	Inside a vehicle accelerating
D39	The removal of a vertical unpredictable/involuntary imposed external force	Releasing from suspension
D40	The removal of a lateral unpredictable/involuntary imposed external force	Inside vehicle coming out of a bend
D 41	The removal of an anterior-posterior unpredictable/involuntary imposed external force	Inside a vehicle decelerating
D 42	A real object interaction involving negotiating a fixed object	Stepping over stationary object

Classification code	Classification	Example
D 43	A real object interaction involving negotiating a moving object	Stepping over non-stationary object
D 44	A virtual object interaction involving an application of force	Virtually simulated push
D 45	A virtual object interaction involving a removal of force	Virtually simulated release
D 46	A virtual object interaction involving negotiating a fixed object	Stepping over stationary virtual object
D 47	A virtual object interaction involving negotiating a moving object	Stepping over non-stationary virtual object

Table 4.4 Examples of perception challenges

Classification	Example
P 1	No challenge involved
P 2	Caren Gait system
P 3	Blacked out lens
P 4	Goggles
P 5	Low level lighting/no light
P 6	rapid head movements
P 7	Transcutaneous electrical stimulation
P 8	Stimulation of the ear nerves
P 9	Vibration plate
P 10	Cochlea implant
P 11	Ice bath
P 12	Textured insoles
P 13	Ankle brace
P 14	Feedback
P 15	Dual task

The classification of all balance tests ensures that the taxonomy is robust enough to cover all previously identified task goal and environmental constraints. Additionally, by classifying all dynamic balance tests it provides a method to determine sport-specific tests of dynamic balance.

Figures 4.4 and 4.5 present the frequency of balance measures for postural equilibrium challenges and destabilising challenges, respectively. The highest frequency of postural equilibrium challenges was a non-static base of support, with no flight and a change in supports from 1 to 2; equivalent to walking. Following this was a static base of support with two supports, equivalent of stance; then a static base of support with one support, equivalent of single leg stance. Five postural equilibrium challenges within the taxonomy did not have any components of any tests classified against them. The next most frequent components with destabilising challenges were categorised as a whole body suprapostural vertical acceleration (23 test components) and an external force with a deviation from the reference surface with a change in the size of the support (17 test components). Figure 4.6 displays components of dynamic balance tests that involved a perceptual challenge. Most tests did not involve perceptual challenges. The perceptual challenges identified involved movement of a visual surround, blocked vision, dual tasks, distorted vision, textured insoles and responding to a command to modify a primary task.

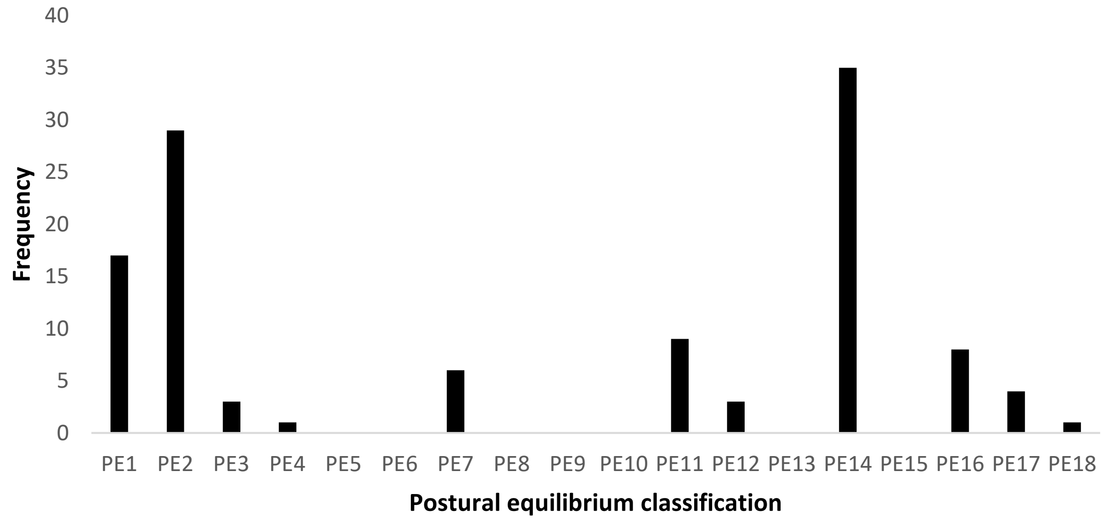

Figure 4.4 Frequency of components of dynamic balance tests classified by postural equilibrium challenge using the newly proposed taxonomy

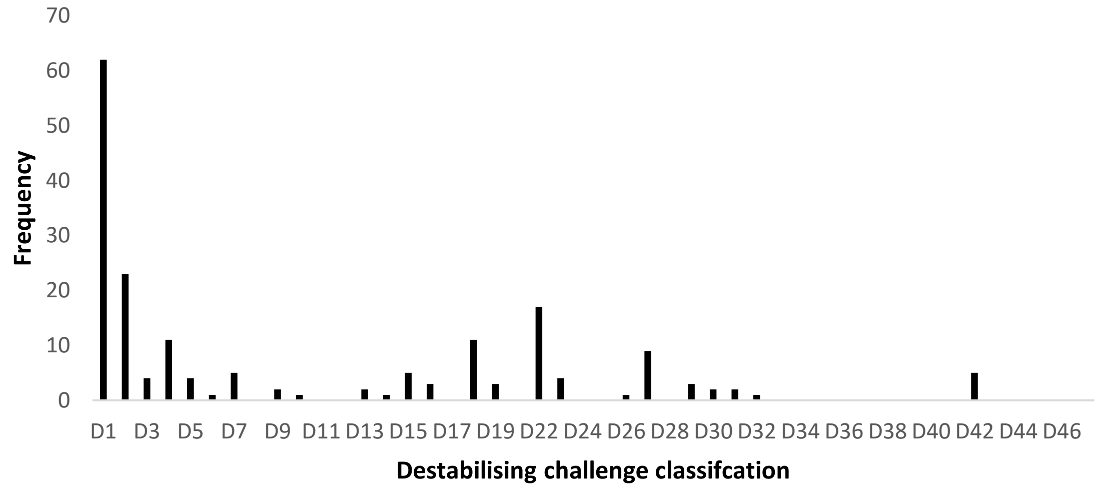

Figure 4.5 Frequency of components of dynamic balance tests classified by destabilising challenge using the newly proposed taxonomy. D20 is missing due to an error in numbering

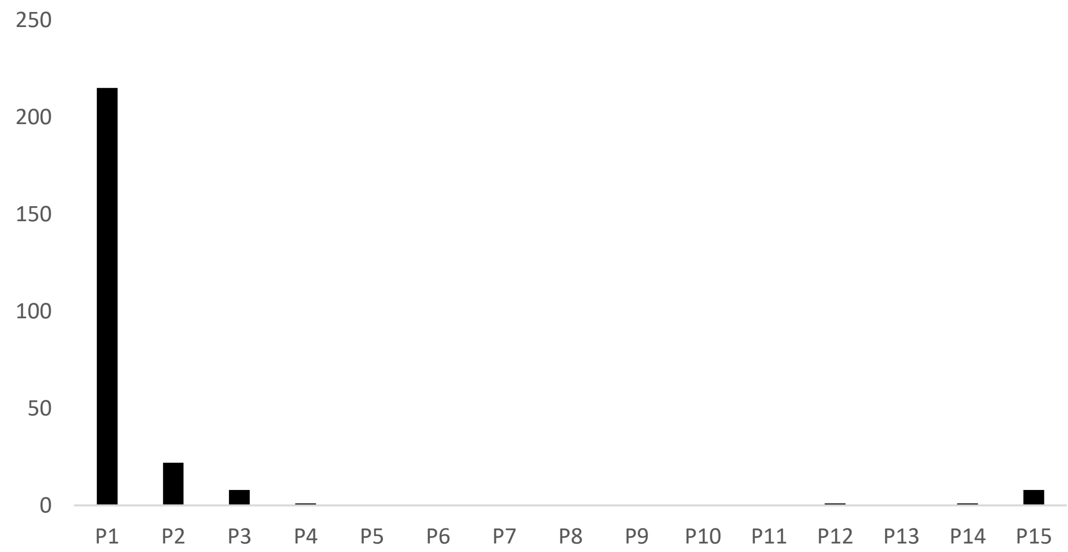

Figure 4.6 Frequency of components of dynamic balance tests classified by perceptual challenge using the newly proposed taxonomy

4.5 Discussion

The results of this body of work identified that most dynamic balance tests used in the literature involve movements akin to walking gait. There is a possibility that this is due to multi-components tests having a high frequency of gait related items for example, walking gait in: the TUG, the Dynamic Gait Index and the Locomotor sensory Organisation Test. Additionally, where tests were named as walking gait but had different methodologies, these were recorded within the results as separate tests which would have increased the number of tests recorded as individual tests involving walking gait. The next highest frequency classifications both involve a static base of support. There were seven classifications for which no dynamic balance tests were classified. This suggests that there are tasks that involve components of postural equilibrium challenges that have never been tested for. It is difficult to determine whether this is because they have not been identified as a component of dynamic balance in previous research or whether the limitation of key words to titles in the literature search may have missed instances where these movements have been tested.

Although the importance of incorporating task and environmental conditions with varying complexity has been previously emphasised (Huxham et al., 2001; Shumway-

Cook & Woollacott, 2007), 62 out of 301 components of tests did not involve any destabilising challenges. It has been suggested that evaluations should include the use of a broad range of activities based on a framework of task and environmental complexity to be representative of activities of daily living (Gentile, 1987) and this would present a more representative design (Davids et al., 2013; Pinder et al., 2011). The most frequent components with destabilising challenges were categorised as a whole body suprapostural vertical acceleration (23 test components) and an external force with a deviation from the reference surface with the deviation being a change in the size of the support (17 test components). There were 23 classifications that existing tests had no components for. The results of this body of work identify that a range of destabilising challenges that arise from the environment are missing from existing tests or they have not been assessed as being important. The new taxonomy provides a method by which future researchers and clinicians can determine how the movements of interest relate to existing tests and determine the most appropriate tool for the population of interest.

Another interesting finding of this study is that the most common dynamic balance tests used in sport, and more specifically football, are the SEBT, LQ-YBT, single leg stance and perturbed single leg stance. Table 4.7 displays the classification from the results of this study for the aforementioned tests. Football rarely involves isolated movements where a single stance leg is non-moving. Additionally, there are many environmental constraints within football that should be varied and assessed with tests. It is not practicable to test every single environmental aspect (Pardasaney et al., 2013) therefore, it is of interest to identify the components of balance important for football. Classifying the most important movements for football performance would identify sport specific dynamic balance tests.

Table 4.7 Classification of postural equilibrium and destabilising challenge for the most common dynamic balance tests used in football

Test	Postural Equilibrium Classification	Destabilising Challenge Classification
SEBT	non-moving base of support, one support	Supra-postural acceleration, lower limb, reaching
LQ-YBT	non-moving base of support, one support	Supra-postural acceleration, lower limb, reaching
Single leg stance	non-moving base of support, one support	No destabilising challenges
Perturbed single leg stance	non-moving base of support, one support	External force, imposed forces, predictable/voluntary, application of A-P, lateral

4.4 Limitations

There are some limitations of this research. Although an extensive literature search was conducted in Section 3, there is a possibility that some balance measures were not identified if they were presented in papers that did not have the balance terms: dynamic balance, dynamic postural control and dynamic postural stability in the title or were outside of the search time window. As a result, some balance tests may not have been included. However, the number of papers included in the study in Chapter 3 is large and the use of additional researchers with expertise in a range of sports as well as the use of previous taxonomies and the BMC, provides confidence that the proposed taxonomy is robust.

4.5 Conclusions

The newly proposed taxonomy, presented in Figure 4.4 has drawn on both models set forth by Huxham et al. (2001) and Pardasaney et al., (2013) as well as considering Newell's constraints model. It provides a more detailed approach to be able to differentiate the range of different components of balance considering the task and the environment within tests and has extended the work of Pardasaney et al. (2013). This new taxonomy together with the classification of all existing dynamic balance tests have significant practical applications. The classification of existing tests through the taxonomy provides a more detailed and comprehensive profile of all existing dynamic balance tests. The taxonomy also provides a method by which any new tests can be profiled. By also providing a method of movement classification, it provides a tool by which appropriate measures can be chosen that align with existing tests. Additionally, it provides a tool whereby researchers and clinicians can identify the strengths and limitations within each test in terms of task goal, environmental challenges, perceptual challenges and action challenges to recognise representative assessments that are adequately challenging for the population being tested. The taxonomy provides a tool to be able to classify movements that are considered important in football and align them with existing dynamic balance tests to provide sport specific tests to be used in Chapter 6.

This body of work proposes a new set of definitions for the most common terms used to describe dynamic balance (dynamic balance, dynamic postural control and dynamic stability) that consider Newell's constraints model. It is recommended that future research in this field refers to these definitions.

Chapter 5 Important measures of dynamic balance in football

5.1 Introduction

Chapter 3 identified that most existing tests of dynamic balance are static in nature, have predictable environments and inadequately represent postural control demands in sport specific situations involving complex and dynamically changing environments. Static balance is essential in sports such as shooting and archery where the BoS remains unchanged (Ball et al., 2013; Mononen et al., 2007; Sattlecker et al., 2014). However, sports such as football involve a wide range of different movements such as accelerations and decelerations, changes of direction and the application and removal of forces from opponents and the ball (Bloomfield et al., 2004; Zemková, 2014). Popular dynamic balance tests in football such as the SEBT, YBT and single leg stance are static in nature as they involve a static BoS. They have been justified in the research as being specific to football as kicking and reaching for a ball involve balancing on one limb (Paillard et al., 2006) however, this is not representative of kicking because it is not an isolated movement and the sport requires quick movements and reactions. Additionally, the performance related outcome variables do not provide information pertaining to control strategy. There is evidence that athletes have better balance than non-athletes and higher skilled athletes show better performance than lower level athletes (Bhat & Moiz, 2013; Bressel et al., 2007; Davlin, 2004; Gerbino et al., 2007; Kioumourtzoglou et al., 1997; Perrin et al., 2002; Thorpe & Ebersole, 2008) however the tests used to assess balance can be considered inappropriate as discussed in Chapter 3. Many of the reasons explaining better performance or differences in performance of athletes of particular sports or different levels is the training experience (Balter et al., 2004; Bressel et al., 2007; Davlin, 2004; Kioumourtzoglou et al., 1997; Perrin et al., 2002; Thorpe & Ebersole, 2008), the nature of the movements involved (Kioumourtzoglou et al., 1997; Perrin et al., 2002) or how proprioceptive and visual cues are handled by the participant (Ashton-Miller et al., 2001).

As a result, these inadequacies were addressed, and a taxonomy was developed to encompass the multi-dimensional aspects of dynamic balance. The new taxonomy classifies movements of everyday living and sport. Chapter 4 classified all existing balance tests identified in Chapter 3. It was of interest to determine what movement demands exist in football and which of those movements are considered important for success of the game. It was also of interest to determine whether these important movements could be aligned with existing balance tests.

Previous literature has ascertained that balance is multi-dimensional and that there are different components of balance (Pollock et al., 2000). There is also the argument that testing should be representative of the sport (Pinder et al., 2011). To the author's knowledge dynamic balance testing within sport and in particular football has not considered the specificity of tests in terms of the task goal, environmental and individual constraints. Chapter 4 identified that existing taxonomies of classifying balance tests (Huxham et al., 2001; Pardasaney et al., 2013) were inadequate due to their limited application within falls and community dwelling older adult populations and extended the work of Pardasaney et al. (2013) to provide a taxonomy through which important movements pertaining to a sport or activity could be determined and matched with existing dynamic balance tests of the same classification. This taxonomy provides a sport specific measure of dynamic balance that references Newell's model of constraints (Newell et al., 1989) through the consideration of task goal and environmental constraints. Chapter 4 reported the classification of all identified existing dynamic balance tests. This chapter firstly, details an investigation into movements that are important for football performance and secondly uses the taxonomy from Section 4 to guide the selection of the most appropriate measures to quantify dynamic balance.

5.1.1 Aims and Objectives

The aim of this chapter was to identify common physical movements in football and use these to determine which of these movements are considered by experts as important for success in the game. The outcome of this work was to provide a set of movements to be put through the movement taxonomy in Chapter 6, to determine which balance test they best align with and subsequently use in testing in Chapter 7.

Objectives:

- Identify important physical movements in football
- Use a panel of experts to rank these movements to identify those that are important for success in the game
- Identify existing balance tests that align with these important movements to identify sport specific measures of dynamic balance

5.2 Method

5.2.1 Participants

All procedures were approved by Sheffield Hallam University Ethics Committee. 15 football professional participants with 6.9 ± 5.4 (mean, SD) years elite level experience were recruited via email through convenience sampling. Inclusion criteria were that respondents worked in the following roles: medical (n = 2), performance analysis (n = 3) or coaching staff (n = 10) in professional football at Football League levels: Premiership (n = 1) and Championship (n = 14). All participants provided written informed consent (Appendix H).

5.2.2 Research Protocol

A questionnaire was developed and piloted through consultation with professional football coaches, performance analysts and players and is presented in appendix I. A glossary of terms, presented in appendix J, was provided with the questionnaire to ensure all respondents understood the questions alike. The questionnaire contained 49, closed pre-coded questions with a 3 category Likert scale: 1: disagree, 2: agree, 3: strongly agree. Participants were required to enter a number 1-3 that represented their expert opinion on how the movement in each question related to each of the four performance categories: Creating a goal scoring opportunity; defending around the box; winning a tackle/regaining possession; and injury risk.

5.2.3 Analysis

Each movement of each question was grouped on responses for all four performance categories. The taxonomy developed in Chapter 4 was then used to categorise each movement for postural equilibrium and destabilising challenges. Each individual movement was classified by one postural equilibrium item, but it was possible to have multiple destabilising challenge items. The movements that fell under the same classification were then grouped together as the same components of dynamic balance. The total score of 3s and 2s for each classified group were summed. The three highest totals for the classified groups were chosen as the most important dynamic balance components. It was then determined which existing tests aligned with these dynamic balance components. Microsoft Excel (Microsoft Office 2011, Microsoft Corporation, USA) was used to record classifications and apply the points system.

5.3 Results

5.3.1 Classification of movements

The most common classification of postural equilibrium was a non-static base of support with no flight and a change in number of supports from one to two or vice versa (PE 14), for example walking, with 12 movements classified in this way (Figure 5.1). There were 9 movements that were classified either as a non-static base of support involving flight, with a change in points of support remaining as one (PE 4), for example running. There were 9 movements that were classified as a non-static base of support involving flight, with a change in points of support from one to two or vice versa (PE 7), for example hop scotch.

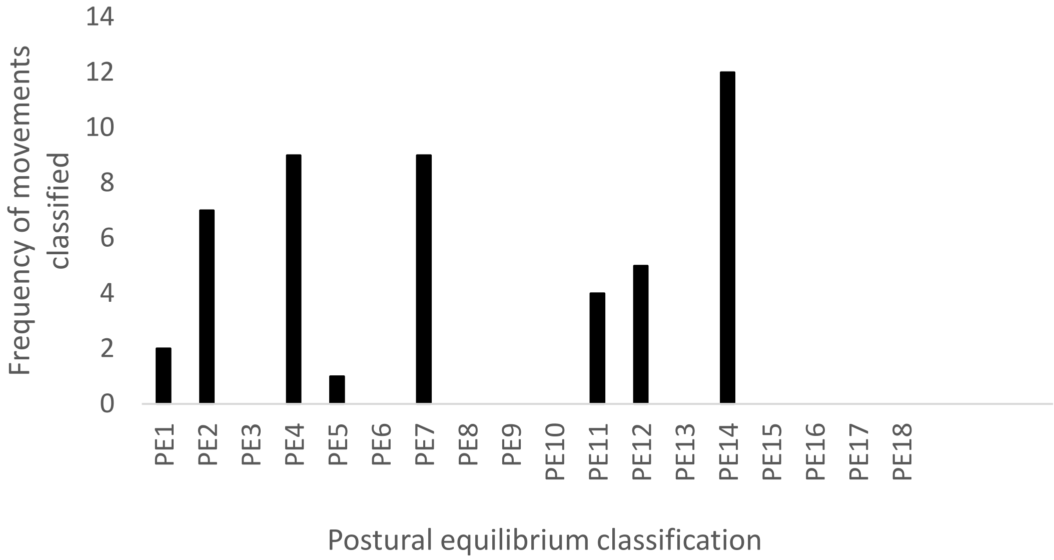

Figure 5.1 Frequency of classification of movements in football for postural equilibrium as classified using the new taxonomy proposed in Chapter 4.

A vertical supra-postural acceleration of the whole body and an anterior-posterior supra-postural acceleration of the whole body were the highest classified destabilisations with 23 instances each displayed in figure 5.2. This was followed by a predictable or voluntary application of an imposed external force laterally (such as that experienced in a shoulder barge) with 20 classifications.

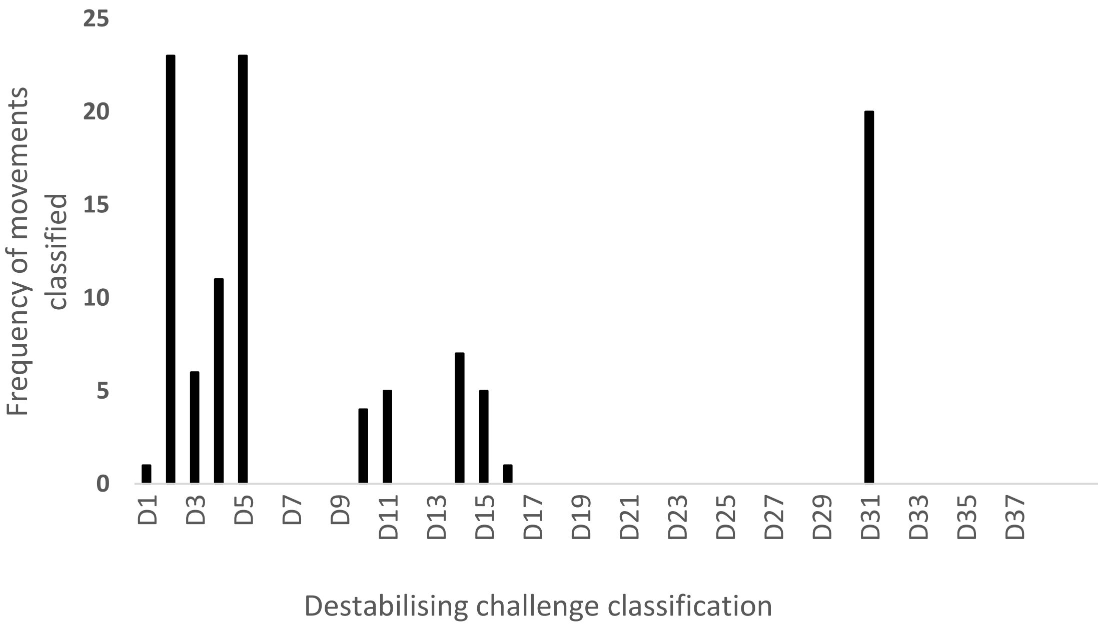

Figure 5.2 Frequency of movements classified in football for destabilising challenges

5.3.2 Dynamic balance components

The results in Table 5.4 show that the most points were allocated to shielding the ball, a shoulder barge whilst running, jostling to win the ball and shielding the ball whilst jostling with 285 points, followed by accelerating and braking with 161 points, and a single leg kick or standing volley with 144 points. Shielding the ball, a shoulder barge whilst running, jostling to win the ball and shielding the ball whilst jostling were classified as PE14 for postural equilibrium and D31, D32, D37 and D38 for destabilising challenge. Within the taxonomy in Chapter 4 this relates to non-static BOS, no flight with a change in supports from 1-2 or vice versa, with a predictable or voluntary application of an imposed external force laterally and anterior-posteriorly, and an unpredictable or involuntary application of an imposed external force laterally and anterior-posteriorly. Accelerating and braking was classified as PE4 for postural equilibrium and D5 for destabilising challenge This relates to a non-static BOS, no flight with a change in supports from 1-2 or vice versa with a whole body suprapostural acceleration in the anterior/posterior direction. Kicking the ball was classified as PE14 for postural equilibrium and D5 and D32 for destabilising challenge. This relates to a non-static BOS, no flight with a change in supports from 1-2 or vice versa with a suprapostural acceleration of the lower limb involving a swing and a predictable or voluntary application of a predictable/voluntary imposed external force anterior-posteriorly.

Table 5.4 Football movements classified using the new taxonomy proposed in Chapter 4. Rankings of 3 (strongly agree), 2 (agree) and their totals by football professionals via a questionnaire relate to responses that the movement is important in the four performance categories: Creating a goal scoring opportunity, defending around the box, winning a tackle/regaining possession, and injury risk. Information in the table is ordered numerically by postural equilibrium challenge.

Performance category and question number	Football Movement	Postural equilibrium	Destabilising challenge	No. of 3s	No. of 2s	Total
A31, B31, C31, D31	Single leg kick	PE1	D11, D32	27	29	144
A32, B32, C32, D32	A standing volley	PE1	D11, D32	15	31	
A34, B34, C34, D34	Single leg balance whilst manipulating the ball	PE2	D10, D11, D31, D32	16	15	47
A35, B35, C35, D35	Receiving a ball	PE2	D10, D31, D32	17	18	52
A36, B36, C36, D36	Heading	PE2	D15, D16, D31, D32,	34	19	87
A48, B48, C48, D48	A shoulder barge while standing	PE2	D3, D31, D37	24	24	72
A12, B12, C12, D12	A squat with outstretched leg	PE2	D2, D10	7	32	46
A11, B11, C11, D11	Squat	PE2	D2	7	28	42
A37, B37, C37, D37	Chesting	PE2	D32	13	34	60
A13, B13, C13, D13	accelerating	PE4	D5	22	29	161
A14, B14, C14, D14	braking	PE4	D5	32	24	
A2, B2, C2, D2	Running with a turn	PE4	D4	21	32	135
A4, B4, C4, D4	Running in an arc	PE4	D4	10	41	

Performance category and question number	Football Movement	Postural equilibrium	Destabilising challenge	No. of 3s	No. of 2s	Total
A33, B33, C33, D33	A volley whilst running	PE4	D11, D32	15	31	61
A6, B6, C6, D6	Dribbling	PE4	D5, D11, D31, D32	15	9	39
A3, B3, C3, D3	Running whilst rotating the trunk	PE4	D14	14	34	62
A5, B5, C5, D5	Running with a cutting/sidestepping movement	PE4	D3, D5	20	28	68
A1, B1, C1, D1	running straight line	PE4	D1	10	35	55
A42, B42, C42, D42	Shielding the ball	PE4	D31, D32, D37, D38	21	26	
A49, B49, C49, D49	A shoulder barge whilst running	PE4	D31, D32, D37, D38	21	29	285
A40, B40, C40, D4	Jostling to win the ball	PE4	D31, D32, D37, D38	24	30	
A41, B41, C41, D41	Shielding the ball whilst jostling	PE4	D31, D32, D37, D38	18	32	
A39, B39, C39, D39	Jockeying	PE4	D3, D4, D5	23	17	63
A44, B44, C44, D44	A scissor kick	PE5	D2, D4, D14	14	21	49
A16, B16, C16, D16	A two-foot jump single leg landing with whole body turn	PE7	D2, D4, D5	10	39	102
A28, B28, C28, D28	A hop two leg landing with whole body turn	PE7	D2, D4, D5	1	41	102
A43, B43, C43, D43	A bicycle kick	PE7	D2, D4, D14	12	21	45
A15, B15, C15, D15	A two-foot jump single leg landing	PE7	D2, D5	11	36	105
A27, B27, C27, D27	A hop two leg landing	PE7	D2, D5	5	37	105

Performance category and question number	Football Movement	Postural equilibrium	Destabilising challenge	No. of 3s	No. of 2s	Total
A18, B18, C18, D18	A two-foot jump single leg landing with head rotation	PE7	D2, D5, D15	9	43	100
A30, B30, 30, D30	A hop two leg landing with head rotation	PE7	D2, D5, D15	2	35	100
A29, B29, C29, D29	A hop two leg landing with trunk rotation	PE7	D2, D5, D14	1	32	91
A17, B17, C17, D17	A two-foot jump single leg landing with trunk rotation	PE7	D2, D5, D14	9	39	91
A25, B25, C25, D25	A hop single leg landing with trunk rotation	PE11	D2, D5, D14	13	31	57
A23, B23, C23, D23	A hop single leg landing	PE11	D2, D5	8	34	50
A26, B26, C26, D26	A hop single leg landing with head rotation	PE11	D2, D5, D15	11	34	56
A24, B24, C24, D24	A hop single leg landing with whole body turn	PE11	D2, D4, D5	11	32	54
A38, B38, C38, D38	Chesting with a jump	PE12	D2, D32	9	30	48
A19, B19, C19, D19	A two-foot jump two leg landing	PE12	D2, D5	8	41	57
A20, B20, C20, D20	A two-foot jump two leg landing with whole body turn	PE12	D2, D4, D5	7	44	58

Performance category and question number	Football Movement	Postural equilibrium	Destabilising challenge	No. of 3s	No. of 2s	Total
A22, B22, C22, D22	A two-foot jump two leg landing with head rotation	PE12	D2, D5, D15	5	48	58
A21, B21, C21, D21	A two-foot jump two leg landing with head rotation	PE12	D2, D5, D14	5	44	54
A47, B47, C47, D47	A feint	PE14	D3, D5	16	14	46
A10, B10, C10, D10	side lunge	PE14	D2, D3	13	41	67
A7, B7, C7, D7	A lunge forward	PE14	D2, D5	19	34	132
A8, B8, C8, D8	A lunge backwards	PE14	D2, D5	12	36	60
A45, B45, C45, D45	A side block tackle	PE14	D4, D31	25	18	68
A46, B46, C46, D46	A sliding tackle	PE14	D4	23	19	65
A9, B9, C9, D9	A lunge with outstretched leg	PE14	D2, D5, D10	20	34	74

5.3.3 Test Specificity

There were no existing dynamic balance tests that aligned with the important movements identified for football. For shielding the ball, jostling to win, and shielding the ball whilst jostling, there were no existing dynamic balance tests that align with classifications of PE4, D31, D32, D37 and. For accelerating and braking there were no existing tests that aligned with PE4 and D5. For a single leg kick/standing volley, there were no existing dynamic balance tests that align with PE1, D11 and D32.

5.4 Discussion

The aim of this investigation was to identify important football movements and their dynamic balance components to align these with existing tests that would provide sport specificity in dynamic balance testing. Football professionals completed a questionnaire to establish which football movements they considered important for success of the game. Football movements were classified through the taxonomy in Chapter 4, then questionnaire ratings were used to identify those considered most important. Finally, the three highest ranked movements were aligned with dynamic balance tests that were classified in Chapter 4 to determine sport specific measures for football. To the author's knowledge this is the first study to report an analysis of movements considered important to the game of football and then use a taxonomy to classify movements based on postural task and environmental constraints

5.4.1 Classification of movements

The present study identifies that shielding and jostling, both involving external forces from an opponent, were most important. Following that were accelerating and braking, both requiring internal forces, and then a single leg kick or volley which involves both internal and external forces. Owing to their varying influence on postural control demands, it has been emphasised in previous literature that incorporating task and environmental conditions with variable complexity is important (Horak et al., 2009; Huxham et al., 2001; Shumway-Cook & Woollacott, 2017). Furthermore the use of a broad range of activities based on task and environmental constraints provide more representativeness of performance (Davids et al., 2013; Gentile, 1987; Pinder et al., 2011). An observation of this study was that only one of the three football movements identified involved a static base of support. This confirms that the previous use of common tests in football involving a static base of support with no environmental constraints are inappropriate. Where the single leg kick or volley was identified as having a static BoS it involved additional environmental constraints that previous tests of dynamic balance in football have not addressed. Whilst the BMC (Bloomfield et al., 2004) identified in Chapter 2 identifies that the physical demands of football it does not take into consideration the types of movements that occur in interactions with opponents and does not consider how these movements relate to success of the game or injury risk. The present study has identified that there are movements with task goal and environmental constraints that are not identified in the physical demands of the game but may be important in terms of performance and dynamic balance.

5.4.3 Test Specificity

These results highlight the lack of tests available that address the components of balance identified as important in football. The movements classified in the present study demonstrate that the postural equilibrium classifications of movements in football were mostly categorised as involving a moving base of support. Additionally, destabilising challenges were often more complex than just the movement of the non-stance limb as in the case of the popular dynamic balance tests in football. All of the common measures of dynamic balance in football (Table 4.7, Section 4.3) involve a postural equilibrium classification of a single leg, non-moving BoS however, most of the football movements classified involved a moving BoS and two of the three groups of important movements involved a moving BoS. No test categorised in the taxonomy developed in Chapter 4 matched the categories of the important football movements at the postural equilibrium level nor the destabilising challenge level of the taxonomy. This provides insights into task goal and environmental constraints that should be incorporated into new measures to provide more representative and comprehensive assessments of dynamic balance.

Common tests of dynamic balance: SEBT, YBT and single leg stance, have been used to demonstrate that footballers have performed better than other athletes and controls (Bressel et al., 2007; Davlin, 2004; Khuman et al., 2014; Matsuda et al., 2017; Teixeira et al., 2011). However there is inconsistency within these studies as they have also demonstrated that footballers perform similarly to other athletes and non-controls (Bressel et al., 2007; Davlin, 2004; Matsuda et al., 2017). These common methods of dynamic balance assessment in football were classified through the newly developed taxonomy in Chapter 4 and it was identified that they do not align with any of the football movements identified in the present study. Furthermore, only the perturbed single leg stance presents with any of the environmental constraints identified in the destabilising challenges of the important movements in football but does not align with the postural equilibrium classification. These common tests can therefore be considered as not sport specific by way of classification. It is necessary to develop more appropriate dynamic balance tests that align with the task goal and environmental constraints of the important football movements through the taxonomy levels postural equilibrium and destabilising challenges.

The results of this work demonstrate that new measures are required to account for the range of task and environmental constraints identified above. It is of interest to determine whether newly created measures can differentiate for skill level.

5.5 Limitations

This study has limitations that require consideration. Movements identified as important may differ at different competition levels of the game. Most of the questionnaire responses were from Championship level football professionals and as such, it is unknown whether the same movements would be considered important to the game at lower or higher levels. There may have been more appropriate methods of identifying important movements in football such as the use of a Delphi Poll or the use of performance analysis software and techniques routinely employed in the assessment of player and team performance in the game. Delphi polls are a group facilitation technique, with an iterative multistage process, designed to transform opinion into group consensus (Hasson et al., 2000). The use of a Delphi poll could have provided a method of gaining opinions from a wide range of individuals within a wide range of playing levels of football so that important football movements could be determined at all levels. However, the use of a Delphi Poll would have required an unacceptable level of time from the football professionals. Delphi polls have their own limitations not limited to researcher skills, interpretation and reporting of findings and as a means of gathering opinion rather than predictions. The use of time-motion analysis would enable the separate identification of important movements related to performance or injury risk as well as at different levels of football. However, this method requires specialist training, is labour intensive and access to data would present difficulties. Additionally, the use of performance analysis techniques would not inform important movements considered to be related to success of the game. The use of a questionnaire provided a practical way of obtaining information as opposed to the use of an interview, was more convenient for participants and provided highly structured data. The test-retest reliability of the questionnaire was not assessed. Therefore, it is recommended that future work assesses the reliability of any questionnaire that is used to determine the most important movements of the activity in question.

5.6 Conclusions

Important movements in football in relation to success of the game have been identified. All football movements have been classified using the taxonomy developed in Chapter 4. It was possible to identify components of dynamic balance and group movements by postural equilibrium and destabilising challenges using the taxonomy. Furthermore, the taxonomy made it possible to discover existing dynamic balance tests that aligned with the most important football movements identified through the results of this study. It was identified that there were no existing balance tests that aligned demonstrating that 1., previous research has not identified the components of balance that should be tested for in football, 2., previous research has not made use of sport specific tests to assess dynamic balance in football and 3., the taxonomy is a useful tool that provides a method of classifying important components of dynamic balance in football and identifying appropriate tests. The taxonomy is a tool that may be useful in other sports in identifying components of balance and aligning existing balance tests for specificity.

Chapter 6 Differentiation of skill level through dynamic balance testing in male footballers

6.1 Introduction

Chapter 2 identified that previous research has shown that athletes perform better than controls in tests of dynamic balance. Additionally, dynamic balance ability is dependent on sport played. Explanations for these differences have been attributed to specificity of training. However, when research has examined the dynamic balance ability of athletes within the same sport at different skill levels there is a lack of consensus that higher-level athletes perform better with some studies showing that within certain aspects of tests lower-ability athletes perform better. An important limitation of previous dynamic balance testing in sporting athletes is that the tests used involve a static base of support and Chapter 2 highlighted the need for sport specific tests. Additionally, whilst existing dynamic balance tests commonly used in sport, and in particular football, provide a measure of the performance they do not provide any detail on the strategies involved that might explain differences between athletes and non-athletes, and between skill levels.

Chapter 4 developed a taxonomy by which existing tests could be categorized according to postural demands and environmental constraints to be able to determine sport specific measures of dynamic balance. Chapter 5 identified football movements considered by experts as important for success in the game through questionnaire data; thereby identifying dynamic balance components important for football. These were identified as shielding and jostling, accelerating, and braking, and a single leg kick or volley. These movements were classified in the proposed taxonomy developed in Chapter 4 with the aim of aligning them with existing balance tests. It was found that not one individual existing balance test had appropriate content that matched that all the movements identified as being important in football, demonstrating that previous research has not identified nor considered the components of balance that should be tested for in football.

This chapter firstly reports the development of new dynamic balance measures specific to football. The development of these new measures includes both performance related outcomes and ways of identifying strategies that might explain the performance. This chapter then applies the developed measures alongside a standard balance measure popular in football to determine whether they can better differentiate for skill level in football players.

6.1.1 Aims and objectives

The aim of this chapter was to determine whether sport specific measures of dynamic balance differentiate for skill level in football players. The objectives were:

- To develop new football specific measures of dynamic balance
- To investigate whether the developed measures and a reference measure differentiate for skill level between elite, recreational and non- football players.
- To determine whether dynamic balance differs for dominant vs non-dominant limbs.

6.2 Development of new measures

For movements where there were no tests that align from the taxonomy, tests that had a matching postural task and/or destabilising challenge were chosen and adapted to provide specificity by including the missing classifications. Existing measures were examined for their environmental constraint applicability to the components of dynamic balance identified as important in Chapter 5 for football players. Additionally, papers from reference lists were also consulted. Table 6.1 presents tests where environmental constraints were investigated to determine whether items would provide specificity and would be practical considering equipment availability and logistics of the study.

Table 6.1 Tests identified with environmental constraints to be considered for development of new football specific measures of dynamic balance.

Football movement	Test	Item specifics	Outcome measures	Reference paper
External force	Perturbation	i. Surface perturbations -translation/rotation ii. Wobble board iii. Slips iv. Trips v. Arm movements vi. Sagittal plane perturbations applied via a pendulum vii. Frontal plane experimenter delivered perturbation viii. Frontal plane torque perturbations applied via robotised ankle-foot orthosis whilst treadmill walking ix. Frontal plane perturbations applied via belt at waist whilst treadmill walking x. Frontal plane perturbations with a motorised waist-pull system	Stability index, time in balance, pivot displacement, Score, margin of stability, total energy power spectrum of the oscillations, platform angle deviation, angle variation, CoP and CoM trajectories	i. 7, 23, 32,56,71, 77, 90, 184, 197, 198, 208, 209, 213, 240, 246, 275, 281, 283, 312, 319, 324,327, 330, 331, 392, 396, 398, 399, 415, 432, 435, 437, 446, 447, 458, 459, 461, 463, 468, 469, 474, 487, 499, 513, 521, 534, 550, 556, 569, 758, 764, 785, 794, 797, 831, 832, 837, 843, 874, 888, 889, 903, 906, 908, 949, 970, 974, 975, 986, 987, 995, 998, 1018, 1029, 1042, 1043, 1044, 1047, 1052, 1053, 1066, 1075, 1107, 1124, 1141, 1188, 1206, 1209, 1220, 1222, 1223, 1248, 1256, 1261. Behan *et al.* (2018) ii. 90, 246, 785, 874, 1066 iii. Marigold et al., 2005 iv. Schillings et al., 2000; Pijnappels, Bobbert and Van Dieen, 2006 v. Fujiwara et al. (2011) vi. Davidson et al. (2009) vii. Rietdyk et al. (1999) viii. Blanchette et al. (2011) ix. Hof, et al. (2010) x. Gray et al. (2017)
Acceleration/Deceleration	Shuttle run Sprint test	sprinting 10 m from a stationary start position	Time	Little & Williams (2005)
Single leg kick/standing volley	Single leg kick	i. Single limb stance, leg swinging, rotation of trunk and hips to simulate kick ii. unipedal stance on force plate performing oscillatory movements in both A-P and M-L leg sway tasks at 3 Hz iii. a). Single limb stance, rapid limb swings in AP and ML direction. b). instep kicking iv. Single limb stance, kick a ball	i. CoP measures ii. CoP excursion iii. a). GRF power spectra. b). GRF, impulse iv. CoP displacement	i. Fernandes et al. (2016) ii. Teixera et al. (2011) iii. Hatzitaki et al. (1999) iv. Rios et al. (2015)

Numerical references refer to literature presented in Appendix A.

6.2.1 External forces

The use of surface perturbations in standing balance applied through platform motion have been used extensively, as well as the use of a wobble board and through arm movement (Fujiwara et al., 2011). These compromise the representativeness of the environmental stimulation due to their narrow and predictable range of perturbations (Rietdyk et al., 1999) and do not satisfy the postural equilibrium challenges and destabilizing challenges (environmental constraints) of shielding and jostling, which involve the removal or application of predictable or unpredictable externally imposed forces in the lateral and anterior-posterior direction. Other more severe challenges have included induced slipping (Marigold et al., 2005) and tripping (Pijnappels et al., 2006; Schillings et al., 2000), and likewise these methods are not representative of the environmental challenge. Standing and walking with perturbations has been studied much less (Rietdyk et al., 1999, Davidson et al., 2009; Hof et al, 2010; Blanchette et al., 2011). These methods include standing whilst perturbed by padded pendulums in the sagittal plane (Davidson et al., 2009) and experimenter delivered perturbations in the frontal plane (Rietdyk et al., 1999), walking on a treadmill: wearing a robotised ankle-foot orthosis through which a torque perturbation was applied (Blanchette et al., 2011), with the perturbation applied through a rod attached via a broad belt around the waist to a pneumatic cylinder (Hof, et al., 2010) and a frontal plane motorised waist pull system . The application of the perturbation through the methods of Blanchette et al. (2011) were not justified for use in this study, as a perturbation at the ankle joint would not provide specificity of perturbations experienced to the upper body during shielding and jostling. Due to practical limitations, perturbations applied via padded pendulums or via a pneumatic cylinder were not possible. The experimenter delivered perturbations of Rietdyk et al. (1999), do not allow a consistent measurable approach within and across participant trials, nor do they allow a measurement of the force applied. The methods of Gray et al. (2017) in applying perturbations at the waist were of interest however, a motorised system was a methodological issue for this study. Adaptions of the discussed techniques above were viable in providing a suitable method. Pilot testing found that a pre-tensioned bungee cord secured to the wall and then attached to the mid front and mid back of a chest harness worn by the participant via a rope provided a method of applying and releasing a force that caused a perturbation of the upper body. Figure 6.1 displays the method of applying perturbations. The bungee was held taut by the tester which allowed the rope to become slack ensuring there was no perturbation to the participant during this time. Application of the perturbation involved the tester releasing the bungee from their grip causing the rope and bungee to become taut. Release of the perturbation involved pulling the bungee towards the participant causing the rope to become slack. Pilot testing determined the time this took to complete across trials and participants was repeatable. The use of a spring scale placed between the rope and bungee allowed a consistent approach to adjusting the force for the individual. During pilot testing participants struggled to maintain their balance with perturbations above 10 % of their body mass and 5 % of body mass was not enough to provide a destabilising force. Feedback from elite and recreational participants in pilot testing was that a perturbation force of 10 % of participant body mass was similar to what was encountered during a game. Therefore, a perturbation force of 10 % was chosen.

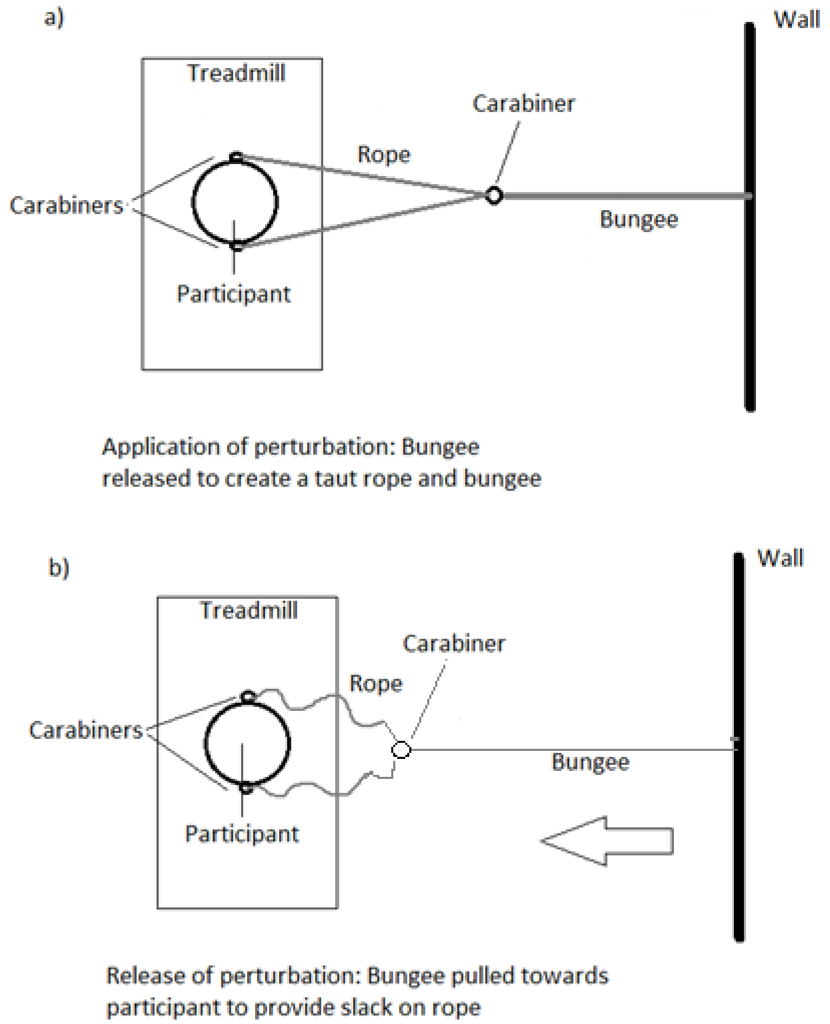

Figure 6.1 Application and release of perturbations during the external forces test. A bungee was secured to a wall, then to the participant via rope and carabiners to the front and rear of a chest harness. a) perturbation application, b) perturbation release.

6.2.2 Acceleration and deceleration

Football match performance is impacted by the ability of players to produce varied high-speed actions (Luhtanen & Ekblom, 1994), with acceleration identified as being a specific quality integral to successful performance outcomes (Harper et al., 2020; Little & Williams, 2005). Critical activities such as being first to the ball, beating an opponent into space, and creating and stopping goal-scoring opportunities during team sports (Carling et al., 2008; Reilly et al., 2000) are dependent on the ability to increase velocity or accelerate. Shuttle runs and sprint tests were identified as familiar performance tests for football and could be modified to include measurements of balance. Modification of shuttle run or sprint test to include measurements of balance would be appropriate. Shuttle runs and sprint tests are usually performed at 18.3 m and 10 m distances, respectively. The laboratory dimensions were 16 m long x 10 m wide however due to storage of equipment the available space was 13 m long x 8 m wide. The laboratory space is not long enough to accommodate the length of a shuttle run and as the sprint tests only involves an acceleration, to be able to successfully record a deceleration after 10 m would prove challenging in the available space. Should the total amount of laboratory space available have been used it would have created a large capture volume for 3D motion capture, and with the amount of cameras available, would reduce the accuracy of the system (van der Kruk & Reijne, 2018). Furthermore, accelerations experienced by elite footballers have been identified as; low, 1-2 ms^{-2}; medium, 2-3 ms^{-2} and high > 3 ms^{-2} (Akenhead et al., 2013; Góralczyk et al., 2003; Hodgson et al., 2014). It was of interest to have all participants experience the same acceleration and deceleration rates therefore, a treadmill was used to accelerate and decelerate participants.

It was identified in pilot testing that the treadmill could accelerate at a rate of 1 ms^{-2}, this did not provide the high threshold that would provide a more destabilising force to participants. Additionally, the treadmill did not have the ability to consistently accelerate at the same speed for every participant because of the limited motor power available of the treadmill belt. Additionally, the treadmill company would not unlock the advanced features to provide higher accelerations as the treadmill did not have a safety arch and means of attaching a harness. Therefore, only the deceleration component of the football movement identified in Chapter 5 was possible. In team sports decelerations are just as common as accelerations (Osgnach et al., 2009; Spencer et al., 2004). There is a greater rate of velocity change in high intensity decelerations which occur more frequently in team sports (Harper et al., 2020). Rapid decelerations are crucial in changes of direction for both attack and defence (Harper et al., 2020; Osgnach et al., 2009; Spencer et al., 2004) Furthermore, greater mechanical loads are imposed with high-intensity decelerations and involve high eccentric braking forces to slow the body's CoM. Deceleration occurs after any sprint performance to slow the body's CoM (Dalen et al., 2016; Hewitt et al., 2011; Vanrenterghem et al., 2017). Deceleration in football may occur in response to other player's movements such as (marking, evading, or collision avoidance) or to stay within a playing area. To safely decelerate the body several shortened gait cycles are used which absorb the high eccentric forces with as little stress to the joints as possible (Andrews et al., 1977). Several body segments are adjusted to slow the forward moving CoM. The body is expected to be positioned with a posterior tilt of the pelvis, erect or posterior lean with elbow flexion and abduction during over ground deceleration (Hewitt et al., 2011). Consequently, high-intensity decelerations are a component of the external load that disproportionately drives neuromuscular fatigue and thereby simultaneously escalating the risk of tissue damage (Harper & Kiely, 2018).

There is no known research to date that has investigated balance ability when decelerating during a run, nor is there a known balance test that has focused on outcome measures related to the deceleration phase in sprinting. Key football literature regarding time motion analysis of player movements was consulted to identify the nature of accelerations and decelerations players experience in the game (Dalen et al., 2016; Newans et al., 2019; Russell et al., 2016; Vigh-Larsen et al., 2018). Decelerations have been classified as: low deceleration, -1 to -2 ms^{-2}; medium, -2 to -3 ms^{-2}; and high, > -3 ms^{-2} (Akenhead et al., 2013). During pilot testing it was found that the treadmill could decelerate at a rate of -1 ms^{-2} using the speed reduction buttons or at a rate of -5 ms^{-2}, using the safety cut off switch. As the use of the reduce speed buttons did not provide a high enough deceleration rate, the use of the safety cut off switch was chosen to provide the most challenging condition. A recent systematic review and meta-analysis reports that spatiotemporal, kinematic and kinetic outcome measures are largely comparable between treadmill and over ground running (Van Hooren, Fuller, & Buckley, 2020), therefore there was confidence that the treadmill would be suitable for use in decelerations.

6.2.3 Kicking

The defining action of football is kicking (Lees et al., 2010). Considerable demands are placed on dynamic balance due to the requirement to control large reactive forces whilst maintaining stability over a narrow base of support (Chew-Bullock et al., 2012). There has been extensive research investigating the kinematics and kinetics of kicking in particular examining the relationship between the mechanics of the kicking leg and kick performance (Dorge et al., 2002; Isokawa & Lees, 1988; Lees et al., 2010; Lees & Nolan, 1998; Nunome et al., Sakurai, 2002; Shan & Westerhoff, 2005). There are equivocal findings in the scant research investigating the mechanics of the plant leg (Kellis et al., 2004; Masuda et al., 2005; Orloff et al., 2008). Remarkably, there is little research examining the relationship between balance ability and kicking and there is no known peer reviewed research to date that has used kicking as a dynamic balance test. Chew-Bullock et al. (2012) examined the relationship between single-leg balance on a force plate and kicking accuracy and velocity. Their results identified a lack of association between single leg balance and kicking velocity. They suggested that the stability requirements associated with balancing on one leg are different from those required to support the body when swinging the kicking leg at maximal velocity. This provides support for the need for dynamic balance tests that address all the task and environmental constraints.

Four articles were identified (table 6.1) where one or more environmental constraints could be classified within the same categories as single leg kicking. Three studies involved single leg stance with flexion/extension and/or adduction/abduction of the non-stance leg to simulate kicking (Fernandes et al., 2016; Hatzitaki et al., 1999; Teixeira et al., 2011). Whilst these methods included movements that would satisfy the environmental constraint of a supra-postural acceleration of the lower limb in the form of a swing, the fixed base of support and no external force that occurs due to impact with the ball meant these tests would not meet the level of specificity required. A study by Rios et al. (2015) launched a ball to their participants meeting the classification required for the external force however, the fixed base of support did not match the postural equilibrium classification. An important consideration of kicking is that there is a destabilising force when contact with the ball occurs, therefore it was decided that a test where participants kicked a ball would be used. As the game of football predominantly involves a moving ball and the classified football movements includes a standing volley it was of interest to be able to include a moving ball in the test. However, difficulties were experienced in pilot testing with allowing participants an approach to the ball and positioning of launch of the ball and a successful foot-ball interaction. Additionally, in the interest of maintaining a consistent ball speed at launch, it was it was decided that a stationary ball placed on top of a lightweight plastic tube to replicate an instance where it would be in the air and afford a volley kick, would be used.

6.3 Existing reference measure

An existing test often referred to as a measure of dynamic balance was included in the study as a reference measure. The SEBT has been used as a common dynamic balance test in football (Anoop et al., 2010; Bhat & Moiz, 2013; Bressel et al., 2007; Cug et al., 2016; Daneshjoo et al., 2012; Haksever et al., 2012). The mSEBT is a shortened version of the SEBT (Hertel et al 2006). Instead of eight reach distances, there are only three. The choice of the mSEBT as opposed to the SEBT is twofold: One, it reduced the time of the full testing protocol and two, there is evidence that it captures the least redundant information (Hertel et al., 2006; Gribble et al., 2012; Hertel et al., 2011). The intra-rater reliability of the SEBT has been reported as moderate to good (Plisky et al., 2009) Due to the measurement error identified in Section 2.2.1.4. in determining reach distance, this was measured from the distance between the anatomical markers of the fifth metatarsal of the stance and reaching foot (Pionnier et al., 2016). It was decided that the use of kinetic analysis with a force plate would provide better information on dynamic postural control strategies to explain any differences in performance, which is missing from previous research in football. Therefore, the mSEBT was performed with the stance limb on a force plate to record kinetic parameters.

As football requires players to be skilled on both limbs in terms performance it was of interest to see if differences exist between skill level and limb in dynamic balance ability for the mSEBT and kicking test. A recent systematic review and meta-analysis indicate that balance performance is not influenced by leg dominance, however this evidence is strongest for tests involving single leg stance (Schorderet, et al., 2021). Where literature included in the review involve tests referred to as sport specific i.e., SEBT, YBT, the limitations of these are that they still involve a static base of support. Furthermore, there were only three studies in the review that used more sport specific measures such as a jump landing (Shiravi et al., 2017; Troester et al., 2018; Wikstrom et al., 2006). Only one study contained athlete participants (Troester et al., 2018), so it is unknown whether these results can be used for comparisons between athletes of different skill levels and non-athlete populations, as well as whether the same outcomes would be found using sport specific tests.

6.4 Methods

6.4.1 Participants

Sheffield Hallam University Local Research Ethics Committee provided ethical approval for all procedures and documents (Converis Ethics Review ID: ER7666529). Male participants were recruited by contacting local professional and male non-league football clubs, the Men's University football team and male University students through flyers, social media and University message boards. Participants were grouped by skill level as elite, recreational and non-footballers. Participants were recruited from Championship level football teams, Collegiate level and non-league football teams within the Sheffield area and students at Sheffield Hallam University. Elite players were recruited from Championship level football teams due to responses from the study in Chapter 5 also being from majority championship level teams. Inclusion criteria were: aged 18+ with an ability to run at 6.1 ms^{-1}. Elite athletes: Playing in the first team or within the academy system of a league club. Recreational athletes: Playing collegiate level/non-league/weekly organised games. Non-footballers: Never have played competitive or and not playing recreational football. Exclusion criteria were: any musculoskeletal injury that was being treated at the time of testing, any balance or vestibular issue, history of fracture or surgery in either limb and any other orthopaedic, muscular or neurological condition that could affect balance or the ability to perform tasks. Table 6.1 describes the group. The preferred leg of participants was determined by asking which foot they would kick a ball with. All participants provided written informed consent (Appendix K) and completed a Physical Activity Readiness Questionnaire (to determine participant safety) (Appendix L) as well as providing details regarding their football playing experience prior to data collection.

Table 6.2 Mean ± standard deviations of the group descriptors for all participants and each skill level group

Descriptive	All	Elite	Recreational	Non-footballers
No	22	5	7	10
Age (years)	24 ± 5	19.7 ± 1.8	23.9 ±5.4	26.6 ± 4.9
Stature (cm)	179.4 ± 5	175.7 ± 5	178.5 ± 1.9	181.6 ± 8.6
Mass (kg)	75.8 ± 8.4	75.3 ± 7.8	79.1 ± 9.8	73.7 ± 7.8

6.4.2 Experimental set up

Kinematic data were collected using 13-camera optoelectronic motion capture system (11 x model Raptor and 2 x model Eagle, Motion Analysis Corporation, Santa Rosa, CA, USA) operating at 240 Hz. The cameras were placed around the force plate, which is located in the centre of the room. To allow for testing both on the treadmill and on the adjacent force plates a large calibration volume was chosen (2.5 m long, 2.5 m wide and 2.5 m tall). There was a two-step process employed for calibration. First, a rigid L-frame with four markers of known locations was used to define a right-handed global coordinate system. Second, individual camera views were scaled using a three-marker wand of 500 mm. The averages of the 3D residuals were below 0.4 mm for each calibration. Kinetic data was collected on a force plate (9287CA, Kistler Instrumente, AG, Switzerland) at 240 Hz. All data were collected in the biomechanics lab at Sheffield Hallam University.

A scaffold tower (figure 6.2) was used in the place of a safety arm on the treadmill to secure participants via a harness, rope and carabiners during the external forces and deceleration test. The scaffold tower consisted of connecting six aluminium frames and three cylindrical aluminium poles. A single horizontal pole was used to connect two diagonal corners of the frame to prevent tilting. Two horizontal poles at the top of the tower were used to prevent tilting and to secure rope and carabiners to secure participants via a harness. Claw hook ratchet straps were used to prevent frame connections from separating (visible in figure 6.4) in each of the four corners of the frame. The purpose of the scaffold tower was to secure participants via carabiners, rope and harness, as a risk assessment identified that participants were at a risk of a fall. The treadmill did not have a safety arm therefore, the scaffold tower mitigated the risk and would prevent serious injury should a fall occur. Despite arranging the cameras for optimal position and view, the scaffold tower, would occasionally occlude markers on the head and legs on certain participants due to the positioning of the bars and the participant's height. The use of cluster markers provided a more robust marker set to mitigate this problem. As identifying the control of the CoM was important to be able to determine the dynamic balance strategies of participants, a full marker set was chosen to ensure that any important movements of the trunk, upper limbs and the head would contribute to calculation of the CoM.

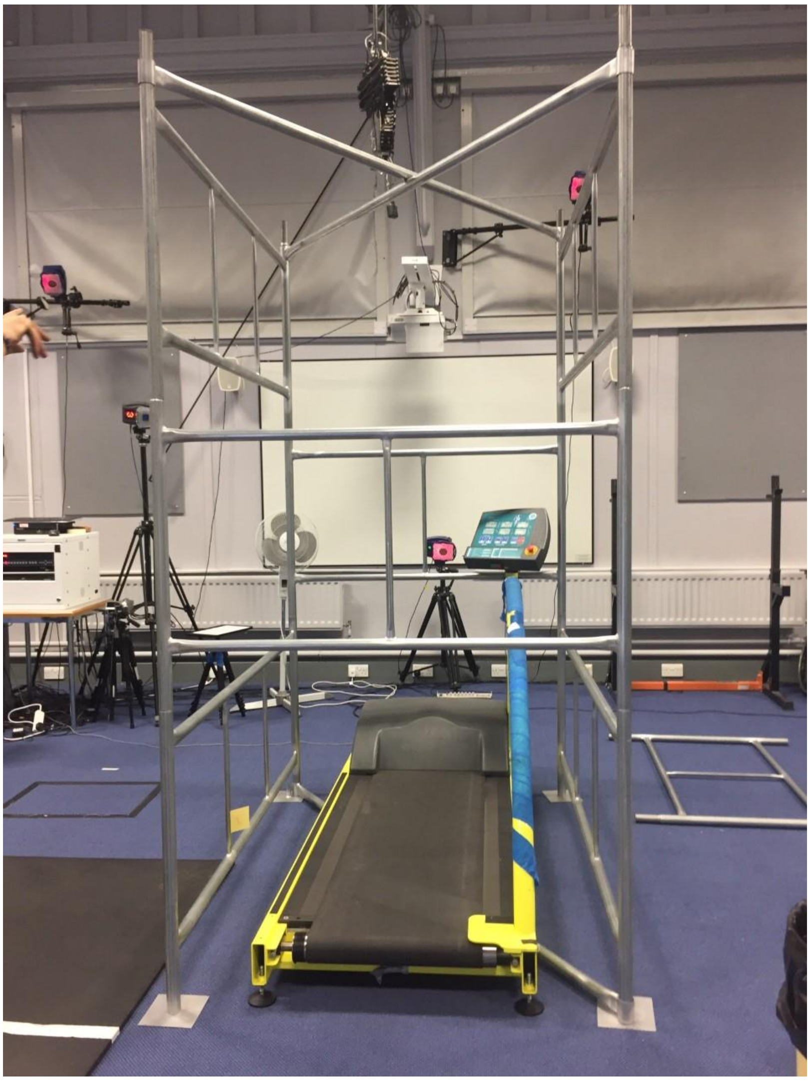

Figure 6.2 Safety scaffold tower to secure participants to via chest harness, rope and carabiners.

A full body marker set was modified from (Davis et al., 1991) in accordance with Cappozzo et al., 1995) to model 13 segments (head, arms, forearms, torso, pelvis, thighs, shanks and feet). 53 retro-reflective spherical markers (12.5 mm) were affixed by adhesive tape to the following anatomical landmarks: head, C7, xiphoid process, acromioclavicular joint, lateral humeral epicondyle, mid-point between the ulnar styloid and radial styloid, anterior superior iliac spine (ASIS), posterior superior iliac spine (PSIS), sacrum, greater trochanter, medial femoral epicondyle, lateral femoral epicondyle, medial malleolus, lateral malleolus, posterior calcaneus, medial calcaneus, lateral calcaneus, and the 2nd and 5th metatarsal base (figure 6.3). Four non co-linear markers were fitted to moulded thermoplastic shells to create rigid segment clusters and were secured on the arms, forearms, thighs and shanks with double sided tape and elastic cohesive bandage (Cappozzo et al., 1997; Lees et al., 2009; Manal et al., 2000). Adhesive spray was applied to the skin at the locations of pelvis markers and segment clusters for better adhesion (Milner, 2008).

A static trial was completed prior to data collection, with the participant in the anatomic position for three seconds. For dynamic trials, the following markers were removed: acromioclavicular joint, lateral humeral epicondyle, mid-point between the ulnar styloid and radial styloid, sacrum greater trochanter, medial femoral epicondyle, lateral femoral epicondyle, medial malleolus, lateral malleolus due to marker redundancy and skin movement artefact. To reduce marker placement variability, the marker set was applied by the same researcher for all participants.

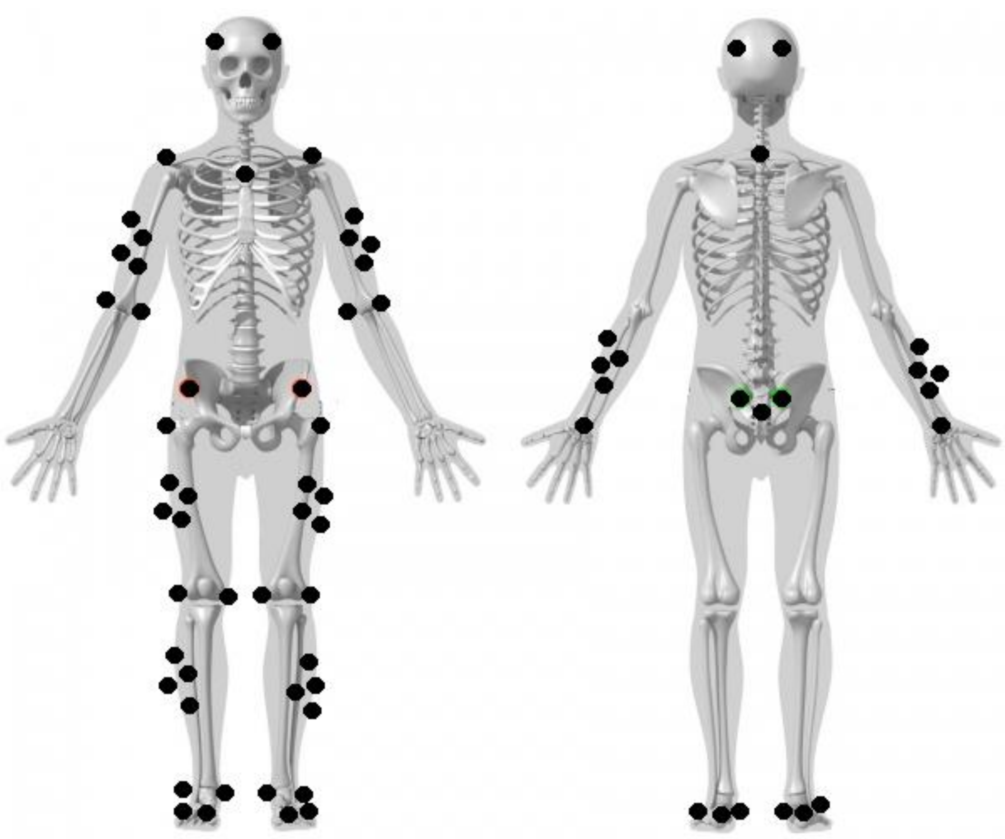

Figure 6.3 Marker set applied to participants. Left to right: front, rear.

6.4.3 Protocol

A warm-up consisting of walking and running on a treadmill (h/p/cosmos pulsar, Nussdorf-Traunstein/Germany) and kicking balls at low velocity was performed prior to the testing. Participants then performed four tests of balance: External forces test, deceleration test, mSEBT and kicking. Participants were topless and wore form-fitting shorts, allowing all markers but the ankle and feet markers to be placed directly onto the skin.

For the running trials, external forces and deceleration test participants ran on the treadmill in the direction of the negative x-axis (anterior-posterior), where the positive z-axis was directed vertically upwards (longitudinal) and the positive y-axis (mediolateral) was pointing to the athletes' right. For the kicking and mSEBT tests participants moved in the direction of the positive y-axis (anterior posterior), where the positive z-axis was directed vertically upwards (longitudinal), and the positive x-axis (mediolateral) was pointing to the athletes' right.

6.4.3.1 External forces

Prior to the external forces test participants ran for 60 s at 12 kmh^{-1} on the treadmill whilst kinematic data was recorded to provide reference data for subsequent analysis. Participants wore a chest harness and were attached to a secure scaffold tower via rope and carabiners (figure 6.4). A treadmill safety cut off clip was attached to the participant to activate the emergency stop in the case of a fall. A rope and bungee cord were attached to the participant at the front and rear of the chest via the harness and then secured to a wall. This provided a lateral perturbation on the right-hand side of the participant and was determined as the most consistent method of applying a lateral perturbation during pilot testing. Participants ran on the treadmill at 12 kmh-1, considered a safe speed for applying perturbations, for a period of 60 s with the force being applied for 3 seconds and removed five times at randomised times within that period. Application and removal of the external force is described in Section 6.2.1.

Participants were instructed to expect the first force application but were not instructed on the timing of any subsequent ones. A warning for the first force application was given, as pilot testing identified that without a warning some participants had to hold the bar to steady themselves. Force applications where holding the handrail occurred were not included in analysis (Maki et al., 2003). This test was performed once. Kinematic data were recorded to determine dependent variables.

Figure 6.4 External forces equipment set up. Participant was attached to a scaffold tower via a chest harness and rope and carabiners. Rope was attached via carabiners to the anterior and posterior of the harness and then via a carabiner to a bungee secured to the wall. Forces were administered and removed on the participants' right-hand side.

6.4.3.2 Deceleration Test

Participants were secured to the scaffold tower as described in Section 6.4.3.1. The test commenced with participants standing on the treadmill followed by an acceleration to 18kmh-1. Participants ran for between 5-10 seconds at this speed at which point the treadmill was stopped abruptly using the emergency stop. The test was repeated 3 times and kinematic data were recorded to determine dependent variables.

6.4.3.3 Kicking

A football (size 5, Mitre) was placed on a lightweight plastic tube as a tee (20 cm x 7 cm). The raised location of the ball was used to mimic the positioning of a ball when performing an instep volley (striking the ball with the top of the foot), considered to be the most accurate and powerful combination kick for passing and shooting (Barfield, 1995; Lees & Nolan, 1998). Participants were instructed to approach the ball at any angle they felt comfortable with as it does not affect kicking accuracy or ball velocity (Scurr & Hall, 2009), but were restricted to a maximum of two steps to mimic the movement that would occur prior to a standing volley. The football was positioned in a way that ensured the participant's stance foot contacted the force plate. Participants were instructed to kick the ball towards a 2 m^2 target 5 m in front of them (Chew-Bullock et al., 2012). The test was performed on dominant and non-dominant limbs as it has been stated that the ability to move the ball up and down the field with both legs is crucial for success (Barfield, 1995). Before data collection, each kicking task was performed twice (dos Santos et al., 2014) to familiarise each participant with the procedure. Three instep volleys were performed by each participant on dominant and non-dominant limbs. The trial with the highest linear foot velocity was selected for further analysis as higher foot linear velocity is related to ball velocity (Dorge et al., 2002; Nunome et al., 2006). The order of testing was randomized between the dominant and non-dominant limbs (Dorge et al., 2002). Kinematic and kinetic data were recorded to determine dependent variables.

6.4.3.4 Modified Star Excursion Balance Test (mSEBT)

Participants' leg length was measured as the distance between the anterior superior iliac spine and the ipsilateral medial malleolus measured in the anatomical reference position (Gribble & Hertel, 2003). The three reach directions were marked out on the floor with white tape using a 360- degree protractor. Participants were instructed to stand on the force plate, with the toes of their stance leg behind a line provided on the floor with hands on hips. Whilst maintaining balance on one leg, they were asked to reach as far as possible along each line, lightly touch the line with the furthest point of the reaching foot without shifting weight or coming to rest on the foot of the reaching limb. Following each reach, the limb was returned to its initial position to assume a bipedal stance (Pionnier et al., 2016). Testing took place on both the dominant and non-dominant limbs. Participants were required to have four practice trials to overcome any learning effect and increase reliability (Munro & Herrington, 2010; Robinson & Gribble, 2008). The recorded trial was redone if the participant performed an observable support transfer on the non-stance limb or the participant could not maintain single leg balance during the test (Pionnier et al., 2016). Kinematic and kinetic data were recorded to determine dependent variables.

6.4.4 Outcome measures and data analysis

Cortex (version 7, Motion Analysis Corporation, Santa Rosa, CA, USA) was used to synchronise, track, and export raw 3D coordinate and kinetic data. For clusters, any gaps in the data were filled using the other three markers where they were present. Automatic gap filling was used as an alternative using a cubic spline where gaps were <10 frames. Visual 3D (version 6, C-Motion, Rockville, MD, USA) was used to defined and construct segments, local coordinate systems and joint centres in line with ISB guidelines (Wu et al., 2002, 2005). A full-body six-degree-of freedom kinematic model was applied using segmental data estimated from De Leva, (1996), considered the most appropriate and representative of the athletic population within the investigation. Whole body CoM trajectory was calculated from the weighted sum of the COM of the parameters of all 13 segments within Visual 3D. Raw kinetic and kinematic data consisting of: CoP trajectories, whole body CoM trajectories, marker trajectories, ground reaction force and segment linear velocities were exported from Visual 3D for filtering and analysis.

Winter's residual (Winter, 2009) was used to determine appropriate cut off frequencies for removing noise of skin marker movement from the data, to address positional changes of the CoM on the treadmill during the external forces test and noise from the kinetic data. It is commonplace in kinematic analyses to apply a single cut off frequency to all markers. However, some studies have applied different cut of frequencies to markers in different locations (Mills et al., 2011). For this reason, the above methods were investigated for one marker on each limb of one participant for each of the four tests. A range of cut off frequencies between 11-20 Hz were applied to a sample of participants for each test. These were then visually inspected to determine the optimal cut off frequency. Visual inspection of the data identified that optimal cut off frequencies for different markers were within 2-3Hz of each other therefore an average of the range of cut off frequencies was used on all markers. Filtering was investigated and applied in MATLAB (vR2019a, MathWorks, Natick, USA). Details of the type of filter and cut off frequencies for each test are provided in the following sections. To avoid endpoint error, the distortion introduced at the start and end of a signal when using digital filters, 100 additional frames of data were included at the start and end of the section of the signal of interest.

6.4.4.1 External forces

The raw markers of the external forces test data were filtered using a 2nd order recursive Butterworth filter with a bandpass filter of 0.1-15Hz to remove low frequencies related to slow changes that occurred due to a change in position on the treadmill and leave the higher frequency changes related to each foot-step and balance. The lowest frequency of interest was the stride frequency approximately 1.5 strides per second. The data were inspected visually with a range of frequencies below 1Hz to determine a suitable cut off that ensured the step-by-step variations were maintained and the amplitude of the peaks was not reduced. Dependent variables calculated in MATLAB were magnitude of the CoM ML displacement and time to stabilisation (TTS). Application of the perturbation force was identified by a positive peak presented in the CoM ML data. The release of the perturbation force was identified by the sudden decrease in the CoM position that continued past the mean of the CoM position and was also verified though visual inspection of the model animation data in Visual 3D. The phase of interest for this test was from the point of release of the perturbation to identification of recovery. The application of perturbation was not analysed, as the application of the force was much slower than the removal therefore, the perturbation was moderate in comparison.

To identify the recovery of the CoM in the ML axis, the mean of the CoM was calculated for the running trial performed before the external forces test. The following standard deviations (SD) of the mean were then calculated: 0.25, 0.5, 0.75, 1 and 2. This mean and range of SDs from the running data were applied to the external forces data for all participants. The data were investigated to determine whether the CoM position fell within one of the ranges of SDs and remained there for at least one cycle. On visual inspection of all participant data, it was observed that participants displayed a return to within 1 SD of the CoM mean following the release of perturbation for at least one cycle for every trial. For some participants, an overshoot of the CoM position was observed, therefore determining the point of stabilisation included this overshoot within the data analysis process. Figure 6.5 displays the overshoot during one force application and release during the external forces for an example participant.

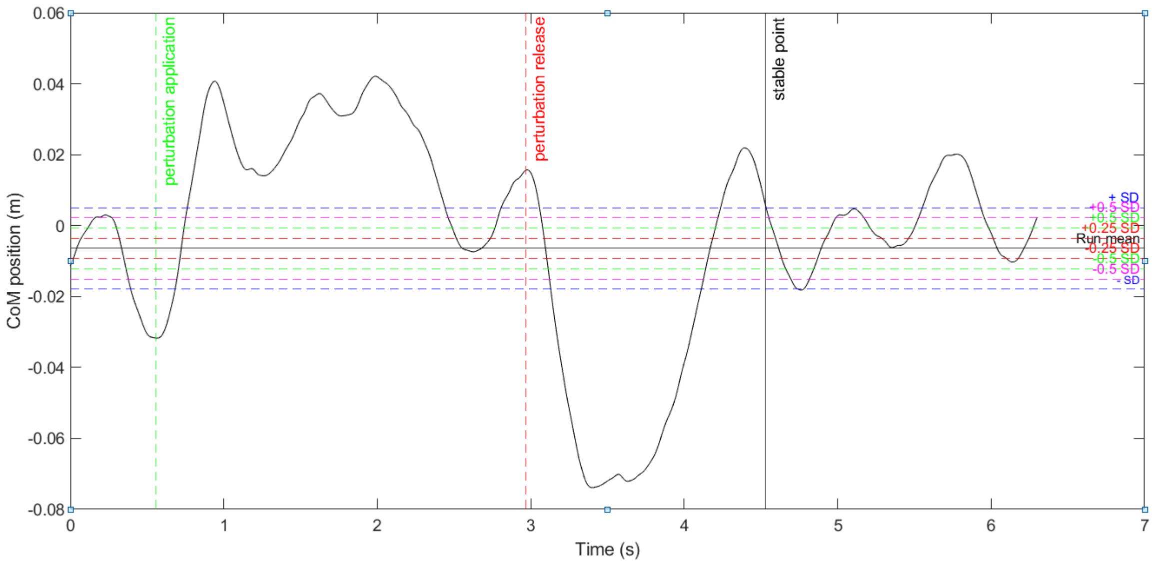

Figure 6.5 CoM position during the external forces test displaying the overshoot of the CoM position. Perturbation application and release and calculated stable point and are identified by vertical lines. Horizontal lines are mean and SD’s at 0.25, 0.5, 0.75, 1 of the separate running trial.

6.4.4.2 Deceleration

The raw markers of the deceleration test data were filtered using a second order recursive Butterworth filter with a cut off frequency of 16Hz. After filtering data were cropped from the point where the treadmill was stopped, which was identified by a sudden decrease in the velocity of the heel markers to the end of the trial. Dependent variables calculated using custom code in MATLAB were: CoM range in AP, TTS and step frequency. Step frequency was determined from the number of steps taken when the treadmill slowed to the point of stabilisation as identified from the TTS.

Time to stabilisation is a commonly used measure to evaluate postural stability following a jump landing (Colby et al., 1999; Gribble et al., 2009; Liu et al., 2013; Ross & Guskiewicz, 2003, 2004; Wikstrom et al., 2004, 2005). Typically, TTS is derived through force plate data and used to evaluate postural stability by measuring the time taken for vertical ground reaction force to reach and stabilise within 5% of the subject's body weight following the landing from a jump (Wikstrom, 2004), or through a sequential estimation method (Colby et al., 1999). As no force plate data were collected during the deceleration test, the sequential estimation method was more appropriate. Custom code (MathWorks, R2019a) was used to calculate a cumulative average of the data points in a series by successively adding 1 point at a time. After the first point, the first two data points were averaged. Then the first three data points were averaged, and so on for the three-second period following the treadmill belt being stationary. The overall mean of the series was then calculated. The cumulative average was compared against the overall series mean, and the CoM was considered to be stable when the sequential average remained within 0.25 standard deviations of the mean of the entire time series (Colby et al., 1999; Wikstrom et al., 2005). This point was taken as the TTS. Some researchers have combined the TTS in the horizontal planes to provide a composite value. However it has been argued that TTS parameters present three separate measures for each trial and do not provide a common characteristic among components and the use of multiple directions are beneficial for indicating directional control deficits (Wikstrom et al., 2005). Because the deceleration occurs in the sagittal plane, CoM and TTS were determined in the AP direction only.

6.4.4.3 Kicking

Kinematic data of the mSEBT test data were filtered in MATLAB using a 2nd order recursive Butterworth filter with a cut off frequency of 18Hz, whilst kinetic data were filtered at 20Hz. Following filtering, data were cropped from impact with the force plate, identified when the vertical ground reaction force was higher than a threshold of 10 N until impact with the ball. Impact with the ball was identified by the movement of markers attached to the lightweight plastic tube upon which the ball was positioned. Dependent variables: linear velocity of the centre of mass of the foot, resultant CoP range normalised to foot length and time to boundary (TtB) on both limbs were calculated with custom code in Matlab. Linear velocity was represented by the velocity of the foot's centre of mass, which was defined by the toe and heel markers.

Measurement of balance by using CoP in both AP and ML directions is a common specific measure assessed in balance testing (Hoffman and Payne, 1995; Hrysomallis, 2008; Le Clair and Riach, 1996; Paillard et al. 2006; Verhagen et al. 2005). The resultant CoP range was chosen to account for different angles of approach by participants. This measure was normalised to foot length by dividing the CoP range by the foot length of the participant and multiplied by 100 to express it as a percentage of foot length. This accounted for the variability in foot length of participants. The markers on the foot were used to determine foot placement on the force plate to calculate time to boundary (TtB). TtB is an estimate of the time it would take for the CoP to reach the BoS boundary if the CoP were to continue on its trajectory at its instantaneous velocity (van Emmerik et al., 2002; Van Wegen et al., 2002). Previous literature has used shank angular velocity as a measure of kicking success (Luhtanen, 1988) however, Dorge et al. (2002) have shown that at instant of impact with the ball, the shank is not at its maximum, and suggest linear velocity of the centre of mass of the foot as the best measure of kicking success. For this reason, linear velocity of the foot was used as a measure of performance.

6.4.4.4 mSEBT

Kinematic data of the mSEBT test data were filtered in MATLAB using a 2nd order recursive Butterworth filter with a cut off frequency of 16Hz, whilst kinetic data were filtered at 20Hz. Following filtering, data were cropped for each reach direction from the start of the reach, identified by anterior movement of the reaching limb, until the furthest reach position, identified as the maximum excursion of the anatomical markers of the fifth metatarsal of the stance and reaching foot (Pionnier et al., 2016). Custom code in MATLAB was used to calculate dependent variables, normalised reach distance, CoP path length and TtB. The reach distance was considered as the maximum excursion of the non- stance leg at the touchpoint divided by leg length and multiplied by 100 to represent reach distance as a percentage of limb length (Gribble et al., 2012). CoP path length is a measure that has been used in previous research to characterise the SEBT (Pionnier et al., 2016). It was calculated as the total trajectory followed by the CoP from its initial position to its maximal position. TtB was calculated by the same method provided in Section 6.4.4.3.

6.4.6 Statistical analysis

Calculations were performed in SPSS, version 24 (SPSS; Inc, Chicago, IL). Descriptive statistics (mean, standard deviation) were calculated for all variables. Differences between dependent measures of the external forces and deceleration tests were assessed using a one-way analysis of variance (ANOVA) where data met the assumptions of parametric data; normal distribution, homogeneity of variance, linearity and independence (Field, 2009). No post hoc procedures were required as planned contrasts were conducted (Field, 2009). For the kicking test, a repeated measures ANOVA was performed. The within subject's condition was stance limb. The between-subjects factor was skill level. For the mSEBT, 2 x 3 mixed design repeated measures ANOVAs were performed as all data met assumptions of parametric data. The within subjects' conditions were stance limb (x 2) and reach direction (x3). The between-subjects factor was skill level (x 3). The effect of stance limb, reach direction and skill level on the dependent variables, as well as the interaction between them were assessed. Assumptions of sphericity were met for all dependent variables (Field, 2009). Gabriel's test was used as a post-hoc test due to unequal sample sizes and a Bonferroni correction was applied (Field, 2009). The level of significance for all statistical procedures was set at $p = 0.05$. For some outcome measures in the kicking and mSEBT tests there were only data available for two participants. For this reason, effect sizes were also considered.

Results were also interpreted using effect size, which places the emphasis on the size of the difference (Coe, 2002). The investigation contained small and unequal sample sizes and therefore was likely to be statistically underpowered, reducing the chance of detecting a true effect. Interpretation of Hedge's g was also reported to correct for the small and uneven sample size using the following equation (Durlak, 2009):

$$g = \frac{M_1 - M_2}{sd} \times \left(\frac{n-3}{n-2.25}\right) \times \sqrt{\frac{n-2}{n}}$$

Equation 1

Where *M1* - *M2* is the difference between the group means (*M*), *sd* is the pooled standard deviation and *n* is the total sample size. Interpretation of Hedge's g followed the guidelines of (Cohen, 1988) where $g < 0.20$ represents a trivial difference, 0.20 ≥ 0.50 indicates a small difference, 0.50 ≥ 0.80 a moderate difference and ≥ 0.80 a large difference between means. Where comparisons between groups contained unequal sample sizes, Hedge's g was reported. Effect sizes for one-way ANOVAs were reported using Hedge's g. Effect sizes for mixed design repeated measures ANOVA were reported using partial eta^2. Partial eta^2 can be defined as the ratio of variance accounted for by an effect and that effect plus its associated error variance within an ANOVA study (Tabachnick & Fidell, 2007).

$$\eta_p^2 = \frac{SS_{effect}}{SS_{effect} + SS_{error}}$$

Equation 2

Where SS_{effect} is the sum of the squares of the effect, and SS error is the sum of the squares of the error. Partial eta^2 was interpreted following recommendations where η_p^2 values of .0099, .0588, and .1379 are benchmarks for small, medium, and large effect sizes, respectively (Cohen, 1969; Richardson, 2011).

6.5 Results

6.5.1 External forces

Experimenter error during data collection and processing resulted in four trials being lost and caused the discrepancies in degrees of freedom for F ratios. Participant numbers for external forces data were elite, n = 5, recreational, n = 5, non-footballers, n = 8. After each application of force, there was no reduction in CoM magnitude or TTS indicating that no learning effect took place. Following release of the force, participants experienced a displacement of their CoM to the release direction before returning to a position that was within 1-2 standard deviations of the mean CoM position during the 12 kmh^{-1} run. Following the initial response in the direction of release, some participants exhibited an overshoot in the opposite direction before returning to within 1-2 standard deviations of the mean run CoM position however, this was not limited to any one skill group. Figure 6.2 presents the mean CoM magnitude of displacement in the ML axis for all participants. Elite football players exhibited the lowest magnitude of CoM ML displacement. There were no statistically significant differences between group means for magnitude of CoM displacement $F(2,15) = 2.12$ $p = 0.155$ as determined by a one-way ANOVA. A large effect size was observed between elite and recreational players ($g = -1.3$) and recreational and non-football players ($g = 0.82$). There was a small effect size between elite and non-football players ($g = -0.43$).

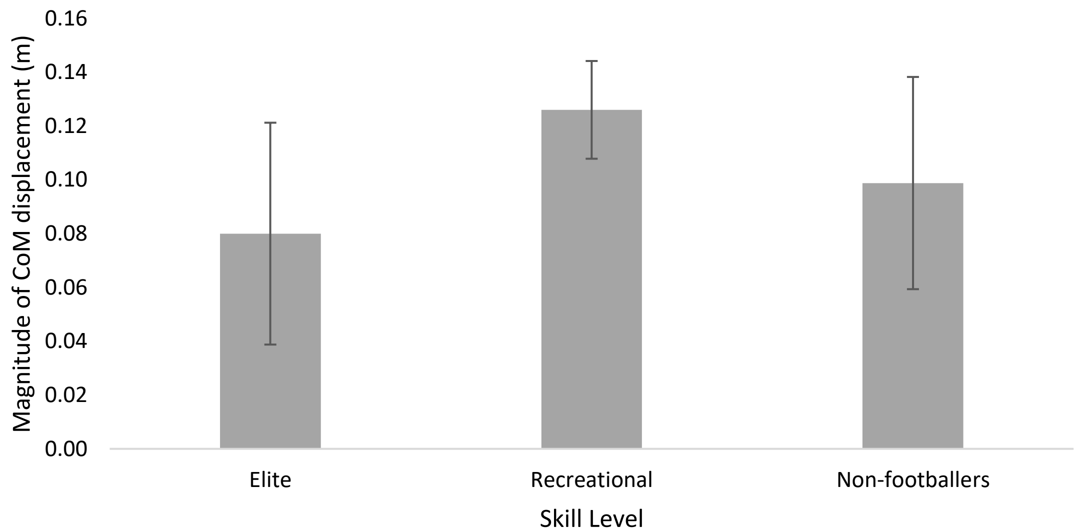

Figure 6.2 Mean magnitude of CoM ML displacement of all participants
for the external forces test. The error bars display +/- 1 SD. A one-way ANOVA revealed no significant differences. Elite; n = 5, recreational; n=5, elite; n=8.

Figure 6.3 presents the mean TTS for all participants. Elite football players exhibited the lowest TTS and non-footballers exhibited the largest TTS. There were no statistically significant differences between group means $F(2,15) = 2.27$, $p = 0.138$ as determined by a one-way ANOVA. There were large effect sizes between elite and recreational players ($g = -0.860$) and elite and non-football players ($g = -1.12$) and a moderate effect size between recreational and non-footballers ($g = -0.51$). Larger standard deviations were observed for non-footballers reflecting larger variability between participants.

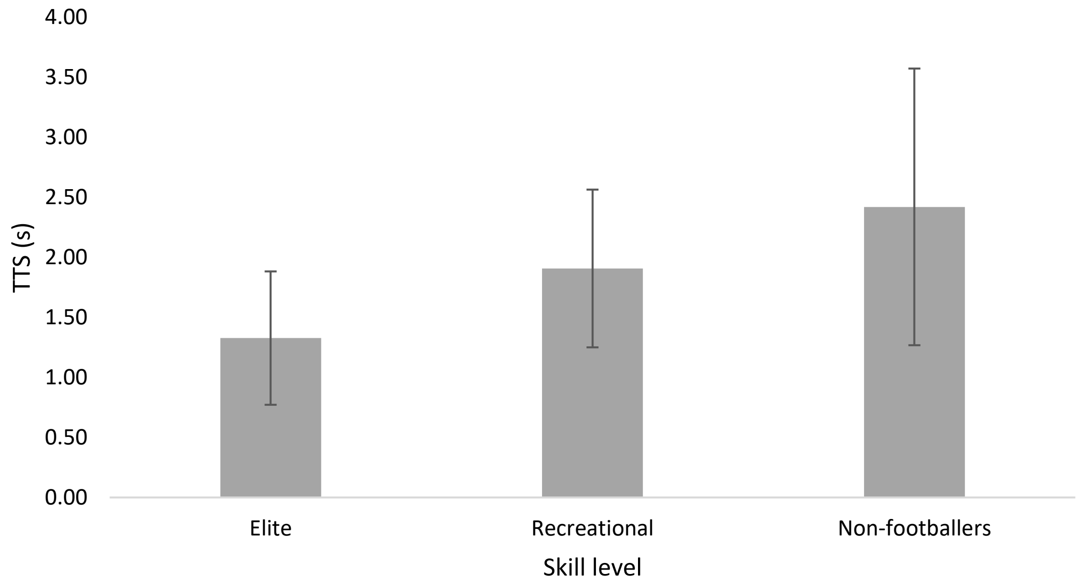

Figure 6.3 Mean TTS of each participant for the external forces test. The error bars display +/- 1 SD. A one-way ANOVA revealed no significant differences. Elite; n = 5, recreational; n=5, elite; n=8.

6.5.2 Deceleration

Experimenter error during data collection and processing resulted in nine trials being lost and caused the discrepancies in degrees of freedom for F ratios. This resulted in participant numbers as follows; elite players, n =5, recreational players, n = 7 and non-footballers, n = 8. Figure 6.4 displays the mean CoM range in AP and ML directions for the deceleration test. A one-way ANOVA revealed the following: there was no statistically significant differences between groups for CoM AP range $F(2, 19) = 0.120$, $p = 0.89$. Trivial to small effect sizes were observed when comparing groups as follows: elite with recreational players ($g = 0.25$), recreational players with non-footballers (g = -

0.23) and elite with non-footballers (g = 0.03). There were no statistically significant differences between skill level for TTS AP F(2,18) = 2.421, p =0.121.

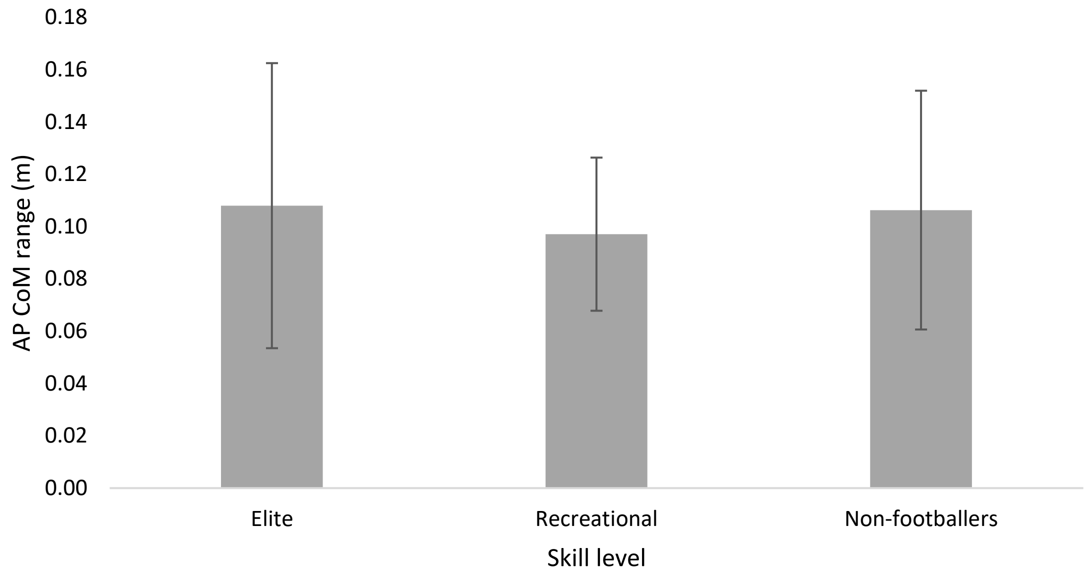

Figure 6.4 Mean CoM range in the AP directions for the deceleration test. The error bars display +/- 1 SD. A one-way ANOVA revealed no significant differences. Elite: n = 5, recreational: n = 6, non-footballers: n = 8.

Figure 6.5 presents mean TTS for participant groups. There were no statistically significant differences between skill levels for step frequency, F(2,19) = 2.592, p = 0.104. Effect sizes were observed as large between elite and recreational players (r = 0.89) and recreational and non-football players (r = 1.18), and small between elite and non-football players (r = 0.18).

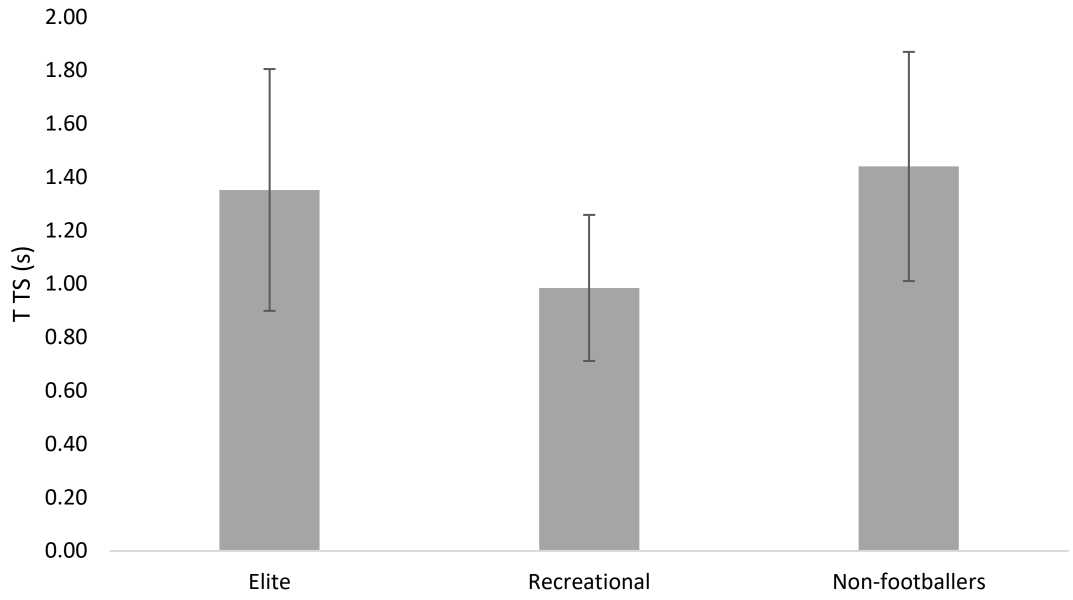

Figure 6.5 Mean TTS range in AP direction for the deceleration test. Error bars are 1 SD. A one-way ANOVA revealed no significant differences. Elite: n = 6, recreational: n = 7, non-footballers: n = 8.

Figure 6.6 displays the mean step frequency during the deceleration phase for each skill level. A one-way ANOVA revealed no significant differences between skill level $F(2,19) = 2.592$, $p = 0.104$. Effect sizes were observed as large when comparing the means between elite and recreational players ($r = 0.4$), elite players and non-footballers ($r = 0.28$) and recreational players and non-footballers ($r = 0.39$). Examination of individual performance in the deceleration test, there appears to be a relationship between higher TTS and a lower step frequency for elite players but no other groups.

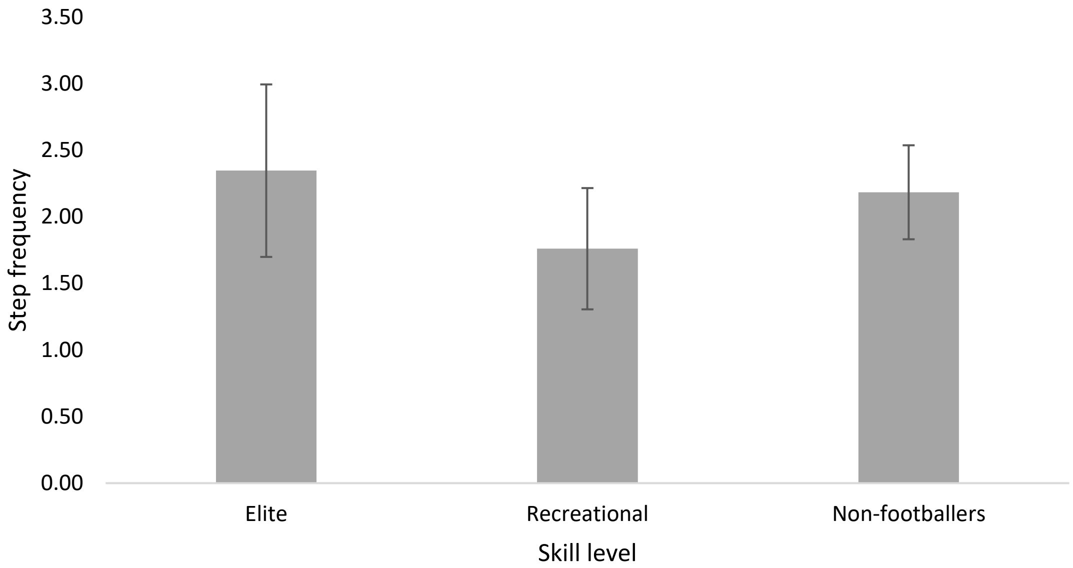

Figure 6.6 Mean step frequency for the deceleration test. Error bars are 1 SD. A One-way ANOVA revealed no significant differences. Elite: n = 2, recreational: n = 6, non-footballers: n = 9.

6.5.3 Kicking

Experimenter error during data collection and processing resulted in a few trials being lost and caused the discrepancies in degrees of freedom for F ratios. This resulted in data being analysed as elite n = 2, recreational n = 6 and non-footballers n = 9. There were no significant differences between groups for maximum foot angular velocity. Figure 6.7 presents the mean maximum linear foot velocity during the kick for all participants. A repeated measures ANOVA revealed a main effect of limb on foot velocity, $F(1,14) = 11.456$, $p = 0.004$, $\eta_p^2 = 0.45$. Foot velocity was higher when kicking the ball with the dominant limb. There was no main effect of skill level on foot velocity, $F(2,14) = 0.452$, $p = 0.645$, $\eta_p^2 = 0.061$. There was no interaction of limb and skill level on foot velocity $F(2,14) = 2.114$, $p = 0.158$, $\eta_p^2 = 0.232$.

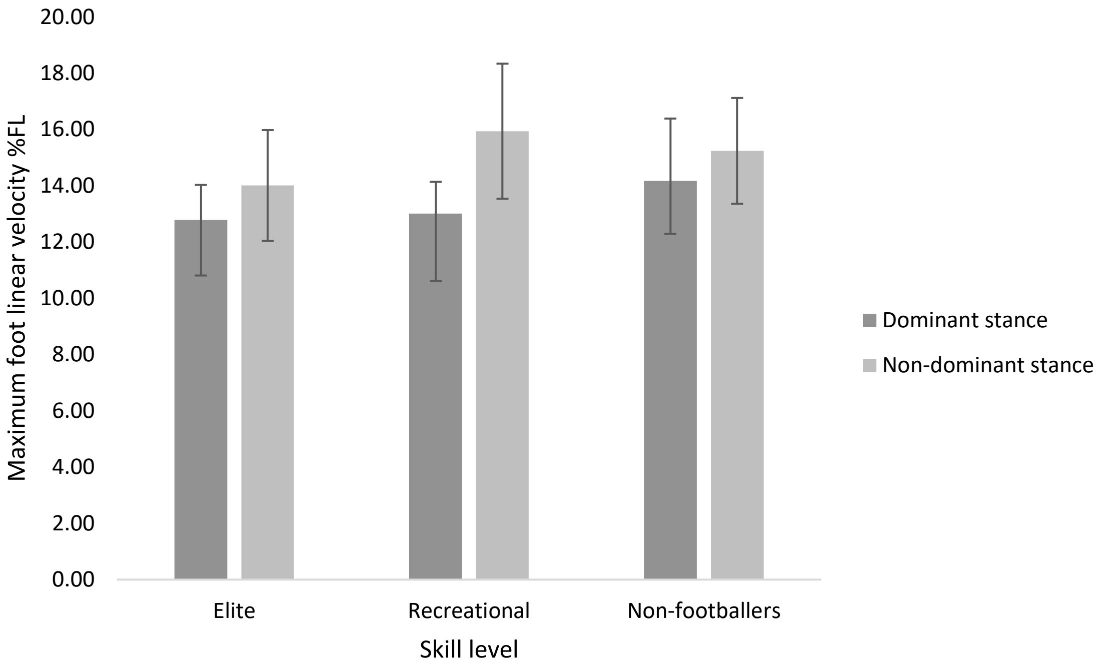

Figure 6.7 Mean maximum foot linear velocity during kicking for dominant and non-dominant stance limbs for all skill groups. A repeated measures ANOVA found no main effects or interactions. Elite: n = 2, recreational: n = 5, non-footballers: n = 9.

Figure 6.8 displays the mean total CoP path length as a percentage of foot length for dominant and non-dominant stance for all skill levels. A repeated measures ANOVA determined a non-significant main effect of limb on total CoP path length, $F(1,14) = 1.945$, $p = 0.184$, $\eta_p^2 = 0.122$. There was a non-significant main effect of skill level on total path length, $F(2,14) = 0.269$, $p = 0.698$, $\eta_p^2 = 0.05$. There was a significant interaction of limb and skill level on total CoP path length, $F(2,14) = 6.175$, $p = 0.012$, $\eta_p^2 = 0.469$. Figure 6.9 displays the interaction between limb and skill level on total CoP path length. Elite players had a lower total CoP path length in dominant limb stance than recreational players and non-footballers, and a higher total CoP path length in non-dominant limb stance than recreational players and non-footballers. In dominant stance, recreational players had a higher total CoP path length, but in non-dominant stance, they had a lower total CoP path length in comparison to elite players and non-footballers.

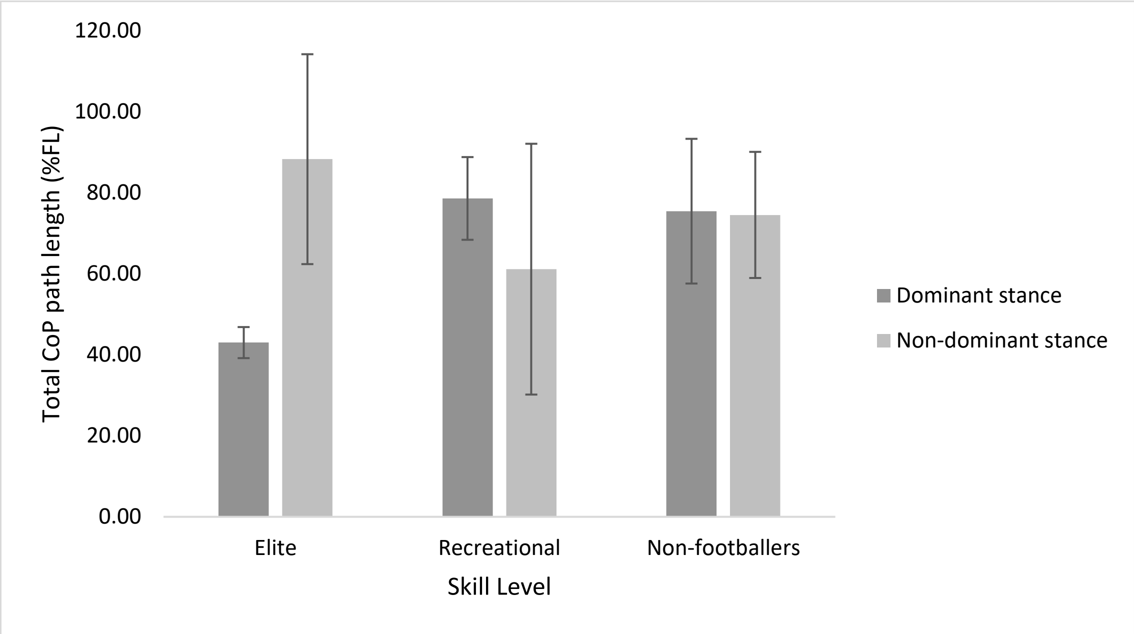

Figure 6.8 Mean total CoP path length normalised to foot length during kicking for dominant and non-dominant stance limbs for all skill groups. A repeated measures ANOVA found no main effects or interactions. %FL: percentage foot length. Elite: n = 2, recreational: n = 5, non-footballers: n = 9.

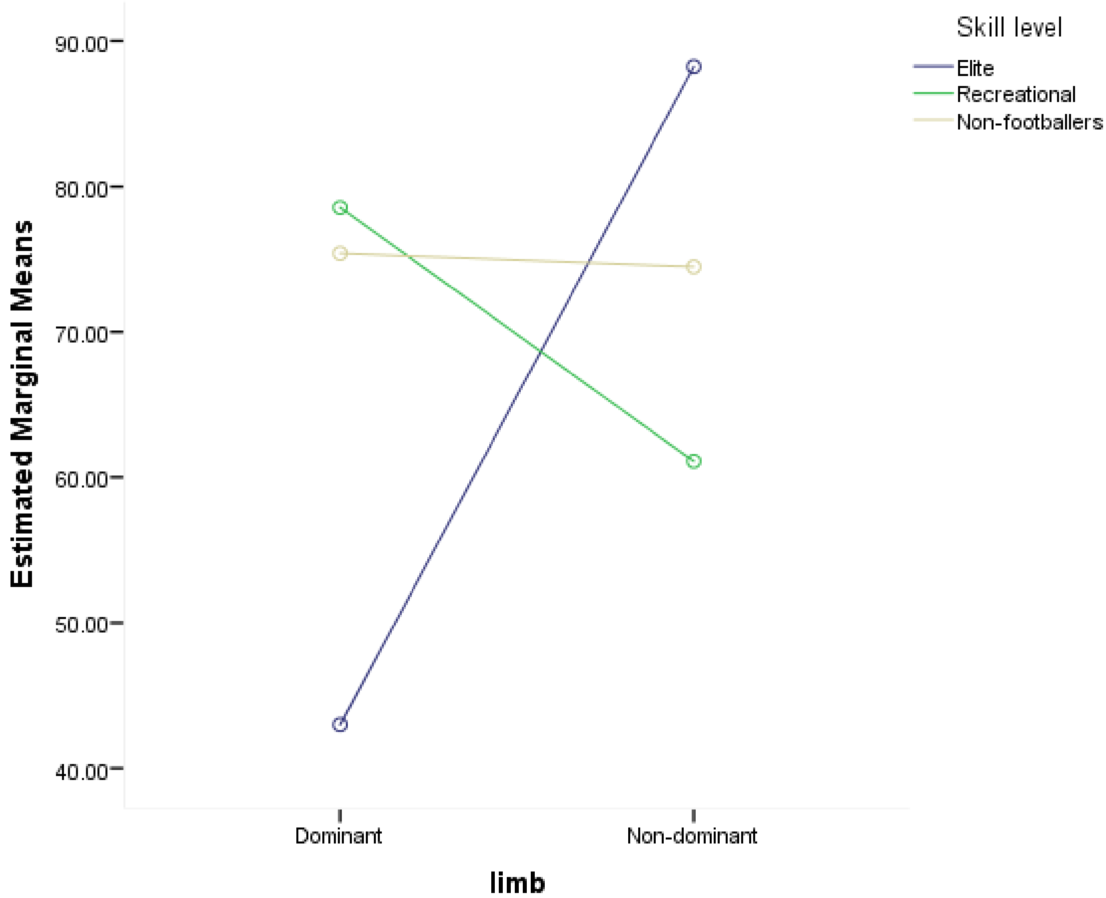

Figure 6.9 Interaction between limb and skill level on total CoP path length

Figure 6.10 displays the mean TtB on dominant and non-dominant limbs for all participants during kicking. A repeated measures ANOVA determined no main effects of limb or skill level on TtB, $F(1,14) = 0.110$, $p = 0.745$, $\eta_p^2 = 0.008$ and $F(2,14) = 0.302$, $p = 0.744$, $\eta_p^2 = 0.041$ respectively. There was no significant interaction of limb and skill level on TtB, $F(2,14) = 0.111$, $p = 0.896$, $\eta_p^2 = 0.016$.

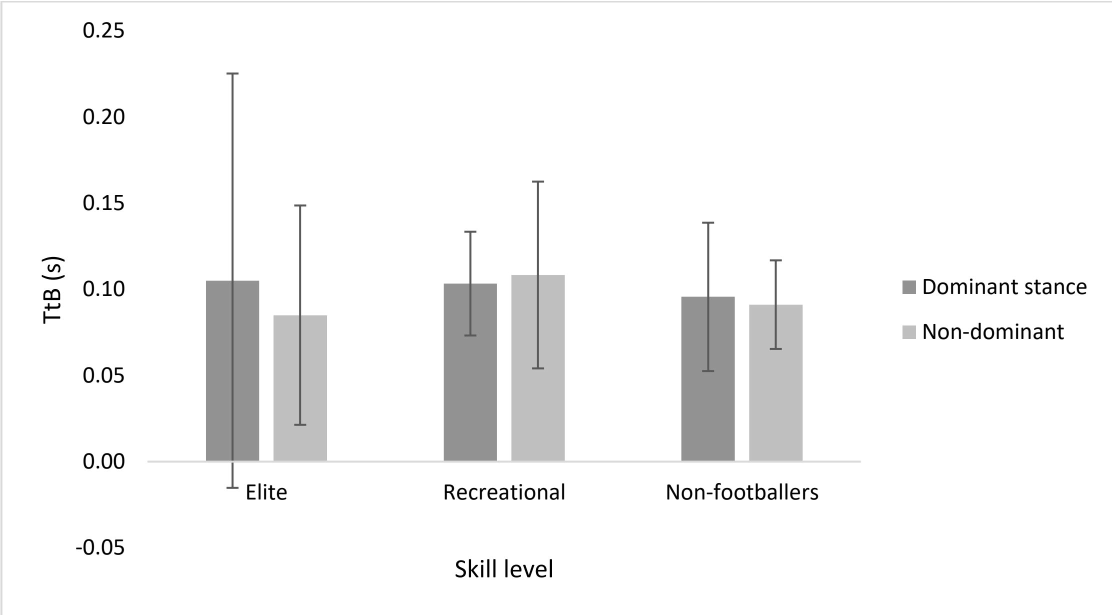

Figure 6.10 TtB in kicking. Error bars are 1 SD. A repeated measures ANOVA found no significant main effects. Elite: n = 2, recreational: n = 5, non-footballers: n = 9.

6.5.4 mSEBT

Experimenter error during data collection and processing resulted in 12 trials being lost and caused the discrepancies in degrees of freedom for F ratios. This resulted in the following: Five elite, six recreational and seven non-footballers were included in the statistical analysis for reach distance. Five elite, and seven recreational and non-footballers were included in the analysis for CoP path length. Two elite, six recreational and seven non-footballers were included in the analysis for TtB. A 3 x 2 x 2 mixed methods repeated measures ANOVA was performed to determine the main effect of, and interaction between limb, reach direction and skill level on all dependent variables.

6.5.4.1 Reach distance

Figure 6.11 presents the mean reach distance achieved by each skill level in all directions of the mSEBT on each limb. There was a non-significant main effect of stance limb on reach distance, F(1,16) = 0.178, p = 0.679, η_p^2 =0.011. There was a non-significant main effect of skill level on reach distance, F(2,16) = 1.295, p = 0.301, η_p^2 = 0.139. There was a significant main effect of reach direction on reach distance, F(2,32) = 151.948, p = <0.01, η_p^2 = 0.905. Anterior and PM reach distances were significantly lower than PM distances F(1,16) = 61.59, p = <0.01, η_p^2 = 0.794, F(1,16) = 143.436, p = <0.01, η_p^2 = 0.9. There was a non-significant interaction of limb and skill level on reach distance, F(2,16) = 2.691, p = 0.098, η_p^2 = 0.252. There was a significant interaction of reach direction and skill level on reach distance, F(4,32) = 3.541, p = 0.017, η_p^2 = 0.307 displayed in figure 6.12. There was a non-significant interaction of limb and reach direction on reach distance, F(2,32) = 2.021, p = 1.49, η_p^2 = 0.112. There was a non-significant interaction of limb, reach direction and skill level on reach distance F(4,32) = 1.612, p = 0.195, η_p^2 = 0.168

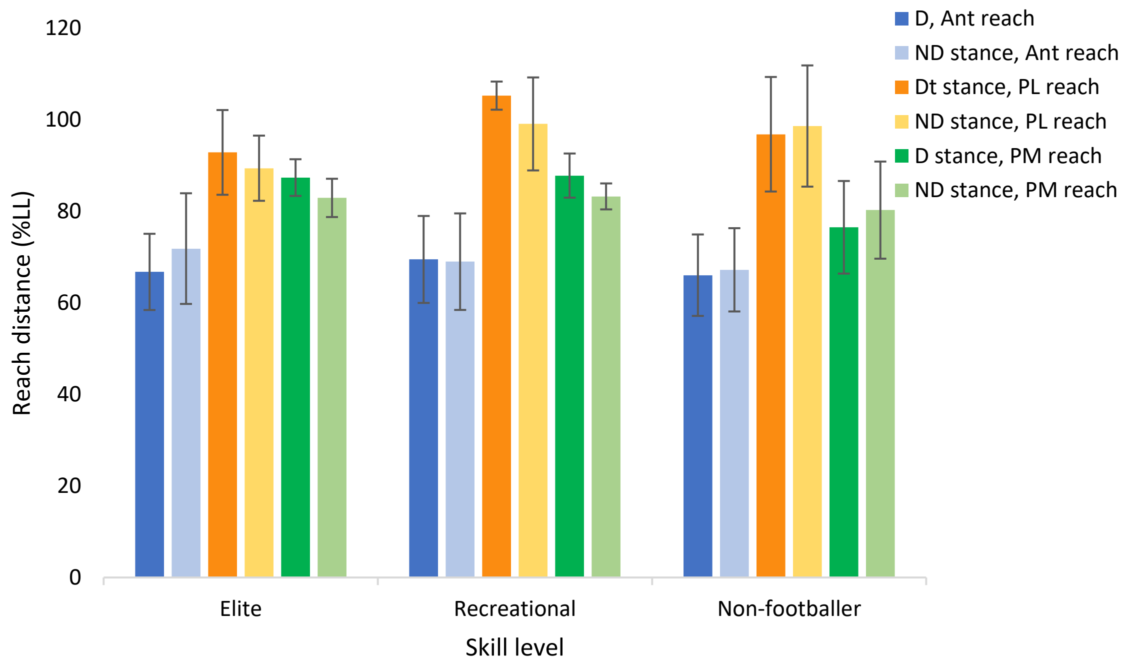

Figure 6.11 Mean normalised reach distance as a percentage of leg length for all skill levels, in each reach direction on each limb for the mSEBT. A mixed method repeated measures ANOVA revealed a significant mean effect of reach direction on reach distance, p = 0.0. D: dominant, ND: non-dominant, Ant: anterior, PL: post-lateral, PM: post-medial; LL: leg length. Elite, n = 5; recreational, n = 6; non-footballers, n = 7.

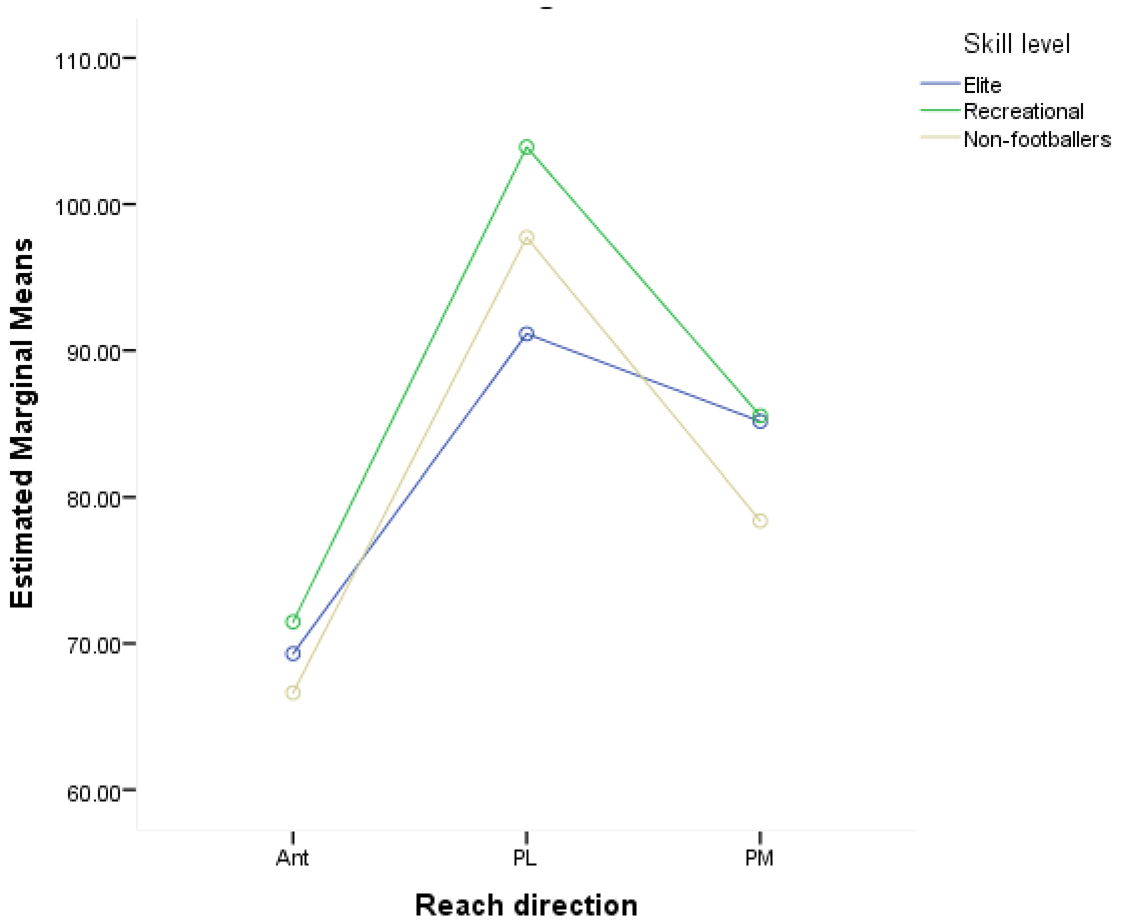

Figure 6.12 Interaction of means of reach direction and skill level on reach distance. A mixed design repeated measures ANOVA demonstrated a significant interaction of reach direction and skill level on reach distance.

6.5.4.2 CoP path length

Figure 6.12 displays CoP path length for participants of each skill level during each reach direction on dominant and non-dominant limbs. There were no significant differences between any main effects on CoP path length as follows: Limb $F(1,16) = 1.670$, $p = 0.215$, $\eta_p^2 = 0.95$; reach direction $F(2,32) = 3.212$, $p = 0.054$, $\eta_p^2 = 0.167$; skill level $F(2,16) = 0.582$, $p = 0.57$, $\eta_p^2 = 0.068$. There no significant interactions for the following and CoP path length: limb and skill level $F(2,16) = 1.535$, $p = 0.246$, $\eta_p^2 = 0.161$; Reach direction and skill level $F(4,32) = 0.938$, $p = 0.430$, $\eta_p^2 = 0.109$; limb and reach direction $F(2,32) = 2.007$, $p = 0.151$, $\eta_p^2 = 0.111$; limb, reach direction and skill level $F(4,32) = 2.472$, $p = 0.064$, $\eta_p^2 = 0.236$.

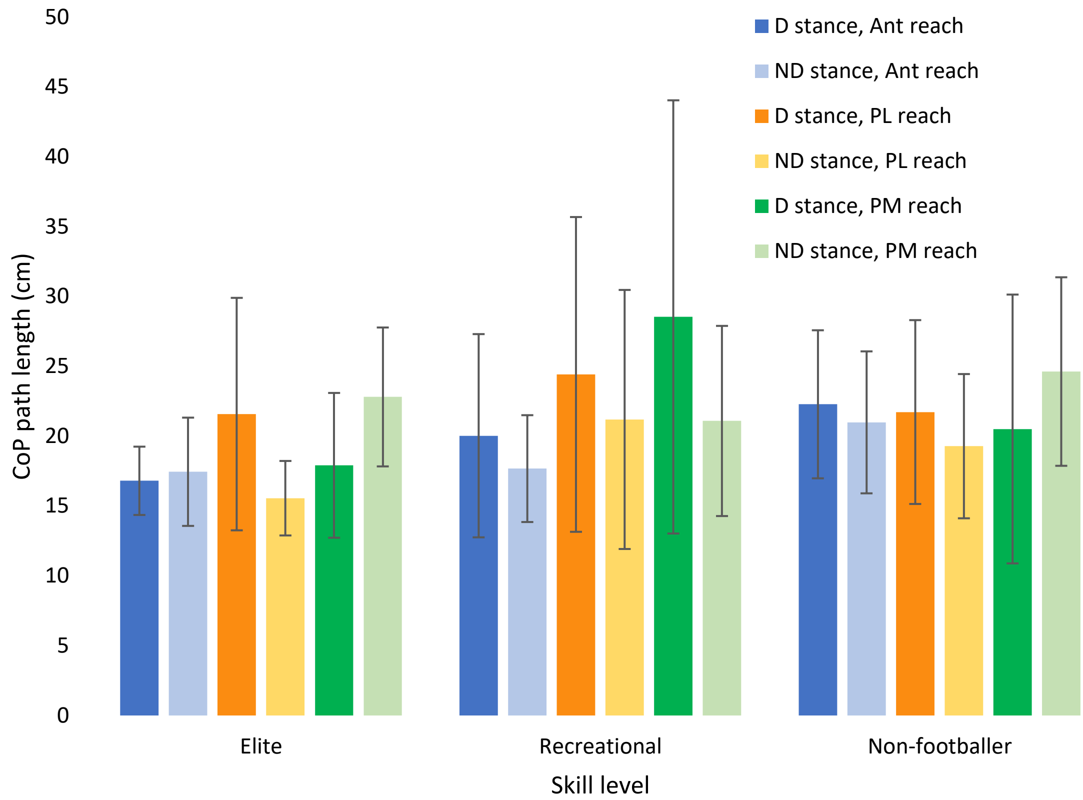

Figure 6.12 Mean normalised CoP path length as a percentage of foot length for all skill levels during the mSEBT. Non-significant main effects and interactions as determined by a mixed method, repeated measures ANOVA. D: dominant, ND: non-dominant, Ant: anterior, PL: post-lateral, PM: post-medial, FL: foot length. Elite, n = 2; recreational, n = 6; non-footballers, n = 7.

6.5.4.3 TtB

Figure 6.13 displays the TtB for participants in each skill group for all reach directions on dominant and non-dominant limbs. There were no significant differences between any main effects on TtB as follows: limb $F(1,12) = 0.038$, $p = 0.849$, $\eta_p^2 = .003$; reach direction $F(2,24) = 0.867$, $p = 0.433$, $\eta_p^2 = 0.067$; skill level $F(2,12) = 0.778$, $p = 0.481$, $\eta_p^2 = 0.115$. There were no significant interactions for the following and TtB: limb and skill level $F(2,12) = 1.171$, $p = 0.343$, $\eta_p^2 = 0.163$; reach direction and skill level $F(4,24) = 1.738$, $p = 0.175$, $\eta_p^2 = 0.225$; limb and reach direction $F(2,24) = 1.377$, $p = 0.272$, η_p^2 0.103; limb, reach direction and skill level $F(4, 24) = 2.318$, $p = 0.086$, $\eta_p^2 = 0.279$.

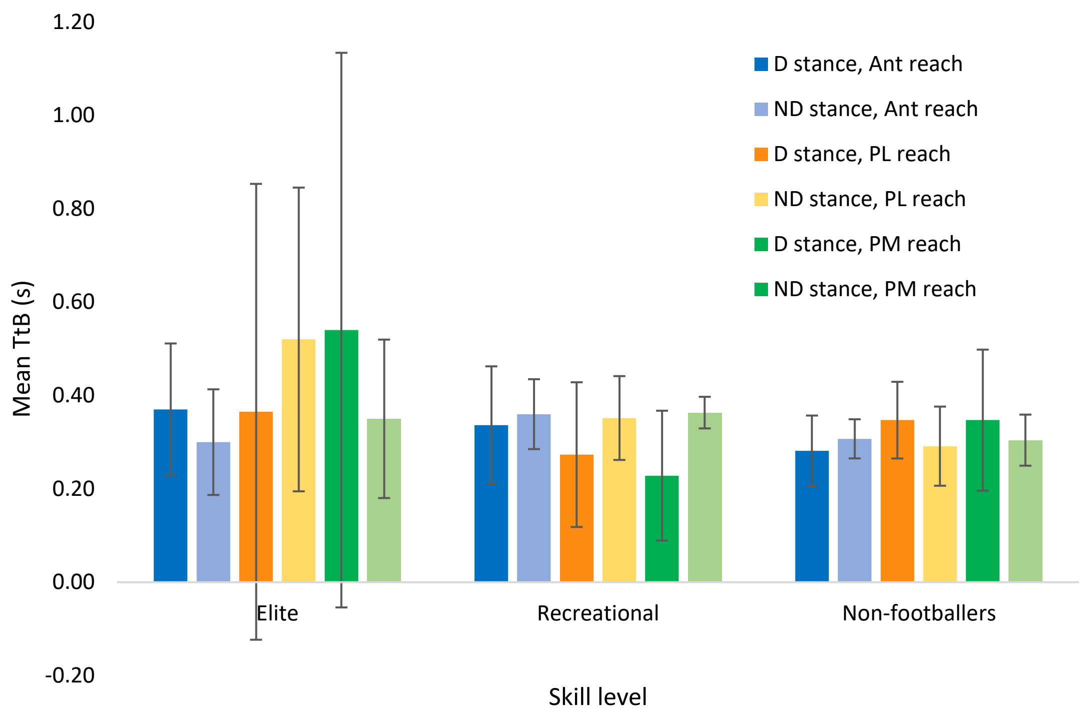

Figure 6.13 Mean TtB for all skill levels during the mSEBT. Non-significant main effects and interactions as determined by a mixed method, repeated measures ANOVA. D: dominant, ND: non-dominant, Ant: anterior, PL: post-lateral, PM: post-medial. Elite, n = 2; recreational, n = 6; non-footballers, n = 7.

6.6 Discussion

This study aimed to investigate whether sport specific measures of dynamic balance could differentiate for skill level in football players. A secondary aim was to determine whether any relationship existed between limbs and skill level for kicking and mSEBT. Eighteen volunteers were recruited into three skill groups: Elite football players, recreational football players and non-football players. 3D motion capture and force plates were used to capture kinematic and kinetic data during three newly developed sport specific balance measures; external forces test, deceleration test, and kicking. Additionally, a common measure of dynamic balance in football; the mSEBT was employed as a comparative measure. Outcome measures were compared between groups to determine their ability to differentiate between skill level and to establish whether any relationships exist between limbs for kicking and mSEBT.

6.6.1 External forces

This is the first known study to assess dynamic balance response to lateral perturbations during running. Elite players were able to maintain their CoM within a smaller distance and recover quicker following the perturbation than recreational and non-football players. Despite there being no statistical differences between groups for both CoM displacement and TTS, the large effect size observed between elite and recreational players for CoM displacement, and between elite and recreational players and elite and non-football players for TTS suggests a relationship between skill level and ability to control the whole-body CoM. Due to small sample sizes further research would be needed to confirm this.

Within previous football participant research there has been an investigation of CoM displacement utilising perturbations applied via a translation in the support surface in the anterior and posterior directions (Behan et al., 2018). This method is not representative when considering perturbations experienced by players during training or a game situation occur due to contact with an opponent. Previous research investigating standing perturbations have found CoM displacements of 0.6-0.64 cm (Rietdyk et al., 1999). As running is a more challenging activity in terms of the control of the CoM, it would be expected that higher CoM displacements were experienced by the participants in this study.

Recreational footballers experienced the largest CoM displacement, which was unexpected. If one was to consider that previous research has proposed that higher level athletes possess better dynamic balance ability than lower-level athletes, it would be expected that the recreational athletes would have a CoM displacement that was larger than elite players but smaller than non-footballers. Elite players presented the lowest value of TTS, whereas non-footballers displayed the highest TTS. Higher TTS values have been identified in previous research as being indicative of dynamic postural stability with lower TTS scores reflective of better balance (Ross & Guskiewicz, 2004; Wikstrom et al., 2005). The values of TTS within this study are much lower than reported in previous research (Ross & Guskiewicz, 2004; Wikstrom et al., 2004), which can be attributed to the calculation method of TTS and the difference in task performed. Although there were no statistical differences between groups, there were large effect sizes for elite compared to recreational players and elite compared to non-football players, as well as a moderate effect for recreational compared to non-football players. It would be of interest to determine whether the differences observed in this study could be replicated in a study with more statistical power.

Differences are evident between groups for magnitude of CoM and TTS and the effect sizes suggest a relationship between the outcomes at the different skill levels, with differences between groups of; 2 - 4 cm, and 0.5 - 1.08 s for CoM magnitude and TTS respectively. It is difficult to determine whether the results of this test indicate that a lower CoM displacement and quicker time to stabilise following the release of lateral perturbation force are associated with a higher skill level in football due to the small sample size used within this investigation. A power analysis performed with Gpower (G Power version 3.1.9.4, Franz Faul, Universitat Kiel, Germany) indicated that a sample size of 81 participants would be necessary to identify whether there was a significant difference between groups for CoM displacement and TTS and therefore, to confirm whether these differences are present in the wider population groups.

It is important to consider that when the perturbation was applied and released that the point in the gait cycle of participants was different. This is because depending on which foot was in stance phase when the perturbation was applied or released would affect the recovery of the participant. For example, if the release of the perturbation occurred when the participant's right foot was in contact with the treadmill, they would not be able to correct until a full stride later. The lateral perturbation was performed multiple times within the trial, these were randomised, and an average of outcome measures was calculated. Although this may have reduced systematic differences there is still a chance that this may have affected the results. A robust and computerised method of identifying the phase of the gait cycle on each leg and apply the perturbation at different points within the gait cycle would have added complexity to the study and any results would only apply to those points of the gait cycle. Further research should look to address whether differences are evident with perturbations applied and released on both sides of participants and at different magnitudes and times.

6.6.2 Deceleration Test

The lack of statistical significance between groups, small differences (up to 1 mm) and trivial and small effect sizes would suggest that CoM AP range is not sensitive enough to identify differences in dynamic balance ability across skill levels during a deceleration test. The large effect sizes observed for both TTS and step frequency between elite and recreational players and recreational and non-footballers may be spurious and related to the larger variability of values in the elite and non-football players. As recreational players had a lower CoM range it may be that the lower TTS was related to this. A relationship between a lower TTS and higher step frequency was observed for elite players only. Individual step frequency identified that the participant with the highest step frequencies were midfielders and forwards. As the elite players will train more often than recreational players and the non-footballers will not be subjected to performing decelerations, the higher step frequency demonstrated by elite players may have been developed through these experiences. However, it is difficult to know whether inherent predispositions are present in the higher level footballers (Balter et al., 2004; Paillard & Noe, 2006; Perrin et al., 2002). Further investigation with a larger number of participants is required to determine whether this relationship is meaningful.

It is possible that performance on the deceleration test might be related to playing position. It has been demonstrated that different elite playing positions experience different numbers of accelerations within games with forward and midfield playing positions experience higher and more decelerations than other playing positions (Mara et al., 2017; Oliva-Lozano et al., 2020; Vigh-Larsen et al., 2018). It is possible that the methodological choices of the deceleration test had an impact on the outcomes. Decelerations have been identified as being as common as accelerations (Harper et al., 2020; Osgnach et al., 2009; Spencer et al., 2004) and important to success for players (Carling et al., 2008; Haroer et al., 2020; Reilly et al., 2000). In this investigation the deceleration rate of the treadmill was 5 ms^{-2}, categorised as a very high deceleration (Akenhead et al., 2013; Góralczyk et al., 2003; Hodgson et al., 2014). This is higher than deceleration rates experienced by elite players during game scenarios (Oliva-Lozano et al., 2020). There is a possibility that the very high deceleration rate caused a lot of variability in the data. Further work should investigate whether a range of decelerations typical for those experienced in the game lead to differences in balance control at varying skill levels. Previous research has identified the dynamic postural control strategies in controlling the CoM during decelerations. When decelerating the position of the CoM should be posterior to the point of contact with the ground, the stiffness of joints is decreased, flight time is minimised and there is a maximised landing distance (Andrews et al., 1977). For this reason, it may be of interest in future work to determine how the CoM of participants relates to the base of support during this deceleration phase to determine any differences in control strategy. During decelerations there are predominantly eccentric muscle contractions, with most contractions occurring in the hip flexors, knee extensors and planter flexors (Andrews et al., 1977). It is not known how the body segments contribute to the control of CoM. It may be more beneficial to look at postural control strategies through kinematic analysis to assess any differences in limb positions and between participants. Running on an accelerating or decelerating treadmill is mechanically different to running overground due to the absence of linear whole-body acceleration (Van Caekenberghe et al., 2013). Therefore, the deceleration test may be considered inadequate at accurately assessing balance strategies. Further work is required to determine whether balance is less critical in deceleration or acceleration using methods that best represent the linear whole-body acceleration that is experienced in over ground running. This will help determine whether acceleration tests can differentiate for skill level and whether any relationships exist between dynamic balance control in acceleration and deceleration.

6.6.3 Kicking

The main biomechanical indicator of kicking success is the speed of the ball and is influenced by many factors (Kellis & Katis, 2007). This study did not measure speed of the ball, however faster ball velocities have been attributed to faster linear velocities of the centre of mass of the foot (Nunome et al., 2006). The results of this study found that foot velocity was lower than that reported in previous literature (Dorge et al., 2002; Nunome et al., 2006). There was no difference in foot velocity between skill level. Participants were instructed to kick the ball as hard as they could towards a target. No emphasis was placed on the accuracy of the kick and trials were not deemed unsuccessful if an accurate kick was not achieved.

Elite players performed worst as indicated by a lower linear foot velocity, however there were not any statistical differences between groups in performance. There were only data available for analysis from two participants within the elite group and one participant with the elite group, had returned to play from an ACL injury. Inspection of this individual's results revealed that the linear velocity of their foot was lower than all other participants when kicking with their dominant limb and one of the lowest velocities for the non-dominant limb. The second elite participant had linear foot velocities on each limb higher than 50% of the other participants. Together with only two participants, this reduced the mean foot velocity. The lower performance of the elite players may also be explained by their interpretation of the task. When accuracy of kicking is the focus, there is a reduction in ball speed and linear velocities when compared with a powerful kick (Lees & Nolan, 1998; Teixeira et al., 2018). When players are instructed to produce a maximal kick, they increase their approach speed and the kick is less accurate (Godik et al., 1993). Elite players were more accurate in this kicking task than recreational and non-football players. It is possible that for elite players the target provided a constraint on the task whereby they traded off speed for accuracy and therefore utilised a lower foot speed. There were small effect sizes between groups. A larger sample size providing more statistical power is required to determine whether any significant differences are present.

Higher foot velocity was exhibited when kicking with the dominant limb ($p = 0.004$) which is comparable to previous research (Dorge et al., 2002). Differences in linear velocity of the foot between limbs has been reported to be due to larger angular velocity of the shank due to moments of force originated from the muscle forces on the segment and from the joint reaction forces (Dorge et al., 2002).

There has been little research that has investigated the importance of balance during football kicking tasks, despite the intuitive demands on balance control. Deviations in the location of the CoP during the kick in this study provided a way of identifying differences in strategies of control of the balance for different skill levels. Previous research investigating balance ability and kicking performance has compared the results of static balance tests in single leg stance with kicking performance (Chew-Bullock et al., 2012). The lack of correlations found in the study by Chew-Bullock et al. (2012) is likely due to the use of a static balance test. There were no significant effects of limb or skill level on CoP path length, however the results of this study identified a significant crossover interaction of limb and skill level on total CoP path length (p = 0.012). Elite players presented a much lower CoP path length when kicking with the non-dominant limb whereas recreational and non-footballers had a much smaller difference in path length between limbs with a longer path length when kicking with the dominant limb. Despite elite players having a lower CoP path length, TtB values were similar between limbs and across groups with no significant main effects of limb or skill level nor interactions. The small effect sizes suggest that CoP path length and TtB are not sensitive enough to differentiate for skill level in footballers during a kicking task. It is important to note that for the kicking test data analysed for the elite group included two participants. A larger sample size would be needed to provide more statistical power in this task.

6.6.4 mSEBT

The non-significant main effect of stance limb on reach distance is comparable to a recent meta-analysis of SEBT performances in sporting athletes (Schorderet et al., 2021). This study identified a significant main effect of reach direction on reach distance with Anterior and PL reach distances significantly lower than PM reach distances (p = <0.01). There was a significant interaction of reach direction and skill level on reach distance with elite players having a significantly lower reach score in the PL direction (p = 0.017) than the other skill groups. In this study all participants reached furthest in the PL direction and least in the anterior direction which is comparable with previous research in basketball and football players (Ates, 2017; Emirzeoğlu & Ülger, 2020). However, there are studies where higher reach distances were observed for anterior reach direction (Akinci et al., 2019) and PM reach direction (Bhat & Moiz, 2013; John et al., 2018) in football players. When comparing footballers to controls, previous research has identified that football players reached significantly further in the anterior and posterior directions (Thorpe & Ebersole, 2008) however, there is also evidence that lower level footballers have reached further in the anterior reach than elite footballers (Butler et al., 2012). Thorpe & Ebersole (2008) explained differences as being associated with a training effect. Butler et al., (2012) suggested that previous research highlighting the effect of ankle instability might explain the differences. As this study and that of Butler et al., (2012) did not collect information regarding previous injury history it is difficult to establish any direct relationship.

The results of the mSEBT reach distance as a performance measure in this study does not support the viewpoint that higher-level athletes perform better in dynamic balance tests. Whilst recreational players did reach further than controls in all reach directions, they also reached further than elite players, which does not support the argument of the effect of training on performance. The kinetic measures employed in this research were included to provide a way of identifying strategies that might explain differences in performance. There were no significant main effects or interactions observed for CoP path length or TtB. Visual inspection of the data provides little information regarding any obvious trends.

For CoP path length, elite players demonstrated slightly lower values and recreational players demonstrated slightly higher values. It is possible that the reach distance might have influenced the path length; however, observing individual performances within groups does not support this. On observation of the participants performing the test, the most challenging reach direction in terms of unsuccessful attempts was in the PM reach, however there is not an obvious trend that would indicate that the CoP path length was higher or lower based on the difficulty of the reach direction. For TtB elite players displayed a higher value overall which might be attributed to better dynamic postural stability, however there were only two participants' data used in the analysis and there are very large variances. Additionally, observing the individual values for the two participants, the highest and lowest values fall within the highest and lowest values within the other groups.

Movements involved in the mSEBT are multi-limb and multi-articular (Kinzey & Armstrong, 1998). There is a controlled lowering of the body involved in achieving the reach. Previous research has suggested that reach distances are greatly affected by joint range of motion and muscular strength. Anterior reach distance is affected by knee flexion and ankle dorsiflexion range of motion of the stance limb and hip flexion, knee extension and ankle plantarflexion of the reaching limb. The hip flexors have an increased role in the support of the stance leg during the PL reach, with hip internal rotators providing stability of the pelvis in the 90° lateral movement (Akinci et al., 2019). Additionally, research suggests that lower limb isometric strength plays a role in performance of the mSEBT (Chtara et al., 2016). A reliability study by Kinzey & Armstrong (1998) found moderate estimates of reliability in maximal reach distances and discuss different movement trajectories as a possible explanation for random high and low reach distances. The kinematic strategies involved in achieving reach distances has not been assessed for this study but may provide further information regarding differences in strategies employed by participants. It may be of interest to determine if the kinematics of stance and reaching limbs may explain the lower distances of elite football players. Inherently, there is more variability associated with the movements of the mSEBT than single limb and uniarticular movements (Walter et al., 1993). In activities of daily living and sport, a person would not normally challenge their state of equilibrium in single leg stance to the extent required in this test. Additionally, the static base of support of the mSEBT identified discussed in Chapter 2 and the taxonomy classification of a non-moving base of support with suprapostural acceleration providing a destabilising challenge, identifies the mSEBT as a non-sport specific measure of dynamic balance. Furthermore, the methodological difficulties associated with the mSEBT identified in Chapter 2 can influence individual performance.

The results of this study indicate that a test involving a lateral perturbation during running can differentiate for skill level in football players. With highly skilled players demonstrating a better stability and quicker recovery of the CoM. Tests of deceleration, mSEBT and kicking were not able to differentiate for skill level. Within these tests, the elite players often performed in a way that could be considered inferior to recreational and non-footballers. It is possible that fatigue prior to the testing session may have impaired the performance of these players. A Player's physical performance is often temporarily impaired due to the stress associated with training and competition (Thorpe et al., 2015). The impairment can be acute, last minutes or hours possible stemming from metabolic disturbances and substrate utilisation associated with high intensity exercise. Additionally, impairment can last for days with exercise induced muscle impairment and delayed-onset muscle soreness (Barnett, 2006). Biomechanical and biochemical changes such as decline in leg power, maximum isometric force alterations and activity of the quadriceps (Nicol et al., 1991), decline in the vertical jumping ability (Rodacki et al., 2001), changes in ground reaction forces and joint kinematics of running (Mizrahi et al., 2000; Williams et al., 1991) and increased lactate production (Bangsbo, 1997) are caused by fatigue. Training levels and activities prior to testing were not recorded for participants so it is difficult to determine whether this may have been a factor in the performance. Elite participants within this study were tested in the middle of the in-season. The performance of elite footballers is strongest during pre-season and declines as the season progresses as identified in personal communication with Sport Science staff of a professional football club. As the elite players within this study were tested in the middle of the season, it is possible that their performance does not reflect their abilities when at their peak. Additionally, as one participant had returned to play from injury there is a possibility that their performance was affected by this.

6.7 Limitations

The participants recruited into the recreational players' skill group were from a wide range of playing levels from collegiate level to non-league to Sunday league teams. Additionally, some of the non-footballer participants were involved in other sports such as cycling and athletics. It is unknown how involvement in other sports and such a large range of skill level within the recreational group may have influenced performance measures and dynamic postural control strategies chosen in these groups. Additionally, the very small sample size of elite players in the kicking task and mSEBT mean it is difficult to determine whether the performance and dynamic postural control strategies displayed by these participants is reflective of this skill level.

The elite players displayed a reduced performance in the deceleration, kicking and mSEBT tests. A possible limitation of these tests are that they do not represent all the environmental constraints of the tasks in the real world and are therefore lacking in representative design (Pinder et al., 2011). During kicking for example, footballers would be influenced by the size of the goal and the presence of a goalkeeper. Additionally, elite footballers may have underperformed due to motivational cues missing from the task such as evading an opponent or a goal scoring opportunity.

During the kicking task an assumption was made that the foot markers remained in the same position from heel contact to impact with the ball. The TtB was calculated from impact with the force plate and as participants brought their swing leg through their heel raised off the force platform. As heel movement was not analysed in this task it is not known how this may have impacted CoP path length and the calculation of TtB.

Future research should investigate the use of non-linear methods of analysis, for example fractal dimension and detrended fluctuation analysis, to identify whether they provide more sensitive measures with the potential to reveal whether different postural control strategies exist between groups. There are aspects of the tests that could have been improved to provide more sensitive performance measures. For example, kicking accuracy and linear ball speed in the kicking task may have been more sensitive in detecting performance differences between groups. In the deceleration test, the use of a performance measure over ground such as time and/or distance to achieve a pre-determined change in velocity may have been better at differentiating deceleration ability between highly skilled and less skilled footballers.

6.8 Conclusion

The external forces test shows promise at being a measure that can differentiate for skill level in football. Interpretation of effect sizes for the deceleration and kicking tests indicate that the test or the outcome measures chosen are not able to differentiate for skill level in football. The mSEBT is not a good test to measure performance nor is it able to differentiate skill level of male footballers. Further work is required to determine the best performance measures to be used in the mSEBT, kicking task and deceleration task and to identify measures that are sensitive enough to differentiate for skill level in male footballers by identifying dynamic postural control strategies. Due to the many factors that affect performance in these tests and the inability to determine dynamic postural control strategies between groups, further work should look to modify the tests to make them more sensitive.

Previous research has highlighted that in measurements of CoP deviations in balance tasks, large deviations may represent poor postural control in some individuals and in others an effective means of achieving balance (Palmieri et al., 2002). The lack of obvious trends between performance measure and dynamic postural control measures in the deceleration test, kicking test and mSEBT makes it difficult to determine whether a smaller CoP path length relates to a better performance. Further work should investigate whether other measures provide a better indication of dynamic postural control strategies. As well trained individuals may use different strategies to perform the same task over repeated trials (Palmieri et al., 2002) and within this body of research elite players performed in unexpected ways, it is of interest to use a larger sample of elite players to determine how much variability occurs between trials and within participants.

Due to small and unequal sample sizes within this investigation, the degree to which these results are representative of the wider population groups in unknown. Caution should be used when interpreting and generalising these results to the wider population of these skill levels. Further work using larger sample sizes is required to confirm any differences between and within groups.

Chapter 7 Overall Discussion

7.1 Introduction

This chapter discusses the results of this programme of research. An overview is presented by summarising the findings of each objective. This is followed by implications, limitations of the findings, future directions and finally a conclusion.

7.2 Summary of findings

Objective 1: To provide a critical review of literature in dynamic balance, establishing current knowledge and identifying gaps that require further research.

Initially a literature review informed the current programme of research by identifying that there was ambiguity surrounding the definition of dynamic balance and associated terms and that there were many dynamic balance tests available with no method of identifying an appropriate test. The importance of dynamic balance in elite level sport was discussed as well as its multidimensional nature and dependence on context. Evidence was presented demonstrating that in some sports higher-level athletes have better balance skill, and athletes in some sports have better balance than in other sports. It was identified that dynamic balance measures used within sport and in particular football, underrepresent the demands placed on the postural control system and that different sports are likely to have different balance requirements. Therefore, there was a need for sport specific balance measures. The literature review identified that two methods of determining test suitability exist (Huxham et al., 2001; Pardasaney et al., 2013). However, due to their limited assessment of tests relating to falls and community dwelling older people there was no evidence that they would be valuable tools for assessing balance measures for other populations and more specifically for sport. As there is a lack of research that has investigated different components of balance nor a method for identifying these components and suitable tests, a framework for identifying components and aligning suitable tests would complement definitions encompassing all scenarios of dynamic balance.

Objective 2: To understand and provide an encompassing definition of dynamic balance and associated terms.

A scoping review was performed to identify definitions of dynamic balance and associated terms and to identify the range of tests available. A key paper (Pollock et al., 2000) was identified that aspired to bring the terms into concordance and it was identified that this has not been satisfied, as existing definitions were identified as not providing coverage of a full range of dynamic balance circumstances (Hof et al., 2005). The ambiguity of terms and lack of specificity in tests were identified as barriers to development of research in this area. The evidence provided a clear need for dynamic balance, dynamic postural control, and dynamic stability to have distinct and precise meanings. The definitions developed in Chapter 3 extended the proposed definitions of Pollock et al. (2000) by incorporating organismic and environmental constraints based on Newell's constraints model (Newell et al., 1989) providing independent terms that account for real-world scenarios in sports and clinical settings.

Objective 3: To identify the important dimensions of dynamic balance in football and to identify sport specific measures of dynamic balance in football.

The existing taxonomies of Huxham et al. (2001) and Pardasaney et al. (2013) are methods of classifying balance tests by task and environment; they were found to be inadequate in classifying components of balance identified in the wide range of tests due to their targeted application within falls and community dwelling older adult populations. As a result, a new taxonomy was developed which extended that of Pardasaney et al. (2013) with a focus on the task and environmental constraints of Newell's constraints model (Newell et al., 1989). The benefits of the newly developed taxonomy are threefold. Firstly, it provides a method by which components of balance considered important within a population and/or sport can be classified. Secondly, it allows researchers and clinicians to identify the strengths and limitations within dynamic balance tests and select assessments that are adequately challenging for the population being tested. Finally, it provides a tool by which appropriate measures can be chosen through alignment with existing tests.

An investigation was conducted into important components of balance within football. All movements occurring in football were identified through the Bloomfield Movement Classification (Bloomfield et al., 2004) and presented in a questionnaire to football professionals. A rating scale (3,2,1) was employed to determine football professionals' expert opinion on how the movement in each question related to each of the four performance categories: creating a goal scoring opportunity, defending around the box, winning a tackle/regaining possession, injury risk. Additionally, all the movements were classified through the taxonomy developed in Chapter 4 and grouped where classifications were the same. The results of the classification identified that the highest frequency of postural equilibrium involved a non-static BoS, yet popular dynamic balance measures used in football populations involve a static BoS. Furthermore, the highest frequency of destabilising challenges classified from football movements were vertical and anterior-posterior whole- body accelerations, and an imposed external lateral force which are also not represented in commonly used dynamic balance tests in football. The results of the questionnaire identified that the highest rated groups of movement were: 1., shielding the ball, a shoulder barge whilst running, jostling to win the ball and shielding the ball whilst jostling; 2., accelerating and braking; and 3., a single leg kick or standing volley. None of the existing dynamic balance tests aligned with these classifications, suggesting that previous research has not identified the components of balance that should be tested for in football. The outcomes of the present study also suggest that previous research has not made use of sport specific tests to assess dynamic balance in football and that the taxonomy is a useful tool that provides a method of classifying important components of dynamic balance in sport and identifying appropriate tests.

As none of the existing dynamic balance tests aligned with the movements identified as important in Chapter 5, football specific measures of dynamic balance were developed to provide the required specificity. Existing dynamic balance tests and performance tests used in football were considered and critiqued where they satisfied either the postural equilibrium or destabilising challenges of the classification of the football movements using the taxonomy. Logistical constraints were also taken into consideration in development of the new measures.

Objective 4: To investigate the extent to which dynamic balance ability differentiates between skill levels in football and whether differences exist between limbs.

The final study within this programme of research investigated whether the newly developed sport specific measures of dynamic balance could differentiate for skill level in football players. A common measure of dynamic balance in football, the mSEBT, was also used to determine its suitability as a measure of dynamic balance when outcomes measures pertaining to the dynamic postural control strategies were investigated, and as a reference measure due to its popularity. A secondary aim of the final study was to determine whether any relationship in dynamic postural control existed between limbs and skill level in kicking and the mSEBT. 3D motion capture and force plates were used to determine performance measures and dynamic postural control strategies in footballers to determine whether they could differentiate for skill level. Three new dynamic balance tests were employed following identification through the taxonomy in Chapter 5. These were external forces test, deceleration test, kicking test. The results of the final study in this programme of research identified that the external forces test shows promise at differentiating for skill level between footballers as determined by effect size. The performance measures of the dependent variables of the mSEBT, kicking task and deceleration task may not suggest a higher dynamic balance ability for elite players compared to recreational or non-players. Additionally, it was not possible to identify dynamic postural control strategies that indicated a better or worse performance. The small and unequal sample sizes within this final study suggests that the degree to which these results are representative of the wider population groups in unclear. Therefore, further work using larger sample sizes is required to determine any differences between and within groups.

7.3 Limitations

The results of this programme of research may have been influenced by various limitations. These limitations have been discussed in detail in each individual chapter. For this reason, there will be a brief discussion of the limitations in the current section.

A scoping review was chosen as a method of synthesising the research on dynamic balance, dynamic postural control and dynamic postural stability. Therefore, the literature that informed the newly proposed definitions and taxonomy of movements and tests was not critically appraised and did not produce a synthesised result unlike other forms of systematic review. However, the indication for a scoping review was to identify current knowledge in a broad topic area, and to determine the range and quantities of tests of dynamic balance used which has been recommended as an appropriate methodology in this case (Munn et al., 2018). The scoping review was conducting following Arksey and O'Malley's (Arskey & O'Malley, 2005) 5-stage framework and the recommendations of (Levac et al., 2010). Any relevant papers or tests that may have been missed due: to the confinement of search terms to the title, the limited range of publication dates selected and the restriction to English language publications may have impacted the tests classified through the taxonomy and in turn the development of sport specific tests in Chapter 6. However, there was a clear pattern of the literature in the scoping view and development of the tests investigated key literature and citation searching to inform decisions. Furthermore, in development of the definitions and taxonomy, a multidisciplinary team was employed in the discussion and decision making, suggesting a sufficiently broad coverage was likely.

The important movements identified for use in determining dynamic balance components in football were based on success of the game and injury implications. A questionnaire was used to determine football professionals' considerations. There is a possibility that due to most questionnaire respondents being Championship level professionals, the movement choices may only be specific for that level of football. Therefore, it is not known whether these movements would be considered equally as important in the Premier league or lower professional leagues below Championship. Championship level teams were targeted for recruitment of elite participants in the final study of this programme of research and the results may be indicative of that skill level. Furthermore, it was not identified whether some components of dynamic balance are more important for either injury risk or performance as during the classification of the football movements the scores were grouped. Further work may wish to determine whether dynamic balance components may be different based on determination of injury risk or performance ability. Use of a Delphi poll or time-motion analysis in football may provide alternative methods for determining the important movements in football, however within this study they were deemed inappropriate and questionnaire data provided highly structured data with more convenience for participants. It is not known whether important movements might differ at different skill levels and there is no research to date that has addressed this. For this study it was considered more appropriate to determine the components of balance for the higher skilled athletes.

In the final study of this programme of research, small and unequal sample sizes may have influenced the results. Therefore, caution must be applied when generalising the results to the wider football community. The participants recruited into the recreational players skill group were from a wide range of playing levels from collegiate level to non-league to Sunday league teams. Additionally, some of the non-footballer participants were involved in other sports such as cycling and athletics. It is not known how involvement in other sports and such a large range of skill level within the recreational group may influence and performance measures and dynamic postural control strategies chosen in these groups. Additionally, the very small sample size of elite players in the kicking task and mSEBT mean it is difficult to determine whether the performance and dynamic postural control strategies displayed by these participants is reflective of this skill level.

The elite players displayed a reduced performance in the deceleration, kicking and mSEBT tests. A possible limitation of these tests are that they do not represent all the environmental constraints of the tasks in the real world and are therefore lacking in representative design (Pinder et al., 2011). During kicking for example, footballers would be influenced by the size of the goal and the presence of a goalkeeper. Elite footballers may have underperformed due to motivational cues missing from the task such as evading or a goal scoring opportunity. Additionally, injury and fatigue may be a factor that should be considered in relation to performance of elite players.

Finally, during the kicking task an assumption was made that the foot markers remained in the same position from heel contact to impact with the ball. The TtB was calculated from impact with the force plate and as participants brought their swing leg through their heel raised off the force platform. As heel movement was not analysed in this task it is not known how this may have impacted the calculation of TtB if there was a rearwards movement of the CoP involved in the stabilisation. It is possible that some of the measures within the tests were not sensitive enough to differentiate between skill level both in the balance and performance aspects of the tests. Alternative methods of assessing performance and additional measures using non-linear methods should be investigated to determine whether they are more sensitive at detecting differences between groups.

7.4 Implications of findings

The findings of the programme of research have significant implications in furthering knowledge of this research area. This body of work proposes a new set of definitions for the most common terms used to describe dynamic balance (dynamic balance, dynamic postural control and dynamic stability) that consider Newell's constraints model (Newell et al., 1989) and accounts for the full range of dynamic balance situations not accounted for in previous definitions. It is recommended that future research in this field refers to these definitions. The benefit of the adoption of these new definitions would provide less ambiguity in the use of these terms and would result in the removal of barriers in the development of a coherent research base in dynamic balance.

The findings of Chapters 4 and 5 support the view that dynamic balance is not a single construct and is multi-dimensional. A taxonomy has been developed that has the potential to categorise components of dynamic balance in football as well as other sports and activities based on postural task and environmental constraints. Additionally, through classification of existing dynamic balance tests it provides a method of assessing the suitability of a dynamic balance test for a particular population and in identifying whether a test exists that provides specificity for movements of interest. The use of the taxonomy in future research when identifying dynamic balance components and sport specific tests in the assessment of dynamic balance would strengthen the evidence in identifying whether higher skilled athletes demonstrate better dynamic balance ability and whether dynamic balance ability differs between athletes of different sports based on the important movements identified in those sports.

This research has practical implications relevant to football development in particular the training of footballers and the decision process in retain and release of players at academy level. Within Academy football provision, players can be anecdotally referred to as a “poor mover”, based largely on fitness scores and subjective opinion of observed movements. The use of dynamic balance testing, such as those within this research, would provide an objective measure, which would support multidisciplinary team decisions in either retaining or releasing a player, and individual training programme planning. The outcomes of testing would contribute to the rationale of developing an individual’s balance, other skills or released based decisions. The use of sport specific measures of dynamic balance tests in pre-season screening would provide benchmarks for injured players and new players joining the club.

7.5 Future directions

The results of this thesis provide a basis for future research in dynamic balance. Three of the dynamic balance tests used in the final study: deceleration, kicking and mSEBT did not demonstrate the ability to differentiate for skill level in footballers. A major limitation of this study was the small sample sizes. Further work should identify whether these tests remain unlikely to identify dynamic postural control strategies with a larger sample size which would provide more power. As it was not possible to identify different postural control strategies between the recreational players and non-footballer groups, this work should also seek to identify whether movement strategy differences exist at an individual level. Bartlett et al. (2007) suggests that in more complex tasks variability of movement strategies occurs between individuals and between trials, it is of interest to determine whether performance and control strategies of individual participants differ in this way. This variability might help explain the inability of the tests to identify any dynamic postural control strategies related to performance measures. Finally, there is no consensus in the literature as to which measurable parameter quantifies postural control (Palmieri et al., 2002). The use of joint kinetics and kinematic variables may help to explain strategies in dynamic postural control. Additionally, investigation of non-linear methods may provide a method of quantification of the time-varying structure of dynamic postural control patterns (Zemkova, 2011).

7.6 Conclusion

The goal of this research was to investigate whether sport specific measures of dynamic balance could differentiate for skill level in footballers. The newly proposed definitions provide independent terms that consider the organismic, task and environmental constraints necessary to account for real-world scenarios. The taxonomy provides a method of categorising movements and dynamic balance tests in order to determine appropriate and specific measures of dynamic balance for any sport or activity. The external forces test suggested that highly skilled footballers performed better than lower-level footballers and that the dynamic postural control strategy involved maintaining the CoM within a smaller range. Larger sample sizes are required before this can be interpreted as definitively representing these populations. The deceleration test, kicking test and mSEBT were not able to determine differences in performance of dynamic balance nor was it possible to identify what dynamic postural control strategies explained the performance. Further work should address the use of these tests and outcome variables as methods of differentiating for skill level in footballers in larger sample sizes and incorporate the use of joint kinematics and kinetics, and the use of non-linear variables for assessing dynamic postural control strategies.

Chapter 8 References

Abdelghany, A. I., Elkablawy, M. A., Gharib, S. El, Salem, A., & Ahmed, N. (2016). Relationship between head postural changes and dynamic balance in a symptomatic forward head posture student. *International Journal of PharmTech Research*, *9*(7), 93–98.

Akbari, A., Ghiasi, F., Mir, M., & Hosseinifar, M. (2016). The Effects of Balance Training on Static and Dynamic Postural Stability Indices After Acute ACL Reconstruction. *Global Journal of Health Science*, *8*(4). https://doi.org/10.5539/gjhs.v8n4p68

Akenhead, R., Hayes, P. ., Thompson, K. ., & French, G. (2013). Diminutions of acceleration and deceleration output during professional football match play. *Journal of Science and Medicine in Sport*, *16*(6), 556–561.

Akhbari, B., Salavati, M., Mohammadi, F., & Safavi-Farokhi, Z. (2015). Intra-and Inter-session Reliability of Static and Dynamic Postural Control in Participants with and without Patellofemoral Pain Syndrome. *Physiotherapy Canada*, *67*(3), 248–253. https://doi.org/10.3138/ptc.2014-51

Akinci, B., Erdem, B., Hatipoğlu, H., & Özdinçler, A. R. (2019). The determiner role of dynamic balance, flexibility and aerobic endurance on change of direction ability in young male soccer players. *Medicina Sportiva*, *15*(2), 3097–3104.

Alghadir, A. H., Al-Eisa, E. S., Anwer, S., & Sarkar, B. (2018). Reliability, validity, and responsiveness of three scales for measuring balance in patients with chronic stroke. *BMC Neurology*, *18*(1), 1–7.

Andrews, J., McLeod, W., Ward, T., & Howard, K. (1977). The cutting mechanism. *American Journal of Sports Medicine*, *5*, 111–121.

Anoop, A., Zutshi, K., Jitender, M., & Suraj, K. (2010). Effect of core stabilisation on dynamic balance in non-professional sports players. *Indian Journal of Physiotherapy and Occupational Therapy*, *4*(4), 18–22.

Arskey, H., & O’Malley, L. (2005). Scoping studies: towards a methodological framework. *International Journal of Social Research Methodology*, *8*(1), 19–32.

Asadi, A., & Arazi, H. (2012). Effects of high-intensity plyometric training on dynamic balance, agility, vertical jump and sprint performance in young male basketball players. *Journal of Sport & Health Research*, *4*(1), 35–44.

Ashton-Miller, J, A., Wojtys, E, M., Huston, L, J., & Fry-Welch, D. (2001). Can proprioception really be improved by exercises. *Knee Surg Sports Traumatol Arthrosc*, *9*(128–136).

Assaiante, C., Mallau, S., Viel, S., Jover, M., & Schmitz, C. (2005). Development of postural control in healthy children: a functional approach. *Neural Plasticity*, *12*(2/3), 109–118.

Ates, B. (2017). Investigation of static and dynamic student-athletes and non-athletes between 12 and 14 years of age. *Journal of Physical Education & Sports Science/Beden Egitimi ve Spor Bilimleri Dergisi*, *11*(1), 1–9.

Aydoğ, E., Aydoğ, S. T., Çakci, A., & Doral, M. N. (2006). Dynamic postural stability in blind athletes using the Biodex Stability System. *International Journal of Sports Medicine*. https://doi.org/10.1055/s-2005-865777

Ball, K., Best, R., & Wrigley, T. (2013). Body sway, aim point fluctuation and performance in rifle shooters: inter- and intra-individual analysis. *Journal of Sports Sciences*, *7*(559–66).

Balter, S. ., Stokroos, R. ., Akkermans, E., & Kingma, H. (2004). Habituation to galvanic vestibular stimulation for analysis of postural control abilities in gymnasts. *Neuroscience Letters*, *366*(1), 71–75.

Bangsbo, J. (1997). The physiology of intermittent activity in football. In Reilly, T., J. Bangsbo, & M. Hughes (Eds.), *Science and Football III* (pp. 43–53). London: E & FN Spon.

Barfield, W. (1995). Effects of selected kinematic and kinetic variables on instep kicking with dominant and non-dominant limbs. *Journal of Human Movement Studies*, *29*, 251–272.

Barnett, A. (2006). Using recovery modalities between training sessions in elite athletes. *Spors Medicine*, *36*(9), 781–796.

Bartlett, R., Wheat, J., & Robins, M. (2007). Is movement variability important for sports biomechanists. *Sports Biomechanics*, *6*(2), 224–243.

Bass, R. (1939). An analysis of the components of tests of semicircular canal function and of static and dynamic balance. *Research Quarterly of the American Association for Health, Physical Education, and Recreation*, *10*, 33–52.

Beauchet, O., Fantino, B., Allali, G., Muir, S., Montero-Odasso, M., & Annweiler, C. (2011). Timed up and go test and risk of falls in older adults: A systematic review. *Journal of Nutrition, Health and Ageing*, *15*(933–938).

Behan, F., Willis, S., Pain, M., & Folland, J. (2018). Effects of football simulated fatigue on neuromuscular function and whole-body response to disturbances in balance. *Scandinavian Journal of Medicine and Science in Sports*, *28*(12), 2547–2557.

Behrman, A., Light, K., Flynn, S., & Thigpen, M. (2002). Is the functional reach test useful for identifying falls risk among individuals with Parkinson's disease? *Archives of Physical Medicine and Rehabilitation*, *83*, 538–542.

Berg, K, Wood-Dauphinee, S., & Williams, J. I. (1995). The Balance Scale: reliability assessment with elderly residents and patients with an acute stroke. *Scandinavian Journal of Rehabilitation Medicine*, *27*(1), 27–36.

Berg, Katherine. (1989). Balance and its measure in the elderly: A review. *Physiotherapy Canada*, *41*(5), 240–246.

Bhat, R., & Moiz, J. A. (2013). Comparison of dynamic balance in collegiate field hockey and football players using star excursion balance test. *Asian Journal of Sports Medicine*.

Blanchette, A., Lambert, S., Richards, C., & Bouyer, L. (2011). Walking while resisting a perturbation: Effects on ankle dorsiflexor activation during swing and potential for rehabilitation. *Gait & Posture*, *34*(3), 358–363.

Bloem, B., VIssueer, J., & Allum, J. H. J. (2009). *Movement disorders - handbook of clinical neurophysiology*. (H. M, Ed.), *Posturography*. Elsevier.

Bloomfield, J., Polman, R., & O'Donoghue, P. (2004). The 'Bloomfield Movement Classification': Motion Analysis of Individual Players in Dynamic Movement Sports. *International Journal of Performance Analysis in Sport*, *4*(2), 20–31.

Bloomfield, J., Polman, R., & O'Donoghue, P. (2007). Physical demands of different positions in FA premier league soccer. *Journal of Sports Science and Medicine*, *6*, 63–70.

Bonnyaud, C., Pradon, D., Vaugier, I., Vuillerme, N., Bensmail, D., & Roche, N. (2016). Timed Up and Go test: Comparison of kinematics between patients with chronic stroke and healthy subjects. *Gait & Posture*, *49*(258–263).

Booysen, M. J., Gradidge, J.-L., & Watson, E. (2015). The relationships of eccentric strength and power with dynamic balance in male footballers. *Journal of Sports Sciences*, *33*(20), 2157–2165.

Bressel, E., Yonker, J. C., Kras, J., & Heath, E. M. (2007). Comparison of static and dynamic balance in female collegiate soccer, basketball, and gymnastics athletes.

Journal of Athletic Training, *42*(1), 42–46.

Browne, J. E., & O'Hare, N. J. (2001). Review of the Different Methods for Assessing Standing Balance. *Physiotherapy*, *87*(9), 489–495. https://doi.org/http://dx.doi.org/10.1016/S0031-9406(05)60696-7

Butler, R. J., Lehr, M. E., Fink, M. L., Kiesel, K. B., & Plisky, P. J. (2013). Dynamic balance performance and noncontact lower extremity injury in college football players- an initial study. *Sports Health*, *5*(5), 417–422.

Butler, R. J., Southers, C., Gorman, P. P., Kiesel, K. B., & Plisky, P. J. (2012). Differences in soccer players' dynamic balance across levels of competition. *Journal of Athletic Training*, *47*(6), 616–620.

Cappozzo, A., Cappello, A., Croce, U. D., & Pensalfini, F. (1997). Surface-marker cluster design criteria for 3-D bone movement reconstruction. *IEEE Transactions on Biomedical Engineering*, *44*(12).

Cappozzo, A., Catani, F., Della Croce, U., & Leardini, A. (1995). Position and orientation in space of bones during movement: anatomical frame definition and determination. *Clinical Biomechanics*, *10*(4), 171–178.

Carling, C., Bloomfield, J., Nelsen, L. and Reilly, T. (2008). The role of motion analysis in elite soccer: Contemporary performance measurement techniques and work rate data. *Sports Medicine*, *38*(839–862).

Catena, R. D., Van Donkelaar, P., & Chou, L.-S. (2011). The effects of attention capacity on dynamic balance control following concussion. *Journal of NeuroEngineering and Rehabilitation*, *8*, 8. https://doi.org/10.1186/1743-0003-8-8

Chew-Bullock, T. S. Y., Anderson, D. I., Hamel, K. A., Gorelick, M. L., Wallace, S. A., & Sidaway, B. (2012). Kicking performance in relation to balance ability over the support leg. *Human Movement Science*, *31*(6), 1615–1623. https://doi.org/10.1016/j.humov.2012.07.001

Chtara, M., RouIssuei, M., Bragazzi, N. L., Owen, A. L., Haddad, M., & Chamari, K. (2018). Dynamic balance ability in young elite soccer players:implication of isometric strength. *Journal of Sports Medicine and Physical Fitness*, *58*(4), 414–420. https://doi.org/10.23736/S0022-4707.16.06724-4

Chtara, Moktar, RouIssuei, M., Bragazzi, N. L., Owen, A. L., Haddad, M., & Chamari, K. (2016). Dynamic balance ability in young elite soccer players implication of isometric strength. *Journal of Sports Medicine and Physical Fitness*.

Coe, R. (2002). It's the effect size, stupid: what effect size is and why it is important. In *Paper presented at the Annual Conference of the British Educational Research Association, University of Exeter, England.*

Cohen, J. (1969). *Statistical power analysis for the behavioural sciences*. New York: Academic Press.

Cohen, J. (1988). *Statistical power analysis for the behavioural sciences*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Colby, S. M., Hintermeister, R. A., Torry, M. R., & Steadman, J. R. (1999). Lower limb stability with ACL impairment. *Journal of Orthopaedic & Sports Physical Therapy*, *29*(8), 444–454.

Costa, P. B., Graves, B. S., Whitehurst, M., & Jacobs, P. L. (2009). THE ACUTE EFFECTS OF DIFFERENT DURATIONS OF STATIC STRETCHING ON DYNAMIC BALANCE PERFORMANCE. *Journal of Strength and Conditioning Research*, *23*(1), 141–147.

Coughlan, G. F., Fullam, K., Delahunt, E., GIssueane, C., & Caulfield, B. M. (2012). A comparison between performance on selected directions of the star excursion balance test and the Y balance test. *Journal of Athletic Training*, *47*(4), 366–371. https://doi.org/10.4085/1062-6050-47.4.03

Crockett, N. J., & Sandrey, M. A. (2015). Effect of Prophylactic Ankle-Brace Use During a High School Competitive Basketball Season on Dynamic Postural Control. *Journal of Sport Rehabilitation*, *24*(3), 252–260.

Cug, M., Wikstrom, E., Golshaei, B., & Kirazci, S. (2016). The effects of sex, limb dominance, and soccer participation on knee proprioception and dynamic postural control. *Journal of Sport Rehabilitation*, *25*(1), 31–39.

Dalen, T., Ingebrigsten, J., Ettema, G., Havard, G., & Wisloff, U. (2016). Player Load, Acceleration, and Deceleration During Forty-Five Competitive Matches of Elite Soccer. *Journal of Strength and Conditioning Research*, *30*(2), 351–359.

Dalen, T., Ingebrigsten, J., Ettema, G., Hjelde, G. ., & Wisloff, U. (2016). Player Load, Acceleration, and Deceleration During Forty-Five Competitive Matches of Elite Soccer. *Journal of Strength and Conditioning Research*, *30*(2), 351–359.

Dallinga, J. M., van der Does, H. T. D., Benjaminse, A., & Lemmink, K. A. P. M. (2016). Dynamic postural stability differences between male and female players with and without ankle sprain. *Physical Therapy in Sport*. https://doi.org/10.1016/j.ptsp.2015.05.002

Daneshjoo, A., Mokhtar, A. H., Rahnama, N., & Yusof, A. (2012). The Effects of Comprehensive Warm-Up Programs on Proprioception, Static and Dynamic Balance on Male Soccer Players. *PLoS ONE*. https://doi.org/10.1371/journal.pone.0051568

Davids, K., Button, C., & Bennett, S. J. (2008). *Dynamics of Skill Acquisition*. Human Kinetics Publishers, Inc.

Davids, Keith, Araújo, D., Vilar, L., Renshaw, I., & Pinder, R. (2013). An Ecological Dynamics Approach to Skill Acquisition: Implications for Development of Talent in Sport Theoretical Principles of Ecological Dynamics. *Talent Development and Excellence*, *5*(1), 21–34.

Davidson, B., Madigan, M., Nussbaum, M., & Wojcik, L. (2009). Effects of localized muscle fatigue on recovery from a postural perturbation without stepping. *Gait & Posture*, *29*(4), 552–557.

Davlin-Pater, c. (2008). Perceptual style and visual contribution t o dynamic balance: a pilot study. *Perceptual and Motor Skills*, *106*, 291–294.

Davlin, C. C. (2004). Dynamic balance in high level athletes. *Perceptual and Motor Skills*, *98*, 1171–1176.

De Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov's segment inertia parameters. *Journal of Biomechanics*, *29*(9), 1223–1230.

De Lima, M. A. C., De Medeiros Barbosa, G., Ribeiro, J. D. C., De Almeida Ferreira, J. J., De Andrade, P. R., & Dos Santos, H. H. (2015). The influence of the external ankle support on the dynamic balance in volleyball athletes. *Motriz. Revista de Educacao Fisica*. https://doi.org/10.1590/S1980-65742015000300008

Delahunt, E., Chawke, M., Kelleher, J., Murphy, K., Prendiville, A., Sweeny, L., & Patterson, M. (2013). Lower limb kinematics and dynamic postural stability in anterior cruciate ligament-reconstructed female athletes. *Journal of Athletic Training*. https://doi.org/10.4085/1062-6050-48.2.05

Distefano, L. J., Clark, M. A., & Padua, D. A. (2009). Evidence supporting balance training in healthy individuals: A systemic review. *Journal of Strength and Conditioning Research*, *23*(9), 2718–2731.

Doherty, C, Bleakley, C., Hertel, J., Caulfield, B., Ryan, J., & Delahunt, E. (2015). Laboratory Measures of Postural Control During the Star Excursion Balance Test After Acute First-Time Lateral Ankle Sprain. *Journal of Athletic Training*, *50*(6), 651–664. https://doi.org/10.4085/1062-6050-50.1.09

Doherty, Cailbhe, Bleakley, C., Hertel, J., Caulfield, B., Ryan, J., & Delahunt, E. (2016). Dynamic balance deficits in individuals with chronic ankle instability compared to ankle sprain copers 1 year after a first-time lateral ankle sprain injury. *Knee Surgery, Sports Traumatology, Arthroscopy*. https://doi.org/10.1007/s00167-015-3744-z

Donath, L., Roth, R., Zahner, L., & Faude, O. (2017). Slackline training (balancing over narrow nylon ribbons) and balance performance. A meta-analytical review. *Sports Medicine*, *47*(6), 1075–1086.

Dorge, H. C., Anderson, T. B., Sorensen, H., & Simonsen, E. B. (2002). Biomechanical differences in soccer kicking with the preferred and the non-preferred leg. *Journal of Sports Sciences*, *20*, 293–299.

Douglas, M., Bivens, S., Pesterfi eld, J., Clemson, N., Castle, W., Sole, G., … Wassinger, C. (2013). IMMEDIATE EFFECTS OF CRYOTHERAPY ON STATIC AND DYNAMIC BALANCE CORRESPONDING AUTHOR. *The International Journal of Sports Physical Therapy*, *8*(10).

Duncan, P. W., Weiner, D. K., Chandler, J., & Studenski, S. (1990). Functional Reach: A New Clinical Measure of Balance. *Journal of Gerontology*, *45*(6), M192--M197. https://doi.org/10.1093/geronj/45.6.M192

Dunsky, A., Barzilay, I., & Fox, O. (2017). Effect of a specialized injury prevention program on static balance, dynamic balance and kicking accuracy of young soccer players. *World Journal of Orthopedics*, *8*(4), 317–321. https://doi.org/10.5312/wjo.v8.i4.317

Durlak, J. A. (2009). How to select, calculate, and interpret effect sizes. *Journal of Pediatric Psychology*, *34*(9), 917–928.

Ekdahl, C., Jarnlo, G., & Andersson, S. (1989). Standing balance in healthy subjects. Evaluation of a quantitative test battery on a force platform. *Scandinavian Journal of Rehabilitation Medicine*, *21*(4), 187–195.

Emery, C A. (2003). Is there a clinical standing balance measurement appropriate for use in sports medicine? A review of the literature. *Journal of Science and Medicine in Sport*, *6*(4), 492–504.

Emery, C A, & MeeuwIssuee, W. H. (2010). The effectiveness of a neuromuscular prevention strategy to reduce injuries in youth soccer : a cluster-randomised controlled trial. *British Journal of Sports Medicine*, *44*, 555–562. https://doi.org/10.1136/bjsm.2010.074377

Emery, Carolyn A, Cassidy, J. D., Klassen, T. P., Rosychuk, R. J., & Rowe, B. H. (2005). Development of a clinical static and dynamic standing balance measurement tool appropriate for use in adolescents. *Physical Therapy*, *85*(6), 502–514.

Emirzeoğlu, M., & Ülger, Ö. (2020). The Acute Effects of Cognitive-Based Neuromuscular Training and Game-Based Training on the Dynamic Balance and Speed Performance of Healthy Young Soccer Players: A Randomized Controlled Trial. *Games for Health Journal.*

Falk, E., Seeley, M., Hunter, I., Park, J., & JT, H. (2014). Effect of experimental anterior knee pain on measures of static and dynamic postural control. *Athletic Training and Sports Healthcare*, *6*, 1–8.

Farajzadeh, F., Ghaderi, F., Jafarabadi, M. A., Azghani, M. R., Oskoui, M. A. E., Rezaie, M., & Ghorbanpour, A. (2017). Effects of Mcgill Stabilization Exercise on Pain and Disability , Range of Motion and Dynamic Balance Indices in Patients with Chronic. *Journal of Babol University of Medical Sciences*, *19*(10), 21–27.

Fatma, A., Kaya, M., Baltaci, G., Taùkin, H., & Erkmen, N. (2010). The effect of eight-week proprioception training program on dynamic postural control in taekwondo athletes. *Ovidius University Annals, Series Physical Education and Sport / Science, Movement and Health*, *10*(1).

Fernandes, T. L., Cristina, E., Felix, R., Sugimoto, D., Jú, V., D ’, M., … Hernandez, J. (2016). Evaluation of static and dynamic balance in athletes with anterior cruciate ligament injury – A controlled study. *Clinics*, *71*(8), 425–429. https://doi.org/10.6061/clinics/2016(08)03

Field, A. (2009). *Discovering statistics using SPSS* (Third edit). Los Angeles: Sage Publications.

Filipa, A., Byrnes, P. T. R., Paterno, P. T. M. V, Myer, P. T. G. D., & Hewett, M. S. T. E. (2010). Neuromuscular Training Improves Performance on the Star Excursion Balance Test in Young Female Athletes. *Journal of Orthopaedic & Sports Physical Therapy*, *40*(9), 551–558. https://doi.org/10.2519/jospt.2010.3325

Fregly, A., & Graybiel, A. (1968). An ataxia test battery not requiring rails. *Aerospace Medicine*, *39*, 277–282.

Fregly, A., Smith, M., & Graybiel A. (1973). Revised normative standards of performance of men on a quantitative ataxia test battery. *Acta Otolaryngo*, *75*, 10–16.

Fujisawa, T., Takuma, S., Koseki, H., Kimura, K., & Fukushima, K. (2005). Assessment of the recovery of dynamic balance after intravenous sedation with midazolam. *Journal of Anesthesia*. https://doi.org/10.1007/s00540-004-0286-9

Fujisawa, T., Takuma, S., Koseki, H., Kimura, K., & Fukushima, K. (2007). Correlation between precise and simple tests in recovery of dynamic balance function after intravenous sedation with midazolam in the elderly. *Journal of Anesthesia*, *21*, 153–158. https://doi.org/10.1007/s00540-007-0496-z

Fujiwara, K., Toyama, H., Asai, H., Yaguchi, C., Irei, M., Naka, M., & Kaida, C. (2011). Effects of regular heel-raise training aimed at the soleus muscle on dynamic balance associated with arm movement in elderly women. *Journal of Strength Conditioning Research*, *25*(9), 2605–2615.

Fullam, K., Caulfield, C., Coughlan, G., & Delahunt, E. (2014). Kinematic analysis of selected reach directions of the Star Excursion Balance Test compared with the Y-Balance Tes. *Journal of Sport Rehabilitation*, *23*(1), 27–35.

Gallahue, D. L. (1987). *Developmental Physical Education for Today's Elementary School Children*. New York: Macmillan Publishing.

Gentile, A. (1987). Skill acquisition: action, movement, and neuromotor processes. In J. Carr & R. Shepherd (Eds.), *Movement Science: Foundations for Physical Therapy in Rehabilitation* (2nd ed, pp. 2000: 111–188). Gaithersburg, MD: Aspen Publishers Inc.

Gerbino, P. G., Griffin, E. D., & Zurakowski, D. (2007). Comparison of standing balance between female collegiate dancers and soccer players. *Gait & Posture*, *26*, 501–507. https://doi.org/10.1016/j.gaitpost.2006.11.205

Giboin, L., Gruber, M., & Kramer, A. (2015). Human Movement Science Task-specificity of balance training. *Human Movement Science*, *44*, 22–31. https://doi.org/10.1016/j.humov.2015.08.012

Gkrilias, P., Zavvos, A., Fousekis, K., Billis, E., Matzaroglou, C., & Tsepis, E. (2018). Dynamic balance asymmetries in pre-season injury-prevention screening in healthy young soccer players using the Modified Star Excursion Balance Test-a pilot study. *Journal of Physical Therapy Science*, *30*(9), 1141–1144. https://doi.org/10.1589/jpts.30.1141

Glazier, P. S. (2017). Towards a Grand Unified Theory of sports performance. *Human Movement Science*, *56*, 139–156. https://doi.org/10.1016/j.humov.2015.08.001

Godik, M., Fales, I., & I., B. (1993). Changing the kicking accuracy of soccer players depending on the type, value and aims of training and competitive loads. In T. Reilly & C. Stibb (Eds.), *Science and soccer II* (pp. 254–260). London: E&FN Spon.

Goldberg, A., Casby, A., & Wasielewski, M. (2011). Minimum detectable change for single-leg-stance-time in older adults. *Gait & Posture*, *33*(4), 737–739.

Goldie, P. A., Bach, T. M., & Evans, O. M. (1989). Force platform measures for evaluating postural control: reliability and validity. *Archives of Physical Medicine and Rehabilitation*, *70*, 510–517.

Góralczyk, R., Mikolajec, K., Poprzecki, S., Zajac, A., Szyngiera, W., & Waskiewicz, Z. (2003). Kinematic analysis of intermittent sprints of elite soccer players. *Journal of Human Kinetics*, *10*, 107–120.

Gorman, P. P., Butler, R. J., Rauh, M. J., Kiesel, K., & Plisky, P. J. (2012). DIFFERENCES IN DYNAMIC BALANCE SCORES IN ONE SPORT VERSUS MULTIPLE SPORT HIGH SCHOOL ATHLETES. *The International Journal of Sports Physical Therapy*, *7*(2).

Gray, V., Yang, C., McCombe Waller, S., & Rogers, M. (2017). Lateral perturbation induced stepping: Strategies and predictors in persons post-stroke. *Journal of Neurological Phsical Therapy*, *41*(4), 222–228.

Greig, M., & Walker-Johnson, C. (2007). The influence of soccer-specific fatigue on functional stability. *Physical Therapy in Sport*, *8*, 185–190. https://doi.org/10.1016/j.ptsp.2007.03.001

Gribble, P., & Hertel, J. (2003). Considerations for normalizing measures of the Star Excursion Balance Test. *Measurement in Physical Education and Exercise Science*, *7*(2), 89–100. https://doi.org/10.1207/S15327841MPEE0702

Gribble, P A, Robinson, R. H., Hertel, J., & Denegar, C. R. (2009). The effects of gender and fatigue on dynamic postural control. *J. Sport Rehabil.*, *18*(2), 240–257.

Gribble, Phillip A., Hertel, J., & Plisky, P. (2012). Using the star excursion balance test to assess dynamic postural-control deficits and outcomes in lower extremity injury: A literature and systematic review. *Journal of Athletic Training*. https://doi.org/10.4085/1062-6050-47.3.08

Gribble, Phillip A., Kelly, S. E., Refshauge, K. M., & Hiller, C. E. (2013). Interrater reliability of the Star Excursion Balance Test. *Journal of Athletic Training*, *48*(5), 621–626. https://doi.org/10.4085/1062-6050-48.3.03

Gribble, Phillip A, & Robinson, R. H. (2009). An examination of ankle, knee, and hip torque production in individuals with chronic ankle instability. *Journal of Strength and Conditioning Research / National Strength & Conditioning Association*, *23*(2), 395–400. https://doi.org/10.1519/JSC.0b013e31818efbb2

Gusi, N., Carmelo Adsuar, J., Corzo, H., del Pozo-Cruz, B., Olivares, P. R., & Parraca, J. A. (2012). Balance training reduces fear of falling and improves dynamic balance and isometric strength in institutionalised older people: A randomised trial. *Journal of Physiotherapy*. https://doi.org/10.1016/S1836-9553(12)70089-9

Gusi, N., Parraca, J. A., Olivares, P. R., Leal, A., & Adsuar, J. C. (2010). Tilt vibratory exercise and the dynamic balance in fibromyalgia: A randomized controlled trial. *Arthritis Care and Research*. https://doi.org/10.1002/acr.20180

Guskiewicz, K.M, & Perrin, D. . (1996). Research and clinical applications of assessing balance. *Journal of Sport Rehabilitation*, *5*, 45–63.

Guskiewicz, Kevin M, & Perrin, D. H. (1996). Research and clinical applications of assessing balance. *Journal of Sport Rehabilitation*, *5*, 45–63.

Haksever, B., Aktas, G., & Baltaci, G. (2012). Effect of kinesiotaping on static and dynamic balance during soccer. *Medicina Dello Sport*, *65*(2), 223–234.

Halabchi, F., Abbasian, L., Mirshahi, M., Mazaheri, R., & Pourgharib Shahi, M. H., Mansournia, M. A. (2020). Comparison of Static and Dynamic Balance in Male Football and Basketball Players. *Foot & Ankle Specialist*, *13*(3), 228–235.

Hale, S. ., & O'Donoghue, P. . (2007). Addressing turning and direction changes when using the Bloomfield Movement Classification. *International Journal of Performance Analysis of Sport*, *7*(3), 84–88.

Hall, S. J. (1999). *Basic Biomechanics* (3rd editio). Singapore: McGraw-Hill.

Harper, D., Cohen, D., Carling, C., & Kiely, J. (2020). Can Countermovement Jump Neuromuscular Performance Qualities Differentiate Maximal Horizontal Deceleration Ability in Team Sport Athletes? *Sports*, *8*(6), 76.

Harper, D. J., & Kiely, J. (2018). Damaging Nature of Decelerations: Do We Adequately Prepare Players? *BMJ Open Sport Exercise Medicine*, *4*, e000379.

Hasson, F., Keeney, S., & HP, M. (2000). Research guidelines for the Delphi Survey Technique. *Journal of Advanced Nursing*, *32*(4), 1008–1015.

Hatzitaki, V., Kollias, I., Papaiakovou, G., & Nikodelis, T. (1999). The role of dynamic equilibrium in instep kicking performance of young soccer players. *Journal of Human Movement Studies*, *36*, 273–288.

Hatzitaki, V., Zisi, V., Kollias, I., & Kioumourtzoglou. (2002). Perceptual-motor contributions to static and dynamic balance control in children. *Journal of Motor Behavior Jun*, *34*(2).

Hertel, J., Braham, R., Hale, S., & Olmsted-Kramer, L. (2006). Simplifying the star excursion balance test: analyses of subjects with and without chronic ankle instability. *Journal of Orthopaedic & Sports Physical Therapy*, *36*(3), 131–137.

Hewitt, J., Cronin, J., Button, C., & Hume, P. (2011). Understanding deceleration in sport. *Strength and Conditioning Journal*, *33*(1), 47–52.

Hill, S. W., Patla, A. E., Perry, S. D., Ishac, M. G., & Marigold, D. S. (2001). Base of support changes ensure a constant stability margin following unexpected lateral trunk perturbations during overground walking., In Control of Posture and Gait (ed. J. Duysens, B.

Hoch, M. C., Andreatta, R. D., Mullineaux, D. R., English, R. A., Medina McKeon, J. M., Mattacola, C. G., & McKeon, P. O. (2012). Two-week joint mobilization intervention improves self-reported function, range of motion, and dynamic balance in those with chronic ankle instability. *Journal of Orthopaedic Research*. https://doi.org/10.1002/jor.22150

Hoch, M. C., Staton, G. S., Medina McKeon, J. M., Mattacola, C. G., & McKeon, P. O. (2012). Dorsiflexion and dynamic postural control deficits are present in those with chronic ankle instability. *Journal of Science and Medicine in Sport*. https://doi.org/10.1016/j.jsams.2012.02.009

Hodgson, C., Akenhead, R., & Thomas, K. (2014). Time-motion analysis of acceleration demands of 4v4 small-sided soccer games player on different pitch sizes. *Journal of Human Movement Science*, *33*, 25–32.

Hof, A. L., Gazendam, M. G. J., & Sinke, W. E. (2005). The condition for dynamic stability. *Journal of Biomechanics*, *38*(1), 1–8. https://doi.org/10.1016/j.jbiomech.2004.03.025

Hof, A. L., Vermerris, S. M., & Gjaltema, W. A. (2010). Balance responses to lateral perturbations in human treadmill walking. *Journal of Experimental Biology*, *213*, 2655–2664. https://doi.org/10.1242/jeb.042572

Horak, F. (2006). Postural orientation and equilibrium: what do we need to know about neural control of balance to prevent falls? *Age and Ageing*, *35*(S2), 7–11. https://doi.org/10.1093/ageing/afl077

Horak, F. B., Wrisley, D. M., & Frank, J. (2009). The Balance Evaluation Systems Test (BESTest) to Differentiate Balance Deficits. *Physical Therapy*, *89*, 484–498.

Hrysomallis, C. (2011). Balance Ability and Athletic Performance. *Sports Medicine*, *41*(3), 221–232.

Hrysomallis, C., McLaughlin, P., & Goodman, C. (2006). Relationship between static and dynamic balance tests among elite Australian Footballers. *Journal of Science and Medicine in Sport*. https://doi.org/10.1016/j.jsams.2006.05.021

Hrysomallis, Con. (2007). Relationship between balance ability, training and sports injury risk. *Sports Medicine*. https://doi.org/10.2165/00007256-200737060-00007

Hrysomallis, Con. (2011). Balance Ability and Athletic Performance. *Sports Medicine*, *41*(3), 221–232.

Huxham, F. E., Goldie, P. A., & Patla, A. E. (2001). Theoretical considerations in balance assessment. *Australian Journal of Physiotherapy*, *47*, 89–100.

Isokawa, M., & Lees, A. (1988). A biomechanical analysis of the in-step kick motion in soccer. In T. Reilly, A. Lees, K. Davids, & W. Murphy (Eds.), *Science and football* (pp. 449–455). London: Routledge.

Jadczak, L., Grygorowicz, M., Dzudzinski, W., & Sliwowski, R. (2019). Comparison of static and dynamic balance at different levels of sport competition in professional and junior elite soccer players. *The Journal of Strength & Conditioning Research*, *33*(12), 3384–3391.

Jlid, M. C., Racil, G., Coquart, J., Paillard, T., Bisciotti, G. ., & Chamari, K. (2019). Multidirectional plyometric training: very efficient way to improve vertical jump performance, change of direction performance and dynamic postural control in young soccer players. *Frontiers in Physiology*, *10*, 1462.

John, C., Rahlf, A. L., Hamacher, D., & Zech, A. (2018). Influence of biological maturity on static and dynamic postural control among male youth soccer players. *Gait & Posture*, *68*, 18–22. https://doi.org/10.1016/j.gaitpost.2018.10.036

Jonsson, E., Henriksson, M., & Hirschfeld, H. (2002). Does the functional reach test reflect stability limits in elderly people? *J Rehabil Med*, *35*, 26–30.

Keith, T. R., Condon, T. A., Phillips, A., Mckeon, P. O., King, D. L., & College, I. (2016). Postural Control Strategies are Dependent on Reach Direction in the Star

Excursion Balance Test. *International Journal of Athletic Therapy and Training*, *21*(November), 33–39.

Kellis, E., & Katis, A. (2007). Biomechanical Characteristics and Determinants of Instep Soccer Kick. *Journal of Sport Science and Medicine*, *6*(2), 154–165.

Kellis, E., Katis, A., & GIssueis, I. (2004). Knee biomechanics of the support leg in soccer kicks from three angles of approach. *Medicine and Science in Sports and Exercise*, *36*, 1017–1028.

Khuman, P. R., Kamlesh, T., & Surbala, L. (2014). Comparison of static and dynamic balance among collegiate cricket , soccer and volleyball male players. *International Journal of Health & Allied Services*, *3*(1), 9–13. https://doi.org/10.4103/2278-344X.130599

Kinzey, S. J., & Armstrong, C. W. (1998). The Reliability of the Star-Excursion Test in Assessing Dynamic Balance. *Journal of Orthopaedic & Sports Physical Therapy*, *27*(5), 356–360. https://doi.org/10.2519/jospt.1998.27.5.356

Kioumourtzoglou, E., Derri, V., Mertzanidou, O., & Tzetzis, G. (1997). Experience with perceptual and motor skills in rhythmic gymnastics. *Perceptual and Motor Skills*, *84*(July), 1363–1372. https://doi.org/10.2466/pms.1997.84.3c.1363

Klos, K., Czesław, G., & Dziuba-Słonina, A. (2019). Body balance in people practicing snowboarding. *Acta of Bioengineering and Biomechanics*, *21*(1).

Koşullarda, D., Baskınlığının, B., Bacak, T., Duruş, Ü., Etkisi, Ü., Sağlıklı, :, … Ak, E. (2014). Influence of Leg Dominance on Single-Leg Stance Performance During Dynamic Conditions: An Investigation into the Validity of Symmetry Hypothesis for Dynamic Postural Control in Healthy Individuals. *Turk J Phys Med Rehab Türk Fiz T›p Rehab Derg*, *6060*, 22–622. https://doi.org/10.5152/tftrd.2014.59354

Kovacevic, E., Bradic, J., Bejdic, A., Abazovic, E., & Bradic, A. (2010). Unilateral profile of dynamic balance of female students of faculty of sport and physical education. *Homo Sporticus*, *12*(1), 25–30.

Kümmel, J., Kramer, A., Giboin, L.-S., & Gruber, M. (2016). Specificity of Balance Training in Healthy Individuals: A Systematic Review and Meta-Analysis. *Sports Medicine*, *46*(9), 1261–1271. https://doi.org/10.1007/s40279-016-0515-z

Kunugi, S., Koumura, T., Myotsuzono, R., Masunari, A., Yoshida, N., Miyakawa, S., & Mukai, N. (2020). Directions of single-leg landing affect multi-segment foot kinematics and dynamic postural stability in male collegiate soccer athletes. *Gait*

& Posture, *80*(285–291).

Kuo, F.-C., Wang, N.-H., & Hong, C.-Z. (2010). Impact of Visual and Somatosensory Deprivation on Dynamic Balance in Adolescent Idiopathic Scoliosis. *SPINE*, *35*(23), 2084–2090.

Lange, D. (2020). Sport participation England. Retrieved July 1, 2020, from https://www.statista.com/statistics/975115/sport-participation-england/

Lee, D., & Han, S. (2017). Effects of Static Stretching of the Calf Muscle after Microwave Diathermy on Joint Position Sensation and Dynamic Balance Ability. *Journal of the Korean Society for Precision Engineering*, *34*(11), 829–833.

Lees, A., Asai, T., Andersen, T., Nunome, H., & Sterzing, T. (2010). The biomechanics of kicking in soccer: A review. *Journal of Sports Sciences*, *28*(8), 805–817.

Lees, A., & Nolan, L. (1998). Biomechanics of soccer: A review. *Journal of Sports Sciences*, *16*(211–234).

Lees, A., Steward, I., Rahnama, N., & Barton, G. (2009). Understanding lower limb function in the performance of the maximal instep kick in soccer. In T. Reilly & G. Atkinson (Eds.), *Proceedings of the 6th International Conference on Sport, Leisure and Ergonomics* (pp. 149–160). London: Routledge.

Levac, D., Colquhoun, H., & O'Brien, K. K. (2010). Scoping studies: advancing the methodology. *Implementation Science*, *5*, 69. https://doi.org/10.1186/1748-5908-5-69

Little, T., & Williams, A. (2005). Specificity of acceleration, maximum speed and agility in professional soccer players. *Journal of Strength and Conditioning Research*, *19*(1), 76–78.

Liu, K., Glutting, J., Wikstrom, E., Gustavsen, G., Royer, T., & Kaminski, T. W. (2013). Examining the diagnostic accuracy of dynamic postural stability measures in differentiating among ankle instability status. *Clinical Biomechanics*. https://doi.org/10.1016/j.clinbiomech.2012.11.003

Lockie, R. G., Schultz, A. B., Callaghan, S. J., & Jeffriess, M. D. (2013). The effects of isokinetic knee extensor and flexor strength on dynamic stability as measured by functional reaching. *Isokinetics and Exercise Science*. https://doi.org/10.3233/IES-130501

Lopez-Valenciano, A., Ayala, F., De Ste Croix, M., Barbado, D., & Vera-Garcia, F. J. (2019). Different neuromuscular parameters influence dynamic balance in male and female football players. *Knee Surgery, Sports Traumatology, Arthroscopy*, *27*(3), 962–970. https://doi.org/10.1007/s00167-018-5088-y

Luhtanen, P. (1988). Kinematics and kinetics of maximal instep kicking in junior soccer players. In Science and Football. In T. Reilly, A. Lees, K. Davids, & W. Murphy (Eds.), *Science and football* (pp. 449–455). London: E & FN Spon.

Luhtanen, P., & Ekblom, B. (Eds.). (1994). *Biomechanical aspects. In: Football (Soccer)*. Oxford: Blackwell Scientific Publications.

Maki, B. E., McIlroy, W. E., & Fernie, G. R. (2003). Change-in-support reactions for balance recovery. *IEEE Engineering in Medicine and Biology Magazine*, *22*, 20–26.

Manal, K., McClay, I., Stanhope, S., Richards, J., & Galinat, B. (2000). Comparison of surface mounted markers and attachment methods in estimating tibial rotations during walking: an in vivo study. *Gait and Posture*, *11*(1), 38–45.

Mancini, M., & Horak, F. (2010). The relevance of clinical balance assessment tools to differentiate balance deficits. *European Journal of Physical and Rehabilitation Medicine*, *46*(2), 239–248.

Manolopoulos, K., GIssueis, I., Galazoulas, C., Manolopoulos, E., Patikas, D., & Gollhofer, A., Kotzamanidis, C. (2016). Effect of combined sensorimotor-resistance training on strength, balance, and jumping performance of soccer players. *The Journal of Strength & Conditioning Research*, *30*(1), 53–59.

Mara, J. K., Thompson, K. G., Pumpa, K. L., & Morgan, S. (2017). The acceleration and deceleration profiles of elite female soccer players during competitive matches. *Journal of Science and Medicine in Sport*, *20*(9), 867–872.

Marigold, D. S., Bethune, A. J., & Patla, A. E. (2005). The role of the swing limb and arms in the reactive recovery response to an unexpected slip during locomotion. *Journal of Neurophysiology*, *89*(1727–1237).

Massion, J., & Woollacott, M. (1996). Posture and equilibrium. In A. Bronstein, T. Brandt, & M. Woollacott (Eds.), *Clinical Disorders of Balance Posture and Gait* (pp. 1–18). London: Arnold.

Masuda, K., Kikuhara, N., Demura, S., Katsuta, S., & Yamanaka, K. (2005). Relationship between muscle strength in various isokinetic movements and kick performance among soccer players. *Journal of Sports Medicine and Physical Fitness*, *45*, 44–52.

Mathias, S., Nayak, U. ., & Isaacs, B. (1986). Balance in elderly patients: the" get-up and go" test. *Archives of Physical Medicine and Rehabilitation*, *67*(6), 387–389.

Matsuda, S., Demura, S., & Uchiyama, M. (2017). Centre of pressure sway characteristics during static one-legged stance of athletes from different sports. *Journal of Sports Sciences*, *27*(7), 775–779. https://doi.org/10.1080/02640410701824099

McGuine, T., & Keene, J. (2006). The Effect of a Balance Training Program on the Risk of Ankle Sprains in High School Athletes. *American Journal of Sports Medicine*, *34*(7), 1103–1111. https://doi.org/10.1177/0363546505284191

Mills, C., Scurr, J., & Wood, L. (2011). A protocol for monitoring soft tIssueue motion under compression garments during drop landings. *Journal of Biomechanics*, *44*, 1821–1823.

Milner, C. E. (2008). Motion analysis using online systems. In C. Payton & R. Bartlett (Eds.), *Biomechanical Analysis of Movement in Sport and Exercise: The British Association of Sport and Exercise Sciences Guide*. UK: Routledge.

Mizrahi, J., Verbitsky, O., Isakov, E., & Daily, D. (2000). Effect of fatigue on leg kinematics and impact acceleration in long distance running. *Human Movement Science*, *19*, 139–151.

Mkaouer, B., Jemni, M., & Hammoudi-Nassib, S. (2017). Kinematic analysis of postural control in gymnasts vs. athletes practicing different sports. *Sports Science Health*, *13*, 573–581.

Mohammadi-Rad, S., Salavati, M., Ebrahimi-Takamjani, I., Akhbari, B., Sherafat, S., Negahban, H., … Mazaheri, M. (2016). Dual-Tasking Effects on Dynamic Postural Stability in Athletes With and Without Anterior Cruciate Ligament Reconstruction. *Journal of Sport Rehabilitation*, *25*(4), 324–329. https://doi.org/10.1123/jsr.2015-0012

Mohsen, H. A., & Emara, A. H. (2015). Effect of a new physical therapy concept on dynamic balance in children with spastic diplegic cerebral palsy. *Egyptian Journal of Medical Human Genetics*, *16*, 77–83. https://doi.org/10.1016/j.ejmhg.2014.09.001

Mononen, K., Konttinen, N., & Viitasalo, J. (2007). Relationship between postural balance, rifle stability and shooting accuracyamong novice rifle shooters. *Scandinavian Journal of Medicine and Science in Sports*, *17*(2), 180–185.

Montoya, R., Rivie, T., Marion, V., Montoya, R., & Dupui, P. (2006). Postural performance and strategy in the unipedal stance of soccer players at different levels of competition. *Journal of Athletic Training*, *41*(2), 172–176.

Muehlbauer, T., Besemer, C., Wehrle, A., Gollhofer, A., & Granacher, U. (2012). Relationship between strength, power and balance performance in seniors. *Gerontology*, *58*, 504–512. https://doi.org/10.1159/000341614

Munn, Z., Peters, M., Stern, C., Tufanaru, C., McArthur, A., & Aromataris, E. (2018). Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Medical Research Methodology*, *18*, 143.

Munro, A. G., & Herrington, L. . (2010). Between-session reliability of the star excursion balance test. *Physical Therapy in Sport*, *11*(4), 128–132.

Navarro-Santana, M. J., Asín-Izquierdo, I., Gómez-Chiguano, G. F., Albert-Lucena, D., Plaza-Manzano, G., & Pérez-Silvestre, Á. (2020). Effects of two exercise programmes on joint position sense, dynamic balance and countermovement jump in male amateur football players. A randomised controlled trial. *Journal of Sports Sciences*, *38*(22), 2620–2630.

Neptune, R., Wright, I., & Van Den Bogert, A. (1999). Muscle coordination and function during cutting movements. *Medicine & Science in Sport & Exercise*, *31*, 294–302.

Newans, T., Bellinger, P., Dodd, K., & Minahan, C. (2019). Modelling the Acceleration and Deceleration Profile of Elite-level Soccer Players. *International Journal of Sports Medicine*, *40*, 331–335.

Newell, K. M., Van Emmerik, R. E. A., & McDonald, P. V. (1989). Biomechanical constraints and action theory. *Human Movement Science*, *8*(4), 403–409.

Nicol, C., Komi, P., & Marconnet, P. (1991). Fatigue effects of marathon running on neuromuscular performance. I. Changes in muscle force and stiffness characteristics. *Scandinavian Journal of Medicine and Science in Sports1*, *1*, 10–17.

Noe, F., & Paillard, T. (2005). Is postural control affected by expertise in alpine skiing? *British Journal of Sports Medicine*, *39*, 835–837.

Nunome, H., Asai, T., Ikegami, Y., and Sakurai, S. (2002). Three-dimensional kinetic analysis of side-foot and instep soccer kicks. *Medicine and Science in Sports and Exercise*, *34*, 2028–2036.

Nunome, H., Ikegami, Y., Kozakai, R., Apriantono, T., & Sano, S. (2006). Segmental dynamics of soccer instep kicking with the preferred and non-preferred leg. *Journal of Sports Sciences*, *24*(5), 529–541.

Ogaya, S., Ikezoe, T., Soda, N., & Ichihashi, N. (2011). Effects of balance training using wobble boards in the elderly. *Journal of Strength and Conditioning Research*, *25*(9), 2616–2622.

Oliva-Lozano, J., Fortes, V., Krustrup, P., & Muyor, J. (2020). Acceleration and sprint profiles of professional male football players in relation to playing position. *PLoS ONE*, *15*(8), e0236959.

Onofrei, R. R., Amaricai, E., Petroman, R., Surducan, D., & Suciu, O. (2019). Preseason dynamic balance performance in healthy elite male soccer players. *American Journal of Men's Health*, *13*(1).

Orloff, H., Sumida, B., Chow, J Habibi, L., Fujino, A., & Kramer, B. (2008). Ground reaction forces and kinematics of plant leg position during instep kicking in male and female collegiate soccer players. *Sports Biomechanics*, *7*(238–247).

Osgnach, C., Poser, S., Bernardini, R., Rinaldo, R., & di Prampero, P. E. (2009). Energy cost and metabolic power in elite soccer: A new match analysis approach. *Medicine and Science in Sports and Exercise*, *42*, 170–178.

Paillard, T, & Noe, F. (2006). Effect of expertise and visual contribution on postural control in soccer. *Scandinavian Journal of Medicine and Science in Sports*, *16*, 345–348. https://doi.org/10.1111/j.1600-0838.2005.00502.x

Paillard, Thierrry, Rivire, T., Marion, V., Montoya, R., & Dupui, P. (2006). Postural Performance and Strategy in the unipedal stance of soccer players at different levels of competition. *Journal of Athletic Training*, *41*(2), 172–176.

Palmieri, R. M., Ingersoll, C. D., Stone, M. B., & Krause, B. A. (2002). Center-of-Pressure Parameters Used in the Assessment of Postural Control. *Journal of Sport Rehabilitation*, *11*, 51–66.

Pardasaney, P. K., Slavin, M. D., Wagenaar, R. C., Latham, N. K., Ni, P., & Jette, A. M. (2013a). Conceptual Limitations of Balance Measures for Community-Dwelling Older Adults. *Physical Therapy*, *93*(10), 1351–1368. https://doi.org/10.2522/ptj.20130028

Pardasaney, P. K., Slavin, M. D., Wagenaar, R. C., Latham, N. K., Ni, P., & Jette, A. M. (2013b). Conceptual Limitations of Balance Measures for Community-Dwelling Older Adults. *Physical Therapy*, *93*(10), 1351–1368. https://doi.org/10.2522/ptj.20130028

Pau, M., Arippa, F., Leban, B., Corona, F., Ibba, G., Todde, F., & Scorcu, M. (2015).

Relationship between static and dynamic balance abilities in Italian professional and youth league soccer players. *Physical Therapy in Sport*, *16*, 236–241. https://doi.org/10.1016/j.ptsp.2014.12.003

Pau, M., Porta, M., Arippa, F., Pilloni, G., Sorrentino, M., Carta, M., … Leban, B. (2019). Physical Therapy in Sport Dynamic postural stability , is associated with competitive level, in youth league soccer players. *Physical Therapy in Sport*, *35*, 36–41. https://doi.org/10.1016/j.ptsp.2018.11.002

Paul, J., Nagaraj, M. S., & Solomon, J. (2019). Effectiveness of Coordination Exercise on Dynamic Balance of Knee Injured Male Professional Footballers. *Indian Journal of Public Health Research & Development*, *10*(10).

Perrin, P., Deviterne, D., Hugel, F., & Perrot, C. (2002). Judo, better than dance, develops sensorimotor adaptabilities involved in balance control. *Gait and Posture*, *15*(2), 187–194. https://doi.org/10.1016/S0966-6362(01)00149-7

Pijnappels, M., Bobbert, M., & Van Dieen, J. (2006). EMG modulation in anticipation of a possible trip during walking in young and older adults. *Journal of Electromyography and Kinesiology*, *16*, 137–143.

Pinder, R., Davids, K., Renshaw, I., & Araújo, D. (2011). Representative Learning Design and Functionality of Research and Practice in Sport. *Journal of Sport and Exercise Psychology*, *3*(1), 146–155.

Pionnier, R., Découfour, N., Barbier, F., Popineau, C., & Simoneau-Buessinger, E. (2016). A new approach of the Star Excursion Balance Test to assess dynamic postural control in people complaining from chronic ankle instability. *Gait and Posture*. https://doi.org/10.1016/j.gaitpost.2016.01.013

Plisky, P. J., Gorman, P. P., Butler, R. J., Kiesel, K. B., Underwood, F. B., & Elkins, B. (2009). The reliability of an insrumented device for measuring components of the star excursion balance test. *North American Journal of Sports Physical Therapy*, *4*(2), 92–99.

Pollock, a. S., Durward, B. R., Rowe, P. J., & Paul, J. P. (2000). What is balance? *Clinical Rehabilitation*, *14*(4), 402–406. https://doi.org/10.1191/0269215500cr342oa

Pollock, A. S., Durward, B. R., Rowe, P. J., & Paul, J. P. (2000). What is balance? *Clinical Rehabilitation*, *14*, 402–406.

Ragnarsdottir, M. (1996). The concept of balance. *Physiotherapy*, *82*(6), 368–375. https://doi.org/10.1016/S0031-9406(05)66484-X

Ramírez-Campillo, R., Henríquez-Olguín, C., Burgos, C., Andrade, D. C., Zapata, D., Martínez, C., & Izquierdo, M. (2015). Effect of progressive volume-based overload during plyometric training on explosive and endurance performance in young soccer players. *The Journal of Strength & Conditioning Research*, *29*(7), 1884–1893.

Reilly, T., Bangsbo, J., & Franks, A. (2000). Anthropometric and physiological predispositions for elite soccer. *Journal of Sports Sciences*, *18*, 669–683.

Richardson, J. T. . (2011). Eta squared and partial eta squared as measurements of effect size in educational research. *Educational Research Review*, *6*, 135–147.

Riemann, B. L., Guskiewicz, K. M., & Shields, E. W. (1999). Relationship between clinical and forceplate measures of postural stability. *Journal of Sport Rehabilitation*, *8*, 71–82.

Rietdyk, S., Patla, A., Winter, D., Ishac, M., & Little, C. (1999). Balance recovery from medio-lateral perturbations of the upper body during standing. *Journal of Biomechanics*, *32*(11), 1149–1158.

Ringhof, S., & Stein, T. (2018). Biomechanical assessment of dynamic balance: Specificity of different balance tests. *Human Movement Science*, *58*, 140–147. https://doi.org/10.1016/j.humov.2018.02.004

Rios, J., Gorges, A., & Dos Santos, M. (2015). Individuals with chronic ankle instability compensate for their ankle deficits using proximal musculature to maintain reduced postural sway while kicking a ball. *Human Movement Science*, *43*(33–44).

Ritzer, G. (Ed.). (2012). *The Wiley-Blackwell encyclopedia of globalization*. Wiley-Blackwell.

Robinson, R., & Gribble, P. (2008). Support for a reduction in the number of trials needed for the Star Excursion Balance Test. *Archives of Physical Medicine and Rehabilitation*, *89*, 364–370.

Robinson, R. H., & Gribble, P. A. (2008). Kinematic predictors of performance on the star excursion balance test. *Journal of Sport Rehabilitation*, *17*(347–357).

Rodacki, A. L. F., Fowler, N. E., & Bennet, S. (2001). Multi-segment coordination: fatigue effects. *Medicine and Science in Sports and Exercise2*, *33*(1157–1167).

Ross, S. E., & Guskiewicz, K. (2003). Time to stabilisation: A method for analysing dynamic postural stability. *Athletic Therapy Today*, *8*(3), 37–39.

Ross, S. E., & Guskiewicz, K. M. (2004). Examination of static and dynamic postural stability in individuals with functionally stable and unstable ankles. *Clinical Journal of Sport Medicine*, *14*(6), 332–338.

RouIssuei, M., Haddad, M., Bragazzi, N. L., Owen, A. L., Moalla, W., Chtara, M., & Chamari, K. (2018). Implication of dynamic balance in change of direction performance in young elite soccer players is angle dependent. *Journal of Sports Medicine and Physical Fitness*, *58*(4), 442–449. https://doi.org/10.23736/S0022-4707.17.06752-4

Rowe, A., Wright, S., Nyland, J., Caborn, D., & Kling, R. (1999). Effects of a 2-Hour Cheerleading Practice on Dynamic Postural Stability, Knee Laxity, and Hamstring Extensibility. *Journal of Orthopaedic & Sports Physical Therapy*, *29*(8), 455–462.

Russell, M., Spareks, W., Northeast, J., Cook, C. ., Love, T. ., Bracken, R. ., & Kilduff, L. . (2016). Changes in acceleration and deceleration capacity throughout professional soccer match-play. *Journal of Strength and Conditioning Research*, *30*(10), 2839–2844.

Salavati, M., Akhbari, B., Ebrahimi Takamjani, I., Bagheri, H., Ezzati, K., & Hossein Kahlaee, A. (2016). Effect of spinal stabilization exercise on dynamic postural control and visual dependency in subjects with chronic non-specific low back pain. *Journal of Bodywork and Movement Therapies*, *20*, 441–448. https://doi.org/10.1016/j.jbmt.2015.10.003

Salek, S., Bahrpeyma, F., & Mohajeri-Tehrani, M.-R. (2015). Intermittent pneumatic compression therapy improves functional and dynamic balance and neuropathy severity in neuropathic patients with type 2 diabetes. *International Journal of Diabetes in Developing Countries*, *35*(Suppl 3), S439--S448. https://doi.org/10.1007/s13410-015-0378-0

Sattlecker, G., Buchecker, M., Müller, E., & Lindinger, S. J. (2014). Postural balance and rifle stability during standing shooting on an indoor gun range without physical stress in different groups of biathletes. *International Journal of Sports Science & Coaching*, *9*(1), 171–184.

Schillings, A. M., Wezel, B. M. H., van Mulder, T., & Duysens, J. (2000). Muscular responses and movement strategies during stumbling over obstacles. *Journal of Neurophysiology*, *83*, 2093–2102.

Schmitz, R., & Arnold, B. (1998). lntertester and lntratester Reliability of a Dynamic Balance Protocol Using the Biodex Stability System. *Journal of Sport*

Rehabilitation, *7*, 95–101.

Schorderet, C., Allet, L., & Hilfiker, R. (2021). The role of the dominant leg while assessing balance performance. A systematic review and meta-analysis. *Gait & Posture*, *84*, 66–78.

Scurr, J., & Hall, B. (2009). The Effects of Approach Angle on Penalty Kicking Accuracy and Kick Kinematics with Recreational Soccer Players. *Journal of Sports Science and Medicine*, *8*(2), 230–234.

Sell, T. C. (2012). Physical Therapy in Sport An examination , correlation , and comparison of static and dynamic measures of postural stability in healthy , physically active adults. *Physical Therapy in Sport*, *13*(2), 80–86. https://doi.org/10.1016/j.ptsp.2011.06.006

Shan, G., & Westerhoff, P. (2005). Full-body kinematic characteristics of the maximal instep soccer kick by male soccer players and parameters related to kick quality. *Sports Biomechanics*, *4*, 59–72.

Sherafat, S., Salavati, M., Takamjani, I. E., Akhbari, B., Mohammadi Rad, S., Mazaheri, M., … Lali, P. (2014). Effect of dual-tasking on dynamic postural control in individuals with and without nonspecific low back pain. *Journal of Manipulative and Physiological Therapeutics*. https://doi.org/10.1016/j.jmpt.2014.02.003

Shimada, H., Obuchi, S., Kamide, N., Shiba, Y., Okamoto, M., & Kakurai, S. (2003). Relationship with Dynamic Balance Function During Standing and Walking. *American Journal of Physical Medicine & Rehabilitation*, *82*, 511–516. https://doi.org/10.1097/01.PHM.0000064726.59036.CB

Shiravi, Z., Shadmehr, A., Moghadam, S. T., & Moghadam, B. A. (2017). Comparison of dynamic postural stability scores between athletes with and without chronic ankle instability during lateral jump landing. *Muscles, Ligaments and Tendons Journal*, *7*(1), 119–124. https://doi.org/10.11138/mltj/2017.7.1.119

Shultz, S. J., Perrin, D. H., Adams, J. M., Arnold, B. L., Gansneder, B. M., & Granata, K. P. (2000). Assessment of neuromuscular response characteristics at the knee following a functional perturbation. *Journal of Electromyography and Kinesiology*, *10*, 159–170.

Shumway-Cook, Anne Woollacott, M. (2000). Attentional demands and postural control: the effect of sensory context. *Of Gerontology-Biological Sciences and Medical Sciences*, *55*(1), M10.

Shumway-Cook, A., & Woollacott, M. (1985). The growth of stability: postural control from a development perspective. *Journal of Motor Behavior*, *17*(2), 131–147.

Shumway-Cook, Anne, & Woollacott, M. (1995). Control of posture and balance. In *Motor control: Theory and practical implications* (pp. 119–168). Baltimore: Williams & Wilkins.

Shumway-Cook, Anne, & Woollacott, M. H. (2007). *Motor Control: Translating Research Into Clinical Practice* (3rd ed.). Philadelphia: Lippincott Williams & Wilkins.

Shumway-Cook, Anne, & Woollacott, M. H. (2017). *Motor Control: Translating Research into Clinical Practice* (5th ed.). Philadelphia: Lippincott Williams & Wilkins.

Song, J., Sigward, S., Fisher, B., & Salem, G. J. (2012). Altered dynamic postural control during step turning in persons with early-stage Parkinson's disease. *Parkinson's Disease*. https://doi.org/10.1155/2012/386962

Spencer, M., Lawrence, S., Rechichi, C., Bishop, D., Dawson, B., & Goodman, C. (2004). Time–motion analysis of elite field hockey, with special reference to repeated-sprint activity. *Journal of Sports Sciences*, *22*, 843–850.

Stamm, H., & Lamprecht, M. (2001). *Big count: football 2000 worldwide: official FIFA survey*. Zurich.

Staniszewski, M. (2019). Biomechanical conditions of maintaining balance in snowboarding. *The Journal of Sports Medicine and Physical Fitness*, *59*(11), 1870–1877.

Stolen, T., Chamari, K., Castagna, C., & Wisloff, U. (2005). Physiology of soccer: an update. *Sport Medicine*, *35*(501–536).

Tabachnick, B. G., & Fidell, L. S. (2007). *Using multivariate statistics* (15th ed.). Chicago: Pearson/Allyn & Bacon.

Teixeira, Luis Augusto, Coutinho, J. de F. S., & Coelho, D. B. (2018). Regulation of dynamic postural control to attend manual steadiness constraints. *Journal of Neurophysiology*, *120*(2), 693–702. https://doi.org/10.1152/jn.00941.2017

Teixeira, Luis Augusto, Oliveira, D. L. De, Romano, R. G., & Correa, S. C. (2011). Leg Preference and Interlateral Asymmetry of Balance Stability in Soccer Players. *Research Quarterly for Exercise and Sport*, *82*(1), 21–27.

Thorpe, J. L., & Ebersole, K. T. (2008). Unilateral balance performance in female collegiate soccer athletes. *The Journal of Strength & Conditioning Research*, *22*(5), 1429–1433.

Thorpe, R., Strudwick, A., Buchheit, M., Atkinson, G., Drust, B., & Gregson, W. (2015). Monitoring Fatigue During the In-Season Competitive Phase in Elite Soccer Players. *International Journal of Sports Physiology and Performance*, *10*, 958–964.

Trampas, A., Mpeneka, A., Malliou, V., Godolias, G., & Vlachakis, P. (2015). Immediate effects of core stability exercises and clinical massage on dynamic balance performance of patients with chronic specific low back pain. *Journal of Sport RehabilitationJournal of Sport Rehabilitation*, *24*(4), 373–383.

Troester, J. ., Jasmin, J. G., & Duffield, R. (2018). Reliability of single-leg balance and landing tests in rugby union; prospect of using postural control to monitor fatigue. *Journal of Sports Science and Medicine*, *17*(2), 174–180.

Van Caekenberghe, I., Segers, V., Willems, P., Gosseye, T., Aerts, P., & De Clercq, D. (2013) Mechanics of overground accelerated running vs. running on an accelerated treadmill. *Gait and Posture*, *38*, 125-131.

van der Kruk, E., & Reijne, M. (2018). Accuracy of human motion capture systems for sport applications; state-of-the-art review. *European Journal of Sport Science*, *18*(6), 806–819.

van Emmerik, R. E. A., van Wegen, E. E. H., Emmerik, V., & Van Wegen, E. (2002). On the Functional Aspects of Variability in Postural Control. *Exerc. Sport Sci. Rev*, *30*(4), 177–183.

Van Hooren, B., Fuller, J. T., & Buckley, J. . (2020). Is Motorized Treadmill Running Biomechanically Comparable to Overground Running? A Systematic Review and Meta-Analysis of Cross-Over Studies. *Sports Med*, *50*(785–813).

van Meulen, F. ., Weenk, D., Buurke, J. ., van Beijnum, B. J. F., & Veltink, P. . (2016). Ambulatory assessment of walking balance after stroke using instrumented shoes. *Journal of Neuroengineering and Rehabilitation*, *13*(1), 48.

Van Wegen, E. E. ., Van Emmerik, R. E. ., & Riccio, G. E. (2002). Postural orientation: Age-related changes in variability and time-to-boundary. *Human Movement Science*, *21*(1), 61–84.

Vanrenterghem, J., Nedergaard, N. J., Robinson, M. A., & Drust, B. (2017). Training Load Monitoring in Team Sports: A Novel Framework Separating Physiological and Biomechanical Load-Adaptation Pathways. *Sports Medicine*, (47), 2135–2142.

Vigh-Larsen, J. ., Dalgas, U., & Anderson, T. . (2018). Position-Specific Acceleration and Deceleration Profiles in Elite Youth and Senior Soccer Players. *Journal of Strength and Conditioning Research*, *32*(4), 1114–1122.

Vistamehr, A., Kautz, S. A., Bowden, M. G., & Neptune, R. R. (2016). Erratum: Corrigendum to ???Correlations between measures of dynamic balance in individuals with post-stroke hemiparesis??? (Journal of Biomechanics (2016) 49(13) (3127) (S0021929016000051) (10.1016/j.jbiomech.2015.12.047)). *Journal of Biomechanics*. https://doi.org/10.1016/j.jbiomech.2016.08.001

Vuillerme, N., & Nougier, V. (2004). Attentional demand for regulating postural sway: the effect of expertise in gymnastics. *Brain Research Bulletin*, *63*(2), 161–165.

Walter, C., Swinnen, S., & Franz, E. (1993). Stability of symmetric and asymmetric discrete bimanual actions. In K. Newell & D. Corcos (Eds.), *Variability and Motor Control* (pp. 359–380). Champaign, IL: Human Kinetics Publishers, Inc.

Whitney, S. L., Marchetti, G. F., Schade, A., & Wrisley, D. M. (2004). The sensitivity and specificity of the Timed" Up & Go" and the Dynamic Gait Index for self-reported falls in persons with vestibular disorders. *Journal of Vestibular Research*, *14*(5), 397–409.

Wikstrom, E. A., Powers, M. E., & Tillman, M. D. (2004). Dynamic stabilization time after isokinetic and functional fatigue. *Journal of Athletic Training*, *39*(3), 247–253.

Wikstrom, E. A., Tillman, M. D., Kline, K. J., & Borsa, P. A. (2006). Gender and Limb Differences in Dynamic Postural Stability During Landing. *Clinical Journal of Sport Medicine*, *16*, 311–315.

Wikstrom, E. A., Tillman, M. D., Smith, A. N., & Borsa, P. A. (2005). A new force-plate technology measure of dynamic postural stability: The dynamic postural stability index. *Journal of Athletic Training*, *40*(4), 305–309.

Williams, K., Smow, R., & C, A. (1991). Changes in distance running kinematics with fatigue. *International Journal of Sport Biomechanics*, *7*, 138–162.

Williams, R., & O’Donoghue, P. (2005). Lower limb injury risk in netball: a timemotion analysis investigation. *Journal of Human Movement Studies*, *49*, 315–331.

Winter, D. A., Patla, A. E., & Frank, J. S. (1990). Assessment of balance control in humans. *Medical Progress through Technology*, *16*(1–2), 31–51. https://doi.org/10.3138/ptc.42.2.089

Winter, D. (2009). *Biomechanics and Motor Control of Human Movement* (Fourth edi). Hoboken, New Jersey: John Wiley & Sons.

Winter, DA. (1995a). *ABC (Anatomy, Biomechanics and Control) of Balance During Standing and Walking*. Waterloo, Ontario: Waterloo Biomechanics.

Winter, DA. (1995b). Human balance and posture control during standing and walking. *Gait and Posture*, *3*, 193–214.

Woollacott, M., & Tang, P.-F. (1997). Balance Control During Walking in the Older Adult: Research and Its Implications. *Physical Therapy*, *77*(6), 646–660.

Wu, G., Siegler, S., Allard, P., Kirtley, C., Leardini, A., Rosenbaum, D., … Witte, H. (2002). ISB recommendation on definitions of joint coordinate system of various joints for the reporting of human joint motion—Part I: Ankle, hip, and spine. *Journal of Biomechanics*, *35*, 543–548.

Wu, G., Van der Helm, F. ., Veeger, H. D., Makhsous, M., Van Roy, P., Anglin, C., … Wang, X. (2005). ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion—Part II: Shoulder, elbow, wrist and hand. *Journal of Biomechanics*, *38*(981–992).

Yaggie, J. A., & Campbell, B. M. (2006). Effects of balance training on selected skills. *Journal of Strength and Conditioning Research*, *20*(2), 422–428.

Zech, A., Steib, S., Hentschke, C., Eckhardt, H., & Pfeifer, K. (2012). Effects of localized and general fatigue on static and dynamic postural control in male team handball athletes. *Journal of Strength and Conditioning Research*, *26*(4), 1162–1168.

Zemkova, E. (2011). Assessment of balane in sport: science and reality. *Serbian Journal of Sports Sciences*, *5*(4), 127–139.

Zemková, E. (2014). Significantly and practically meaningful differences in balance research: P values and/or effect sizes? *Sports Medicine*. https://doi.org/10.1007/s40279-014-0185-7

Chapter 9 Appendices

Appendices

Appendix A: Scoping review literature extracted

All articles identified in the scoping review using the terms dynamic balance, dynamic postural control or dynamic postural stability in the title only.

ID	Authors	Title	Pub Year	Periodical	Vol	Issue
6	Abbasi,A.;Tabrizi,H. B.;Sarvestani,H. J.;Rahmanpourmoghaddam,J.	Dynamic Balance In Inactive Elder Males Changes After Eight Weeks Functional And Core Stabilization Training	2012	Middle East Journal Of Scientific Research	11	3
7	Abdelghany, A.I., Elkablawy, M.A., Salem, S.E.G.A., Ahmed, N.	Relationship Between Head Postural Changes And Dynamic Balance In A Symptomatic Forward Head Posture Student	2016	International Journal Of Pharmtech Research	9	7
8	Abdolvahabi,Z.;Bonab,S. S.;Rahmati,H.;Naini,S. S.	The Effects Of Ankle Plantar Flexor And Knee Extensor Muscles Fatigue On Dynamic Balance Of The Female Elderly	2011	World Applied Sciences Journal	15	9
11	Adegoke,B. O. A.;Ogwumike,O. O.;Olatemiju,A.	Dynamic Balance And Level Of Lesion In Spinal Cord Injured Patients	2002	African Journal Of Medicine And Medical Sciences	31	4
15	Adelman,DL.;Pamukoff,DN.;Goto,S;Guskiewicz,KM. ; Ross,SE.;Blackburn,JT.	Acute Effects Of Whole-Body Vibration On Dynamic Postural Control And Muscle Activity In Individuals With Chronic Ankle Instability	2016	Athletic Training & Sports Health Care: The Journal For The Practicing Clinician	8	2

ID	Authors	Title	Pub Year	Periodical	Vol	Issue
21	Ahn,C. S.;Kim,H. S.;Kim,M. C.	The Effect Of The Emg Activity Of The Lower Leg With Dynamic Balance Of The Recreational Athletes With Functional Ankle Instability	2011	Journal Of Physical Therapy Science	23	4
23	Akbari A, Ghiasi F, Mir M, Hosseinifar M.	The Effects Of Balance Training On Static And Dynamic Postural Stability Indices After Acute Acl Reconstruction.	2016	Glob J Health Sci	8	4
31	Lindsey,D.;O'neal,J.	Static And Dynamic Balance Skills Of Eight Year Old Deaf And Hearing Impaired Children	1976	American Annals Of The Deaf	121	1
32	Akhbari B, Salavati M, Mohammadi F, Safavi-Farokhi Z.	Intra- And Inter-Session Reliability Of Static And Dynamic Postural Control In Participants With And Without Patellofemoral Pain Syndrome.	2015	Physiother Can	67	3
34	Akhbari, Behnam; Salavati, Mahyar; Ahadi, Jalal; Ferdowsi, Forough; Sarmadi, Alireza; Keyhani, Sohrab; Mohammadi, Farshid	Reliability Of Dynamic Balance Simultaneously With Cognitive Performance In Patients With Acl Deficiency And After Acl Reconstructions And In Healthy Controls	2015	Knee Surgery Sports Traumatology Arthroscopy	23	11
42	Alabdulwahab,Sami Saleh;Kachanathu,Shaji John;Oluseye,Kamaldeen	Physical Activity Associated With Prayer Regimes Improves Standing Dynamic Balance Of Healthy People	2013	Journal Of Physical Therapy Science	25	12
43	Al-Khlaifat L, Herrington Lc, Tyson Sf, Hammond A, Jones Rk.	The Effectiveness Of An Exercise Programme On Dynamic Balance In Patients With Medial Knee Osteoarthritis: A Pilot Study.	2016	Knee	23	5

ID	Authors	Title	Pub Year	Periodical	Vol	Issue
45	Alpini,D.;Hahn,A.;Riva,D.	Static And Dynamic Postural Control Adaptations Induced By Playing Ice Hockey	2007	Sport Sciences For Health	2	3
52	Ambegaonkar,Jp; Redmond,Cj.;Winter,C; Cortes,N; Ambegaonkar,S; Thompson,B; Guyer,Sm.	Ankle Stabilizers Affect Agility But Not Vertical Jump Or Dynamic Balance Performance	2011	Foot & Ankle Specialist	4	6
53	Aminaka,Naoko;Gribble,Phillip A.	Patellar Taping, Patellofemoral Pain Syndrome, Lower Extremity Kinematics, And Dynamic Postural Control	2008	Journal Of Athletic Training (National Athletic Trainers' Association)	43	1
54	Amiri-Khorasani M.	Acute Effects Of Different Stretching Methods On Static And Dynamic Balance In Female Football Players	2015	International Journal Of Therapy And Rehabilitation	22	2
55	Anoop,Aggarwal;Kalpana,Zutshi;Jitender,Munjal;Suraj,Kumar	Effect Of Core Stabilization Training On Dynamic Balance In Non-Professional Sports Players	2010	Indian Journal Of Physiotherapy & Occupational Therapy	4	4
56	Araki,Kaori;Mintah,Joseph K.;Mack,Mick G.;Huddleston,Sharon;Larson,Laura;Jacobs,Kelly	Belief In Self-Talk And Dynamic Balance Performance	2006	Athletic Insight	8	4
65	Arvin,Mina;Kamyab,Mojtaba;Moradi,Vahideh;Hajiaghaei,Behnam;Maroufi,Nader	Influence Of Modified Solid Ankle-Foot Orthosis To Be Used With And Without Shoe On Dynamic Balance And Gait Characteristic In Asymptomatic People	2013	Prosthetics And Orthotics International	37	2
67	Asadi,A.;Arazi,H.	Effects Of High-Intensity Plyometric Training On Dynamic Balance, Agility, Vertical Jump And Sprint Performance In Young Male Basketball Players	2012	Journal Of Sport & Health Research	4	1

ID	Authors	Title	Pub Year	Periodical	Vol	Issue
70	Assaiante,C.;Amblard,B.	Peripheral Vision And Age-Related Differences In Dynamic Balance	1992	Human Movement Science	11	5
71	Atilgan,Oya Erkut	Effects Of Trampoline Training On Jump, Leg Strength, Static And Dynamic Balance Of Boys	2013	Science Of Gymnastics Journal	5	2
75	Austad,Hanne;Van Der Meer,Audrey,L.H.	Prospective Dynamic Balance Control In Healthy Children And Adults	2007	Experimental Brain Research	181	2
76	Avelar,Nãƒâº;Bastone,Alessandra C.;Alcãƒâ¢Ntara,Marcus,A.;Gomes,Wellington Fabiano	Effectiveness Of Aquatic And Non-Aquatic Lower Limb Muscle Endurance Training In The Static And Dynamic Balance Of Elderly People	2010	Revista Brasileira De Fisioterapia (Sãƒâ£O Carlos (Sãƒâ£O Paulo, Brazil))	14	3
77	Aydog,E.;Aydog,S. T.;Cakci,A.;Doral,M. N.	Dynamic Postural Stability In Blind Athletes Using The Biodex Stability System	2006	International Journal Of Sports Medicine	27	5
81	Baghbani F; Woodhouse Lj; Gaeini Aa	Dynamic Postural Control In Female Athletes And Nonathletes After A Whole-Body Fatigue Protocol	2016	Journal Of Strength And Conditioning Research	30	7
84	Baghbaninaghadehi,Fatemeh;Reza Ramezani,Ali;Hatami,Farzaneh	The Effect Of Functional Fatigue On Static And Dynamic Balance In Female Athletes	2013	International Sportmed Journal	14	2
89	Bakirhan,S.;Angin,S.;Karatosun,V.;√É≈Ìnver,B.;G√É¬ºnal,I.	A Comparison Of Static And Dynamic Balance In Patients With Unilateral And Bilateral Total Knee Arthroplasty	2009	Eklem Hastaliklari Ve Cerrahisi	20	2
90	Bal,Baljinder Singh;Dureja,Gaurav;Kaur,Parminderjeet	An Empirical Study Of Backward Walking Treadmill Training On Static And Dynamic Balance In Adolescent Girls	2012	Sports Medicine Journal / Medicina Sportivãƒâ¢	8	1

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95	Balint, G; Spulber, F	Testing The Dynamic Balance And Proprioception In Team A Romanian Ski Jumping Athletes	2011	Gymnasium: Journal Of Physical Education & Sports	12	1
96	Barnett,C. T.;Vanicek,N.;Polman,R. C. J.	Postural Responses During Volitional And Perturbed Dynamic Balance Tasks In New Lower Limb Amputees: A Longitudinal Study	2013	Gait & Posture	37	3
97	Baroni,G.;Pedrocchi,A.;Ferrigno,G.;Massion,J.;Pedotti,A.	Static And Dynamic Postural Control In Long-Term Microgravity: Evidence Of A Dual Adaptation	2001	Journal Of Applied Physiology (Bethesda, Md.: 1985)	90	1
98	Basnett,CR.;Hanish,MJ.; Wheeler,T.;Miriovsky,DJ.; Danielson,EL.;Barr,J.B.; Grindstaff,TL.	Ankle Dorsiflexion Range Of Motion Influences Dynamic Balance In Individuals With Chronic Ankle Instability	2013	International Journal Of Sports Physical Therapy	8	2
104	Behal,Kavita;Bansal,Anu	Correlation Between Parallel Walk Test And Timed Up And Go Test For Assessment Of Dynamic Balance In Elderly	2013	Indian Journal Of Physiotherapy & Occupational Therapy	7	2
105	Bello Ai, Ababio E, Antwi-Baffoe S, Seidu Ma, Adjei Dn.	Pain, Range Of Motion And Activity Level As Correlates Of Dynamic Balance Among Elderly People With Musculoskeletal Disorder.	2014	Ghana Med J	48	4
106	Bento Pc, Lopes Mde F, Cebolla Ec, Wolf R, Rodacki Al.	Effects Of Water-Based Training On Static And Dynamic Balance Of Older Women.	2015	Rejuvenation Res	18	4
107	Berger,L.;Klein,C.;Commandeur,M.	Evaluation Of The Immediate And Midterm Effects Of Mobilization In Hot Spa Water On Static And Dynamic Balance In Elderly Subjects	2008	Annales De Réadaptation Et De Médecine Physique	51	2

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110	Bhat,Rashi;Moiz,Jamal Ali	Comparison Of Dynamic Balance In Collegiate Field Hockey And Football Players Using Star Excursion Balance Test	2013	Asian Journal Of Sports Medicine	4	3
111	Bird,Marie-Louise;Hill,Keith D.;Fell,James W.	A Randomized Controlled Study Investigating Static And Dynamic Balance In Older Adults After Training With Pilates	2012	Archives Of Physical Medicine & Rehabilitation	93	1
115	Bischoff-Ferrari,H.; Conzelmann,M.;Stahelin,H.B.;Dick,W.;Carpenter,M.G.;Adkin,A.L.;Theiler,R.;Pfeifer,M.;Allum,J. H. J.	Is Fall Prevention By Vitamin D Mediated By A Change In Postural Or Dynamic Balance?	2006	Osteoporosis International	17	5
116	Black,B. C.	The Effect Of An Outdoor Experiential Adventure Program On The Development Of Dynamic Balance And Spatial Veering For The Visually Impaired Adolescent	1983	Therapeutic Recreation Journal	17	3
119	Boonstra,Tjeerd W.;Daffertshofer,Andreas; Roerdink,Melvyn;Flipse,Ivo;Groenewoud,Karin;Beek,Peter J.	Bilateral Motor Unit Synchronization Of Leg Muscles During A Simple Dynamic Balance Task	2009	The European Journal Of Neuroscience	29	3
120	Booysen Mj, Gradidge Pj, Watson E.	The Relationships Of Eccentric Strength And Power With Dynamic Balance In Male Footballers.	2015	J Sports Sci	33	20
123	Boswell,B.	Comparison Of Two Methods Of Improving Dynamic Balance Of Mentally Retarded Children	1991	Perceptual & Motor Skills	73	3

ID	Authors	Title	Pub Year	Periodical	Vol	Issue
126	Bouillon,Lucinda E.;Baker,Joshua L.	Dynamic Balance Differences As Measured By The Star Excursion Balance Test Between Adult-Aged And Middle-Aged Women	2011	Sports Health: A Multidisciplinary Approach	3	5
136	Bower,K. J.;Mcginley,J. L.;Miller,K. J.;Clark,R. A.	Instrumented Static And Dynamic Balance Assessment After Stroke Using Wii Balance Boards: Reliability And Association With Clinical Tests	2014	Plos One	9	12
140	Boyle, M.J., Butler, R.J., Queen, R.M.	Functional Movement Competency And Dynamic Balance After Anterior Cruciate Ligament Reconstruction In Adolescent Patients	2016	Journal Of Pediatric Orthopaedics	36	1
154	Bressel,Eadric;Yonker,Joshua C.;Kras,John;Heath,Edward M.	Comparison Of Static And Dynamic Balance In Female Collegiate Soccer, Basketball, And Gymnastics Athletes	2007	Journal Of Athletic Training (National Athletic Trainers' Association)	42	1
155	Bril,Blandine;Breniã¨Re,Yvon	Chapter 13 Posture And Independent Locomotion In Early Childhood: Learning To Walk Or Learning Dynamic Postural Control?	1993	Advances In Psychology	97	0
156	Brown, C.N., Ko, J., Rosen, A.B., Hsieh, K.	Individuals With Both Perceived Ankle Instability And Mechanical Laxity Demonstrate Dynamic Postural Stability Deficits	2015	Clinical Biomechanics	30	10
158	Brown,Cathleen N.;Bowser,Bradley;Orellana,Alexander	Dynamic Postural Stability In Females With Chronic Ankle Instability	2010	Medicine & Science In Sports & Exercise	42	12

ID	Authors	Title	Pub Year	Periodical	Vol	Issue
161	Buckley,Thomas A.;Pitsikoulis,Chris;Hass,Chris J.	Dynamic Postural Stability During Sit-To-Walk Transitions In Parkinson Disease Patients	2008	Movement Disorders: Official Journal Of The Movement Disorder Society	23	9
162	Bullock Spt Gs, Brookerson N, Knab Am, Butler Rj.	Examining Fundamental Movement Competency And Closed Chain Upper Extremity Dynamic Balance In Swimmers.	2016	J Strength Cond Res. 2016		
163	Busing,J. K.	Determining The Effects Of Tai Chi On Dynamic Balance And Fear Of Falling In An Elderly Population	2005	Activities, Adaptation & Aging	30	2
164	Butler,K. G.;Naliboff,E.	An Investigation Of Dynamic Balance And Other Perceptual--Motor Tasks Among Speech Defective Children	1969	American Corrective Therapy Journal	23	4
168	Butler,RJ.;Lehr,ME.;Fink,ML.;Kiesel,KB.;Plisky,P.	Dynamic Balance Performance And Noncontact Lower Extremity Injury In College Football Players: An Initial Study	2013	Sports Health: A Multidisciplinary Approach	5	5
175	Butler,R J.;Queen,R M.;Beckman,B; Kiesel,KB.;Plisky,P J.	Comparison Of Dynamic Balance In Adolescent Male Soccer Players From Rwanda And The United States	2013	International Journal Of Sports Physical Therapy	8	6
178	Butler,RJ.;Queen,RM.;Wilson,B;Stephenson,J;Barnes,C.L.	The Effect Of Extension Constraint Knee Bracing On Dynamic Balance, Gait Mechanics, And Joint Alignment	2014	Pm & R: The Journal Of Injury, Function, And Rehabilitation	6	4
180	Butler,RJ.;Southers,C;Gorman,P.;Kiesel,KB.;Plisky,J	Differences In Soccer Players' Dynamic Balance Across Levels Of Competition	2012	Journal Of Athletic Training (Allen Press)	47	6
181	Butterfield,S. A.;Lehnhard,R. A.;Martens,D.;Moirs,K.	Kinematic Analysis Of A Dynamic Balance Task By Children Who Are Deaf	1998	Clinical Kinesiology (Online Edition)	52	4

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182	Butz, S.M., Sweeney, J.K., Roberts, P.L., Rauh, M.J.	Relationships Among Age, Gender, Anthropometric Characteristics, And Dynamic Balance In Children 5 To 12 Years Old	2015	Pediatric Physical Therapy ,	27	2
183	Byrne,Jeannette M.;Roberts,Joni;Squires,Heidi;Rohr,Linda E.	The Effect Of A Three-Week Wii Fit Balance Training Program On Dynamic Balance In Healthy Young Adults	2012	International Sportmed Journal	13	4
184	Cankaya S., Gokmen B., Tasmektepligil M.Y., Con M.	Special Balance Developer Training Applications On Young Males' Static And Dynamic Balance Performance	2015	Anthropologist	19	1
187	Carter,N. D.;Khan,K. M.;Mallinson,A.;Janssen,P. A.;Heinonen,A.;Petit,M. A.;Mckay,H. A.	Knee Extension Strength Is A Significant Determinant Of Static And Dynamic Balance As Well As Quality Of Life In Older Community-Dwelling Women With Osteoporosis	2002	Gerontology	48	6
191	Catena,Robert D.;Van Donkelaar,Paul;Chou,Li-Shan	The Effects Of Attention Capacity On Dynamic Balance Control Following Concussion	2011	Journal Of Neuroengineering And Rehabilitation	8	
194	Cattaneo D, Jonsdottir J, Coote S.	Targeting Dynamic Balance In Falls-Prevention Interventions In Multiple Sclerosis: Recommendations From The International Ms Falls Prevention Research Network.	2014	Int J Ms Care	16	4

Id	Authors	Title	Pub Year	Periodical	Vol	Issue
197	Cauquil,A. S.;Bessou,M.;Dupui,P.;Bessou,P.	Lateral Dynamic Balance Reactions To Circular Translation Of The Visual Field	1998	Comptes Rendus De Sciences De La Vie	321	4
198	Cauquil,Alexandra SãVerac;Bousquet,Philippe;Salon,Marie-Claude Costes;Dupui,Philippe;Bessou,Paul	Monaural And Binaural Galvanic Vestibular Stimulation In Human Dynamic Balance Function	1997	Gait & Posture	6	3
208	Cauquil,As;Bessou,M.;Dupui,P.;Bessou,P.	Anteroposterior Dynamic Balance Reactions Induced By Circular Translation Of The Visual Field	1996	Journal Of Physiology-Paris	90	2
209	Cauquil,As;Dupui,P.;Salon,Mcc;Bessou,P.;Guell,A.	Unusual Vestibular And Visual Input In Human Dynamic Balance As A Motion Sickness Susceptibility Test	1997	Aviation Space And Environmental Medicine	68	7
210	Chander H., Wade C., Garner J.C.	The Influence Of Occupational Footwear On Dynamic Balance Perturbations	2015	Footwear Science	7	2
211	Chang,H.;Krebs,D. E.	Dynamic Balance Control In Elders: Gait Initiation Assessment As A Screening Tool	1999	Archives Of Physical Medicine And Rehabilitation	80	5
213	Chaudhuri,S.;Aruin,A. S.	The Effect Of Shoe Lifts On Static And Dynamic Postural Control In Individuals With Hemiparesis	2000	Archives Of Physical Medicine And Rehabilitation	81	11
215	Chen,Y. -Y;Chen,C. -H;Wang,C. -C;Liaw,L. -J;Guo,L. -Y;Wu,W. -L	Comparison Of Dynamic Balance Under Dual And Simple Task Conditions In Children With Attention Deficit Hyperactivity Disorder	2012	Journal Of Physical Therapy Science	24	8

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216	Chern,J. S.;Lo,C. Y.;Wu,C. Y.;Chen,C. L.;Yang,S.;Tang,F. T.	Dynamic Postural Control During Trunk Bending And Reaching In Healthy Adults And Stroke Patients	2010	American Journal Of Physical Medicine & Rehabilitation / Association Of Academic Physiatrists	89	3
217	Chern,J. S.;Yang,S. W.;Wu,C. Y.	Whole-Body Reaching As A Measure Of Dynamic Balance In Patients With Stroke	2006	American Journal Of Physical Medicine & Rehabilitation / Association Of Academic Physiatrists	85	3
220	Chevidikunnan Mf, Al Saif A, Gaowgzeh Ra, Mamdouh Ka.	Effectiveness Of Core Muscle Strengthening For Improving Pain And Dynamic Balance Among Female Patients With Patellofemoral Pain Syndrome.	2016	J Phys Ther Sci	28	5
221	Chia-Cheng Lin;Whitney,Susan, L.	Quantification Of Static And Dynamic Balance While Maintaining And Changing Body Position	2012	Topics In Geriatric Rehabilitation	28	1
224	Chien Jh; Mukherjee M; Stergiou N,	Mastoid Vibration Affects Dynamic Postural Control During Gait	2016	Scientific Reports	7	
227	Cho,Ki Hun;Lee,Kyoung Jin;Song,Chang Ho	Virtual-Reality Balance Training With A Video-Game System Improves Dynamic Balance In Chronic Stroke Patients	2012	The Tohoku Journal Of Experimental Medicine	228	1
231	Cho,Kihun;Lee,Gyuchang	Impaired Dynamic Balance Is Associated With Falling In Post-Stroke Patients	2013	The Tohoku Journal Of Experimental Medicine	230	4
233	Choi, A., Sim, T., Mun, J.H.	Improved Determination Of Dynamic Balance Using The Centre Of Mass And Centre Of Pressure Inclination Variables In A Complete Golf Swing Cycle	2016	Journal Of Sports Sciences	34	10
235	Choi, Ahnryul; Kang, Tae Geon; Mun, Joung Hwan	Biomechanical Evaluation Of Dynamic Balance Control Ability During Golf Swing	2016	Journal Of Medical And Biological Engineering	36	3

ID	Authors	Title	Pub Year	Periodical	Vol	Issue
238	Chtara M, Rouissuei M, Bragazzi Nl, Owen Al, Haddad M, Chamari K.	Dynamic Balance Ability In Young Elite Soccer Players: Implication Of Isometric Strength.	2016	J Sports Med Phys Fitness. 2016		
240	Chuang,Shih-Hung;Huang,Mao-Hsiung;Chen,Tien-Wen;Weng,Ming-Chang;Liu,Chin-Wei;Chen,Chia-Hsin	Effect Of Knee Sleeve On Static And Dynamic Balance In Patients With Knee Osteoarthritis	2007	The Kaohsiung Journal Of Medical Sciences	23	8
241	Cinelli,B.;De Paepe,J. L.	Dynamic Balance Of Learning Disabled And Nondisabled Children. / L' Equilibre Dynamique Chez Des Enfants Ayant Des Difficultes D' Apprentissueage Et Des Enfants Normaux	1984	Perceptual & Motor Skills	58	1
246	Clark, C. J.; Clark, S.; Dorey, C.; Williams, J.	Correlation Of The Functional Difficulties Questionnaire (Fdq-9) With Dynamic Balance Using The Smart Instrumented Wobbleboard	2016	Physical Therapy In Sport	21	
248	Clark,S.;Rose,D. J.	Evaluation Of Dynamic Balance Among Community-Dwelling Older Adult Fallers: A Generalizability Study Of The Limits Of Stability Test	2001	Archives Of Physical Medicine And Rehabilitation	82	4
249	Clark,S.;Rose,D. J.;Fujimoto,K.	Generalizability Of The Limits Of Stability Test In The Evaluation Of Dynamic Balance Among Older Adults	1997	Archives Of Physical Medicine And Rehabilitation	78	10
251	Clyse,S. J.;Short,M. A.	The Relationship Between Dynamic Balance And Postrotary Nystagmus In Learning Disabled Children	1983	Physical & Occupational Therapy In Pediatrics	3	3

ID	Authors	Title	Pub Year	Periodical	Vol	Issue
252	Cohen,H S.;Kimball,K T.;Mulavara,A;Bloomberg, JJ.;Paloski,WH.	Posturography And Locomotor Tests Of Dynamic Balance After Long-Duration Spaceflight	2012	Journal Of Vestibular Research: Equilibrium & Orientation	22	4
253	Gagnon,I.;Swaine,B.;Fried man,D.;Forget,R.	Children Show Decreased Dynamic Balance After Mild Traumatic Brain Injury	2004	Archives Of Physical Medicine & Rehabilitation	85	3
257	Coleman Td, Lawrence Hj, Childers Wl.	Standardizing Methodology For Research With Uneven Terrains Focused On Dynamic Balance During Gait.	2016	J Appl Biomech. 2016		
259	Collings R, Paton J, Chockalingam N, Gorst T, Marsden J.	Effects Of The Site And Extent Of Plantar Cutaneous Stimulation On Dynamic Balance And Muscle Activity While Walking.	2015	Foot (Edinb)	25	3
264	Colnat-Coulbois,S.;Gauchard,G. C.;Maillard,L.;Barroche,G.; Vespignani,H.;Auque,J.;Pe rrin,P. P.	Management Of Postural Sensory Conflict And Dynamic Balance Control In Late-Stage Parkinson's Disease	2011	Neuroscience	193	
274	Cone Bl, Levy Ss, Goble Dj.	Wii Fit Exer-Game Training Improves Sensory Weighting And Dynamic Balance In Healthy Young Adults.	2015	Gait Posture	41	2
275	Costa,Pablo B.;Graves,Barbara S.;Whitehurst,Michael;Jac obs,Patrick L.	The Acute Effects Of Different Durations Of Static Stretching On Dynamic Balance Performance	2009	Journal Of Strength & Conditioning Research (Lippincott Williams & Wilkins)	23	1
279	Cote,Karen P.;Brunet Ii,Michael E.;Gansneder,Bruce M.;Shultz,Sandra J.	Effects Of Pronated And Supinated Foot Postures On Static And Dynamic Postural Stability	2005	Journal Of Athletic Training (National Athletic Trainers' Association)	40	1

ID	Authors	Title	Pub Year	Periodical	Vol	Issue
281	Courtney,Carol A.;Rine,Rose M.	Central Somatosensory Changes Associated With Improved Dynamic Balance In Subjects With Anterior Cruciate Ligament Deficiency	2006	Gait & Posture	24	2
283	Craig, C.E., Goble, D.J., Doumas, M.	Proprioceptive Acuity Predicts Muscle Co-Contraction Of The Tibialis Anterior And Gastrocnemius Medialis In Older Adults' Dynamic Postural Control	2016	Neuroscience ,	322	
309	Crockett, Nathan J.; Sandrey, Michelle A	Effect Of Prophylactic Ankle-Brace Use During A High School Competitive Basketball Season On Dynamic Postural Control	2015	Journal Of Sport Rehabilitation	24	3
311	Cug, Mutlu; Wikstrom, Erik A.; Golshaei, Bahman; Kirazci, Sadettin	The Effects Of Sex, Limb Dominance, And Soccer Participation On Knee Proprioception And Dynamic Postural Control	2016	Journal Of Sport Rehabilitation	25	1
312	Cug,Mutlu;Ozdemir,Recep Ali;Ak,Emre	Influence Of Leg Dominance On Single-Leg Stance Performance During Dynamic Conditions: An Investigation Into The Validity Of Symmetry Hypothesis For Dynamic Postural Control In Healthy Individuals	2014	Turkish Journal Of Physical Medicine And Rehabilitation	60	1
315	Curtze C, Hof Al, Postema K, Otten B.	Staying In Dynamic Balance On A Prosthetic Limb: A Leg To Stand On?	2016	Med Eng Phys	38	6
316	Dabholkar,Ajit;Shah,Ankita;Yardi,Sujata	Comparison Of Dynamic Balance Between Flat Feet And Normal Individuals Using Star Excursion Balance Test	2012	Indian Journal Of Physiotherapy & Occupational Therapy	6	3

ID	Authors	Title	Pub Year	Periodical	Vol	Issue
319	Daehee,L. E. E.;Sangyong,L. E. E.;Park,Jungseo	Effects Of Indoor Horseback Riding And Virtual Reality Exercises On The Dynamic Balance Ability Of Normal Healthy Adults	2014	Journal Of Physical Therapy Science	26	12
320	Dallinga, JM.; Van Der Does, HT.D.; Benjaminse, A; Lemmink, K	Dynamic Postural Stability Differences Between Male And Female Players With And Without Ankle Sprain	2016	Physical Therapy In Sport	17	
321	Damiano,DL.;Wingert,JR.; Stanley,CJ.;Curatalo,L	Contribution Of Hip Joint Proprioception To Static And Dynamic Balance In Cerebral Palsy: A Case Control Study	2013	Journal Of Neuroengineering And Rehabilitation	10	1
322	Daneshjoo,A; Mokhtar,A; Rahnama,N;Yusof,A	The Effects Of Comprehensive Warm-Up Programs On Proprioception, Static And Dynamic Balance On Male Soccer Players	2012	Plos One	7	12
324	Davlin,Christina D.	Dynamic Balance In High Level Athletes	2004	Perceptual & Motor Skills	98	3
327	Davlin-Pater,Christina	Perceptual Style And Visual Contribution To Dynamic Balance: A Pilot Study	2008	Perceptual & Motor Skills	106	1
330	Davlin-Pater,Christina	The Effects Of Visual Information And Perceptual Style On Static And Dynamic Balance	2010	Motor Control	14	3
331	De Kam D, Kamphuis Jf, Weerdesteyn V, Geurts Ac.	The Effect Of Weight-Bearing Asymmetry On Dynamic Postural Stability In Healthy Young Individuals.	2016	Gait Posture	45	
333	De Lima M.A.C., De Medeiros Barbosa G., Ribeiro J.D.C., De Almeida Ferreira J.J., De Andrade P.R., Dos Santos H.H.	The Influence Of The External Ankle Support On The Dynamic Balance In Volleyball Athletes	2015	Motriz. Revista De Educacao Fisica	21	3

Id	Authors	Title	Pub Year	Periodical	Vol	Issue
354	Carvalho, A; Almeida, G; Magalhães, M; Franca, F; Ramos, L; Comachio J; Marques, A.	Dynamic Postural Stability And Muscle Strength In Patellofemoral Pain: Is There A Correlation?	2016	Knee	16	
361	De Ridder R, Willems Tm, Vanrenterghem J, Roosen P.	Effect Of Tape On Dynamic Postural Stability In Subjects With Chronic Ankle Instability.	2015	Int J Sports Med	36	4
365	De Ridder, R.Willems, T. M.Vanrenterghem, J.Roosen, P	Effect Of A Home-Based Balance Training Protocol On Dynamic Postural Control In Subjects With Chronic Ankle Instability	2015	International Journal Of Sports Medicine	36	7
368	Delahunt,E;Chawke,Mark;Kelleher,Judy;Murphy,Katie;Prendiville,Anna;Sweeny,Lauren;Patterson,Matt	Lower Limb Kinematics And Dynamic Postural Stability In Anterior Cruciate Ligament-Reconstructed Female Athletes	2013	Journal Of Athletic Training (Allen Press)	48	2
369	Delahunt,Eamonn;Mcgrath,Angela;Doran,Naoise;Coughlan,Garrett F.	Effect Of Taping On Actual And Perceived Dynamic Postural Stability In Persons With Chronic Ankle Instability	2010	Archives Of Physical Medicine & Rehabilitation	91	9
371	Dello Iacono,A.;Martone,D.;Alfieri,A.;Ayalon,M.;Buono,P.	Core Stability Training Program (Cstp) Effects On Static And Dynamic Balance Abilities	2014	Gazzetta Medica Italiana Archivio Per Le Scienze Mediche	173	4
372	Demura,Shinichi;Sohee,Shin;Yamaji,Shunsuke	Sex And Age Differences Of Relationships Among Stepping Parameters For Evaluating Dynamic Balance In The Elderly	2008	Journal Of Physiological Anthropology	27	4
381	Deoreo,K. L.	Dynamic Balance In Preschool Children: Quantifying Qualitative Data	1976	Research Quarterly	47	3
384	Depaepe,J. L.;Ciccaglione,S.	A Dynamic Balance Measure For Persons With Severe And Profound Mental Retardation	1993	Perceptual And Motor Skills	76	2

Id	Authors	Title	Pub Year	Periodical	Vol	Issue
385	Desai,Ankur;Goodman,Valerie;Kapadia,Naaz;Shay,Barbara L.;Szturm,Tony	Relationship Between Dynamic Balance Measures And Functional Performance In Community-Dwelling Elderly People	2010	Physical Therapy	90	5
386	Desroches,Guillaume;Gagnon,Dany;Nadeau,Sylvie;Popovic,Milos	Magnitude Of Forward Trunk Flexion Influences Upper Limb Muscular Efforts And Dynamic Postural Stability Requirements During Sitting Pivot Transfers In Individuals With Spinal Cord Injury	2013	Journal Of Electromyography & Kinesiology	23	6
389	Di Cagno,A; Fiorilli,G; Iuliano,E; Aquino,G; Giombini,A; Battaglia,C; Piazza,M; Tsopani,D; Calcagno,G	Time-Of-Day Effects On Static And Dynamic Balance In Elite Junior Athletes And Untrained Adolescents	2014	International Journal Of Sports Science & Coaching	9	4
390	Dibrezzo,Ro;Shadden,Barbara B.;Raybon,Blake H.;Powers,Melissuea	Exercise Intervention Designed To Improve Strength And Dynamic Balance Among Community-Dwelling Older Adults	2005	Journal Of Aging & Physical Activity	13	2
392	Diener,H. C.;Dichgans,J.	On The Role Of Vestibular, Visual And Somatosensory Information For Dynamic Postural Control In Humans	1988	Progress In Brain Research	76	
393	Dodd,Karen;Hill,Keith;Haas,Romi;Luke,Carolyn;Millard,Stephanie	Retest Reliability Of Dynamic Balance During Standing In Older People After Surgical Treatment Of Hip Fracture	2003	Physiotherapy Research International	8	2
394	Doherty C, Bleakley C, Hertel J, Caulfield B, Ryan J, Delahunt E.	Dynamic Balance Deficits 6 Months Following First-Time Acute Lateral Ankle Sprain: A Laboratory Analysis.	2015	J Orthop Sports Phys Ther	45	8

Id	Authors	Title	Pub Year	Periodical	Vol	Issue
395	Doherty, C ;Bleakley, C; Hertel, J ;Caulfield, B, John;Delahunt, E	Dynamic Balance Deficits In Individuals With Chronic Ankle Instability Compared To Ankle Sprain Copers 1 Year After A First-Time Lateral Ankle Sprain Injury	2016	Knee Surgery, Sports Traumatology, Arthroscopy	24	4
396	Douglas,M;Bivens,S;Pesterfield,J;Clemson,N;Castle,W;Sole,G;Wassinger,Ca.	Immediate Effects Of Cryotherapy On Static And Dynamic Balance	2013	International Journal Of Sports Physical Therapy	8	1
398	Dvir,Z.;Danielatrakci,R.;Mirovski,Y.	The Effect Of Frontal Loading On Static And Dynamic Balance Reactions In Patients With Chronic Low Back Dysfunction	1997	Basic And Applied Myology	7	2
399	Dvir,Z.;Trousil,T.	Electromyographic Study Of Several Lower Limb Muscles During Maintenance Of Dynamic Balance In The Frontal Plane	1982	Agressologie: Revue Internationale De Physio-Biologie Et De Pharmacologie Appliques Aux Effets De L'agression	23	2
401	Eechaute,Christophe;Vaes,Peter;Duque,William	The Dynamic Postural Control Is Impaired In Patients With Chronic Ankle Instability: Reliability And Validity Of The Multiple Hop Test	2009	Clinical Journal Of Sport Medicine	19	2
403	Egerton,Thorlene;Brauer,Sandra G.;Cresswell,Andrew G.	Dynamic Postural Stability Is Not Impaired By Moderate-Intensity Physical Activity In Healthy Or Balance-Impaired Older People	2010	Human Movement Science	29	6
404	Elena,Sabau;Georgeta,Niculescu;Florentina,Popescu;Cristiana,Porfirescu;Cecilia,Gevat;Elena,Lupu	Study Of Dynamic Postural Control In Young Adults	2015	Ovidius University Annals, Series Physical Education & Sport/Science, Movement & Health	15	2

Id	Authors	Title	Pub Year	Periodical	Vol	Issue
410	Eltoukhy M, Kuenze C, Jun Hp, Asfour S, Travascio F.	Assessment Of Dynamic Balance Via Measurement Of Lower Extremities Tortuosity.	2015	Sports Biomech	14	1
411	Cushing,S; L.;Chia,R; ;James,A ;Papsin,B; C.; Gordon,K.	A Test Of Static And Dynamic Balance Function In Children With Cochlear Implants: The Vestibular Olympics	2008	Archives Of Otolaryngology--Head & Neck Surgery	134	1
415	Emara,Hatem Abdel Mohsen Abdel Hamid	Effect Of A New Physical Therapy Concept On Dynamic Balance In Children With Spastic Diplegic Cerebral Palsy	2015	Egyptian Journal Of Medical Human Genetics	16	1
416	Ericksen,Hayley;Gribble,Phillip A.	Sex Differences, Hormone Fluctuations, Ankle Stability, And Dynamic Postural Control	2012	Journal Of Athletic Training (National Athletic Trainers' Association)	47	2
423	Eshraghi,A; Maroufi,N ;Sanjari,M.A.; Saeedi,H ;Keyhani,M.R;Gholizadeh,H ;Osman, N.A.A	Effect Of Milwaukee Brace On Static And Dynamic Balance Of Female Hyperkyphotic Adolescents	2013	Prosthetics And Orthotics International	37	1
426	Eun-Jung Chung;Jung-Hee,K. I. M.;Byoung-Hee,L. E. E.	The Effects Of Core Stabilization Exercise On Dynamic Balance And Gait Function In Stroke Patients	2013	Journal Of Physical Therapy Science	25	7
427	Faigenbaum,AD.;Bagley,J;Boise,S;Farrel,A;Bates,N;Myer,GD.	Dynamic Balance In Children: Performance Comparison Between Two Testing Devices	2015	Athletic Training & Sports Health Care: The Journal For The Practicing Clinician	7	4
428	Faigenbaum,Ad.; Myer,G.D.; Perez,F.M ;Carrasco,E; Gomez;Bates,N;Farrell,A.; Ratamess,Na.; Kang,J	Feasibility And Reliability Of Dynamic Postural Control Measures In Children In First Through Fifth Grades	2014	International Journal Of Sports Physical Therapy	9	2

Id	Authors,	Title	Pub Year	Periodical	Vol	Issue
429	Falk,E.E; Seeley,Mk.; Hunter,I ;Park,J; Hopkins,J. T.	Effect Of Experimental Anterior Knee Pain On Measures Of Static And Dynamic Postural Control	2014	Athletic Training & Sports Health Care: The Journal For The Practicing Clinician	6	1
431	Falkerslev, S., C. Baagø, Tine Alkjær, L. Remvig, J. Halkjaer-Kristensen, Peter Kastmand Larsen, B. Juul-Kristensen, And E. B. Simonsen.	Dynamic Balance During Gait In Children And Adults With Generalized Joint Hypermobility	2013	Clinical Biomechanics	28	3
432	Fatma,A; Kaya,M; Baltaci,G; Taskin,H; Erkmen,N	The Effect Of Eight-Week Proprioception Training Program On Dynamic Postural Control In Taekwondo Athletes	2010	Ovidius University Annals, Series Physical Education & Sport/Science, Movement & Health	10	1
433	Fayson,Shirleeah D.;Needle,Alan R.;Kaminski,Thomas W.	The Effects Of Ankle Kinesio Taping On Ankle Stiffness And Dynamic Balance	2013	Research In Sports Medicine	21	3
435	Fernandes, T; Lazzaretti; R F; Ellen, C ; Bessa, F; Luna, N.M.S.; Sugimoto, D; D'andrea Greve, J.M; Hernandez, A.J	Evaluation Of Static And Dynamic Balance In Athletes With Anterior Cruciate Ligament Injury - A Controlled Study	2016	Clinics	71	8
437	Ferraye,M.U;Debu,B; ; Heil,L; Carpenter,M; Bloem,B; Toni,I	Using Motor Imagery To Study The Neural Substrates Of Dynamic Balance	2014	Plos One	9	3

Id	Authors,	Title	Pub Year	Periodical	Vol	Issue
441	Field-Fote,E.;Ray,S. S.	Seated Reach Distance And Trunk Excursion Accurately Reflect Dynamic Postural Control In Individuals With Motor-Incomplete Spinal Cord Injury	2010	Spinal Cord	48	10
442	Fitzgerald,Diarmaid;Trakarnratanakul,Nanthana;Smyth,Barry;Caulfield,Brian	Effects Of A Wobble Board-Based Therapeutic Exergaming System For Balance Training On Dynamic Postural Stability And Intrinsic Motivation Levels	2010	The Journal Of Orthopaedic And Sports Physical Therapy	40	1
444	Fitzpatrick,C.;Simpson,J. M.;Valentine,J. D.;Ryder,S.;Peacock-Edwards,T.;Sidnell,P.;Colognese,M.	The Measurement Properties And Performance Characteristics Among Older People Of Turn180,A Test Of Dynamic Postural Stability	2005	Clinical Rehabilitation	19	4
445	Forte,R;Boreham,C; De Vito,G; Ditroilo,M; Pesce,C	Measures Of Static Postural Control Moderate The Association Of Strength And Power With Functional Dynamic Balance	2014	Aging Clinical And Experimental Research	26	6
446	Fotiadou,Eg;Neofotistou,Kh.; Sidiropoulou,Mp; Tsimaras,Vk.;Mandroukas,Ak.; Angelopoulou,Na.	The Effect Of A Rhythmic Gymnastics Program On The Dynamic Balance Ability Of Individuals With Intellectual Disability	2009	Journal Of Strength & Conditioning Research (Lippincott Williams & Wilkins)	23	7
447	Fotios,M.;Miltiadis,P.;Eirini,A.;Andromahi,S.	Dynamic Balance In Girls Practicing Recreational Rhythmic Gymnastics And Greek Traditional Dances	2013	Science Of Gymnastics Journal	5	1
448	Fournier Belley, A., Bouffard, J., Brochu, K., Mercier, C., Roy, J.-S., Bouyer, L.	Development And Reliability Of A Measure Evaluating Dynamic Proprioception During Walking With A Robotized Ankle-Foot Orthosis, And Its Relation To Dynamic Postural Control	2016	Gait And Posture	49	

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450	Fournier,Ka.;Kimberg,Ci.; Radonovich,Kj.;Tillman,MD.;Chow,Jw.;Lewis,Mh.; Bodfish,Jw.;Hass,Cj.	Decreased Static And Dynamic Postural Control In Children With Autism Spectrum Disorders	2010	Gait & Posture	32	1
451	Franchignoni F., Godi M., Guglielmetti S., Nardone A., Giordano A.	Enhancing The Usefulness Of The Mini-Bestest For Measuring Dynamic Balance: A Rasch Validation Study	2015	European Journal Of Physical And Rehabilitation Medicine	51	4
454	Fujimoto,Masahiro;Chou,Li-Shan	Dynamic Balance Control During Sit-To-Stand Movement: An Examination With The Center Of Mass Acceleration	2012	Journal Of Biomechanics	45	3
457	Fujisawa,T.;Takuma,S.;Koseki,H.;Kimura,K.;Fukushima,K.	Recovery Of Intentional Dynamic Balance Function After Intravenous Sedation With Midazolam In Young And Elderly Subjects	2006	European Journal Of Anaesthesiology	23	5
458	Fujisawa,T.;Takuma,S.;Koseki,H.;Kimura,K.;Fukushima,K.	Study On The Usefulness Of Precise And Simple Dynamic Balance Tests For The Evaluation Of Recovery From Intravenous Sedation With Midazolam And Propofol	2007	European Journal Of Anaesthesiology	24	5
459	Fujisawa,T;Iida,A;Takuma,S;Koseki,H;Kimura,K; Fukushima,Ki	Recovery Of Dynamic Balance After Additional Small Divided Doses Of Midazolam Given Intravenously For Sedation	2007	The British Journal Of Oral & Maxillofacial Surgery	45	3
460	Fujisawa,T;Miyamoto,E; Takuma,S;Shibuya,M; Kurozumi,A;Kimura,Y; Kamekura,N;Fukushima,K	Recovery Of Dynamic Balance After General Anesthesia With Sevoflurane In Short-Duration Oral Surgery	2009	Journal Of Anesthesia	23	1

Id	Authors,	Title	Pub Year	Periodical	Vol	Issue
461	Fujisawa,Toshiaki;Takuma,Shigeru;Koseki,Hiroyo;Kimura,Kunie;Fukushima,Kazuaki	Assessment Of The Recovery Of Dynamic Balance After Intravenous Sedation With Midazolam	2005	Journal Of Anesthesia	19	1
463	Fujisawa,Toshiaki;Takuma,Shigeru;Koseki,Hiroyo;Kimura,Kunie;Fukushima,Kazuaki	Correlation Between Precise And Simple Tests In Recovery Of Dynamic Balance Function After Intravenous Sedation With Midazolam In The Elderly	2007	Journal Of Anesthesia	21	2
464	Fujita,D;Kobara,Kosaka,H;Watanabe,S;Sintani,T;Sugimura,T;Makini,K;Cleminson,T;Morikawa,T	The Influence Of Rollators With Forearm Support On Walking Speed, Endurance And Dynamic Balance	2012	Journal Of Physical Therapy Science	24	8
468	Fujiwara,Katsuo;Maekawa,Maki;Kiyota,Naoe;Yaguchi,Chie	Adaptation Changes In Dynamic Postural Control And Contingent Negative Variation During Backward Disturbance By Transient Floor Translation In The Elderly	2012	Journal Of Physiological Anthropology	31	
469	Fujiwara,Katsuo;Toyama,Hiroshi;Asai,Hitoshi;Yaguchi,Chie;Irei,Mariko;Naka,Masami;Kaida,Chizuru	Effects Of Regular Heel-Raise Training Aimed At The Soleus Muscle On Dynamic Balance Associated With Arm Movement In Elderly Women	2011	Journal Of Strength & Conditioning Research (Lippincott Williams & Wilkins)	25	9
472	Fullam, Karl; Caulfield, Brian; Coughlan, Garrett F.; Mcgroarty, Mark; Delahunt, Eamonn	Dynamic Postural-Stability Deficits After Cryotherapy To The Ankle Joint	2015	Journal Of Athletic Training	50	9

Id	Authors	Title	Pub Year	Periodical	Vol	Issue
474	Gauchard,G. C.;Lascombes,P.;Kuhnast, M.;Perrin,P. P.	Influence Of Different Types Of Progressive Idiopathic Scoliosis On Static And Dynamic Postural Control	2001	Spine	26	9
479	Giacalone,Wr;Rarick,Gl	Dynamic Balance Of Preschool-Children As Reflected By Performance On Beam-Walking Tasks	1985	Journal Of Genetic Psychology	146	3
485	Gilbreath,Julie P.;Gaven,Stacey L.;Van Lunen,Bonnie L.;Hoch,Matthew C.	The Effects Of Mobilization With Movement On Dorsiflexion Range Of Motion, Dynamic Balance, And Self-Reported Function In Individuals With Chronic Ankle Instability	2014	Manual Therapy	19	2
486	Goel,Nitya;Bhatia,Shipra	Effect Of Patellar Taping On Dynamic Balance During Star Excursion Balance Test In Patients With Patellofemoral Pain Syndrome	2012	Indian Journal Of Physiotherapy & Occupational Therapy	6	1
487	Golem D.L., Arent S.M.	Effects Of Over-The-Counter Jaw-Repositioning Mouth Guards On Dynamic Balance, Flexibility, Agility, Strength, And Power In College-Aged Male Athletes	2015	Journal Of Strength And Conditioning Research	29	2
489	Golomer,E.;Dupui,P.;Bessou,P.	Spectral Frequency Analysis Of Dynamic Balance In Healthy And Injured Athletes	1994	Archives Internationales De Physiologie, De Biochimie Et De Biophysique	102	3
490	Gongbing,Shan;Xiang,Zhang;Xi,Li;Weiya,Hao;Kerstin,Witte	Quantification Of Golfer-Club Interaction And Club-Type's Affect On Dynamic Balance During A Golf Swing	2011	International Journal Of Performance Analysis In Sport	11	3
491	Gorman,Pp.;Butler,Rj.;Rauh,Mj.;Kiesel,K;Plisky,P J.	Differences In Dynamic Balance Scores In One Sport Versus Multiple Sport High School Athletes	2012	International Journal Of Sports Physical Therapy	7	2

Id	Authors	Title	Pub Year	Periodical	Vol	Issue
493	Granacher,Urs;Lacroix,Andre;Muehlbauer,Thomas;Roettger,Katrin;Gollhofer,Albert	Effects Of Core Instability Strength Training On Trunk Muscle Strength, Spinal Mobility, Dynamic Balance And Functional Mobility In Older Adults	2013	Gerontology	59	2
495	Gribble,Phillip A.;Hertel,Jay;Denegar,Craig R.;Buckley,William E.	The Effects Of Fatigue And Chronic Ankle Instability On Dynamic Postural Control	2004	Journal Of Athletic Training (National Athletic Trainers' Association)	39	4
496	Gribble,Phillip A.;Hertel,Jay;Plisky,Phil	Using The Star Excursion Balance Test To Assess Dynamic Postural-Control Deficits And Outcomes In Lower Extremity Injury: A Literature And Systematic Review	2012	Journal Of Athletic Training (Allen Press)	47	3
499	Gribble,Phillip A.;Robinson,Richard H.;Hertel,Jay;Denegar,Craig R.	The Effects Of Gender And Fatigue On Dynamic Postural Control	2009	Journal Of Sport Rehabilitation	18	2
500	Gribble,Phillip A.;Tucker,W. S.;White,Paul A.	Time-Of-Day Influences On Static And Dynamic Postural Control	2007	Journal Of Athletic Training (National Athletic Trainers' Association)	42	1
501	Groters,S.;Groen,B. E.;Van Cingel,R.;Duysens,J.	Double-Leg Stance And Dynamic Balance In Individuals With Functional Ankle Instability	2013	Gait & Posture	38	4
508	Guillou,Emmanuel;Dupui,Philippe;Golomer,Eveline	Dynamic Balance Sensory Motor Control And Symmetrical Or Asymmetrical Equilibrium Training	2007	Clinical Neurophysiology: Official Journal Of The International Federation Of Clinical Neurophysiology	118	2

Id	Authors	Title	Pub Year	Periodical	Vol	Issue
509	Gusi,N;Carmelo Adsuar,J;Corzo,H;Del Pozo-Cruz,B;Olivares,Pr.; Parraca,J.	Balance Training Reduces Fear Of Falling And Improves Dynamic Balance And Isometric Strength In Institutionalised Older People: A Randomised Trial	2012	Journal Of Physiotherapy	58	2
511	Gusi,Narcis;Parraca,Jose A.;Olivares,Pedro R.;Leal,Alejo;Adsuar,Jose C.	Tilt Vibratory Exercise And The Dynamic Balance In Fibromyalgia: A Randomized Controlled Trial	2010	Arthritis Care & Research	62	8
512	Haksever,B.;Aktas,C.;Baltaci,G.	Effect Of Kinesiotaping On Static And Dynamic Balance During Soccer	2012	Medicina Dello Sport	65	2
513	Hammaran,E;Ohlsson,Ja;Lindberg,C;Kjellby-Wendt,G	Reliability Of Static And Dynamic Balance Tests In Subjects With Myotonic Dystrophy Type 1	2012	Advances In Physiotherapy	14	2
514	Hammaren,Elisabet;Kjellby-Wendt,Gunilla;Kowalski,Jan;Lindberg,Christopher	Factors Of Importance For Dynamic Balance Impairment And Frequency Of Falls In Individuals With Myotonic Dystrophy Type 1 - A Cross-Sectional Study - Including Reference Values Of Timed Up & Go, 10m Walk And Step Test	2014	Neuromuscular Disorders: Nmd	24	3
516	Han, S., Lee, D., Lee, S.	A Study On The Reliability Of Measuring Dynamic Balance Ability Using A Smartphone	2016	Journal Of Physical Therapy Science	28	9
517	Harkey,M;Mcleod,M;Van Scoit,A;Terada,M;Tevald,M;Gribble,P;Pietrosimone,B	The Immediate Effects Of An Anterior-To-Posterior Talar Mobilization On Neural Excitability, Dorsiflexion Range Of Motion, And Dynamic Balance In Patients With Chronic Ankle Instability	2014	Journal Of Sport Rehabilitation	23	4

Id	Authors	Title	Pub Year	Periodical	Vol	Issue
519	Harris Dm, Rantalainen T, Muthalib M, Johnson L, Teo Wp.	Exergaming As A Viable Therapeutic Tool To Improve Static And Dynamic Balance Among Older Adults And People With Idiopathic Parkinson's Disease: A Systematic Review And Meta-Analysis.	2015	Front Aging Neurosci	7	
521	Hashish,Rami;Samarawickrame,Sachithra D.;Wang,Man-Ying;Yu,Sean S. -Y;Salem,George J.	The Association Between Unilateral Heel-Rise Performance With Static And Dynamic Balance In Community Dwelling Older Adults	2015	Geriatric Nursing (New York, N.Y.)		
522	Hass,C J.;Waddell,De.;Fleming,R P.;Juncos,Jl.;Gregor,R J.	Gait Initiation And Dynamic Balance Control In Parkinson's Disease	2005	Archives Of Physical Medicine And Rehabilitation	86	11
524	Hatzitaki,V.;Zisi,V.;Kollias,I.;Kioumourtzoglou,E.	Perceptual-Motor Contributions To Static And Dynamic Balance Control In Children	2002	Journal Of Motor Behavior	34	2
525	Heebner N.R., Akins J.S., Lephart S.M., Sell T.C.	Reliability And Validity Of An Accelerometry Based Measure Of Static And Dynamic Postural Stability In Healthy And Active Individuals	2015	Gait And Posture	41	2
531	Heinbaugh Em, Smith Dt, Zhu Q, Wilson Ma, Dai B.	The Effect Of Time-Of-Day On Static And Dynamic Balance In Recreational Athletes.	2015	Sports Biomech	14	3
533	Hoch,Mc.;Andreatta,Rd.;Mullineaux,Dr.;English,Ra.;Medina Mckeon,J,M.;Mattacola,Cg.;Mckeon,P.	Two-Week Joint Mobilization Intervention Improves Self-Reported Function, Range Of Motion, And Dynamic Balance In Those With Chronic Ankle Instability	2012	Journal Of Orthopaedic Research: Official Publication Of The Orthopaedic Research Society	30	11
534	Hoch,Mc.;Staton,Gs.;Medina Mckeon,Jm.;Mattacola,Cg.;Mckeon,P.	Dorsiflexion And Dynamic Postural Control Deficits Are Present In Those With Chronic Ankle Instability	2012	Journal Of Science & Medicine In Sport	15	6

Id	Authors	Title	Pub Year	Periodical	Vol	Issue
539	Hoffman,M. A.;Koceja,D. M.	Dynamic Balance Testing With Electrically Evoked Perturbation: A Test Of Reliability	1997	Archives Of Physical Medicine And Rehabilitation	78	3
541	Hohtari-Kivimaki,Ulla;Salminen,Marika;Vahlberg,Tero;Kivela,Sirkka-Liisa	Short Berg Balance Scale - Correlation To Static And Dynamic Balance And Applicability Among The Aged	2012	Aging Clinical And Experimental Research	24	1
543	Holden S, Boreham C, Doherty C, Wang D, Delahunt E	A Longitudinal Investigation Into The Progression Of Dynamic Postural Stability Performance In Adolescents.	2016	Gait Posture	48	
544	Holden,Sinãƒâ©Ad;Boreham,Colin;Doherty,Cailbhe;Wang,Dan;Delahunt,Eamonn	Dynamic Postural Stability In Young Adolescent Male And Female Athletes	2014	Pediatric Physical Therapy: The Official Publication Of The Section On Pediatrics Of The American Physical Therapy Association	26	4
546	Holviala,J.;Kraemer,W.;Sillan,E.;Karppinen,H.;Avela,J.;Kauhanen,A.;Hafakkinen,A.;Hafakkinen,K.	Effects Of Strength, Endurance And Combined Training On Muscle Strength, Walking Speed And Dynamic Balance In Aging Men	2012	European Journal Of Applied Physiology	112	4
550	Hooper,Troy L.;James,C. Roger;Brismée,Jean-Michel;Rogers,Toby J.;Gilbert,Kerry K.;Browne,Kevin L.;Sizer,Phillip S.	Dynamic Balance As Measured By The Y-Balance Test Is Reduced In Individuals With Low Back Pain: A Cross-Sectional Comparative Study	2016	Physical Therapy In Sport	22	
556	Hosseini Sisi,S. Z.;Sadeghi,H.;Massood Nabavi,S.	The Effects Of 8 Weeks Of Rebound Therapy And Pilates Practices On Static And Dynamic Balances In Males With Multiple Sclerosis	2014	Advances In Environmental Biology	7	13

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561	Hosseini,S. S.;Rostamkhany,H.;Hashemi,M.;Jalili,M.	A Comparison Of The Effect Of Whole-Body Vibration And Strength Training On Certain Physical Fitness Factors And Dynamic Balance In Students	2012	Middle East Journal Of Scientific Research	11	3
563	Hosseini,S. S.;Rostamkhany,H.;Panahi,M.;Ramandi,L. D.	Exercise-Related Fatigue Change Dynamic Postural Control In Healthy Males	2012	Middle East Journal Of Scientific Research	11	2
568	Hosseinimehr,H.;Norasteh,A.;Daneshmandi,H.;Rahpymay-Rad,K.;Rahimi,R.	The Effect Of Vibration On Leg Muscles Proprioception In Static Ana Dynamic Postural Control	2009	Medicina Dello Sport	62	4
569	Hosseinimehr,Seyed Hossein;Norasteh,Ali Asghar	The Role Of Leg And Trunk Muscles Proprioception On Static And Dynamic Postural Control	2010	Journal Of Physical Education & Sport / Citius Altius Fortius	26	1
573	Hrysomallis,C.;Mclaughlin,P.;Goodman,C.	Relationship Between Static And Dynamic Balance Tests Among Elite Australian Footballers	2006	Journal Of Science & Medicine In Sport	9	4
576	Hsiao-Wecksler,E; Katdare,K;Matson,J;Liu,W; Lipsitz,L.;Collins,Jj.	Predicting The Dynamic Postural Control Response From Quiet-Stance Behavior In Elderly Adults	2003	Journal Of Biomechanics	36	9
577	Hsue,Bih-Jen;Miller,Freeman;Su,Fong-Chin	The Dynamic Balance Of The Children With Cerebral Palsy And Typical Developing During Gait: Part Ii: Instantaneous Velocity And Acceleration Of Com And Cop And Their Relationship	2009	Gait & Posture	29	3
579	Hsue,Bih-Jen;Miller,Freeman;Su,Fong-Chin	The Dynamic Balance Of The Children With Cerebral Palsy And Typical Developing During Gait. Part I: Spatial Relationship Between Com And Cop Trajectories	2009	Gait & Posture	29	3

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594	Huntley Ah; Zettel Jl; Vallis La	Effect Of Aging On Dynamic Postural Stability And Variability During A Multi-Directional Lean And Reach Object Transportation Task	2016	Archives Of Gerontology And Geriatrics	66	
595	Hutt,Kimberley;Redding,Emma	The Effect Of An Eyes-Closed Dance-Specific Training Program On Dynamic Balance In Elite Pre-Professional Ballet Dancers	2014	Journal Of Dance Medicine & Science	18	1
596	Hyong Ih.	The Effects On Dynamic Balance Of Dual-Tasking Using Smartphone Functions.	2015	Sports Biomech	27	2
597	Ikai,Tetsuo;Kamikubo,Takeshi;Takehara,Itaru;Nishi,Masanori;Miyano,Satoshi	Dynamic Postural Control In Patients With Hemiparesis	2003	American Journal Of Physical Medicine & Rehabilitation / Association Of Academic Physiatrists	82	6
600	Ilbeigi, Saied; Khirkhah, Mahin; Mahjur, Mahdi; Soltani, Hossein; Jafarkhoshbakhti	Investigating The Effects Of 8 Weeks Of Rope Skipping On Static And Dynamic Balance Of Educable Mentally Retarded Boys	2016	International Journal Of Medical Research & Health Sciences	5	5
601	In Hyouk Hyongjong Ho Kang	Comparison Of Dynamic Balance Ability In Healthy University Students According To Foot Shape	2016	Journal Of Physical Therapy Science	28	2
602	Isbilir,Mert;Zuša,Anna;Oral,Onur;Cabuk,Refik	Relationship Between Muscle Strength Of Dominant And Non-Dominant Ankle And Dynamic Balance In Football Players	2015	Baltic Journal Of Sport & Health Sciences	98	3
603	Jazi,S. D.;Purrajabi,F.;Movahedi, A.;Jalali,S.	Effect Of Selected Balance Exercises On The Dynamic Balance Of Children With Visual Impairments	2012	Journal Of Visual Impairment And Blindness	106	8

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605	Jelsma Ld, Smits-Engelsman Bc, Krijnen Wp, Geuze Rh.	Changes In Dynamic Balance Control Over Time In Children With And Without Developmental Coordination Disorder.	2016	Hum Mov Sci. 2016		
606	Johnson,Eric G.;Larsen,Andrea;Ozawa, Hiromi;Wilson,Christine A.;Kennedy,Karen L.	The Effects Of Pilates-Based Exercise On Dynamic Balance In Healthy Adults	2007	Journal Of Bodywork & Movement Therapies	11	3
608	Johnson-Kramer,C.;Sherwood,D.;French,R.;Canabal,M. Y.	Performance And Learning Of A Dynamic Balance Task By Visually Impaired Children	1992	Clinical Kinesiology (Online Edition)	45	4
609	Jones, G.D., James, D.C., Thacker, M., Green, D.A.	Sit-To-Stand-And-Walk From 120% Knee Height: A Novel Approach To Assess Dynamic Postural Control Independent Of Lead-Limb	2016	Journal Of Visualized Experiments	11	4
613	Jones,C. J.;Robichaux,J.;Williams,P. ;Rikli,R.	The Effects Of A 16-Week Exercise Program On The Dynamic Balance Of Older Adults	1992	Journal Of Clinical And Experimental Gerontology	14	2
616	Judge,J. O.;King,M. B.;Whipple,R.;Clive,J.;Wolfson,L. I.	Dynamic Balance In Older Persons: Effects Of Reduced Visual And Proprioceptive Input	1995	The Journals Of Gerontology.Series A, Biological Sciences And Medical Sciences	50	5
620	Kachanathu,Shaji John;Dhamija,Eshu;Malhotra,Mimansa	A Comparative Study On Static And Dynamic Balance In Male Collegiate Soccer And Basketball Athletes	2013	Sports Medicine Journal / Medicina Sportivãƒâ¢	9	2
622	Kahle,Nicole L.;Gribble,Phillip A.	Core Stability Training In Dynamic Balance Testing Among Young, Healthy Adults	2009	Athletic Training & Sports Health Care: The Journal For The Practicing Clinician	1	2

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623	Kaminski, E.A, Steele, C.J.Ab, Hoff, M.Ac, Gundlach, C.Ad, Rjosk, V.A, Sehm, B.A, Villringer, A.Ae, Ragert, P.	Transcranial Direct Current Stimulation (Tdcs) Over Primary Motor Cortex Leg Area Promotes Dynamic Balance Task Performance	2016	Clinical Neurophysiology	127	6
624	Kara,Bilge;Genc,Arzu;Colakoglu,Beril Donmez;Cakmur,Raif	The Effect Of Supervised Exercises On Static And Dynamic Balance In Parkinson's Disease Patients	2012	Neurorehabilitation	30	4
625	Karinkanta,S.;Heinonen,A.;Sievanen,H.;Uusi-Rasi,K.;Kannus,P.	Factors Predicting Dynamic Balance And Quality Of Life In Home-Dwelling Elderly Women	2005	Gerontology	51	2
626	Kawabata,Haruka;Demura,Shinichi;Uchiyama,Masanobu;Takahashi,Kenji	Relations Among Dynamic Balance Tests And A Coordination Test Using Center Of Pressure To Pursue A Randomly Moving Target	2013	Perceptual & Motor Skills	117	3
627	Kawaishi,Yu;Domen,Kazuhisa	The Relationship Between Dynamic Balancing Ability And Posture-Related Modulation Of The Soleus H-Reflex	2016	Journal Of Electromyography And Kinesiology	26	
628	Kennedy,Ashleigh;Guevel,Arnaud;Sveistrup,Heidi	Impact Of Ankle Muscle Fatigue And Recovery On The Anticipatory Postural Adjustments To Externally Initiated Perturbations In Dynamic Postural Control	2012	Experimental Brain Research	223	4
629	Ki Ki, Kim Ms, Moon Y, Choi Jd.	Effects Of Auditory Feedback During Gait Training On Hemiplegic Patients' Weight Bearing And Dynamic Balance Ability.	2015	J Phys Ther Sci	27	4
630	Kihun,C.; Kyoungsuk,L; Byungjoon,L.;Hwangjae,L.; Wanhee,L	Relationship Between Postural Sway And Dynamic Balance In Stroke Patients	2014	Journal Of Physical Therapy Science	26	12

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632	Ki-Hyeon Parkjin-Yong Limtae-Ho Kim	The Effects Of Ankle Strategy Exercises On Unstable Surfaces On Dynamic Balance And Changes In The Cop	2016	Journal Of Physical Therapy Science	28	2
635	Kim, Hyeong-Dong ;Hyun,Dong Je;Ji,Hoon Jeong;Kwang-Ho Cho	Tai Chi And Its Effects On Dynamic Postural Control In The Initiation Of Gait By Older People	2012	Journal Of Physical Therapy Science	24	2
636	Kim,Hyeong-Dong;Je,Hyun Dong;Jeong,Ji Hoon;Cho,Kwang-Ho;Ma,Sang-Yeol	Effects Of Obstacle Crossing On Dynamic Postural Control Of Parkinson's Disease Patients	2012	Journal Of Physical Therapy Science	24	5
639	Kim,Hyeong-Dong;Kim,Tae-You;Jae,Hyun Dong;Son,Seon-Tae	The Effects Of Tai Chi Based Exercise On Dynamic Postural Control Of Parkinson's Disease Patients While Initiating Gait	2011	Journal Of Physical Therapy Science	23	2
643	Kinzey,S. J.;Armstrong,C. W.	The Reliability Of The Star-Excursion Test In Assessing Dynamic Balance	1998	Journal Of Orthopaedic & Sports Physical Therapy	27	5
644	Kluenter,Heinz-Dieter;Lang-Roth,Ruth;Guntinas-Lichius,Orlando	Static And Dynamic Postural Control Before And After Cochlear Implantation In Adult Patients	2009	European Archives Of Oto-Rhino-Laryngology	266	10
645	Ko,Ji-Hyun;Challis,John H.;Newell,Karl M.	Transition Of Com-Cop Relative Phase In A Dynamic Balance Task	2014	Human Movement Science	38	
648	Ko,Mansoo;Chiu,Yi-Po;Hung,You-Jou	Dynamic Postural Control In Older People With Diabetes During Gait Initiation	2013	Physical & Occupational Therapy In Geriatrics	31	4
649	Ko,Y. G.;Challis,J. H.;Newell,K. M.	Learning To Coordinate Redundant Degrees Of Freedom In A Dynamic Balance Task	2003	Human Movement Science	22	1

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650	Kodesh E, Dar G.	The Effect Of Kinesiotape On Dynamic Balance Following Muscle Fatigue In Individuals With Chronic Ankle Instability.	2015	Res Sports Med	23	4
651	Kollen,L.;Bjerlemo,B.;Olsen,M. F.;Moller,C.	Static And Dynamic Balance And Well-Being After Acute Unilateral Vestibular Loss	2008	Audiological Medicine	6	4
653	Kovacevic,Erol; Bradic, Josipa; Bejdic Almir; Abazovic, Ensar; Bradic, Asim	Unilateral Profile Of Dynamic Balance Of Female Students Of Faculty Of Sport And Physical Education	2010	Homo Sporticus	12	1
654	Kuo,Fang-Chuan;Wang,Nai-Hwei;Hong,Chang-Zern	Impact Of Visual And Somatosensory Deprivation On Dynamic Balance In Adolescent Idiopathic Scoliosis	2010	Spine	35	23
657	Kwon,Y. J.;Park,S. J.;Jefferson,J.;Kim,K.	The Effect Of Open And Closed Kinetic Chain Exercises On Dynamic Balance Ability Of Normal Healthy Adults	2013	Journal Of Physical Therapy Science	25	6
658	Kwon,Yong Hyun;Choi,Yong Won;Nam,Seok Hyun;Lee,Myoung Hee	The Influence Of Time Of Day On Static And Dynamic Postural Control In Normal Adults	2014	Journal Of Physical Therapy Science	26	3
661	Laessoe, Uffe; Grarup, Bo; Bangshaab, Jette	The Use Of Cognitive Cues For Anticipatory Strategies In A Dynamic Postural Control Task - Validation Of A Novel Approach To Dual-Task Testing	2016	Plos One	11	8
672	Langhammer,Birgitta;Lindmark,Birgitta;Stanghelle,Johan K.	The Relation Between Gait Velocity And Static And Dynamic Balance In The Early Rehabilitation Of Patients With Acute Stroke	2006	Advances In Physiotherapy	8	2

Id	Authors	Title	Pub Year	Periodical	Vol	Issue
674	Lao,Miko L. M.;Chow,Daniel H. K.;Guo,Xia;Cheng,Jack C. Y.;Holmes,Andrew D.	Impaired Dynamic Balance Control In Adolescents With Idiopathic Scoliosis And Abnormal Somatosensory Evoked Potentials	2008	Journal Of Pediatric Orthopedics	28	8
675	Le Blanc,D.;French,R.;Shultz, B.	Static And Dynamic Balance Skills Of Trainable Children With Down's Syndrome	1977	Perceptual And Motor Skills	45	2
689	Leavey,Vincent J.;Sandrey,Michelle A.;Dahmer,Greg	Comparative Effects Of 6-Week Balance, Gluteus Medius Strength, And Combined Programs On Dynamic Postural Control	2010	Journal Of Sport Rehabilitation	19	3
690	Lee Bg, Lee Jh.	Immediate Effects Of Ankle Balance Taping With Kinesiology Tape On The Dynamic Balance Of Young Players With Functional Ankle Instability.	2015	Technol Health Care	23	3
696	Lee Dh, Lee Jh, Jeong Hj, Lee Sj.	Lack Of Correlation Between Dynamic Balance And Hamstring-To-Quadriceps Ratio In Patients With Chronic Anterior Cruciate Ligament Tears.	2015	Knee Surg Relat Res	27	2
711	Lee Jh.	Effects Of Forward Head Posture On Static And Dynamic Balance Control.	2016	J Phys Ther Sci	28	1
713	Lee,Dongjin;Ko,Taesung;Cho,Youmi	Effects On Static And Dynamic Balance Of Task-Oriented Training For Patients In Water Or On Land	2010	Journal Of Physical Therapy Science	22	3
729	Lee,Szu-Ping;Souza,Richard B.;Powers,Christopher M.	The Influence Of Hip Abductor Muscle Performance On Dynamic Postural Stability In Females With Patellofemoral Pain	2012	Gait & Posture	36	3

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730	Lemay,Jean-Francois;Duclos,Cyril;Nadeau,Sylvie;Gagnon,Dany;Desrosiers,Amilie	Postural And Dynamic Balance While Walking In Adults With Incomplete Spinal Cord Injury	2014	Journal Of Electromyography & Kinesiology	24	5
732	Liao, Ying-Yiyang, Yea-Rucheng, Shih-Jungwu, Yih-Rufuh, Jong-Lingwang, Ray-Yau	Virtual Reality–Based Training To Improve Obstacle-Crossing Performance And Dynamic Balance In Patients With Parkinson's Disease	2015	Neurorehabilitation & Neural Repair	29	7
734	Lim, H.S., Kim, Y.L., Lee, S.M.	The Effects Of Pilates Exercise Training On Static And Dynamic Balance In Chronic Stroke Patients: A Randomized Controlled Trial	2016	Journal Of Physical Therapy Science	28	6
735	Lim,Kyoung Il;Hwnagbo,Gak;Hyung Chun,N. A. M.;Cho,Yong Ho	Comparison Of The Effects On Dynamic Balance Ability Of Warming Up In Water Versus On The Ground	2014	Journal Of Physical Therapy Science	26	4
736	Liu,Kathy;Glutting,Joseph;Wikstrom,Erik;Gustavsen,Geoff;Royer,Todd;Kaminski,Thomas W.	Examining The Diagnostic Accuracy Of Dynamic Postural Stability Measures In Differentiating Among Ankle Instability Status	2013	Clinical Biomechanics	28	2
737	Lopes Pb, Pereira G, Lodovico A, Bento Pc, Rodacki Al.	Strength And Power Training Effects On Lower Limb Force, Functional Capacity, And Static And Dynamic Balance In Older Female Adults.	2016	Rejuvenation Res	3	
740	Lui,Tun Hing	Correlation Between Dynamic Postural Stability And Muscle Strength, Anterior Instability, And Knee Scale In Anterior Cruciate Ligament Deficient Knees	2010	Archives Of Orthopaedic And Trauma Surgery	130	8

Id	Authors	Title	Pub Year	Periodical	Vol	Issue
746	Lynn,Scott K.;Padilla,Ricardo A.;Tsang,Kavin K. W.	Differences In Static- And Dynamic-Balance Task Performance After 4 Weeks Of Intrinsic-Foot-Muscle Training: The Short-Foot Exercise Versus The Towel-Curl Exercise	2012	Journal Of Sport Rehabilitation	21	4
747	Lythgo,Noel;Marmaras,Bill;Connor,Helen	Physical Function, Gait, And Dynamic Balance Of Transfemoral Amputees Using Two Mechanical Passive Prosthetic Knee Devices	2010	Archives Of Physical Medicine & Rehabilitation	91	10
748	Maccracken,Mary Jo;Stadulis,Robert E.	Social Facilitation Of Young Children's Dynamic Balance Performance	1985	Journal Of Sport Psychology	7	2
749	Maciaszek,Janusz;Borawska,Sylwia;Wojcikiewicz,Jacek	Influence Of Posturographic Platform Biofeedback Training On The Dynamic Balance Of Adult Stroke Patients	2014	Journal Of Stroke And Cerebrovascular Diseases: The Official Journal Of National Stroke Association	23	6
752	Maciaszek, J., Osiński, W., & Szeklicki, R.	Age, Bmi, Psychomotor And Functional Fitness As Determinants Of Static And Dynamic Balance In Elderly Men With Osteopenia Or Osteoporosis	2006	Studies In Physical Culture & Tourism	13	1
758	Maeda Y., Tanaka T., Nakajima Y., Miyasaka T., Izumi T., Kato N.	Age-Related Changes In Dynamic Postural Control Ability In The Presence Of Sensory Perturbation	2015	Journal Of Medical And Biological Engineering	35	1
759	Maeda, N., Urabe, Y., Fujii, E., Moriyama, N., Iwata, S., Sasadai, J.	The Effect Of Different Stretching Techniques On Ankle Joint Range Of Motion And Dynamic Postural Stability After Landing	2016	Journal Of Sports Medicine And Physical Fitness	56	6

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760	Maeda,Noriaki;Urabe,Yukio;Tsutsumi,Shogo;Numano,Shuhei;Morita,Miho;Takeuchi,Takuya;Iwata,Shou;Kobayashi,Toshiki	Effect Of Semi-Rigid And Soft Ankle Braces On Static And Dynamic Postural Stability In Young Male Adults	2016	Journal Of Sports Science & Medicine	15	2
764	Maekawa,Maki;Fujiwara,Katsuo;Kiyota,Naoe;Yaguchi,Chie	Adaptation Changes In Dynamic Postural Control And Contingent Negative Variation During Repeated Transient Forward Translation In The Elderly	2013	Journal Of Physiological Anthropology	32	
766	Maldonado G, Bitard H, Watier B, Soueres P.	Evidence Of Dynamic Postural Control Performance In Parkour Landing.	2015	Comput Methods Biomech Biomed Engin	18	Suppl 1
767	Malling, A.S.B., Jensen, B.R.	Motor Intensive Anti-Gravity Training Improves Performance In Dynamic Balance Related Tasks In Persons With Parkinson's Disease	2016	Gait And Posture ,	43	
768	Malone A, Kiernan D, French H, Saunders V, O'brien T.	Obstacle Crossing During Gait In Children With Cerebral Palsy: Cross-Sectional Study With Kinematic Analysis Of Dynamic Balance And Trunk Control.	2016	Phys Ther	18	
769	Marandi,Sayyed Mohammad;Nejad,Vahid Shayegan;Shanazari,Zohreh;Zolaktaf,Vahid	A Comparison Of 12 Weeks Of Pilates And Aquatic Training On The Dynamic Balance Of Women With Mulitple Sclerosis	2013	International Journal Of Preventive Medicine	4	
774	Maranhao-Filho,Pa.; Maranhao,E;Lima,M;Silva,M	Rethinking The Neurological Examination Ii: Dynamic Balance Assessment	2011	Arquivos De Neuro-Psiquiatria	69	6

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775	Ochoa Martinez, P.Y., Hall López,Ja., Alarcón Meza,E, Rentería,I, Botelho Teixeira, Amm., Lara Zazueta,H, & Martin Dantas, E	Comparison Of Agility And Dynamic Balance In Elderly Women With Endomorphic Mesomorph Somatotype With Presence Or Absence Of Metabolic Syndrome	2012	International Journal Of Morphology	30	2
777	Matjacic,Z.;Burger,H.	Dynamic Balance Training During Standing In People With Trans-Tibial Amputation: A Pilot Study	2003	Prosthetics And Orthotics International	27	3
780	Matjacic,Z.;Zupan,A.	Effects Of Dynamic Balance Training During Standing And Stepping In Patients With Hereditary Sensory Motor Neuropathy	2006	Disability And Rehabilitation	28	23
782	Matjacic,Zlatko	Apparatus For Dynamic Balance Training During Treadmill Walking	2007	Journal Of Rehabilitation Medicine	39	1
784	Mattacola,Carl G.;Lloyd,John Wills	Effects Of A 6-Week Strength And Proprioception Training Program On Measures Of Dynamic Balance:..	1997	Journal Of Athletic Training (National Athletic Trainers' Association)	32	2
785	Mbongo,Fabienne;Huy,Tran Ba;Vidal,Pierre-Paul;De Waele,Catherine	Relationship Between Dynamic Balance And Self-Reported Handicap In Patients Who Have Unilateral Peripheral Vestibular Loss	2007	Otology & Neurotology	28	7
786	Mccrory,J. L.;Chambers,A. J.;Daftary,A.;Redfern,M. S.	Dynamic Postural Stability In Pregnant Fallers And Non-Fallers	2010	Bjog: An International Journal Of Obstetrics And Gynaecology	117	8
789	Mccrory,J. L.;Chambers,A. J.;Daftary,A.;Redfern,M. S.	Dynamic Postural Stability During Advancing Pregnancy	2010	Journal Of Biomechanics	43	12
790	Meardon S, Klusendorf A, Kernozek T.	Influence Of Injury On Dynamic Postural Control In Runners.	2016	Int J Sports Phys Ther	11	3

Id	Authors	Title	Pub Year	Periodical	Vol	Issue
792	Menayo,R.;Encarnacin,A.; Gea,G. M.;Marcos,P. J.	Sample Entropy-Based Analysis Of Differential And Traditional Training Effects On Dynamic Balance In Healthy People	2014	Journal Of Motor Behavior	46	2
793	Michael Pack,D.;Cotten,D. J.;Biasiotto,J.	Effect Of Four Fatigue Levels On Performance And Learning Of A Novel Dynamic Balance Skill	1974	Journal Of Motor Behavior	6	3
794	Miller,P. K.;Bird,A. M.	Localized Muscle Fatigue And Dynamic Balance	1976	Perceptual And Motor Skills	42	1
795	Miyake,Yuki;Nakamura,Shinichiro;Nakajima,Masaaki	The Effect Of Trunk Coordination Exercise On Dynamic Postural Control Using A Core Noodle	2014	Journal Of Bodywork And Movement Therapies	18	4
797	Mohammadi Rad S; Salavati M; Takamjani Ie; Akhbari B; Sherafat S; Negahban H; Lali P; Mazaheri M	Dual-Tasking Effects On Dynamic Postural Stability In Athletes With And Without Anterior Cruciate Ligament Reconstruction	2016	Journal Of Sport Rehabilitation	25	4
798	Mohammadi,F.;Taghizadeh,S.;Ghaffarinejad,F.;Khorrami,M.;Sobhani,S.	Proprioception, Dynamic Balance And Maximal Quadriceps Strength In Females With Knee Osteoarthritis And Normal Control Subjects	2008	International Journal Of Rheumatic Diseases	11	1
799	Mohammadi,F;Salavati,M; Akhbari,;Mazaheri,M; Khorrami,M; Negahban,H	Static And Dynamic Postural Control In Competitive Athletes After Anterior Cruciate Ligament Reconstruction	2012	Knee Surgery, Sports Traumatology, Arthroscopy	20	8
801	Montgomery,Roger E.;Hartley,Geoffrey L.;Tyler,Christopher J.;Cheung,Stephen S.	Effect Of Segmental, Localized Lower Limb Cooling On Dynamic Balance	2015	Medicine & Science In Sports & Exercise	47	1

Id	Authors	Title	Pub Year	Periodical	Vol	Issue
825	Moon,Dong-Chul;Kim,Kyoung;Lee,Su-Kyoung	Immediate Effect Of Short-Foot Exercise On Dynamic Balance Of Subjects With Excessively Pronated Feet	2014	Journal Of Physical Therapy Science	26	1
831	Moreau,M. S.;Cauquil,A. S.;Costes Salon,M.C.	Static And Dynamic Balance Function In Spasmodic Torticollis	1999	Movement Disorders: Official Journal Of The Movement Disorder Society	14	1
832	Muller,J.;Ebersbach,G.;Wissueel,J.;Brenneis,C.;Badry,L.;Poewe,W.	Disturbances Of Dynamic Balance In Phasic Cervical Dystonia	1999	Journal Of Neurology, Neurosurgery, And Psychiatry	67	6
837	Muller,J.;Ebersbach,G.;Wissueel,J.;Poewe,W.	Dynamic Balance Function In Phasic Cervical Dystonia Following Botulinum Toxin Therapy	2001	Movement Disorders	16	5
838	Nagai,Koutatsu;Yamada, Minoru;Mori,Shuhei;Tanaka,Buichi;Uemura,Kazuki;Aoyama,Tomoki;Ichihashi, Noriaki;Tsuboyama,Tadao	Effect Of The Muscle Coactivation During Quiet Standing On Dynamic Postural Control In Older Adults	2013	Archives Of Gerontology And Geriatrics	56	1
839	Nakajima,Mikiko A.;Baldridge,Carolann	The Effect Of Kinesio Tape On Vertical Jump And Dynamic Postural Control	2013	International Journal Of Sports Physical Therapy	8	4
841	Nakano, W., Fukaya, T., Kobayashi, S., Ohashi, Y.	Age Effects On The Control Of Dynamic Balance During Step Adjustments Under Temporal Constraints	2016	Human Movement Science	47	
843	Nederhand,Marc J.;Van Asseldonk,Edwin H. F.;Der Kooij,Herman Van;Rietman,Hans S.	Dynamic Balance Control (Dbc) In Lower Leg Amputee Subjects; Contribution Of The Regulatory Activity Of The Prosthesis Side	2012	Clinical Biomechanics	27	1

Id	Authors	Title	Pub Year	Periodical	Vol	Issue
844	Niu,Wenxin;Zhang,Ming;Fan,Yubo;Zhao,Qinping	Dynamic Postural Stability For Double-Leg Drop Landing	2013	Journal Of Sports Sciences	31	10
845	Nnodim,Jo.;Strasburg,D;Nabozny,M;Nyquist,L;Galecki,A;Chen,S;Alexander,N B.	Dynamic Balance And Stepping Versus Tai Chi Training To Improve Balance And Stepping In At-Risk Older Adults	2006	Journal Of The American Geriatrics Society	54	12
849	Nora E. Fritz, Dpt, Phd1,2, Rhul Evans R. Marasigan1, Peter A. Calabresi, Md2, Scott D. Newsome, Do2, And Kathleen M. Zackowski,	The Impact Of Dynamic Balance Measures On Walking Performance In Multiple Sclerosis	2015			
852	Norris E.S., Wallmann H.W.	Static And Dynamic Balance After Ankle Plantarflexor Fatigue In Older Adults	2016	Physical And Occupational Therapy In Geriatrics	34	1
854	Novak Ac, Komisar V, Maki Be, Fernie Gr.	Age-Related Differences In Dynamic Balance Control During Stair Descent And Effect Of Varying Step Geometry.	2016	Appl Ergon	52	
855	Nyland,J.;Smith,S.;Beickman,K.;Armsey,T.;Caborn,D. N. M.	Frontal Plane Knee Angle Affects Dynamic Postural Control Strategy During Unilateral Stance.	2002	Medicine & Science In Sports & Exercise	34	7
856	Oldham Jr, Munkasy Ba, Evans Km, Wikstrom Ea, Buckley Ta.	Altered Dynamic Postural Control During Gait Termination Following Concussion.	2016	Gait Posture. 2016		
859	Olivier,B.;Stewart,A. V.;Olorunju,S. A. S.;Mckinon,W.	Static And Dynamic Balance Ability, Lumbo-Pelvic Movement Control And Injury Incidence In Cricket Pace Bowlers	2015	Journal Of Science And Medicine In Sport / Sports Medicine Australia		

Id	Authors	Title	Pub Year	Periodical	Vol	Issue
864	Olmsted,Lauren C.;Hertel,Jay	Influence Of Foot Type And Orthotics On Static And Dynamic Postural Control	2004	Journal Of Sport Rehabilitation	13	1
865	Olson,Sharon L.;Shu-Shi Chen;Ching-Yi Wang	Effect Of A Home Exercise Program On Dynamic Balance In Elderly With A History Of Falls	2011	Journal Of Aging & Physical Activity	19	4
866	Onigbinde,Ayodele Teslim;Awotidebe,Taofeek;Awosika,Henry	Effect Of 6 Weeks Wobble Board Exercises On Static And Dynamic Balance Of Stroke Survivors	2009	Technology And Health Care: Official Journal Of The European Society For Engineering And Medicine	17	####
868	Ortuno-Cortes,M. A.;Martin-Sanz,E.;Barona-De Guzman,R.	Value Of Dynamic Postural Control Tests On Elderly People With Vestibulopathy	2009	Acta Otorrinolaringologica Espanola	60	3
870	Oshita K, Yano S.	The Effect Of Lightly Gripping A Cane On The Dynamic Balance Control.	2015	Open Biomed Eng J	9	
871	Ozmen, T., Aydogmus, M.	Effect Of Core Strength Training On Dynamic Balance And Agility In Adolescent Badminton Players	2015	Journal Of Bodywork And Movement Therapies	20	3
873	Ozrudi, Mf; Aliabadi, Sr; Barzegari, H	The Effect Of Six Week Mixed Exercise (Power & Plyometric) Of Dynamic Balance In Takhti School Physical Education Students In Babol City	2015	International Journal Of Applied Exercise Physiology	4	2
874	Paillard,T.;Lafont,C.;Costessalon,M.;Riviãƒâ¨Re,D.;Dupui,P.	Effects Of Brisk Walking On Static And Dynamic Balance, Locomotion, Body Composition, And Aerobic Capacity In Ageing Healthy Active Men	2004	International Journal Of Sports Medicine	25	7
876	Palumbo,Nicole;George,Brad;Johnson,Amanda;Cade,Dennis	The Effects Of Backpack Load Carrying On Dynamic Balance As Measured By Limits Of Stability	2001	Work (Reading, Mass.)	16	2

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877	Pan, Tao; Liao, Ke; Roenigk, Kristen; Daly, Janis J.; Walker, Mark F	Static And Dynamic Postural Stability In Veterans With Combat-Related Mild Traumatic Brain Injury	2015	Gait & Posture	42	4
879	Panjan A., Supej M., Rosker J., Sarabon N.	Reliability And Sensitivity Of A Novel Dynamic Balance Test For Alpine Skiers	2016	Measurement: Journal Of The International Measurement Confederation	85	
880	Park, M.H.A, Yu, J.H.A, Hong, J.H.A, Kim, J.S.A, Jung, S.W.B, Lee, D.Y.A	Effect Of Core Muscle Thickness And Static Or Dynamic Balance On Prone Bridge Exercise With Sling By Shoulder Joint Angle In Healthy Adults	2016	Journal Of Physical Therapy Science	28	3
881	Park,Seol;Yu-Min,K. O.;Ji-Won Park	The Correlation Between Dynamic Balance Measures And Stance Sub-Phase Cop Displacement Time In Older Adults During Obstacle Crossing	2013	Journal Of Physical Therapy Science	25	9
882	Patterson,Matthew R.;Delahunt,Eamonn	A Diagonal Landing Task To Assess Dynamic Postural Stability In Acl Reconstructed Females	2013	The Knee	20	6
883	Patton,J. L.;Pai,Y.;Lee,W. A.	Evaluation Of A Model That Determines The Stability Limits Of Dynamic Balance	1999	Gait & Posture	9	1
884	Pau,M;Arippa,F;Leban,B; Corona,F;Ibba,G;Todde,F; Scorcu,M	Relationship Between Static And Dynamic Balance Abilities In Italian Professional And Youth League Soccer Players	2015	Physical Therapy In Sport	16	3
887	Pau,Massimiliano;Mereu, Federico;Melis,Marco;Leban,Bruno;Corona,Federica ;Ibba,Gianfranco	Dynamic Balance Is Impaired After A Match In Young Elite Soccer Players	2016	Physical Therapy In Sport	22	11

Id	Authors	Title	Pub Year	Periodical	Vol	Issue
888	Penman,K. A.	A New Dynamic Balance Testing Device: The "Dynabalometer"	1966	Perceptual And Motor Skills	23	1
889	Perrin,P. P.;Jeandel,C.;Perrin,C. A.;Bãƒâ©Nãƒâ©,M.C.	Influence Of Visual Control, Conduction, And Central Integration On Static And Dynamic Balance In Healthy Older Adults	1997	Gerontology	43	4
890	Perry,Stephen D.;Radtke,Alison;Goodwin,Chris R.	Influence Of Footwear Midsole Material Hardness On Dynamic Balance Control During Unexpected Gait Termination	2007	Gait & Posture	25	1
892	Pfile Kr, Gribble Pa, Buskirk Ge, Meserth Sm, Pietrosimone Bg.	Sustained Improvements In Dynamic Balance And Landing Mechanics Following A 6-Week Neuromuscular Training Program In Collegiate Female Basketball Players.	2015	J Sport Rehabil	9	
893	Piedrahita,Hugo;Oksa,Juha;Rintami,Hannu;Malm,Christer	Effect Of Local Leg Cooling On Upper Limb Trajectories And Muscle Function And Whole Body Dynamic Balance	2009	European Journal Of Applied Physiology	105	3
903	Piirainen,JM.;Avela,J; Sippola,N;Linnamo,V	Age Dependency Of Neuromuscular Function And Dynamic Balance Control	2010	European Journal Of Sport Science	10	1
906	Piirainen,Jarmo M.;Cronin,Neil J.;Avela,Janne;Linnamo,Vesa	Effects Of Plyometric And Pneumatic Explosive Strength Training On Neuromuscular Function And Dynamic Balance Control In 60-70year Old Males	2014	Journal Of Electromyography & Kinesiology	24	2
908	Piirainen,Jarmo M.;Linnamo,Vesa;Cronin, Neil J.;Avela,Janne	Age-Related Neuromuscular Function And Dynamic Balance Control During Slow And Fast Balance Perturbations	2013	Journal Of Neurophysiology	110	11
910	Pionnier, R; Découfour, N; Barbier, F; Popineau, C; Simoneau-Buessinger,E	A New Approach Of The Star Excursion Balance Test To Assess Dynamic Postural Control In People Complaining From Chronic Ankle Instability	2016	Gait & Posture	45	

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911	Poliszczuk,Tatiana;Broda, Daria;Poliszczuk,Dmytro	Changes In Somatic Parameters And Dynamic Balance In Female Rhythmic Gymnasts Over A Space Of Two Years	2012	Polish Journal Of Sport & Tourism	19	4
912	Pompeu,Josa Eduardo;Romano,Renata Sorroche Loureno;Pompeu,Sandra Maria Alvarenga Anti;Lima,S	Static And Dynamic Balance In Subjects With Ankylosing Spondylitis: Literature Review	2012	Revista Brasileira De Reumatologia	52	3
914	Pozzi F, Moffat M, Gutierrez G.	Neuromuscular Control During Performance Of A Dynamic Balance Task In Subjects With And Without Ankle Instability.	2015	Int J Sports Phys Ther	10	4
915	Proffitt,Rachel;Lange,Belinda;Chen,Christina;Winstein,Carolee	A Comparison Of Older Adults' Subjective Experiences With Virtual And Real Environments During Dynamic Balance Activities	2015	Journal Of Aging & Physical Activity	23	1
917	Prpic,T; Tudor,A; Ruziic, L; Sestan,B; Canaki,M; Gulan,G; Prpic,M; Madarevic,T; Legovic,D; Rakovac,I	The Influence Of Test Repetition On Bipodal Visually Controlled Static And Dynamic Balance	2010	Collegium Antropologicum	34 Suppl 1	
918	Psalman,Vladimar	Dynamic Balance And Its Diagnostics By Using 3d Biomechanical Analysis.	2008	Facta Universitatis: Series Physical Education & Sport	6	2
920	Jelsma,Dorothee;Geuze,Reint H.; Mombarg,Remo;Smits-Engelsman,Bouwien	The Impact Of Wii Fit Intervention On Dynamic Balance Control In Children With Probable Developmental Coordination Disorder And Balance Problems	2014	Human Movement Science	33	

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921	Punakallio,A.	Trial-To-Trial Reproducibility And Test-Retest Stability Of Two Dynamic Balance Tests Among Male Firefighters	2004	International Journal Of Sports Medicine	25	3
925	Purohit,Roma, Dilip;Sadhale,Aparna	Co-Relation Between Static And Dynamic Balance In Healthy Individuals Between 18-25 Years Using One Leg Stance Test And Multi Directional Reach Test	2014	Indian Journal Of Physiotherapy & Occupational Therapy	8	2
926	Rad,Amir Ghiami;Abdolvahhabi,Zahra;Zadeh,Nasrin Golmagni	The Effects Of Ankle Plantar Flexor And Knee Extensor Muscles Fatigue On Dynamic Balance Of The Female Elderly	2010	Ovidius University Annals, Series Physical Education & Sport/Science, Movement & Health	10	2
928	Ragab,Marwan;Alfailakawi,Ahmed	Eye Movements And Dynamic Balance Between Egyptian Handball Players And Kuwaiti Handball Players	2016	Ovidius University Annals, Series Physical Education & Sport/Science, Movement & Health	16	1
929	Rahal Ma, Alonso Ac, Andrusaitis Fr, Rodrigues Ts, Speciali Ds, Greve Jm, Leme Le.	Analysis Of Static And Dynamic Balance In Healthy Elderly Practitioners Of Tai Chi Chuan Versus Ballroom Dancing.	2015	Clinics (Sao Paulo)	70	3
936	Rasool,J.;George,K.	Get The Balance Right: The Star Excursion Balance Test (Sebt) And Single-Leg Dynamic Balance Training	2009	Sportex Medicine		41
937	Rasool,Jaffar;George,Keith	The Impact Of Single-Leg Dynamic Balance Training On Dynamic Stability	2007	Physical Therapy In Sport	8	4
940	Rasouli, Omid; Stensdotter, Ann-Katrin; Van Der Meer, Audrey L. H.	Taug-Guidance Of Dynamic Balance Control During Gait Initiation In Patients With Chronic Fatigue Syndrome And Fibromyalgia	2016	Clinical Biomechanics	37	

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942	Raty,H.P.;Impivaara,O.;Karppi,S-L	Dynamic Balance In Former Elite Male Athletes And In Community Control Subjects	2002	Scandinavian Journal Of Medicine & Science In Sports	12	2
943	Remaud A; Thuong-Cong C; Bilodeau M	Age-Related Changes In Dynamic Postural Control And Attentional Demands Are Minimally Affected By Local Muscle Fatigue	2016	Frontiers In Aging Neuroscience	7	
944	Remelius,J. G.;Hamill,J.;Van Emmerik, R. E. A.	Prospective Dynamic Balance Control During The Swing Phase Of Walking: Stability Boundaries And Time-To-Contact Analysis	2014	Human Movement Science	36	
945	Rendon,Abel Angel;Lohman,Everett B.;Thorpe,Donna;Johnson, Eric G.;Medina,Ernie;Bradley,Bruce	The Effect Of Virtual Reality Gaming On Dynamic Balance In Older Adults	2012	Age And Ageing	41	4
946	Khasawneh A.	Anthropometric Measurements And Their Relation To Static And Dynamic Balance Among Junior Tennis Players	2015	Sport Science	8	
948	Reynard,F.;Terrier,P.	Role Of Visual Input In The Control Of Dynamic Balance: Variability And Instability Of Gait In Treadmill Walking While Blindfolded	2014	Experimental Brain Research		
949	Ribadi,Hani;Rider,Robert A.;Toole,Tonya	A Comparison Of Static And Dynamic Balance In Congenitally Blind, Sighted, And Sighted Blindfolded Adolescents	1987	Adapted Physical Activity Quarterly	4	3
950	Ricotti,Leonardo	Static And Dynamic Balance In Young Athletes	2011	Journal Of Human Sport & Exercise	6	4

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951	Ring,C.;Matthews,R.;Nayak,U. S.;Isaacs,B.	Visual Push: A Sensitive Measure Of Dynamic Balance In Man	1988	Archives Of Physical Medicine And Rehabilitation	69	4
954	Roberston,S.;Collins,J.;Elliott,D.;Starkes,J.	The Influence Of Skill And Intermittent Vision On Dynamic Balance	1994	Journal Of Motor Behavior	26	4
955	Robertson,S.;Elliott,D.	Specificity Of Learning And Dynamic Balance	1996	Research Quarterly For Exercise & Sport	67	1
957	Robertson,S.;Elliott,D.	The Influence Of Skill In Gymnastics And Vision On Dynamic Balance (Influence Du Niveau De Competence En Gymnastique Et De La Vision Sur L'equilibre Dynamique)	1996	International Journal Of Sport Psychology	27	4
958	Rodriguez Lopez,S;Nilsson,C;Lund,R;Montero,P;Fernãndez-Ballesteros,R;Avlund,K	Social Inequality In Dynamic Balance Performance In An Early Old Age Spanish Population: The Role Of Health And Lifestyle Associated Factors	2012	Archives Of Gerontology And Geriatrics	54	2
960	Rogers,Helen L.;Cromwell,Ronita L.;Grady,James L.	Adaptive Changes In Gait Of Older And Younger Adults As Responses To Challenges To Dynamic Balance	2008	Journal Of Aging & Physical Activity	16	1
961	Rogers,M. W.;Hedman,L. D.;Johnson,M. E.;Cain,T. D.;Hanke,T. A.	Lateral Stability During Forward-Induced Stepping For Dynamic Balance Recovery In Young And Older Adults	2001	The Journals Of Gerontology.Series A, Biological Sciences And Medical Sciences	56	9
962	Rome,K.;Dixon,J.;Gray,M.;Woodley,R.	Evaluation Of Static And Dynamic Postural Stability In Established Rheumatoid Arthritis: Exploratory Study	2009	Clinical Biomechanics	24	6
963	Ross,S. E.;Guskiewicz,K. M.	Research Digest. Time To Stabilization: A Method For Analyzing Dynamic Postural Stability	2003	Athletic Therapy Today	8	3

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964	Ross,Scott E.;Guskiewicz,Kevin M.	Examination Of Static And Dynamic Postural Stability In Individuals With Functionally Stable And Unstable Ankles	2004	Clinical Journal Of Sport Medicine	14	6
966	Roth,AE.;Miller,MG.;Ricard,M;Ritenour,D;Chapman,BL.	Comparisons Of Static And Dynamic Balance Following Training In Aquatic And Land Environments	2006	Journal Of Sport Rehabilitation	15	4
968	Row,Brandi S.;Cavanagh,Peter R.	Reaching Upward Is More Challenging To Dynamic Balance Than Reaching Forward	2007	Clinical Biomechanics	22	2
970	Rowe,A.;Wright,S.;Nyland,J.;Caborn,D. N. M.;Kling,R.	Effect Of A 2-Hour Cheerleading Practice On Dynamic Postural Stability, Knee Laxity, And Hamstring Extensibility	1999	Journal Of Orthopaedic & Sports Physical Therapy	29	8
971	Rugelj D.	The Relationship Between Innervation Density And Dynamic Balance Function.	2002	Cell Mol Biol Lett	7	1
972	Sabzi,A. H.;Vaezmousavi;Mokhtari,P.	Arousal And Activation In A Dynamic Balance Task	2012	Middle East Journal Of Scientific Research	12	3
973	Saito K, Miyakoshi N, Matsunaga T, Hongo M, Kasukawa Y, Shimada Y.	Eldecalcitol Improves Muscle Strength And Dynamic Balance In Postmenopausal Women With Osteoporosis: An Open-Label Randomized Controlled Study.	2016	J Bone Miner Metab	25	
974	Salavati, M., Akhbari, B., Takamjani, I.E., Bagheri, H., Ezzati, K., Kahlaee, A.H	Effect Of Spinal Stabilization Exercise On Dynamic Postural Control And Visual Dependency In Subjects With Chronic Non-Specific Low Back Pain	2015	*Journal Of Bodywork And Movement Therapies*	20	2
975	Salek S., Bahrpeyma F., Mohajeri-Tehrani M.-R.	Intermittent Pneumatic Compression Therapy Improves Functional And Dynamic Balance And Neuropathy Severity In Neuropathic Patients With Type 2 Diabetes	2015	International Journal Of Diabetes In Developing Countries	35	

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976	Samaan M.A., Greska E.K., Hoch M.C., Weinhandl J.T., Bawab S.Y., Ringleb S.I.	Dynamic Postural Control Two Years Following Anterior Cruciate Ligament Reconstruction In A Female Collegiate Soccer Player	2015	International Journal Of Athletic Therapy And Training	20	2
977	Sandrey,Michelle A.;Mitzel,Jonathan G.	Improvement In Dynamic Balance And Core Endurance After A 6-Week Core-Stability-Training Program In High School Track And Field Athletes	2013	Journal Of Sport Rehabilitation	22	4
978	Sangyong,L. E. E.;Daehee,L. E. E.;Park,Jungseo	Effects Of Extracorporeal Shockwave Therapy On Patients With Chronic Low Back Pain And Their Dynamic Balance Ability	2014	Journal Of Physical Therapy Science	26	1
979	Sarabon,N.;Mlaker,B.;Markovic,G.	A Novel Tool For The Assessment Of Dynamic Balance In Healthy Individuals	2010	Gait And Posture	31	2
980	Sarabon,N.;Zacirkovnik,T.;Rosker,J.;Loefler,S.	Metric Characteristics Of The Tests For Dynamic Balance Evaluation	2013	Physikalische Medizin Rehabilitationsmedizin Kurortmedizin	23	3
982	Sarshin,A;Mohammadi,S;Shahrabad,HBP;Sedighi,M	The Effects Of Functional Fatique On Dynamic Postural Control Of Badminton Players	2011	Biology Of Exercise	7	2
983	Sarvestani,H. J.;Tabrizi,H. B.;Abbasi,A.;Rahmanpour moghaddam,J.	The Effect Of Eight Weeks Aquatic Balance Trainingand Core Stabilization Training On Dynamic Balance In Inactive Elder Males	2012	Middle East Journal Of Scientific Research	11	3
984	Sarvestani,H. J.;Tabrizi,H. B.;Abbasi,A.;Rahmanpour moghaddam,J.	The Effect Of Ten Weeks Aquatic Balance Training and Functional Training On Dynamic Balance In Inactive Elder Males	2012	Middle East Journal Of Scientific Research	11	3

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985	Schaefer,Jessica L.;Sandrey,Michelle A.	Effects Of A 4-Week Dynamic-Balance-Training Program Supplemented With Graston Instrument-Assisted Soft-Tissueue Mobilization For Chronic Ankle Instability	2012	Journal Of Sport Rehabilitation	21	4
986	Schmidt D, Germano Am, Milani Tl.	Aspects Of Dynamic Balance Responses: Inter- And Intra-Day Reliability.	2015	Plos One	10	9
987	Schmitz,Randy;Arnold,Brent	Intertester And Intratester Reliability Of A Dynamic Balance Protocol Using The Biodex Stability..	1998	Journal Of Sport Rehabilitation	7	2
988	Sell,TC.;Pederson,JJ.;Abt,JP.;Nagai,T;Deluzio,J;Wirt,MD.;Mccord,LJ.;Lephart,S.	The Addition Of Body Armor Diminishes Dynamic Postural Stability In Military Soldiers	2013	Military Medicine	178	1
989	Seo K, Park Sh, Park K.	The Effects Of Stair Gait Training Using Proprioceptive Neuromuscular Facilitation On Stroke Patients' Dynamic Balance Ability.	2015	J Phys Ther Sci	27	5
990	Seo Kc, Kim Ha.	The Effects Of Ramp Gait Exercise With Pnf On Stroke Patients' Dynamic Balance.	2015	J Phys Ther Sci	27	6
991	Seo-Hyun Jeonsuk-Min Leejung-Hyun Kim	Therapeutic Effects Of Reaching With Forward Bending Of Trunk On Postural Stability, Dynamic Balance, And Gait In Individuals With Chronic Hemiparetic Stroke	2015	Journal Of Physical Therapy Science	27	8
994	Sesma, A.R.;Mattacola,C.G..;Uhl,T.J..;Nitz, A.J.;Mceon,P.O.	Effect Of Foot Orthotics On Single-And Double-Limb Dynamic Balance Tasks In Patients With Chronic Ankle Instability	2010	Foot And Ankle Specialist		
995	Séverac, Alexandra ; Bessou, Paul ; Pagès, Bernard	Unusual Visual Stimulation In Dynamic Balance Conditions: Proposal For A Space Motion Sickness Test	1994	Advances In Space Research	14	8

Id	Authors	Title	Pub Year	Periodical	Vol	Issue
997	Jelsma D, Ferguson Gd, Smits-Engelsman Bc, Geuze Rh.	Short-Term Motor Learning Of Dynamic Balance Control In Children With Probable Developmental Coordination Disorder.	2015	Res Dev Disabil	38	
998	Sherafat,Shiva;Salavati,Mahyar;Takamjani,Ismail Ebrahimi;Akhbari,Behnam;Rad,Shahrzad Mohammadi;Mazaheri,Masood;Negahben,Hossein;Lali,Pezhman	Effect Of Dual-Tasking On Dynamic Postural Control In Individuals With And Without Nonspecific Low Back Pain	2014	Journal Of Manipulative And Physiological Therapeutics	37	3
1000	Shimada,H.;Obuchi,S.;Kamide,N.;Shiba,Y.;Okamoto,M.;Kakurai,S.	Relationship With Dynamic Balance Function During Standing And Walking	2003	American Journal Of Physical Medicine & Rehabilitation	82	7
1001	Shin,Sohee;Demura,Shinichi	Effective Tempo Of The Step Test For Dynamic Balance Ability In The Elderly	2007	Journal Of Physiological Anthropology	26	6
1004	Siddiqui,Tarannum;Sharma,Amit;Gupta,Ruchika;Ram,C. S.	Effect Of Flexible Flatfoot On Static And Dynamic Balance In School Going Children	2016	Indian Journal Of Physiotherapy & Occupational Therapy	10	3
1005	Simon, A.L., Ilharreborde, B., Souchet, P., Kaufman, K.R.	Dynamic Balance Assessment During Gait In Spinal Pathologies - A Literature Review	2015	Orthopaedics And Traumatology: Surgery And Research ,	101	2
1006	Simon,Janet;Donahue,Matt	Effect Of Ankle Taping Or Bracing On Creating An Increased Sense Of Confidence, Stability, And Reassurance When Performing A Dynamic-Balance Task	2013	Journal Of Sport Rehabilitation	22	3
1009	Simoneau,Martin;Bãƒâ©Gin,Franãƒâ§Ois;Teasdale,Normand	The Effects Of Moderate Fatigue On Dynamic Balance Control And Attentional Demands	2006	Journal Of Neuroengineering And Rehabilitation	3	

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1010	Simpson,J. M.;Worsfold,C.;Reilly,E.;Nye,N.	A Standard Procedure For Using Turn180: Testing Dynamic Postural Stability Among Elderly People	2002	Physiotherapy	88	6
1011	Si-Nae Jeonjung-Hyun Choi	The Effects Of Ankle Joint Strategy Exercises With And Without Visual Feedback On The Dynamic Balance Of Stroke Patients	2015	Journal Of Physical Therapy Science	27	8
1012	Sofianidis,Giorgos;Hatzitaki,Vassilia;Douka,Stella;Grouios,Giorgos	Effect Of A 10-Week Traditional Dance Program On Static And Dynamic Balance Control In Elderly Adults	2009	Journal Of Aging & Physical Activity	17	2
1014	Song,Jooeun;Sigward,Susan;Fisher,Beth;Salem,George J.	Altered Dynamic Postural Control During Step Turning In Persons With Early-Stage Parkinson's Disease	2012	Parkinson's Disease	2012	
1015	Souissuei,Nafaa;Zouita,Amira;Chtourou,Hamdi;Ferchichi,Hbiba;Dziri,Catherine;Abedelmalek,Salma;Souissuei,Nizar	The Effect Of Ramadan Intermittent Fasting On Dynamic Postural Control In Judo Athletes	2014	Biological Rhythm Research	45	1
1016	Spencer,Lynn-Mari;Van,Der Meer	Taug-Guidance Of Dynamic Balance Control During Gait Initiation Across Adulthood	2012	Gait & Posture	36	3
1017	Steib,Simon;Zech,Astrid;Hentschke,Christian;Pfeifer,Klaus	Fatigue-Induced Alterations Of Static And Dynamic Postural Control In Athletes With A History Of Ankle Sprain	2013	Journal Of Athletic Training (Allen Press)	48	2
1018	Steiner, KM; Enders, A; Thier, W; Batsikadze, G; Ludolph, N; Ilg, W; Timmann, D	Cerebellar Tdcs Does Not Improve Learning In A Complex Whole Body Dynamic Balance Task In Young Healthy Subjects	2016	Plos One	11	9
1020	Streepey,J. W.;Angulo-Kinzler,R.	The Role Of Task Difficulty In The Control Of Dynamic Balance In Children And Adults	2002	Human Movement Science	21	4

Id	Authors	Title	Pub Year	Periodical	Vol	Issue
1022	Sullivan B, Harding Ag, Dingley J, Gras Lz.	Improvements In Dynamic Balance Using An Adaptive Snowboard With The Nintendo Wii.	2012	Games Health J	1	4
1023	Sung Min,S. O. N.;Myung,Kyu Park;Na Kyung,L. E. E.	Influence Of Resistance Exercise Training To Strengthen Muscles Across Multiple Joints Of The Lower Limbs On Dynamic Balance Functions Of Stroke Patients	2014	Journal Of Physical Therapy Science	26	8
1029	Suttie,S. J.	Differential Effects Of Viewing Four Patterns Of Figure Movement On Performance Of A Dynamic Balance Task	1973	Perceptual And Motor Skills	37	1
1030	Tabrizi,H. B.;Abbasi,A.;Sarvestani,H. J.	Comparing The Static And Dynamic Balances And Their Relationship With The Anthropometrical Characteristics In The Athletes Of Selected Sports	2013	Middle East Journal Of Scientific Research	15	2
1031	Takacs J, Carpenter Mg, Garland Sj, Hunt Ma.	Factors Associated With Dynamic Balance In People With Knee Osteoarthritis.	2015	Arch Phys Med Rehabil	96	10
1033	Takacs,Judit;Carpenter,Mark G.;Garland,S. J.;Hunt,Michael A.	The Role Of Neuromuscular Changes In Aging And Knee Osteoarthritis On Dynamic Postural Control	2013	Aging And Disease	4	2
1034	Takatori K, Matsumoto D.	Relationships Between Simple Toe Elevation Angle In The Standing Position And Dynamic Balance And Fall Risk Among Community-Dwelling Older Adults.	2015	Pm R	7	10
1035	Takeshima,N;Islam,MM.; Rogers,ME.;Koizumi,D; Tomiyama,N;Narita,M; Rogers,NL.	Pattern Of Age-Associated Decline Of Static And Dynamic Balance In Community-Dwelling Older Women	2014	Geriatrics & Gerontology International	14	3

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1036	Terada,Masafumi;Harkey, Matthew S.;Wells,Ashley M.;Pietrosimone,Brian G.;Gribble,Phillip A.	The Influence Of Ankle Dorsiflexion And Self-Reported Patient Outcomes On Dynamic Postural Control In Participants With Chronic Ankle Instability	2014	Gait & Posture	40	1
1037	Teyhen,DS.;Shaffer,SW.; Lorenson,CL.;Greenberg, MD.;Rogers,SM.;Koreerat, CM.;Villena,SL.;Zosel,KL.; Walker,MJ.;Childs,J	Clinical Measures Associated With Dynamic Balance And Functional Movement	2014	Journal Of Strength & Conditioning Research (Lippincott Williams & Wilkins)	28	5
1038	Tomomitsu,M.S.;Alonso,A C.;Morimoto,E.; Bobbio,T. G.;Greve,J. M.	Static And Dynamic Postural Control In Low-Vision And Normal-Vision Adults	2013	Clinics (Sãƒâ£O Paulo, Brazil)	68	4
1040	Toshi Teruya,T;Machado Matareli,B;Soares Romano,F;Mochizuki,L	The Effect Of A Silicone Wristband In Dynamic Balance	2013	Perceptual & Motor Skills	117	2
1041	Toulotte,Claire;Thevenon, Andre;Fabre,Claudine	Effects Of Training And Detraining On The Static And Dynamic Balance In Elderly Fallers And Non-Fallers: A Pilot Study	2006	Disability & Rehabilitation	28	2
1042	Trampas,Athanasios;Mpeneka,Anastasia;Malliou,Vivian;Godolias,George;Vlachakis,Periklis	Immediate Effects Of Core Stability Exercises And Clinical Massage On Dynamic Balance Performance Of Patients With Chronic Specific Low Back Pain	2014	Journal Of Sport Rehabilitation		
1043	Trousil,T.;Dvir,Z.	Dynamic Balance: A Learning Strategy	1983	Human Movement Science	2	3
1044	Tsang,William W. N.;Hui-Chan,Christina	Static And Dynamic Balance Control In Older Golfers	2010	Journal Of Aging & Physical Activity	18	1
1047	Tsigilis,N.;Zachopoulou,E.; Mavridis,Th	Evaluation Of The Specificity Of Selected Dynamic Balance Tests	2001	Perceptual & Motor Skills	92	3

Id	Authors	Title	Pub Year	Periodical	Vol	Issue
1050	Tsigkanos C, Gaskell L, Smirniotou A, Tsigkanos G	Static And Dynamic Balance Deficiencies In Chronic Low Back Pain.	2016	J Back Musculoskelet Rehabil	29	4
1052	Tsimaras,Vasileios K.;Giamouridou,Genovefa A.;Kokaridas,Dimitrios G.;Sidiropoulou,Maiua P.;Patsiaouras,Asterios I.	The Effect Of A Traditional Dance Training Program On Dynamic Balance Of Individuals With Mental Retardation	2012	Journal Of Strength & Conditioning Research (Lippincott Williams & Wilkins)	26	1
1053	Tsimaras,Vassilios K.;Fotiadou,Eleni G.	Effect Of Training On The Muscle Strength And Dynamic Balance Ability Of Adults With Down Syndrome	2004	Journal Of Strength & Conditioning Research (Allen Press Publishing Services Inc.)	18	2
1054	Abaraogu, Ukachukwu Okoroafor; Opara, Michael Chibuike	Depression And Dynamic Balance Recovery Among Stroke Survivors: A Preliminary Investigation	2016	Polish Annals Of Medicine	24	2
1057	Uritani D, Fukumoto T, Matsumoto D, Shima M.	The Relationship Between Toe Grip Strength And Dynamic Balance Or Functional Mobility Among Community-Dwelling Older Japanese People: A Cross-Sectional Study.	2016	J Aging Phys Act	18	
1061	Vallabhajosula,Srikant;Roberts,Beverly L.;Hass,Chris J.	Tai Chi Intervention Improves Dynamic Postural Control During Gait Initiation In Older Adults: A Pilot Study	2014	Journal Of Applied Biomechanics	30	6
1064	Vistamehr, A.A, Kautz, S.A.Bc, Bowden, M.G.Bc, Neptune, R.R	Correlations Between Measures Of Dynamic Balance In Individuals With Post-Stroke Hemiparesis	2016	Journal Of Biomechanics	49	3
1065	Vistamehr,Arian;Kautz,Steven A.;Neptune,Richard R.	The Influence Of Solid Ankle-Foot-Orthoses On Forward Propulsion And Dynamic Balance In Healthy Adults During Walking	2014	Clinical Biomechanics	29	5

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1066	Wakano,Shimpachi;Takeda,Tomotaka;Nakajima,Kazunori;Kurokawa,Katsuhide;Ishigami,Keiichi	Effect Of Experimental Horizontal Mandibular Deviation On Dynamic Balance	2011	Journal Of Prosthodontic Research	55	4
1067	Walker, Eric R.; Hyngstrom, Allison S.; Schmit, Brian D	Influence Of Visual Feedback On Dynamic Balance Control In Chronic Stroke Survivors	2016	Journal Of Biomechanics	49	5
1069	Wang H, Huo M, Guan P, Onoda K, Chen D, Huang Q, Maruyama H.	Effect Of Progressive Resistance Exercise With Neuromuscular Joint Facilitation On The Dynamic Balance Performance Of Junior Soccer Players.	2015	J Phys Ther Sci	27	11
1070	Wang,Ling-Yi;Liaw,Mei-Yun;Huang,Yu-Chi;Lau,Yiu-Chung;Leong,Chau-Peng;Pong,Ya-Ping;Chen,Chia-Lin	Static And Dynamic Balance Performance In Patients With Osteoporotic Vertebral Compression Fracture	2013	Journal Of Back & Musculoskeletal Rehabilitation	26	2
1075	Wegener,L.;Kisner,C.;Nichols,D.	Static And Dynamic Balance Responses In Persons With Bilateral Knee Osteoarthritis	1997	Journal Of Orthopaedic & Sports Physical Therapy	25	1
1076	Wernick-Robinson,M.;Krebs,D. E.;Giorgetti,M. M.	Functional Reach: Does It Really Measure Dynamic Balance?	1999	Archives Of Physical Medicine And Rehabilitation	80	3
1078	Whyte E, Burke A, White E, Moran K.	A High-Intensity, Intermittent Exercise Protocol And Dynamic Postural Control In Men And Women.	2015	J Athl Train	50	4
1087	Wikstrom,E. A.;Tillman,M. D.;Chmielewski,T. L.;Cauraugh,J. H.;Naugle,K. E.;Borsa,P. A.	Dynamic Postural Control But Not Mechanical Stability Differs Among Those With And Without Chronic Ankle Instability	2010	Scandinavian Journal Of Medicine & Science In Sports	20	1

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1090	Wikstrom,Erik A.;Arrigenna,Mark A.;Tilman,Mark D.;Borsa,Paul A.	Dynamic Postural Stability In Subjects With Braced, Functionally Unstable Ankles	2006	Journal Of Athletic Training (National Athletic Trainers' Association)	41	3
1093	Wikstrom,Erik A.;Tillman,Mark D.;Chmielewski,Terese L.;Cauraugh,James H.;Borsa,Paul A.	Dynamic Postural Stability Deficits In Subjects With Self-Reported Ankle Instability	2007	Medicine & Science In Sports & Exercise	39	3
1095	Wikstrom,Erik A.;Tillman,Mark D.;Kline,Kai J.;Borsa,Paul A.	Gender And Limb Differences In Dynamic Postural Stability During Landing	2006	Clinical Journal Of Sport Medicine	16	4
1096	Wikstrom,Erik A.;Tillman,Mark D.;Schenker,Scott M.;Borsa,Paul A.	Jump-Landing Direction Influences Dynamic Postural Stability Scores	2008	Journal Of Science & Medicine In Sport	11	2
1099	Wikstrom,Erik A.;Tillman,Mark D.;Smith,Andrew N.;Borsa,Paul A.	A New Force-Plate Technology Measure Of Dynamic Postural Stability: The Dynamic Postural Stability Index	2005	Journal Of Athletic Training (National Athletic Trainers' Association)	40	4
1103	Wilson,Marjorie L.;Rome,Keith;Hodgson,David;Ball,Peter	Effect Of Textured Foot Orthotics On Static And Dynamic Postural Stability In Middle-Aged Females	2008	Gait & Posture	27	1
1104	Wingert,Jason R.;Welder,Catherine;Foo,Patrick	Age-Related Hip Proprioception Declines: Effects On Postural Sway And Dynamic Balance	2014	Archives Of Physical Medicine & Rehabilitation	95	2

Id	Authors	Title	Pub Year	Periodical	Vol	Issue
1106	Wong-Yu,Irene;Mak,Margaret K.	Task- And Context-Specific Balance Training Program Enhances Dynamic Balance And Functional Performance In Parkinsonian Nonfallers: A Randomized Controlled Trial With Six-Month Follow-Up	2015	Archives Of Physical Medicine & Rehabilitation	96	12
1107	Worms,G.;Matjav́Ñ¬Çic,Z.;Gollee,H.;Cikajlo,I.;Goljar,N.;Hunt,K. J.	Sensory Electrical Nerve Stimulation For Training Dynamic Balance Responses In A Chronic Stroke Patient	2011	Journal Of Medical And Biological Engineering	31	1
1108	Wrobel,James S.;Edgar,Sarah;Cozzetto,Dana;Maskill,James;Peterson,Paul;Najafi,Bijan	A Proof-Of-Concept Study For Measuring Gait Speed, Steadiness, And Dynamic Balance Under Various Footwear Conditions Outside Of The Gait Laboratory	2010	Journal Of The American Podiatric Medical Association	100	4
1109	Wu, Wen-Lan Wu;Ta-Sen Wei;Shen-Kai Chen;Jyh-Jong Chang;Lan-Yuen Guo;Hwai-Ting Lin	The Effect Of Chinese Yuanji-Dance On Dynamic Balance And The Associated Attentional Demands In Elderly Adults	2010	Journal Of Sports Science & Medicine	9	1
1111	Wyon,Matthew A.;Cloak,Ross;Lucas,Josephine;Clarke,Frances	Effect Of Midsole Thickness Of Dance Shoes On Dynamic Postural Stability	2013	Medical Problems Of Performing Artists	28	4
1113	Yang,Yea-Ru;Lee,Ya-Yun;Cheng,Shih-Jung;Lin,Pei-Yi;Wang,Ray-Yau	Relationships Between Gait And Dynamic Balance In Early Parkinson's Disease	2008	Gait & Posture	27	4
1114	Yom C, Cho Hy, Lee B.	Effects Of Virtual Reality-Based Ankle Exercise On The Dynamic Balance, Muscle Tone, And Gait Of Stroke Patients.	2015	J Phys Ther Sci	27	3

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1115	Zago M, Mapelli A, Shirai Yf, Ciprandi D, Lovecchio N, Galvani C, Sforza C.	Dynamic Balance In Elite Karateka.	2015	J Electromyogr Kinesiol	25	6
1118	Zech,Astrid;Argubi-Wollesen,Andreas;Rahlf,Anna-Lina	Minimalist, Standard And No Footwear On Static And Dynamic Postural Stability Following Jump Landing	2014	European Journal Of Sport Science		
1123	Zech,Astrid;Steib,Simon;Hentschke,Christian;Eckhardt,Holger;Pfeifer,Klaus	Effects Of Localized And General Fatigue On Static And Dynamic Postural Control In Male Team Handball Athletes	2012	Journal Of Strength & Conditioning Research (Lippincott Williams & Wilkins)	26	4
1124	Zemkovãƒâ¡,Erika;Hamar, Duã…Â¡An	The Effect Of Proprioceptive Stimulation Of Different Duration On Static And Dynamic Balance	2008	International Journal Of Applied Sports Sciences	20	1
1125	Zemkovãƒâ¡,Erika;Viitasalo,Jukka;Hannola,Heikki;Blomqvist,Minna;Konttinen,Niilo;Mononen,Kaisu	The Effect Of Maximal Exercise On Static And Dynamic Balance In Athletes And Non-Athletes	2007	Medicina Sportiva	11	3
1129	Zulfikri, N., Bukry, S.A., Justine, M.	Effects Of Kinesio® Taping On Dynamic Postural Control Following Fatigue Induction	2016	Jurnal Teknologi		
1130	Zult T, Gokeler A, Van Raay Jj, Brouwer Rw, Zijdewind I, Hortobã¡Gyi T.	An Anterior Cruciate Ligament Injury Does Not Affect The Neuromuscular Function Of The Non-Injured Leg Except For Dynamic Balance And Voluntary Quadriceps Activation.	2016	Knee Surg Sports Traumatol Arthrosc. 2016		
1131	Bass, Ri	An Analysis Of The Components Of Tests Of Semicircular Canal Function And F Static And Dynamic Balance	1939	Research Quarterly. American Association For Health, Physical Education And Recreation	10	1

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1131	Sofianidis G; Dimitriou Am; Hatzitaki V	A Comparative Study Of The Effects Of Pilates And Latin Dance On Static And Dynamic Balance In Older Adults.	2017	Journal Of Aging And Physical Activity	3	
1132	Espenschade, A; Dable, Rr, Schoendube, R	Dynamic Balance In Adolescent Boys	1953	Research Quarterly. American Association For Health, Physical Education And Recreation	24	3
1133	Elmer A. Gross & Hugh L. Thompson	Relationship Of Dynamic Balance To Speed And To Ability In Swimming	1957	Research Quarterly. American Association For Health, Physical Education And Recreation	28	4
1133	Do Nascimento Ja; Silva Cc; Dos Santos Hh; De Almeida Ferreira Jj; De Andrade Pr	A Preliminary Study Of Static And Dynamic Balance In Sedentary Obese Young Adults: The Relationship Between Bmi, Posture And Postural Balance.	2017	Clinical Obesity	6	
1137	Hsiao My; Li Cm; Lu Is; Lin Yh; Wang Tg; Han Ds	An Investigation Of The Use Of The Kinect System As A Measure Of Dynamic Balance And Forward Reach In The Elderly.	2017	Clinical Rehabilitation		
1140	Kaminski E; Hoff M; Rjosk V; Steele Cj; Gundlach C; Sehm B; Villringer A; Ragert P	Anodal Transcranial Direct Current Stimulation Does Not Facilitate Dynamic Balance Task Learning In Healthy Old Adults.	2017	Frontiers In Human Neuroscience		
1141	Craig Ce; Doumas M	Anodal Transcranial Direct Current Stimulation Shows Minimal, Measure-Specific Effects On Dynamic Postural Control In Young And Older Adults: A Double Blind, Sham-Controlled Study.	2017	Plos One	1	

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1143	Pau, Massimiliano; Porta, Micaela; Corona, Federica; Pilloni, Giuseppina; Coghe, Giancarlo; Lorefice, Lorena; Cocco, Eleonora	Are Static And Dynamic Balance Abilities Correlated In People With Multiple Sclerosis?	2017	Multiple Sclerosis Journal	23	6
1145	Soancatl Aguilar V; Lamoth Cjc; Maurits Nm; Roerdink Jbtm	Assessing Dynamic Postural Control During Exergaming In Older Adults: A Probabilistic Approach.	2017	Gait & Posture		
1147	Mendonça Dlc; Alonso Ac; Greve Jmd; Garcez-Leme Le	Assessment Of The Quality Of Life, Muscle Strength, And Dynamic Balance Of Elderly Kendo Players.	2017	Clinics (Sao Paulo, Brazil)	11	
1153	Tapps, Tyler; Walter, Alysha A.; Tapps, Mary	Cardio-Kickboxing And Dynamic Balance In Adults With Developmental Disabilities.	2017	American Journal Of Recreation Therapy	1	
1154	Ness Bm; Comstock Ba; Schweinle We	Changes In Dynamic Balance And Hip Strength After An Eight-Week Conditioning Program In Ncaa Division I Female Soccer (Football) Athletes	2016	International Journal Of Sports Physical Therapy	7	
1156	Park S; Finley Jm	Characterizing Dynamic Balance During Adaptive Locomotor Learning.	2017	Conference Proceedings: ... Annual International Conference Of The Ieee Engineering In Medicine And Biology Society. Ieee Engineering In Medicine And Biology Society. Annual Conference		

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1160	Hyong, In Hyouk; Kang, Jong Ho	Comparison Of Dynamic Balance Ability In Healthy University Students According To Foot Shape	2016	Journal Of Physical Therapy Science		
1161	Shiravi Z, Shadmehr A, Moghadam St, Moghadam Ba.	Comparison Of Dynamic Postural Stability Scores Between Athletes With And Without Chronic Ankle Instability During Lateral Jump Landing.	2017	Muscles Ligaments Tendons J.	10	7
1162	Krkeljas Z.	Comparison Of Jump-Landing Protocols With Biodex Balance System As Measures Of Dynamic Postural Stability In Athletes.	2017	Sports Biomech.	21	1
1165	Bae Yh; Lee Sm; Ko M	Comparison Of The Effects On Dynamic Balance And Aerobic Capacity Between Objective And Subjective Methods Of High-Intensity Robot-Assisted Gait Training In Chronic Stroke Patients: A Randomized Controlled Trial.	2017	Topics In Stroke Rehabilitation	4	
1166	Merritt Ed, Brown Cn, Queen Rm, Simpson Kj, Schmidt Jd.	Concussion History And Time Since Concussion Do Not Influence Static And Dynamic Balance In Collegiate Athletes.	2017	J Sport Rehabil.	26	6
1174	Iwamoto Y; Takahashi M; Shinkoda K	Differences Of Muscle Co-Contraction Of The Ankle Joint Between Young And Elderly Adults During Dynamic Postural Control At Different Speeds.	2017	Journal Of Physiological Anthropology	1	
1176	Qian D., Li Y., Shu Y., Gu Y., Zhang Y., Awrejcewicz J., Jia X.	Dynamic Balance Analysis Under Different Lower Extremities Tortuosity	2017	Journal Of Applied Biomechanics	3	

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1181	Kent Ja; Stergiou N; Wurdeman Sr	Dynamic Balance Changes Within Three Weeks Of Fitting A New Prosthetic Foot Component.	2017	Gait & Posture		
1188	Goetz M; Schwabova Jp; Hlavka Z; Ptacek R; Surman Cb	Dynamic Balance In Children With Attention-Deficit Hyperactivity Disorder And Its Relationship With Cognitive Functions And Cerebellum.	2017	Neuropsychiatric Disease And Treatment		
1189	Peebles At; Bruetsch Ap; Lynch Sg; Huisinga Jm	Dynamic Balance In Persons With Multiple Sclerosis Who Have A Falls History Is Altered Compared To Non-Fallers And To Healthy Controls.	2017	Journal Of Biomechanics		
1190	Pau M; Mereu F; Melis M; Leban B; Corona F; Ibba G	Dynamic Balance Is Impaired After A Match In Young Elite Soccer Players.	2016	Physical Therapy In Sport: Official Journal Of The Association Of Chartered Physiotherapists In Sports Medicine		11
1191	Peebles At; Bruetsch Ap; Lynch Sg; Huisinga Jm	Dynamic Balance Is Related To Physiological Impairments In Persons With Multiple Sclerosis.	2017	Archives Of Physical Medicine And Rehabilitation		
1197	Takacs J; Krowchuk Nm; Garland Sj; Carpenter Mg; Hunt Ma	Dynamic Balance Training Improves Physical Function In Individuals With Knee Osteoarthritis: A Pilot Randomized Controlled Trial.	2017	Archives Of Physical Medicine And Rehabilitation	8	
1198	Sirois-Leclerc G; Remaud A; Bilodeau M	Dynamic Postural Control And Associated Attentional Demands In Contemporary Dancers Versus Non-Dancers.	2017	Plos One	3	

Id	Authors	Title	Pub Year	Periodical	Vol	Issue
1201	Mehrian, M. M.; Sarshin, A.; Rostamkhani, H.	Effect Of 8-Week Exerciseon Improving The Static And Dynamic Balance Of Supinated Foot	2016	Journal Of Fundamental And Applied Sciences		
1204	Dunsky A; Barzilay I; Fox O	Effect Of A Specialized Injury Prevention Program On Static Balance, Dynamic Balance And Kicking Accuracy Of Young Soccer Players.	2017	World Journal Of Orthopedics	4	
1206	Yong Ms; Lee Ys	Effect Of Ankle Proprioceptive Exercise On Static And Dynamic Balance In Normal Adults.	2017	Journal Of Physical Therapy Science	2	
1209	Abutaleb, Enas Elsayed Mohamed	Effect Of Shoulder Side Pack On Dynamic Postural Stability In Young Healthy Female	2016	International Journal Of Physiotherapy		
1213	Subramaniam S; Bhatt T	Effect Of Yoga Practice On Reducing Cognitive-Motor Interference For Improving Dynamic Balance Control In Healthy Adults.	2017	Complementary Therapies In Medicine		
1214	Ng, Robert S. K.; C. W., Cheung; Raymond, K. W. Sum	Effects Of 6-Week Agility Ladder Drills During Recess Intervention On Dynamic Balance Performance.	2017	Journal Of Physical Education & Sport	1	
1217	Song Cy, Lin Jj, Chang Ah.	Effects Of Femoral Rotational Taping On Dynamic Postural Stability In Female Patients With Patellofemoral Pain.	2017	Clin J Sport Med. 2017 Sep;27(5):438-443. Doi: 10.1097/Jsm.0000000000000392.		
1218	Zulfikri N Mhsc Pt; Justine M Phd Pt	Effects Of Kinesio® Taping On Dynamic Balance Following Fatigue: A Randomized Controlled Trial.	2017	Physical Therapy Research	1	
1219	Gürkan Ac; Demirel H; Demir M; Atmaca Eş; Bozöyük G; Dane S	Effects Of Long-Term Training Program On Static And Dynamic Balance In Young Subjects.	2016	Clinical And Investigative Medicine. Medecine Clinique Et Experimentale	6	

Id	Authors	Title	Pub Year	Periodical	Vol	Issue
1220	Farajzadeh F., Ghaderi F., Asghari Jafarabadi M., Azghani M.R., Eteraf Oskoui M.A., Rezaie M., Ghorbanpour A.	Effects Of Mcgill Stabilization Exercise On Pain And Disability, Range Of Motion And Dynamic Balance Indices In Patients With Chronic Nonspecific Low Back Pain	2017	International Journal Of Applied Engineering Research	15	
1221	Nishi T, Kamogashira T, Fujimoto C, Kinoshita M, Egami N, Sugasawa K, Yamasoba T, Iwasaki S.	Effects Of Peripheral Vestibular Dysfunction On Dynamic Postural Stability Measured By The Functional Reach Test And Timed Up And Go Test.	2017	Ann Otol Rhinol Laryngol. 2017 Jun;126(6):438-444. Doi: 10.1177/0003489417700439. Epub 2017 Mar 22.		
1222	Malmir K, Olyaei Gr, Talebian S, Jamshidi Aa, Ganguie Ma.	Effects Of Peroneal Muscles Fatigue On Dynamic Stability Following Lateral Hop Landing: Time To Stabilization Vs. Dynamic Postural Stability Index.	2017	J Sport Rehabil. 2017 Jul 17:1-21. Doi: 10.1123/Jsr.2017-0095. [Epub Ahead Of Print]		
1223	Lee D., Han S.	Effects Of Static Stretching Of The Calf Muscle After Microwave Diathermy On Joint Position Sensation And Dynamic Balance Ability	2017	Kinesiology	2	
1224	Padala Kp; Padala Pr; Lensing Sy; Dennis Ra; Bopp Mm; Parkes Cm; Garrison Mk; Dubbert Pm; Roberson Pk; Sullivan Dh	Efficacy Of Wii-Fit On Static And Dynamic Balance In Community Dwelling Older Veterans: A Randomized Controlled Pilot Trial.	2017	Journal Of Aging Research		
1225	Mcdermott P; Wolfe E; Lowry C; Robinson K; French Hp	Evaluating The Immediate Effects Of Wearing Foot Orthotics In Children With Joint Hypermobility Syndrome (Jhs) By Analysis Of Temperospatial Parameters Of Gait And Dynamic Balance: A Preliminary Study.	2017	Gait & Posture		61

Id	Authors	Title	Pub Year	Periodical	Vol	Issue
1228	Hemmati L; Rojhani-Shirazi Z; Malek-Hoseini H; Mobaraki I	Evaluation Of Static And Dynamic Balance Tests In Single And Dual Task Conditions In Participants With Nonspecific Chronic Low Back Pain.	2017	Journal Of Chiropractic Medicine	3	
1229	Bullock Gs; Brookreson N; Knab Am; Butler Rj	Examining Fundamental Movement Competency And Closed-Chain Upper-Extremity Dynamic Balance In Swimmers.	2017	Journal Of Strength And Conditioning Research	6	
1231	Krzyszton, Karolina; Stolarski, Jakub; Kochanowski, Jan	Facilitation Of The Dynamic Balance Reactions As Part Of Treatment Of Balance Disorders In Parkinson's Disease	2016	Acta Balneologica		
1234	Lopez-Valenciano, Alejandro; Ayala, Francisco; Luis Lopez-Elvira, Jose; Barbado, David; Jose Vera-Garcia, Francisco	Impact Of Dynamic Balance And Hip Abductor Strength On Chronic Ankle Instability	2016	European Journal Of Human Movement		
1239	Mat, Sumaiyah; Chin Teck Ng; Maw Pin Tan	Influence Of Hip And Knee Osteoarthritis On Dynamic Postural Control Parameters Among Older Fallers.	2017	Journal Of Rehabilitation Medicine (Stiftelsen Rehabiliteringsinformation)	3	
1241	Nunes G.S., Uhlig S., Ribas L.M.D.A., Gonçalves F.B., Wageck B., Noronha M.D.	Influence Of Neural Mobilization Of Lower Limbs On The Functional Performance And Dynamic Balance In Asymptomatic Individuals: A Cross-Over Randomized Controlled Trial	2017	Gait And Posture		
1242	De Sousa V.P.S., Da Silva Santos A., Spaniol A.P., De Souza Ramalho Viana E.	Influence Of Physical Activity And Different Sensory Conditions On Static And Dynamic Balance Of Pregnant Women	2016	Annals Of Biomedical Engineering	9	

Id	Authors	Title	Pub Year	Periodical	Vol	Issue
1245	Ateş, Bahar	Investigation Of Static And Dynamic Balance Performances Of Female Student-Athletes And Non-Athletes Between 12 And 14 Years Of Age.	2017	Journal Of Physical Education & Sports Science / Beden Egitimi Ve Spor Bilimleri Dergisi	1	1
1246	Eltoukhy M; Kuenze C; Oh J; Wooten S; Signorile J	Kinect-Based Assessment Of Lower Limb Kinematics And Dynamic Postural Control During The Star Excursion Balance Test.	2017	Gait & Posture		
1247	Hasegawa N; Takeda K; Sakuma M; Mani H; Maejima H; Asaka T	Learning Effects Of Dynamic Postural Control By Auditory Biofeedback Versus Visual Biofeedback Training.	2017	Gait & Posture		
1248	Cha, Young Joo; Stanley, Megan; Shurtleff, Tim; You, Joshua (Sung) H.	Long-Term Effects Of Robotic Hippotherapy On Dynamic Postural Stability In Cerebral Palsy	2016	Computer Assisted Surgery		
1249	Pouliot-Laforte, Annie; Auvinet, Édouard; Lemay, Martin; Ballaz, Laurent	Low-Cost Active Video Game Console Development For Dynamic Postural Control Training.	2017	Journal Of Alternative Medicine Research	2	
1250	Goto S; Aminaka N; Gribble Pa	Lower Extremity Muscle Activity, Kinematics, And Dynamic Postural Control In Individuals With Patellofemoral Pain.	2017	Journal Of Sport Rehabilitation	1	
1251	Marković, Kamenka Živčić; Krističević, Tomislav; Aleksić-Veljković, Aleksandra	Metric Characteristics Of A New Test For The Evaluation Of Dynamic Balance	2016	Kinesiology	2	
1253	Bansbach Hm, Lovalekar Mt, Abt Jp, Rafferty D, Yount D, Sell Tc.	Military Personnel With Self-Reported Ankle Injuries Do Not Demonstrate Deficits In Dynamic Postural Stability Or Landing Kinematics.	2017	Clin Biomech (Bristol, Avon). 2017 Aug;47:27-32. Doi: 10.1016/J.Clinbiomech.2017.05.008. Epub 2017 May 19.		

Id	Authors	Title	Pub Year	Periodical	Vol	Issue
1254	Bergamini E; Iosa ;Belluscio V; Morone G; Tramontano M; Vannozzi G	Multi-Sensor Assessment Of Dynamic Balance During Gait In Patients With Subacute Stroke.	2017	Journal Of Biomechanics		
1256	Rosso Al; Cenciarini M; Sparto Pj; Loughlin Pj; Furman Jm; Huppert Tj	Neuroimaging Of An Attention Demanding Dual-Task During Dynamic Postural Control.	2017	Gait & Posture		
1260	Steib S; Klamroth S; Gaßner H; Pasluosta C; Eskofier B; Winkler J; Klucken J; Pfeifer K	Perturbation During Treadmill Training Improves Dynamic Balance And Gait In Parkinson's Disease: A Single-Blind Randomized Controlled Pilot Trial.	2017	Neurorehabilitation And Neural Repair	8	
1261	Pilkar, Rakesh; Arzouni, Nibal; Ramanujam, Arvind; Chervin, Kathleen; Nolan, Karen J.	Postural Responses After Utilization Of A Computerized Biofeedback Based Intervention Aimed At Improving Static And Dynamic Balance In Traumatic Brain Injury: A Case Study	2016	Ieee Engineering In Medicine And Biology Society Conference Proceedings		
1264	Pizzi, SD; Bellomo, R; Carmignano, SM; Ancona, E; Franciotti, R; Supplizi, M; Barassi, G; Onofrj, M; Bonanni, L; Saggini, R	Rehabilitation Program Based On Sensorimotor Recovery Improves The Static And Dynamic Balance And Modifies The Basal Ganglia Neurochemistry: A Pilot ^{1}H-Mrs Study On Parkinson's Disease Patients.	2017	Medicine	50	1
1265	Chang-Man An; Young-Lan Son; Young-Hyun Park; Sung-Jun Moon	Relationship Between Dynamic Balance And Spatiotemporal Gait Symmetry In Hemiplegic Patients With Chronic Stroke.	2017	Hong Kong Physiotherapy Journal		
1268	Awotidebe. T; Ativie R; Oke K; Akindele M; Adedoyin R; Olaogun M; Olubayode T; Kolawole Ba	Relationships Among Exercise Capacity, Dynamic Balance And Gait Characteristics Of Nigerian Patients With Type-2 Diabetes: An Indication For Fall Prevention.	2016	Journal Of Exercise Rehabilitation	6	

Id	Authors	Title	Pub Year	Periodical	Vol	Issue
1275	Takeuchi Y	Sagittal Plane Spinal Mobility Is Associated With Dynamic Balance Ability Of Community-Dwelling Elderly People.	2017	Journal Of Physical Therapy Science	1	
1277	Melo Rs; Marinho Seds; Freire Mea; Souza Ra; Damasceno Ham; Raposo Mcf	Static And Dynamic Balance Of Children And Adolescents With Sensorineural Hearing Loss.	2017	Einstein (Sao Paulo, Brazil)	3	
1278	Ozcan Kahraman B; Ozsoy I; Savci S; Acar S; Ozpelit E; Sevinc C; Akdeniz B	Static And Dynamic Balance Performance And Balance Confidence In Individuals With And Without Pulmonary Arterial Hypertension.	2017	Journal Of Cardiopulmonary Rehabilitation And Prevention		
1280	Fronczek-Wojciechowska, Magdalena; Padula, Gianluca; Kowalska, Joanna; Galli, Manuela; Livatino, Salvatore; Kopacz, Karolina	Static Balance And Dynamic Balance Related To Rotational Movement In Ballet Dance Students	2016	International Journal Of Performance Analysis In Sport		
1281	Aguiar Gonçalves, Geiseane; Harudy Kamonseki, Danilo; Reclusa Martinez, Bruna; Amaral Nascimento, Maythe; Lombardi Junior, Império; Liu Chiao Yi	Static, Dynamic Balance And Functional Performance In Subjects With And Without Plantar Fasciitis.	2017	Fisioterapia Em Movimento	1	
1292	Salamifar, Seyedehzahra; Nasermeli, Mohammad Hossein; Namin, Behnaz Ganji	The Effect Of Isometric And Isotonic Exercises Of Lower Limbs Extensor Sling On Static And Dynamic Balance In Basketball Players With Patellofemoral Pain.	2017	Health (1949-4998)	10	

Id	Authors	Title	Pub Year	Periodical	Vol	Issue
1293	Kosik Kb; Gribble Pa	The Effect Of Joint Mobilization On Dynamic Postural Control In Patients With Chronic Ankle Instability: A Critically Appraised Topic.	2016	Journal Of Sport Rehabilitation	1	
1295	Shin Yj; Lee Dh; Kim Mk	The Effect Of Newly Designed Multi Joint Ankle Foot Orthosis On The Gait And Dynamic Balance Of Stroke Patients With Foot Drop.	2017	Journal Of Physical Therapy Science	11	
1296	Kim Mk; Kong Bs; Yoo Kt	The Effect Of Shoe Type On Static And Dynamic Balance During Treadmill Walking In Young Healthy Women.	2017	Journal Of Physical Therapy Science	9	
1297	Nakamura T; Yoshida Y; Churei H; Aizawa J; Hirohata K; Ohmi T; Ohji S; Takahashi T; Enomoto M; Ueno T; Yagishita K	The Effect Of Teeth Clenching On Dynamic Balance At Jump-Landing: A Pilot Study.	2017	Journal Of Applied Biomechanics	3	
1300	Nam Sm; Kim Wh; Yun Ck	The Effects Of A Multisensory Dynamic Balance Training On The Thickness Of Lower Limb Muscles In Ultrasonography In Children With Spastic Diplegic Cerebral Palsy.	2017	Journal Of Physical Therapy Science	4	
1301	Ehsani F, Samaei A, Zoghi M, Hedayati R, Jaberzadeh S.	The Effects Of Cerebellar Transcranial Direct Current Stimulation On Static And Dynamic Postural Stability In Older Individuals: A Randomized Double-Blind Sham-Controlled Study.	2017	Eur J Neurosci. 2017 Dec;46(12):2875-2884. Doi: 10.1111/Ejn.13731. Epub 2017 Nov 6.		

Id	Authors	Title	Pub Year	Periodical	Vol	Issue
1303	Afsharnezhad, Taher; Faghihi, Samane; Hazrati, Amir; Bahrami, Khadije	The Effects Of Cold Water Immersion On Anaerobic Power, Dynamic Balance And Muscle Activation After A Karate Kumite Fighting In Female Karateka	2017	International Journal Of Applied Exercise Physiology	6	3
1304	Kim Mk; Yoo Kt	The Effects Of Open And Closed Kinetic Chain Exercises On The Static And Dynamic Balance Of The Ankle Joints In Young Healthy Women.	2017	Journal Of Physical Therapy Science	5	845
1305	Kim Ek; Kim Js	The Effects Of Short Foot Exercises And Arch Support Insoles On Improvement In The Medial Longitudinal Arch And Dynamic Balance Of Flexible Flatfoot Patients.	2016	Journal Of Physical Therapy Science	11	3136
1306	Mccartney, Kieran Neil; Forsyth, Jacky	The Efficacy Of Core Stability Assessment As A Determiner Of Performance In Dynamic Balance And Agility Tests.	2017	Journal Of Human Sport & Exercise	3	640
1309	Śliwowski R; Grygorowicz M; Wieczorek A; Jadczak Ł	The Relationship Between Jumping Performance, Isokinetic Strength And Dynamic Postural Control In Elite Youth Soccer Players.	2017	The Journal Of Sports Medicine And Physical Fitness		
1315	Yoshimoto Y; Oyama Y; Tanaka M; Sakamoto A	Toe Functions Have Little Effect On Dynamic Balance Ability In Elderly People.	2017	Journal Of Physical Therapy Science	1	158
1318	Kuznetsov Na; Robins Rk; Long B; Jakiela Jt; Haran Fj; Ross Se; Wright Wg; Rhea Ck	Validity And Reliability Of Smartphone Orientation Measurement To Quantify Dynamic Balance Function.	2017	Physiological Measurement		

Appendix B: Definitions of dynamic balance terms extracted from articles in the scoping review

Authors	Title	Year	Balance keyword DB: 1; DPC: 2; DPS:3	Definition Used	Source of definition	Periodical	Vol	Issue	Start Page
Abbasi,A.;Tabrizi,H. B.;Sarvestani,H. J.;Rahmanpourmoghaddam,J.	dynamic balance in inactive elder maleschanges after eight weeks functional and core stabilization training	2012	1	1. active movement of COP while standing, walking, or performing any other skill Punakallioet al. 2. maintaining balance while a prescribed movement is performed (Olmsted et al.and Guskiewiczet al.) 3. active movement of COP within BOS and maintaining the stability of BOS while performing a prescribed task (Gribble , Blackburn , Sebahattin]	Anne Punakallio. Balance abilities of workers in physically demanding jobs: with special reference to firefighters of different ages. Journal of sport science & medicine, 2005; 4(8): 1-46 Olmsted, L.C. and J. Hertel, 2004. Influence of foot type and orthotics on static and dynamic postural control. J. Sport Rehabilitation, 13(1): 54-66. Guskiewicz, K.M. and D.H. Perrin, 1996. Research and clinical applications of assessing balance. J. Sport Rehabilitation, 5: 45-63. Gribble, P.A. and T. Kaminski, 2003. The star excursion balance test as a measurement tool. Athletic Therapy Today, 8(2): 46-47. Blackburn, J.T., W.E. Prentice, K.M. Guskiewicz and M.A. Busby, 2000. Balance and joint stability: the relative contributions of proprioception and muscular strength. J. Sport Rehabilitation, 9(4): 315-328. Sebahattin, D. and G. Ismail, 2011. The effect of an Eight-Week Swimming Training on Capillary Oxygen Saturation and Respiratory Parameters. World Applied Sciences J., 15(11): 1598-1603.	Middle East Journal of Scientific Research	11	3	304

Authors	Title	Year	Balance keyword DB: 1; DPC: 2; DPS:3	Definition Used	Source of definition	Periodical	Vol	Issue	Start Page
Al-Khlaifat L, Herrington LC, Tyson SF, Hammond A, Jones RK.	The effectiveness of an exercise programme on dynamic balance in patients with medial knee osteoarthritis: A pilot study.	2016	1	ability to maintain a stable base of support while performing amovement or a prescribed reaching or leaning task	Guskiewicz KM, Perrin DH. Research and clinical applications of assessing balance. J Sport Rehabil 1996;5:45–63.	Knee	23	5	849
Amiri-Khorasani M.	Acute effects of different stretching methods on static and dynamic balance in female football players	2015	1	requires the ability to maintain balance during a transition from a dynamic to a static state	Ross SE, Guskiewicz KM, Gross MT, Yu B (2009) Balance measures for discriminating between functionally unstable and stable ankles. Med Sci Sports Exerc 41(2): 399–407		22	2	68

Authors	Title	Year	Balance keyword DB: 1; DPC: 2; DPS:3	Definition Used	Source of definition	Periodical	Vol	Issue	Start Page
Anoop,Aggarwal;Kalpana,Zutshi;Jitender,Munjal;Suraj,Kumar	effect of core stabilization training on dynamic balance in non-professional sports players	2010	1	1.person's ability to move the COP (center of pressure) in a given direction within the LOS (limits of stability)1. 2. Ability of maintaining a stable base of support while completing a prescribed movement. 83.balance on a single limb while manipulating the other limb15. 4. def used in method: Dynamic balance in this study is defined as testing maneuvers that required dynamic limb segment or whole body movements whilst maintaining balance on a single foot. (no ref)	Anne Punakallio. Balance abilities of workers in physically demanding jobs: with special reference to firefighters of different ages. Journal of sport science & medicine, 2005; 4(8): 1-46Gribble.P.A, Hertel J. Consideration for normalizing measures of the star excursion balance test. Measure Physical Education Exercise Science. 2003;7(2): 89-100Kinzey Sj . The reliability of the star-excursion test in assessing dynamic balance. JOSPT, 1998; 27(5): 356- 360	Indian Journal of Physiotherapy & Occupational Therapy	4	4	18

Authors	Title	Year	Balance keyword DB: 1; DPC: 2; DPS:3	Definition Used	Source of definition	Periodical	Vol	Issue	Start Page
Baghbaninaghadehi,Fatemeh;Reza Ramezani, Ali;Hatami, Farzaneh	the effect of functional fatigue on static and dynamic balance in female athletes	2013	1	semi dynamic: keeping the status when the base of support is moved dynamic: maintaining a stable base of support while completing prescribed movements	Gribble.P.A, Hertel J. Consideration for normalizing measures of the star excursion balance test. Measure Physical Education Exercise Science. 2003;7(2): 89-100 Zemkova, E., Viitasalo, J., Hannola H., et al (2007) The effect of maximal exercise on static and dynamic balance in athlete and non-athlete. J Medicine Sportive 11(3) 70-77	International SportMed Journal	14	2	77
Bass, RI	An analysis of the components of tests of semicircular canal function and f static and dynamic balance	1939	1	type of balance concerned in keeping one's equilibrium while in motion, or while changing from one balanced position to another. DB then pertains to the equilibrium evidenced through a series of changing positions taken successively	No reference	Research Quarterly. American Association for Health, Physical Education and Recreation	10	1	33

Authors	Title	Year	Balance keyword DB: 1; DPC: 2; DPS:3	Definition Used	Source of definition	Periodical	Vol	Issue	Start Page
Bhat,Rashi;Moiz,Jamal Ali	comparison of dynamic balance in collegiate field hockey and football players using star excursion balance test	2013	1	ability to maintain stable position while performing a task	Winter, D.A., Patla, A.E., and Frank, J.S. (1990) Assessment of balance control in humans. Medical Progress through technology 16 31-51	Asian Journal of Sports Medicine	4	3	221
Booysen MJ, Gradidge PJ, Watson E.	The relationships of eccentric strength and power with dynamic balance in male footballers.	2015	1	the ability to maintain the centre of gravity within the body's base of support whilst performing an intended movement	Butler, Robert J., et al. "Dynamic Balance Performance and Noncontact Lower Extremity Injury in College Football Players An Initial Study." Sports Health: A Multidisciplinary Approach 5.5 (2013): 417-422.		33	20	2157
Bressel,Eadric;Yonker,Joshua C.;Kras,John;Heath,Edward M.	comparison of static and dynamic balance in female collegiate soccer, basketball, and gymnastics athletes	2007	1	ability to perform a task while main-taining a stable position (Winter, 1990)	Winter, D.A., Patla, A.E., and Frank, J.S. (1990) Assessment of balance control in humans. Medical Progress through technology 16 31-51	Journal of Athletic Training (National Athletic Trainers' Association)	42	1	42

Authors	**Title**	**Year**	**Balance keyword DB: 1; DPC: 2; DPS:3**	**Definition Used**	**Source of definition**	**Periodical**	**Vol**	**Issue**	**Start Page**
Brown, C.N., Ko, J., Rosen, A.B., Hsieh, K.	Individuals with both perceived ankle instability and mechanical laxity demonstrate dynamic postural stability deficits	2015	3	a measure of functional performance while stabilizing the body to transition from a moving to a static state	Wikstrom, E. A., Tillman, M. D., Chmielewski, T. L., Cauraugh, J. H., & Borsa, P. A. (2007). Dynamic postural stability deficits in subjects with self-reported ankle instability. Medicine & Science in Sports & Exercise, 39(3), 397–402	Clinical Biomechanics	30	10	1170
Butler,Robert J.;Southers,Corey;Gorman,Paul P.;Kiesel,Kyle B.;Plisky,Phillip J.	differences in soccer players' dynamic balance across levels of competition	2012	1	ability of an individual to maintain stability of the center of mass during movement	No reference	Journal of Athletic Training (Allen Press)	47	6	616
Butz, S.M., Sweeney, J.K., Roberts, P.L., Rauh, M.J.	Relationships among Age, Gender, Anthropometric Characteristics, and Dynamic Balance in Children 5 to 12 Years Old	2015	1	operationally defined as the ability to maintain postural control during movements, such as reaching or walking	Westcott SL, Lowes LP, Richardson PK. Evaluation of postural stability in children: current theories and assessment tools. Phys Ther. 1997;77:629-645.	Pediatric Physical Therapy ,	27	2	126

Authors	Title	Year	Balance keyword DB: 1; DPC: 2; DPS:3	Definition Used	Source of definition	Periodical	Vol	Issue	Start Page
Byrne,Jeannette M.;Roberts,Joni;Squires,Heidi;Rohr,Linda E.	the effect of a three-week wii fit balance training program on dynamic balance in healthy young adults	2012	1	ability to respond to perturbation (either internal or external) in a way that ensures stability s maintained(Horal, 2006)	Horak, FB (2006) Postural orientation and equilibrium: what do we need to know about neural control of balance to prevent falls? Age and Ageing 35 S2 ii7-ii11	International SportMed Journal	13	4	170
Cankaya S., Gokmen B., Tasmekteplilgil M.Y., Con M.	Special balance developer training applications on young males' static and dynamic balance performance	2015	1	ability to transfer from a dynamic state to a static state or to maintain stability while performing dynamic motions	Distefano LJ, Clark MA, Padua DA 2009. Evidence supporting balance training in healthy individuals: A systemic review. Journal of Strength and Conditioning Research, 23: 2718–2731. Ross, SE and Guskiewicz, KM. Examination of static and dynamic postural stability in individuals with functionally stable and unstable ankles. Clin J Sport Med 14: 332–338, 2004.	Anthropologist	19	1	31
Cattaneo D, Jonsdottir J, Coote S.	Targeting Dynamic Balance in Falls-Prevention Interventions in Multiple Sclerosis:	2014	1	refers to situations in which either or both the center of mass and base of support are in motion—for example, transitioning between postures or positions and walking.	no reference	Int J MS Care	16	4	198

Authors	Title	Year	Balance keyword DB: 1; DPC: 2; DPS:3	Definition Used	Source of definition	Periodical	Vol	Issue	Start Page
Chevidikunnan MF, Al Saif A, Gaowgzeh RA, Mamdouh KA.	Effectiveness of core muscle strengthening for improving pain and dynamic balance among female patients with patellofemoral pain syndrome.	2016	1	the capability of having suitable reactions regarding the motor system, in order to be able to cope up with the requirements needed for the quick alterations of position in the torso, while performing activities that add stress on the knee joint	No reference	J Phys Ther Sci	28	5	1518
Choi, Ahnryul; Kang, Tae Geon; Mun, Joung Hwan	Biomechanical Evaluation of Dynamic Balance Control Ability During Golf Swing	2016	1	ability to maintain posture on an unstable surface with minimal movement or to perform a certain task while retaining a stable posture	Kioumourtzoglou, E., Derri, V., Mertzanidou, O., & Tzetzis, G. (1997). Experience with perceptual and motor skills in rhythmic gymnastics. Perceptual and Motor Skills, 84(3 Pt 2), 1363–1372. Paillard, T., & Noe, F. (2006). Effect of expertise and visual contribution on postural control in soccer. Scandinavian Journal of Medicine and Science in Sports, 16, 345–348.	JOURNAL OF MEDICAL AND BIOLOGICAL ENGINEERING	36	3	430

Authors	Title	Year	Balance keyword DB: 1; DPC: 2; DPS:3	Definition Used	Source of definition	Periodical	Vol	Issue	Start Page
Chtara M, RouIssuei M, Bragazzi NL, Owen AL, Haddad M, Chamari K.	Dynamic balance ability in young elite soccer players: implication of isometric strength.	2016	1	ability to maintain the body's centerof mass whilst performing movement or a functional task.	4. Butler RJ, Southers C, Gorman PP, Kiesel KB, Plisky PJ. Differences in soccer players' dynamic balance across levels of competition. J Athl Train 2012;476:616-20. 5. Bressel E, Yonker JC, Kras J, Heath EM. Comparison of static and dynamic balance in female collegiate soccer, basketball, and gymnastics athletes. J Athl Train 2007;421:42-6.	J Sports Med Phys Fitness. 2016	Oct-11		
Clyse,S. J.;Short,M. A.	the relationship between dynamic balance and postrotary nystagmus in learning disabled children	1983	1	maintaining equilibrium when the bdy is moving	No reference	Physical & Occupational Therapy in Pediatrics	3	3	25
Davlin,Christina D.	dynamic balance in high level athletes	2004	1	maintaining equilibrium during motion or re-establishing equilibrium through rapid and successively changing positions	No reference	Perceptual & Motor Skills	98	3	1171

Authors	Title	Year	Balance keyword DB: 1; DPC: 2; DPS:3	Definition Used	Source of definition	Periodical	Vol	Issue	Start Page
Davlin-Pater,Christina	the effects of visual information and perceptual style on static and dynamic balance	2010	1	dynamic balance requires continuous postural adjustments to maintain equilibrium	No reference	Motor control	14	3	362
De Ridder, R.Willems, T. M.Vanrenterghem, J.Roosen, P	Effect of a Home-based Balance Training Protocol on Dynamic Postural Control in Subjects with Chronic Ankle Instability	2015	2	maintaining balance while transitioning from a dynamic to a static state, e. g. during a landing task [	Goldie PA, Bach TM, Evans OM. Force platform measures for evaluating postural control: reliability and validity. Arch Phys Med Rehabil 1989; 70: 510–517	International Journal of Sports Medicine	36	7	596
di Cagno,A;Fiorilli,G;Iuliano,E;Aquino,G;Giombini,A;Battaglia,C;Piazza,M;Tsopani,D;Calcagno,G	time-of-day effects on static and dynamic balance in elite junior athletes and untrained adolescents	2014	1	the ability to maintain equilibrium during motion.	No reference	International Journal of Sports Science & Coaching	9	4	615

Authors	Title	Year	Balance keyword DB: 1; DPC: 2; DPS:3	Definition Used	Source of definition	Periodical	Vol	Issue	Start Page
Eshraghi,A; Maroufi,N; Sanjari,M; Saeedi,H; Keyhani,M;Gholizadeh,H;Osman,N	effect of milwaukee brace on static and dynamic balance of female hyperkyphotic adolescents	2013	1	maintaining dynamic balance requires sufficient torques to keep COM motion exactly over the BOS.	Saha D, Gard S, Fatone S and Ondra S. The effect of trunkflexed postures on balance and metabolic energy expenditure during standing. Spine 2007; 32: 1605–1611.	Prosthetics and orthotics international	37	1	76
Faigenbaum,AD.;Bagley,J;Boise,S;Farrel,A;Bates,N;Myer,G.	Dynamic Balance in Children: Performance Comparison Between Two Testing Devices	2015	1	ability to maintain stability while anticipating and reacting to changes as the body moves through space	No reference	Athletic Training & Sports Health Care: The Journal for the Practicing Clinician	7	4	160
Falk,Emily Elizabeth;Seeley,Matthew K.;Hunter,Iain;Park,Jihong;Hopkins,J. T.	effect of experimental anterior knee pain on measures of static and dynamic postural control	2014	2	ability to control body position to maintain whole body stability and orientation	Shumway-Cook A, Woollacott MH. Control of posture and balance. In: Motor control. Theory and practical applications. Baltimore: Williams & Wilkins; 1995. p. 119-68.	Athletic Training & Sports Health Care: The Journal for the Practicing Clinician	6	1	7

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Field-Fote,E.;Ray ,S. S.	seated reach distance and trunk excursion accurately reflect dynamic postural control in individuals with motor-incomplete spinal cord injury	2010	2	ability to maintain balance while moving, is essential for functional mobility	Nichols DS. Balance retraining after stroke using force platform biofeedback. Phys Ther 1997; 77: 553–558.	Spinal Cord	48	10	745
Fotios,M.; Miltiadis,P. ;Eirini,A.;Andromahi, S.	dynamic balance in girls practicing recreational rhythmic gymnastics and greek traditional dances	2013	1	ability to balance on a moving surface or to maintain balance while moving	Fleishman, E. A. (1972). Structure and measurement of psychomotor abilities. In R.N.Singer (Eds.), The psychomotor domain: movement behavior (pp. 78-106). Philadelphia, PA: Lea & Febiger.	Science of Gymnastics Journal	5	1	61
Fullam, Karl; Caulfield, Brian; Coughlan, Garrett F.; McGroarty , Mark; Delahunt, Eamonn	Dynamic Postural-Stability Deficits After Cryotherapy to the Ankle Joint	2015	3	defined and measured as an assessment of an individual's ability to maintain balance while transitioning from a dynamic to a static state.	Goldie PA, Bach TM, Evans OM. Force platform measures for evaluating postural control: reliability and validity. Arch Phys Med Rehabil. 1989;70(7):510–517	Journal of Athletic Training	50	9	893

Authors	Title	Year	Balance keyword DB: 1; DPC: 2; DPS:3	Definition Used	Source of definition	Periodical	Vol	Issue	Start Page
Gribble,Phillip A.;Hertel,Jay;Denegar,Craig R.;Buckley, William E.	the effects of fatigue and chronic ankle instability on dynamic postural control	2004	2	attempting to maintain a stable base of support while completing a pre- scribed movement	Winter, D.A., Patla, A.E., and Frank, J.S. (1990) Assessment of balance control in humans. Medical Progress through technology 16 31-51	Journal of Athletic Training (National Athletic Trainers' Association)	39	4	321
Gribble,Phillip A.;Robinson,Richard H.;Hertel,Jay;Denegar,Craig R.	the effects of gender and fatigue on dynamic postural control	2009	2	center of mass is controlled while one's base of support is moving	Winter, D.A., Patla, A.E., and Frank, J.S. (1990) Assessment of balance control in humans. Medical Progress through technology 16 31-51	Journal of Sport Rehabilitation	18	2	240
Gribble,Phillip A.;Tucker, W. S.;White,Paul A.	time-of-day influences on static and dynamic postural control	2007	2	as one attempts to maintain a stable base of support while performing another task	Winter, D.A., Patla, A.E., and Frank, J.S. (1990) Assessment of balance control in humans. Medical Progress through technology 16 31-51	Journal of Athletic Training (National Athletic Trainers' Association)	42	1	35

Authors	Title	Year	Balance keyword DB: 1; DPC: 2; DPS:3	Definition Used	Source of definition	Periodical	Vol	Issue	Start Page
Hammaran,Elisabet;Ohlsson,Jennie Ann;Lindberg,Christopher;Kjellby-Wendt,Gunilla	reliability of static and dynamic balance tests in subjects with myotonic dystrophy type 1	2012	1	the concept of postural control could be described not only as the ability to minimize sway (steady-state stability or static balance) but also the ability to remain steady during expected movements - also named anticipatory stability or dynamic balance. The ability to remain steady during unforseen movements/events is a third aspect of postural control also included in dynamic balance.	Shumway-Cook A, Woollacott MH. Postural Control. In: Shumway-Cook A, Woollacott MH, eds. Motor control. Translating research into clinical practice. 3rd ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2007. pp. 212 – 256.	Advances in Physiotherapy	14	2	48

Authors	Title	Year	Balance keyword DB: 1; DPC: 2; DPS:3	Definition Used	Source of definition	Periodical	Vol	Issue	Start Page
Hammaren,Elisabet;Kjellby-Wendt,Gunilla;Kowalski,Jan;Lindberg,Christopher	factors of importance for dynamic balance impairment and frequency of falls in individuals with myotonic dystrophy type 1 - a cross-sectional study - including reference values of timed up & go, 10m walk and step test	2014	1	a subject's ability to manage dynamic balance tests.	No reference	Neuromuscular Disorders: NMD	24	3	207
Heebner N.R., Akins J.S., Lephart S.M., Sell T.C.	Reliability and validity of an accelerometry based measure of static and dynamic postural stability in healthy and active individuals	2015	3	the ability to transfer and control the projection of one's center of mass over a base of support while transitioning from a dynamic to static state	Goldie PA, Bach TM, Evans OM. Force platform measures for evaluating postural control: reliability and validity. Arch Phys Med Rehabil 1989;70(7):510–7.Wikstrom EA, Tillman MD, Smith AN, Borsa PA. A new force-plate technology measure of dynamic postural stability: the dynamic postural stability index. JAthl Train 2005;40(4):305–9.	Gait and Posture	41	2	535

Authors	Title	Year	Balance keyword DB: 1; DPC: 2; DPS:3	Definition Used	Source of definition	Periodical	Vol	Issue	Start Page
Heinbaugh EM, Smith DT, Zhu Q, Wilson MA, Dai B.	The effect of time-of-day on static and dynamic balance in recreational athletes.	2015	1	ability to maintain or regain a stable position during dynamic tasks and make postural changes to voluntary movements or external perturbations	Berg, K. O., Wood-Dauphinee, S. L., Williams, J. I., & Maki, B. (1992). Measuring balance in the elderly: Validation of an instrument. Canadian Journal of Public Health, 83, S7–S11. Hrysomallis, C. (2011). Balance ability and athletic performance. Sports Medicine, 41, 221–232.	Sports Biomech	14	3	361
Holden S, Boreham C, Doherty C, Wang D, Delahunt E	A longitudinal investigation into the progression of dynamic postural stability performance in adolescents.	2016	3	ability to perform a task without compromising the centre of mass (CoM) over the base of support	Winter DA, Patla AE, Frank JS. Assessment of balance control in humans. Med. Prog. Technol. 1990;16(1–2):31–51. Gribble PA, Hertel J, Plisky P. Using the star excursion balance test to assess dynamic postural-control deficits and outcomes in lower extremity injury: a literature and systematic review. J. Athl. Train. 2012;47(3):339–57.	Gait Posture	48		171

Authors	Title	Year	Balance keyword DB: 1; DPC: 2; DPS:3	Definition Used	Source of definition	Periodical	Vol	Issue	Start Page
Holden,Sinead;Boreham,Colin;Doherty,Cailbhe;Wang,Dan;Delahunt,Eamonn	dynamic postural stability in young adolescent male and female athletes	2014	3	requires a certain amount of movement around the base of support aforementioned differences in neuromuscularcontrol. Postural stability is defined as an individual's ability to maintain one's center of mass over the base of support and is an integral component of neuromuscular control	Paterno MV, Schmitt LC, Ford KR, et al. Biomechanical measures during landing and postural stability predict second anterior cruciate ligament injury after anterior cruciate ligament reconstruction and return to sport. Am J Sports Med. 2010;38(10):1968-1978. Gribble PA, Hertel J, Plisky P. Using the Star Excursion Balance Test to assess dynamic postural-control deficits and outcomes in lower extremity injury: a literature and systematic review. J Athl Train. 2012;47(3):339-357.	Pediatric Physical Therapy: The Official Publication Of The Section On Pediatrics Of The American Physical Therapy Association	26	4	447
Hosseini,S.S.;Rostamkhany,H.;Hashemi,M.;Jalili,M.	a comparison of the effect of whole-body vibration and strength training on certain physical fitness factors and dynamic balance in students	2012	1	ability of the individual to maintain balance from the dynamic to static state	Hosseini, S.S., 2011. The Effect of Aquatic and Mental Trainings on Balance in Elderly Males. Middle East J. Scientific Res., 9(5): 296-302.	Middle East Journal of Scientific Research	11	3	336

Authors	Title	Year	Balance keyword DB: 1; DPC: 2; DPS:3	Definition Used	Source of definition	Periodical	Vol	Issue	Start Page
Hosseini,S. S.;Rostamkhany,H.;Panahi,M.;Ramandi,L. D.	exercise-related fatigue change dynamic postural control in healthy males	2012	2	performing a functional task without involvement of a part of base of support	Hosseini, S., 2011. The Effect of Aquatic and Mental Trainings on Balance in Elderly Males. Middle-East J. Scientific Res., 7(3): 296-302.Hosseini, S.S., B. Mirzaei, M. Panahi and H. Rostamkhany, 2011. Effect of Aquatic Balance Training and Detraining on Neuromuscular Performance, Balance and Walking Ability in Healthy Older Men. Middle-East J. Scientific Res., 9(5): 661-666.Abbasi, A., H. Sadeghi, H. Berenjeian, K. Bagheri, A. Ghasemizad and A. KarimiAsl, 2011. Effect of Whole Body Vibration, Aquatic Balance and Combined Training on Neuromuscular Performance, Balance and Walking Ability in Male Elderly Able-Bodied Individual. World Applied Sciences J., 15(1): 84-91. Gribble, P.A. and T. Kaminski, 2003. The star excursion balance test as a measurement tool. Athletic Therapy Today, 8(2): 46-47. 9. Fattahi, A., H. Sadeghi and M.S. Ameli, 2011. Relationship Between Injury Types and Prevalence with Some Anthropometric Properties of Male Elite Volleyball Players of Iran. World Applied Sciences J., 15(5): 667-672.10. Sebahattin, D. and G. Ismail, 2011. The effect of an Eight-Week Swimming Training on Capillary Oxygen Saturation and Respiratory Parameters. World Applied Sciences J., 15(11): 1598-1603.	Middle East Journal of Scientific Research	11	2	230

Authors	Title	Year	Balance keyword DB: 1; DPC: 2; DPS:3	Definition Used	Source of definition	Periodical	Vol	Issue	Start Page
Hosseinimehr,Seyed Hossein;Norasteh,Ali Asghar	the role of leg and trunk muscles proprioception on static and dynamic postural control	2010	2	maintaining a stable base of support while completing a prescribed movement	Winter, D.A., Patla, A.E., and Frank, J.S. (1990) Assessment of balance control in humans. Medical Progress through technology 16 31-51	Journal of Physical Education & Sport / Citius Altius Fortius	26	1	83
Jazi,S. D.;Purrajabi,F.;Movahedi,A.;Jalali,S.	effect of selected balance exercises on the dynamic balance of children with visual impairments	2012	1	ability to maintain one's equilibrium as the center of gravity shifts	Gallahue & Ozmun 2006 Understanding motor development: Infants, children, adolescents, adults (6th ed.). Boston: McGraw-Hill.	Journal of Visual Impairment and Blindness	106	8	466
Johnson,Eric G.;Larsen, Andrea;Ozawa,Hiromi;Wilson,Christine A.;Kennedy,Karen L.	the effects of pilates-based exercise on dynamic balance in healthy adults	2007	1	requires moving a stable postural set over a base of support	Duncan, W.P., Weiner, D.K., Chandler, J., Studenski, S., 1990. Functional reach: a new clinical measure of balance. J. Gerontol. 45 (6),	Journal of Bodywork & Movement Therapies	11	3	238
Johnson-Kramer,C.; Sherwood, D.;French, R.;Canabal, M. Y.	performance and learning of a dynamic balance task by visually impaired children	1992	1	ability to maintain ones equilibrium while changing positions (Gallahue, 1987)	Gallahue D. (1987) Develpmental Physical Education for today's elementary school children. New York: Macmillan publishing	Clinical Kinesiology (Online Edition)	45	4	3

Authors	Title	Year	Balance keyword DB: 1; DPC: 2; DPS:3	Definition Used	Source of definition	Periodical	Vol	Issue	Start Page
Jones,C. J.;Robichaux,J.;Williams,P.;Rikli, R.	the effects of a 16-week exercise program on the dynamic balance of older adults	1992	1	ability to maintain equilibrium while in motion	No reference	Journal of Clinical and Experimental Gerontology	14	2	165
Kahle,Nicole L.;Gribble, Phillip A.	core stability training in dynamic balance testing among young, healthy adults	2009	1	completion of a functional task with purposeful movements without compromising the base of support	Gribble, P.A, Hertel, J., Denegar, C.J., & Buckley, W.E. (2004) The effects of fatigue and chronic ankle instability on dynamic postural control Kinzey S.J., & Armstrong, C.W> . The reliability of the star-excursion test in assessing dynamic balance. JOSPT, 1998; 27(5): 356- 360	Athletic Training & Sports Health Care: The Journal for the Practicing Clinician	1	2	65
Kodesh E, Dar G.	The effect of kinesiotape on dynamic balance following muscle fatigue in individuals with chronic ankle instability.	2015	1	maintaining balance while transitioning from a dynamic to a static state	Wikstrom, E. A., Tillman, M. D., Chmielewski, T. L., Cauraugh, J. H., & Borsa, P. A. (2007). Dynamic postural stability deficits in subjects with self-reported ankle instability. Medicine & Science in Sports & Exercise, 39(3), 397–402	Res Sports Med	23	4	367

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Kovacevic, Erol; Bradic, Josipa; Bejdic Almir; Abazovic, Ensar; Bradic, Asim	unilateral profile of dynamic balance of female students of faculty of sport and physical education	2010	1	ability to establish and maintain a balance posture of body mass centre	No reference	Open Biomed Eng J	12	1	25
Kwon,Y. J.;Park,S. J.;Jefferson ,J.;Kim,K.	the effect of open and closed kinetic chain exercises on dynamic balance ability of normal healthy adults	2013	1	ability to maintain balance while the body is moving by keeping its center of gravity over the base of support5).	Raymakers JA, Samson MM, Verhaar HJ: The assessment of body sway and the choice of stability parameters. Gait Posture, 2005, 21: 48–58	Clinics (Sao Paulo)	25	6	671
Liu,Kathy; Glutting,Joseph;Wikstrom,Erik;Gustavsen,Geoff;Royer, Todd;Kaminski,Thomas W.	examining the diagnostic accuracy of dynamic postural stability measures in differentiating among ankle instability status	2013	3	the ability to maintain balance while transitioning from a dynamic movement to a static state over the base of support	Goldie PA, Bach TM, Evans OM. Force platform measures for evaluating postural control: reliability and validity. Arch Phys Med Rehabil 1989; 70: 510–517 Gribble, P.A., Robinson, R.H., 2009. An examination of ankle, knee, and hip torque production in individuals with chronic ankle instability. J. Strength Cond. Res. 23, 395–400.	Sport Science	28	2	211

Authors	Title	Year	Balance keyword DB: 1; DPC: 2; DPS:3	Definition Used	Source of definition	Periodical	Vol	Issue	Start Page
Niu,Wenxin;Zhang,Ming;Fan,Yubo;Zhao,Qinping	dynamic postural stability for double-leg drop landing	2013	3	an individual's ability to maintain balance while transitioning from a dynamic to a static state	Wikstrom EA, Tillman MD, Smith AN, Borsa PA. A new force-plate technology measure of dynamic postural stability. The dynamic postural stability index. J AthlTrain. 2005; 40(4):305-091.	Clinical Rehabilitation	31	10	1074
Ortuno-Cortes,M. A.;Martin-Sanz,E.;Barona-de Guzman,R.	value of dynamic postural control tests on elderly people with vestibulopathy	2009	2	the regulation of the integral body position (posture) in space with the goal of keeping it in balance at rest (static balance) or moving (dynamic balance).	Shumway-Cook A, Woollacott MH. Control of posture and balance. In: Motor control. Theory and practical applications. Baltimore: Williams & Wilkins; 1995. p. 119-68.	Plos One	60	3	149
Oshita K, Yano S.	The Effect of Lightly Gripping a Cane on the Dynamic Balance Control.	2015	1	ability to anticipate changes in balance and coordinate muscle activity to maintain stability [18], and it means maintaining a stable position while the person undertakes a prescribed movement [19]	M.E. Rogers, N.L. Rogers, N. Takeshima, and M.M. Islam, "Methods to assess and improve the physical parameters associated with fall risk in older adults", Prev. Med., vol. 36, pp. 255-264, 2003. M.T. Karimi, and S. Solomonidis, "The relationship between parameters of static and dynamic stability tests" J. Res. Med. Sci., vol.16, pp. 530-535, 2011	Open Biomed Eng J	9		146

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Ozrudi, MF; Aliabadi, SR; Barzegari, H	The effect of six week mixed exercise (power & plyometric) of dynamic balance in Takhti school physical education students in Babol city	2015	1	DB: individual ability to keep balance from dynamic situation to steady. Balance is defined as the process of keeping the center of gravity within the supporting surface.	Wikstrom EA, Tillman MD, Smith AN, Borsa PA. A new force-plate technology measure of dynamic postural stability. The dynamic postural stability index. J AthlTrain. 2005; 40(4):305-091. Hertel J, Gay MR, Denegar CR. Differences in postural control during single-leg stance among healthy individuals with different foot types. J Athl Train. 2002; 37(2):129-32.Hadi H, Farhady H, Bashiri M. Effect of ix week strength and plyometric training on dynamic balance of male athletic students. Research in Rehabilitation Sciences. 2011; 7(2):215-224.	International Journal Of Applied Exercise Physiology	4	2	34
Purohit,Roma, Dilip;Sadhale,Aparna	co-relation between static and dynamic balance in healthy individuals between 18-25 years using one leg stance test and multi directional reach test	2014	1	ability to maintain equilibrium while moving through space.	V. Hatzitaki,V. Zisi, et al; Journal of Motor Behaviour, 2002, Vol. 34, No. 2, 161–170	Indian Journal of Physiotherapy & Occupational Therapy	8	2	89

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Rahal MA, Alonso AC, Andrusaitis FR, Rodrigues TS, Speciali DS, Greve JM, Leme LE.	Analysis of static and dynamic balance in healthy elderly practitioners of Tai Chi Chuan versus ballroom dancing.	2015	1	maintaining a steady position while sitting, standing and walking	Shumway-Cook A, Woollacott MH. Motor control: translating research into clinical practice. 3rd edition. Philadelphia, PA. Lippincott Williams & Wilkins. 2007	Clinics (Sao Paulo)	70	3	157
Khasawneh A.	Anthropometric measurements and their relation to static and dynamic balance among junior tennis players [Antropometrijska mjerenja i njihov odnos prema statičkoj i dinamičkoj ravnoteži juniora tenisača]	2015	1	body's ability to retain poise or steadiness when moving or shifting from one balanced situation to another	no reference	Sport Science	8		87
Ricotti,Leonardo	static and dynamic balance in young athletes	2011	1	ability to perform a task while maintaining a stable position (Winter et al., 1990).	Winter DA, Patla AE, Frank JS. Assessment of balance control in humans. Med. Prog. Technol. 1990;16(1–2):31–51.	Journal of Human Sport & Exercise	6	4	616

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Rogers,Helen L.;Cromwell,Ronita L.;Grady,James L.	adaptive changes in gait of older and younger adults as responses to challenges to dynamic balance	2008	1	ability to remain balanced while the body is in motion (Cromwell et al., 2002); this definition includes the ability to successfully respond to balance challenges (MacKinnon & Winter, 1993; Patla, 1996)	Cromwell RL, Aadland-Monahan TK, Nelson AT, Stern-Sylvestre SM, Seder B. Sagittal plane analysis of head, neck, and trunk kinematics and electromyographic activity during locomotion. J Orthop Sports Phys Ther. 2001;31:255–262. MacKinnon, C., & Winter, D. (1993). Control of whole body balance in the frontal plane during human walking. Journal of Biomechanics, 26(6), 633-644. Patla, A. (1996). Neurobiological bases for the control of human locomotion. In A. Bronstein, T. Brandt, & M. Woollacott (Eds.), Clinical disorders of balance, posture and ait (pp. 19-40). New York: Oxford Press.	Journal of Aging & Physical Activity	16	1	85
Sarshin,Amir;Mohammadi,Sardar;Shahrabad,Hossein Babaei Pour;Sedighi,Mahboobeh	the effects of functional fatique on dynamic postural control of badminton players	2011	2	performing a functional task without compromising any part of the supporting leg	Erik A, Wikstrom E, Michael E, Mark D, Powers D. Dynamic stabilization time after isokinetic and functional fatigue. J Athl Train 39: 247-53, 2004	Biology of Exercise	7	2	25

Authors	Title	Year	Balance keyword DB: 1; DPC: 2; DPS:3	Definition Used	Source of definition	Periodical	Vol	Issue	Start Page
Sarvestani, H. J.;Tabrizi,H. B.;Abbasi, A.;Rahmanpourmoghaddam,J.	the effect of eight weeks aquatic balance trainingand core stabilization training on dynamic balance in inactive elder males	2012	1	(maintaining balance while a prescribed movement is performed	Olmsted, L.C. and J. Hertel, 2004. Influence of foot type and orthotics on static and dynamic postural control.Journal of Sport Rehabilitation, 13(1): 54-66. Guskiewicz, K.M. and D.H. Perrin, 1996. Research and clinical applications of assessing balance. Journal of Sport Rehabilitation, 5: 45-63.	Middle East Journal of Scientific Research	11	3	279
Sarvestani, H.J.;Tabrizi,H.B.;Abbasi,A.;Rahmanpourmoghaddam,J	the effect of ten weeks aquatic balance trainingand functional training on dynamic balance in inactive elder males	2012	1	active movement of COP while standing, walking, or performing any other skill	Punakallio, A., 2004. Balance Abilities of Workers in Physically Demanding Jobs. University of Kuopio	Middle East Journal of Scientific Research	11	3	296

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Sell,Timothy C.;Pederson,Jonathan J.;Abt,John P.;Nagai,Takashi;Deluzio,Jennifer;Wirt,Michael D.;McCord,Larry J.;Lephart, Scott M.	the addition of body armor diminishes dynamic postural stability in military soldiers	2013	3	Postural stability is the ability to sustain the body in equilibrium by maintaining the projected center of mass within the limits of the base of support (Shumway-Cook & Woollacott, 2001a). It is a dynamic process that requires sensory detection of body motions	Shumway-Cook, A., & Woollacott, M. H. (2001a). Motor control: Theory and practical applications (2nd ed.). Philadelphia: Lippincott Williams & Wilkins	Military medicine	178	1	76
Shin,Sohee;Demura,Shinichi	effective tempo of the step test for dynamic balance ability in the elderly	2007	1	ability to maintain stability of posture during movement	No reference	Journal Of Physiological Anthropology	26	6	563

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Song,Jooeun;Sigward,Susan;Fisher,Beth;Salem,George J.	altered dynamic postural control during step turning in persons with early-stage parkinson's disease	2012	2	Postural control is the ability to alter the magnitude and patterns of segmental kinematics (e.g., trunk and limb movements) in order to direct body position in response to external mechanical demands imposed during static and dynamic tasks such as turning.	S. Colnat-Coulbois, G. C. Gauchard, L. Maillard et al., "Bilateral subthalamic nucleus stimulation improves balance control in Parkinson's disease," Journal of Neurology, Neurosurgery and Psychiatry, vol. 76, no. 6, pp. 780–787, 2005. F. B. Horak, D. Dimitrova, and J. G. Nutt, "Direction-specific postural instability in subjects with Parkinson's disease," Experimental Neurology, vol. 193, no. 2, pp. 504–521, 2005	Parkinson's Disease	2012		
Suttie,S. J.	differential effects of viewing four patterns of figure movement on performance of a dynamic balance task	1973	1	establishing and maintaining equilibrium	No reference	Perceptual and motor skills	37	1	279

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Takeshima,Nobuo;Islam,Mohammod M.;Rogers,Michael E.;Koizumi,Daisuke;Tomiyama,Naoki;Narita,Makoto;Rogers,Nicole L.	pattern of age-associated decline of static and dynamic balance in community-dwelling older women	2014	1	is the ability to anticipate changes and coordinate muscle activity in response to perturbations of stability	No reference	Geriatrics & Gerontology International	14	3	556
Trousil,T.; Dvir,Z.	dynamic balance: a learning strategy	1983	1	maintenance of balance on an unstable (sometimes metastable) support	No reference	Human Movement Science	2	3	211
Tsigilis,N.;Zachopoulou,E.;Mavridis,Th	evaluation of the specificity of selected dynamic balance tests	2001	1	to maintenance equiLbrium during rapid changes of the individual's kmetic condition	No reference	Perceptual & Motor Skills	92	3	827

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Wakano,Shimpachi;Takeda,Tomotaka;Nakajima,Kazunori;Kurokawa,Katsuhide;Ishigami,Keiichi	effect of experimental horizontal mandibular deviation on dynamic balance	2011	1	posture is maintained against various forces exerted by movement of a part of the body or movement of the whole body.	No reference	Journal Of Prosthodontic Research	55	4	228
Wikstrom, Erik A.;Tillman, Mark D.;Chmielewski,Terese L.;Cauraugh,James H.;Borsa,Paul A.	dynamic postural stability deficits in subjects with self-reported ankle instability	2007	3	maintaining balance while transitioning from a dynamic to a static state	GOLDIE, P., T. BACH, and O. EVANS. Force platform measures for evaluating postural control: reliability and validity. Arch. Phys. Med. Rehabil. 70:510–517, 1989.	Medicine & Science in Sports & Exercise	39	3	397

Authors	Title	Year	Balance keyword DB: 1; DPC: 2; DPS:3	Definition Used	Source of definition	Periodical	Vol	Issue	Start Page
Wikstrom, Erik A.;Tillman, Mark D.;Smith,Andrew N.;Borsa,Paul A.	a new force-plate technology measure of dynamic postural stability: the dynamic postural stability index	2005	3	an individual's ability to maintain balance while transitioning from a dynamic to a static state.	Goldie PA, Bach TM, Evans OM. Force platform measures for evaluating postural control: reliability and validity. Arch Phys Med Rehabil. 1989;70:510–517.	Journal of Athletic Training (National Athletic Trainers' Association)	40	4	305
Zech,Astrid;Steib,Simon;Hentschke,Christian;Eckhardt,Holger; Pfeifer,Klaus	effects of localized and general fatigue on static and dynamic postural control in male team handball athletes	2012	2	postural balance control: the center of body mass must be kept over the supporting base,DYNAMIC BALANCE involves achieving a compromise between the forward propulsion of the body and the need to maintain the lateral stability of the body	Assaiante, C and Amblard, B. An ontogenetic model of sensorimotor organization of balance control in humans. Hum Mov Sci 14: 13–43, 1995.	Journal of Strength & Conditioning Research (Lippincott Williams & Wilkins)	26	4	1162

Hsiao MY; Li CM; Lu IS; Lin YH; Wang TG; Han DS	An investigation of the use of the Kinect system as a measure of dynamic balance and forward reach in the elderly.	2017	1	Dynamic balance is the ability to maintain postural stability during the transition from a dynamic to a static state, or while shifting the center of gravity (COG) on a moving base of support.7,8	Ross SE and Guskiewicz KM. Examination of static and dynamic postural stability in individuals with functionally stable and unstable ankles. Clin J Sport Med 2004; 14(6): 332–338. DiStefano LJ, Clark MA and Padua DA. Evidence supporting balance training in healthy individuals: a systemic review. J Strength Cond Res 2009; 23(9): 2718–2731	Clinical Rehabilitation			
Craig CE; Doumas M	Anodal Transcranial Direct Current Stimulation Shows Minimal, Measure-Specific Effects on Dynamic Postural Control in Young and Older Adults: A Double Blind, Sham-Controlled Study.	2017	1	Postural control is an adaptive sensorimotor process involving constant integration of sensory information from three channels; visual, somatosensory (proprioceptive) and vestibular	no reference	Plos One	12	1	e0170331

Authors	Title	Year	Balance keyword DB: 1; DPC: 2; DPS:3	Definition Used	Source of definition	Periodical	Vol	Issue	Start Page
Shiravi Z, Shadmehr A, Moghadam ST, Moghadam BA.	Comparison of dynamic postural stability scores between athletes with and without chronic ankle instability during lateral jump landing.	2017	1	Dynamic postural stability is defined as an individual's ability to maintain balance while transitioning from a dynamic to a static position	Goldie PA, Bach TM, Evans OM (1989) Force platform measures for evaluating postural control: reliability and validity. Arch Phys Med Rehabil. 70(7):510-7.	Muscles Ligaments Tendons	10	7	119
Sirois-Leclerc G; Remaud A; Bilodeau M	Dynamic postural control and associated attentional demands in contemporary dancers versus non-dancers.	2017	1	Dynamic postural control can be defined as the ability to maintain the center of mass within the base of support while the body is subjected to internal or external perturbations that are anticipated or not	Winter DA, Patla AE, Frank JS. Assessment of balance control in humans. Med Prog Technol. 1990; 16: 31–51	Plos One	12	3	e0173795
Abutaleb, Enas ELsayed Mohamed	Effect of shoulder side pack on dynamic postural stability in young healthy female	2016	1	Dynamic postural stability: the ability to maintain postural stability & orientation with CoM over BoSt while the body parts are in motion	Sullivan S., Portnry L. Physical Rehabilitation: 6th Edition. FA Davis; 2014	International Journal Of Physiotherapy			

Authors	Title	Year	Balance keyword DB: 1; DPC: 2; DPS:3	Definition Used	Source of definition	Periodical	Vol	Issue	Start Page
Ng, Robert S. K.; C. W., Cheung; Raymond, K. W. Sum	Effects of 6-week agility ladder drills during recess intervention on dynamic balance performance.	2017	1	Dynamic balance is the ability to maintain a stable base of support while completing a functional task without compromising one's base of support	Winter, D. A., Patla, A. E., & Frank, J. S. (1990). Assessment of balance control in humans. Medical Progress Through Technology, 16(1), 31-51.	Journal of Physical Education & Sport	17	1	306
Zulfikri N MHSc Pt; Justine M PhD Pt	Effects of Kinesio® Taping on Dynamic Balance Following Fatigue: a Randomized Controlled Trial.	2017	1	Dynamic balance is defined as the ability to maintain the stability of the center of mass during movement	Butler RJ, Southers C, et al.: Differences in soccer players' dynamic balance across levels of competition. J Athl Train. 2012; 47: 616-620.	Physical Therapy Research	20	1	16
Gürkan AC; Demirel H; Demir M; Atmaca EŞ; Bozöyük G; Dane S	Effects of Long-Term Training Program on Static and Dynamic Balance in Young Subjects.	2016	1	Dynamic balance is defined as the ability of a subject to predict postural changes during movement, and to give appropriate responses to changes in balance.	Duncan PW, Weiner DK, Chandler J, Studenski S. Functional Reach: A new clinical measure of balance. J Gerontol A Biol Sci Med Sci, 1990; 45: 192-197.	Clinical And Investigative Medicine	39	6	

Authors	Title	Year	Balance keyword DB: 1; DPC: 2; DPS:3	Definition Used	Source of definition	Periodical	Vol	Issue	Start Page
Malmir K, Olyaei GR, Talebian S, Jamshidi AA, Ganguie MA.	Effects of Peroneal Muscles Fatigue on Dynamic Stability Following Lateral Hop Landing: Time to Stabilization vs. Dynamic Postural Stability Index.	2017	1	Postural stability is related to the control of body's center of mass with respect to the center of pressure.	Massion J. Postural control system. Curr Opin Neurobiol. 1994; 4(6): 877-887.	J Sport Rehabil.	17		1
McDermott P; Wolfe E; Lowry C; Robinson K; French HP	Evaluating the immediate effects of wearing foot orthotics in children with Joint Hypermobility Syndrome (JHS) by analysis of temperospatial parameters of gait and dynamic balance: A preliminary study.	2017	1	Dynamic balance refers to the maintenance of the body in equilibrium during activities, such as walking and is an intrinsic requirement for normal gait	no reference	Gait & Posture	60		61

Authors	**Title**	**Year**	**Balance keyword DB: 1; DPC: 2; DPS:3**	**Definition Used**	**Source of definition**	**Periodical**	**Vol**	**Issu e**	**Start Page**
Hemmati L; Rojhani-Shirazi Z; Malek-Hoseini H; Mobaraki I	Evaluation of Static and Dynamic Balance Tests in Single and Dual Task Conditions in Participants With Nonspecific Chronic Low Back Pain.	2017	1	postural control is the control of body position in space to maintain balance and orientation	Shumway-Cook & Woollacott. Motor Control Theory and Practical Applications Baltimore, MD. Williams and Wilkins, 1995	Journal Of Chiropractic Medicine	16	3	189
Ateş, Bahar	Investigation Of Static And Dynamic Balance Performances Of Female Student-Athletes And Non-Athletes Between 12 And 14 Years Of Age.	2017	1	which occurs when the external forces are neutralized by the soft tIssueues around the muscles and joints	Yaggie J.A., & Brian M.C. “Effects of balance training on selected skills” The Journal of Strength and Conditioning Research, 20(2): 422-428, 2006	Journal of Physical Education & Sports Science / Beden Egitimi ve Spor Bilimleri Dergisi	11	1	1

Authors	Title	Year	Balance keyword DB: 1; DPC: 2; DPS:3	Definition Used	Source of definition	Periodical	Vol	Issue	Start Page
Aguiar Gonçalves, Geiseane; Harudy Kamonseki, Danilo; Reclusa Martinez, Bruna; Amaral Nascimento, Maythe; Lombardi Junior, Império; Liu Chiao Yi	Static, dynamic balance and functional performance in subjects with and without plantar fasciitis.	2017	1	dynamically defined as the ability to perform tasks while maintaining a stable body position and without changing the BOS	Plisky PJ, Rauh MJ, Kaminski TW, Underwood FB. Star Excursion Balance Test as a Predictor of Lower Extremity Injury in High School Basketball Players. J Orthop Sports Phys Ther. 2006;36(12):911-9. 11. Bressel E, Yonker JC, Kras J, Heath EM. Comparison of Static and Dynamic Balance in Female Collegiate Soccer, Basketball, and Gymnastics Athletes. J Athl Train 2007, 42(1)42-6	Fisioterapia em Movimento	30	1	19

Appendix C: References for Table 3.1, Section 3.3.2

Table reference number	Reference
1	Rasool J and George K. The impact of single-leg dynamic balance training on dynamic stability. Physical Therapy in Sport 2007. DOI: 10.1016/j.ptsp.2007.06.001.
2	Tsigilis N, Zachopoulou E and Mavridis T. Evaluation of the specificity of selected dynamic balance tests. Percept Mot Skills 2001.
3	Clyse SJ and Short MA. The relationship between dynamic balance and postrotary nystagmus in learning. Physical {\&} Occupational Therapy In Pediatrics 1983.
4	Cagno Ad, Fiorilli G, Iuliano E, et al. Time-of-Day Effects on Static and Dynamic Balance in Elite Junior Athletes and Untrained Adolescents. International Journal of Sports Science & Coaching 2014. DOI: 10.1260/1747-9541.9.4.615.
5	Jones JC, Robichaux J, Williams P, et al. The effects of a 16 week program on the dynamic balance of older adults. Journal of clinical and experimental gerontology 1992.
6	Purohit RD and Sadhale A. Co-relation between Static and Dynamic Balance in Healthy Individuals between 18-25 Years using One Leg Stance Test and Multi Directional Reach Test. Indian Journal of Physiotherapy {\&} Occupational Therapy 2014. DOI: 10.5958/j.0973-5674.8.2.066.
7	Abbasi A and Tabrizi HB. Dynamic Balance in Inactive Elder Males changes after Eight Weeks Functional and Core Stabilization Training. Middle-East Journal of {\ldots} 2012.
8	Fotios M, Miltiadis P, Eirini A, et al. Dynamic balance in girls practising recreational rhythmic gymnastics and greek traditional dances. Science of Gymnastics Journal 2013.
9	Kwon YJ, Park SJ, Jefferson J, et al. The Effect of Open and Closed Kinetic Chain Exercises on Dynamic Balance Ability of Normal Healthy Adults. Journal of Physical Therapy Science 2013.
10	Rogers HL, Cromwell RL and Grady JL. Adaptive changes in gait of older and younger adults as responses to challenges to dynamic balance. J Aging Phys Act 2008.
11	Davlin-Pater C. The effects of visual information and perceptual style on static and dynamic balance. Motor Control 2010.
12	Davlin CC. Dynamic balance in high level athletes. Percept Mot Skills 2004.

13 Johnson-Kramer C, Sherwood D, French R, et al. Performance and learning of a dynamic balance task by visually impaired children. Clinical Kinesiology 1992.

14 Jazi SD, Purrajabi F, Movahedi A, et al. Effect of Selected Balance Exercises on the Dynamic Balance of Children with Visual Impairments. Journal of Visual Impairment {\&} Blindness 2012.

15 McDermott P, Wolfe E, Lowry C, et al. Evaluating the immediate effects of wearing foot orthotics in children with Joint Hypermobility Syndrome (JHS) by analysis of temperospatial parameters of gait and dynamic balance: A preliminary study. Gait {\&} posture 2017. DOI: 10.1016/j.gaitpost.2017.11.005.

16 Hemmati L, Rojhani-Shirazi Z, Malek-Hoseini H, et al. Evaluation of Static and Dynamic Balance Tests in Single and Dual Task Conditions in Participants With Nonspecific Chronic Low Back Pain. Journal of chiropractic medicine 2017. DOI: 10.1016/j.jcm.2017.06.001.

17 Amiri-Khorasani M. Acute effects of different stretching methods on static and dynamic balance in female football players. International journal of therapy and rehabilitation 2015.

18 Hosseini SS, Rostamkhany H, Hashemi M, et al. A comparison of the effect of whole-body vibration and strength training on certain physical fitness factors and dynamic balance in students. Middle East Journal of Scientific Research 2012.

19 Kodesh E and Dar G. The effect of kinesiotape on dynamic balance following muscle fatigue in individuals with chronic ankle instability. Research in Sports Medicine 2015. DOI: 10.1080/15438627.2015.1076417.

20 Ozrudi MF, Aliabadi SR and Barzegari H. The effect of six week mixed exercise (power \& plyometric) of dynamic balance in Takhti school physical education students in Babol city. International Journal of Applied Exercise Physiology 2015.

21 Trousil T and Dvir Z. Dynamic balance: A learning strategy. Human Movement Science 1983. DOI: 10.1016/0167-9457(83)90018-0.

22 Anoop A, Zutshi K, Jitender M, et al. Effect of core stabilisation on dynamic balance in non-professional sports players. Indian Journal of Physiotherapy and Occupational Therapy 2010.

23 Suttie S. Differential effects of viewing four patterns of figure movement on performance of a dynamic balance task. Percept Mot Skills 1973.

24 Bhat R and Moiz JA. Comparison of dynamic balance in collegiate field hockey and football players using star excursion balance test. Asian Journal of Sports Medicine 2013.

25 Bressel E, Yonker JC, Kras J, et al. Comparison of static and dynamic balance in female collegiate soccer, basketball, and gymnastics athletes. Journal of athletic training 2007.

Choi A, Kang TG and Mun JH. Biomechanical Evaluation of Dynamic Balance Control Ability During Golf Swing.
26 Journal of Medical and Biological Engineering 2016. DOI: 10.1007/s40846-016-0141-0.

Heinbaugh EM and Smith DT. The effect of time-of-day on static and dynamic balance in recreational athletes.
Sports Biomechanics, 2015 Vol.14, No.3, 361–373, http://dx.doi.org/10.1080/14763141.2015.1084036 2015. DOI:
27 10.1080/14763141.2015.1084036.

Oshita K and Yano S. The Effect of Lightly Gripping a Cane on the Dynamic Balance Control. The Open Biomedical
28 Engineering Journal 2015.

Faigenbaum AD, Bagley J, Boise S, et al. Dynamic Balance in Children: Performance Comparison Between Two
29 Testing Devices. Athletic Training {\&} Sports Health Care 2015. DOI: 10.3928/19425864-20150707-06.

Ricotti L. Static and dynamic balance in young athletes. Journal of Human Sport and Exercise 2011. DOI:
30 10.4100/jhse.2011.64.05.

Shin S and Demura S. Effective tempo of the step test for dynamic balance ability in the elderly. Journal of
31 physiological anthropology 2007. DOI: 10.2114/jpa2.26.563.

Butz SM, Sweeney JK, Roberts PL, et al. Relationships among age, gender, anthropometric characteristics, and
dynamic balance in children 5 to 12 years old. Pediatric Physical Therapy 2015. DOI:
32 10.1097/PEP.0000000000000128.

Rahal MA^, Alonso A'C, Andrusaitis FR, et al. Analysis of static and dynamic balance in healthy elderly practitioners
33 of Tai Chi Chuan versus ballroom dancing. Clinics (São Paulo, Brazil) 2015. DOI: 10.6061/clinics/2015(03)01.

Hammar 'en E, Ohlsson JA, Lindberg C, et al. Reliability of static and dynamic balance tests in subjects with myotonic
34 dystrophy type 1. Advances in Physiotherapy 2012. DOI: 10.3109/14038196.2012.675352.

Wakano S, Takeda T, Nakajima K, et al. Effect of experimental horizontal mandibular deviation on dynamic balance.
35 Journal of Prosthodontic Research 2011. DOI: 10.1016/j.jpor.2011.03.001.

Byrne J, Roberts J, Squires H, et al. The effect of a three-week wii fit balance training program on dynamic balance in
36 healthy young adults. International SportMed Journal 2012.

Cankaya S, Gokmen B, Tasmektepligil MY, et al. Special balance developer training applications on young males'
37 static and dynamic balance performance. Anthropologist 2015.

Hsiao M, Li C, Lu I, et al. An investigation of the use of the Kinect system as a measure of dynamic balance and
38 forward reach in the elderly. Clin Rehabil 2017. DOI: 10.1177/0269215517730117.

Kovacevic E, Bradic J, Bejdic A, et al. Unilateral profile of dynamic balance of female students of faculty of sport and
39 physical education. Homo Sporticus 2010.

Al-Khlaifat L, Herrington LC, Tyson SF, et al. The effectiveness of an exercise programme on dynamic balance in
40 patients with medial knee osteoarthritis: A pilot study. The Knee 2016. DOI: 10.1016/j.knee.2016.05.006.
Baghbaninaghadehi F, Ramezani AR and Hatami F. The effect of functional fatigue on static and dynamic balance in
41 female athletes. International SportMed Journal 2013.
Kahle NL and Gribble PA. Core stability training in dynamic balance testing among young healthy adults. Athletic
42 Training {\&} Sports Health Care 2009.
Ng RSK, Cheung CW and Sum KW. Effects of 6-week agility ladder drills during recess intervention on dynamic
43 balance performance. Journal of Physical Education and Sport 2017. DOI: 10.7752/jpes.2017.01046.
Gonçalves GA, Kamonseki DH, Martinez BR, et al. Static, dynamic balance and functional performance in subjects
44 with and without plantar fasciitis. Fisioterapia em Movimento 2017. DOI: 10.1590/1980-5918.030.001.ao02.
Chtara M, RouIssuei M, Bragazzi NL, et al. Dynamic balance ability in young elite soccer players implication of
45 isometric strength. J Sports Med Phys Fitness 2016.
Butler RJ, Southers C, Gorman PP, et al. Differences in soccer players' dynamic balance across levels of competition.
46 Journal of Athletic Training 2012. DOI: 10.4085/1062-6050-47.5.14.
Booysen MJ, Gradidge J and Watson E. The relationships of eccentric strength and power with dynamic balance in
47 male footballers. J Sports Sci 2015.
Zulfikri NZ and Justine MJ. Effects of Kinesio Taping on Dynamic Balance Following Fatigue : a Randomized
48 Controlled Trial. Physical therapy research 2017. DOI: 10.1298/ptr.E9887.
Sarvestani HJ, Sarvestani H, Tabrizi H, et al. The Effect of Eight Weeks Aquatic Balance Trainingand Core Stabilization
49 Training on Dynamic Balance in Inactive Elder Males. Middle-East Journal of Scientific Research 2012.
Eshraghi A, Maroufi N, Sanjari MA, et al. Effect of Milwaukee brace on static and dynamic balance of female
50 hyperkyphotic adolescents. Prosthet Orthot Int 2013. DOI: 10.1177/0309364612448805.
Gurkan AC, Demirel H, Demir M, et al. Effects of Long-Term Training Program on Static and Dynamic Balance in
51 Young Subjects. Clinical {\&} Investigative Medicine 2016.
Gribble PA, Hertel J, Denegar CR, et al. The effects of fatigue and chronic ankle instability on dynamic postural
52 control. Journal of Athletic Training 2004.
Gribble PA, Steven Tucker W and White PA. Time-of-Day Influences on Static and Dynamic Postural Control. Journal
53 of Athletic Training 2007.
Sajjad Hosseini Seyed, Hosseini S, Rostamkhany H, et al. Exercise-Related Fatigue Change Dynamic Postural Control
54 in Healthy Males. Middle-East Journal of Scientific Research 2012.

55 Hossein Hosseinimehr Seyed and Norasteh AA. The role of leg and trunk muscles proprioception on static and dynamic postural control. Journal of Physical Education and Sport Citius Altius Fortius -Journal of Physical Education and Sport 2010.

56 De Ridder R, Willems TM, Vanrenterghem J, et al. Effect of a Home-based Balance Training Protocol on Dynamic Postural Control in Subjects with Chronic Ankle Instability. Int J Sports Med 2015.

57 Field-Fote EC and Ray SS. Seated reach distance and trunk excursion accurately reflect dynamic postural control in individuals with motor-incomplete spinal cord injury. Spinal cord : the official journal of the International Medical Society of Paraplegia 2010. DOI: 10.1038/sc.2010.11.

58 Gribble PA and Robinson RH. An examination of ankle, knee, and hip torque production in individuals with chronic ankle instability. Journal of strength and conditioning research / National Strength {\&} Conditioning Association 2009. DOI: 10.1519/JSC.0b013e31818efbb2.

59 Sirois-Leclerc G, Remaud A and Bilodeau M. Dynamic postural control and associated attentional demands in contemporary dancers versus non-dancers. PloS one 2017. DOI: 10.1371/journal.pone.0173795.

60 Falk EE, Seeley MK, Hunter I, et al. Effect of experimental anterior knee pain on measures of static and dynamic postural control. Athletic Training and Sports Healthcare 2014.

61 Ortuño-Cortés MA, Martín-Sanz E and Barona-de Guzmán R. Value of dynamic postural control tests on elderly people with vestibulopathy. Acta Otorrinolaringologica (English Edition) 2009. DOI: 10.1016/S2173-5735(09)70121-8.

62 Sarshin A, Mohammadi S, Babaei H, et al. The effects of functional fatique on dynamic postural control of badminton players. Biology of Exercise 2011. DOI: 10.4127/jbe.2011.0047.

63 Brown CN, Ko J, Rosen AB, et al. Individuals with both perceived ankle instability and mechanical laxity demonstrate dynamic postural stability deficits. Clin Biomech 2015. DOI: 10.1016/j.clinbiomech.2015.08.008.

64 Fullam K, Caulfield B, Coughlan GF, et al. Dynamic postural-stability defecits after cryotherapy to the ankle joint. Journal of Athletic Training 2015. DOI: 10.4085/1062-6050-50.7.07.

65 Liu K, Glutting J, Wikstrom E, et al. Examining the diagnostic accuracy of dynamic postural stability measures in differentiating among ankle instability status. Clin Biomech 2013. DOI: 10.1016/j.clinbiomech.2012.11.003.

66 Niu W, Zhang M, Fan Y, et al. Dynamic postural stability for double-leg drop landing. J Sports Sci 2013. DOI: 10.1080/02640414.2012.762600.

67 Wikstrom EA, Tillman MD, Smith AN, et al. A new force-plate technology measure of dynamic postural stability: The dynamic postural stability index. Journal of Athletic Training 2005.

Wikstrom EA, Tillman MD, Chmielewski TL, et al. Dynamic Postural Stability Deficits in Subjects with Self-Reported
68 Ankle Instability. Med Sci Sports Exerc 2007. DOI: 10.1249/mss0b013e31802d3460.

Shiravi Z, Shadmehr A, Moghadam ST, et al. Comparison of dynamic postural stability scores between athletes with
and without chronic ankle instability during lateral jump landing. Muscles, ligaments and tendons journal 2017. DOI:
69 10.11138/mltj/2017.7.1.119.

Heebner NR, Akins JS, Lephart SM, et al. Reliability and validity of an accelerometry based measure of static and
dynamic postural stability in healthy and active individuals. Gait and Posture 2015. DOI:
70 10.1016/j.gaitpost.2014.12.009.

Holden S, Boreham C, Doherty C, et al. Dynamic postural stability in young adolescent male and female athletes.
Pediatric physical therapy : the official publication of the Section on Pediatrics of the American Physical Therapy
71 Association 2014. DOI: 10.1097/PEP.0000000000000071.

Holden S, Boreham C, Doherty C, et al. A longitudinal investigation into the progression of dynamic postural stability
72 performance in adolescents. Gait & Posture 2016. DOI: 10.1016/j.gaitpost.2016.04.019.

Abutaleb E. Effect of shoulder side pack on dynamic postural stability in young healthy female. International journal
73 of physiotherapy 2016.

Malmir K, Olyaei GR, Talebian S, et al. Effects of Peroneal Muscles Fatigue on Dynamic Stability Following Lateral
Hop Landing: Time to Stabilization vs. Dynamic Postural Stability Index. J Sport Rehab 2017. DOI: 10.1123/jsr.2017-
74 0095.

Appendix D: All tests identified in scoping review classified with Huxham's taxonomy

Perturbation	Stationary BOS	Moving BOS
Unperturbed	Narrow Ridge Balance Test (NRBT)	a modified version of the Springfield Beam-Walking Test (dynamic balance-Seashore 1951)
	single leg stance	6MWT
	stance	8 foot up and go (walking)
	Berg Balance Scale (sitting unsupported, standing unsupported, standing feet together, tandem standing, single leg stand, turning trunk with feet flexed)	mini-BESTest (walking gait, change in gait speed)
	BESS	Community Balance and Mobility Scale (tandem walking)
	mini-BESTest (stand on one leg)	step quick turn test (SQT)
	Community Balance and Mobility Scale (unilateral stance)	Gait Speed test (walking)
	CFP Tracking Test (centre of foot pressure)	walking gait
	Modified Rivermead Mobility Index MRMI	
	Dynamic balance measuring track (balancing on balls of feet)	
	Sensory Organisation Test (condn 1)	
	Dynamic Balance Assessment	
	risk and balance	
	Pediatric Balance Scale	

Perturbation	Stationary BOS	Moving BOS
Self-generated perturbations	8 foot up and go (getting up)	8 foot up and go (turning)
	Bass Dynamic Balance Test (BDBT)	anterior, lateral, and medial jump
	Berg Balance Scale (rising and sitting down in chair, turning trunk feet flexed, picking up an object off the floor, forward reach)	Balance beam gait
	Forward bending of trunk	balance beam speed test 1
	Forward reach test	balance beam speed test 2
	Functional reach	Balance beam tasks (DeOreoand Wade, 1971)
	get up from chair, sit, stand	Berg Balance Scale (turning 360 degrees, stepping one foot up and down off a step, Walk with head turns, horizontal, Walk with pivot turns, Step over obstacles,TUG, TUG with dual task)
	Golf swing	Community Balance and Mobility Scale (180 degree tandem pivot, lateral foot scooting, Hopping forward, crouch & walk, lateral dodging)
	LOS	drop jump
	75% LOS	drop landing
	LQ-YBT	Dynamic Balance Board Test (DBBT)
	mini-BESTest (sit to stand, standing arm raise)	Dynamic balance measuring track (jump on one leg)
	move COP to target	Dynamic Gait Index
	mSEBT	Dynamic Gait Index (brazilian version) obstacle negotiation, dual tasking
	seated reach test	Figure of 8 walking
	SEBT	forward lunge test (FL)
	single leg stance with exercises on other leg	Four Square Step Test
	Sit to stand	Functional mobility test

Perturbation	Stationary BOS	Moving BOS
Self-generated perturbations	sit to walk	gait initiation
	UQ-YBT	mini-BESTest (rise to toes, alternate stair touching,)
	Weight shift	jump landing task
	Rhythmic weight shift	Modified Bass Test
	Community Balance and Mobility Scale (bending component)	
	Dynamic Balance Assessment	single leg hop
	trunk bending	single leg landing task
	reach task	sit to walk
	30s chair stand test	Step Test
	object transport tasks (upper body movement task)	step up and over test (SUO)
	Pediatric Balance Scale	step ups
	Pediatric Reach Test	Stepping in place test
	pulling task	stepping onto unstable surface (gait)
		Stepping over stick
		Stepping Test
		tandem gait
		timed figure 8 run
		treadmill gait
		unipedal step-down test
		Vertical jump
		TURN180
		step quick turn test (SQT)
		Sitting pivot transfers
		risk & balance

Perturbation	Stationary BOS	Moving BOS
Self-generated perturbations		Heel Raise One leg hop test hopping multi hop (Wikstrom et al., 2005) Multi-Directional Dynamic Stability (MDDS) Protocol Multiple hop test obstacle crossing Papcsy-DePaepe Test Pediatric Balance Scale
External perturbation	perturbed single leg stance perturbed stance	Motor control test Motor control test with auditory task perturbed treadmill gait Sensory Organisation Test (condn 4) Motor Coordination Test (MCT).
Sensory manipulation or perturbation	Berg Balance Scale (standing eyes closed) Head Shake Sensory Organisation Test Sensory Organisation Test (condn 2& 3) Dynamic Balance Assessment Pediatric Balance Scale	Sensory Organisation Test (condn 5&6) Stroop walking gait walking gait split squat on JOINFIT balance dome Locomotor sensory organisation test

Appendix E: All tests identified scoping review classified with Pardasaney's taxonomy

Balance Task	Role of Task						Environmental Variation				Object interaction	Obstacle negotiation	External forces	Dual tasking	Moving people or objects
	multicomponent?	static body stability	dynamic body stability	transfers	gait	transfers & gait	No variation	variation of support surfaces	variation of visual conditions	Variation of support surfaces & visual conditions					
30s chair stand test	✓	✓		✓			✓				✓				
6MWT		✓			✓	✓	✓								
8 foot up and go		✓	✓	✓	✓	✓	✓								
a modified version of the Springfield Beam-Walking Test					✓			✓							
anterior, lateral, & medial jump	✓	✓	✓				✓				✓				
Balance beam gait - Giacolone et al 1985					✓			✓			✓				

Balance Task	Role of Task						Environmental Variation				Object interaction	Obstacle negotiation	External forces	Dual tasking	Moving people or objects
	multicomponent?	static body stability	dynamic body stability	transfers	gait	transfers & gait	No variation	variation of support surfaces	variation of visual conditions	Variation of support surfaces					
Balance beam gait - Punakallio 2004		✓			✓		✓				✓				
Balance beam gait - Robertson et al 1994		✓			✓		✓		✓		✓				
balance beam speed test 1		✓			✓		✓				✓				
balance beam speed test 2		✓			✓		✓				✓				
Balance beam tasks - Butterfield et al 1998		✓			✓		✓				✓	✓			
Balance beam tasks - Boswell 1991					✓			✓			✓				
Balance beam tasks - Cinelli		✓			✓	✓	✓				✓	✓			
Bass Dynamic Balance Test (BDBT)		✓			✓		✓								
Berg Balance Scale	✓	✓	✓			✓	✓				✓			✓	
BESS		✓					✓	✓							

Balance Task	Role of Task						Environmental Variation				Object interaction	Obstacle negotiation	External forces	Dual tasking	Moving people or objects
	multicomponent?	**static body stability**	**dynamic body stability**	**transfers**	**gait**	**transfers & gait**	**No variation**	**variation of support surfaces**	**variation of visual conditions**	**Variation of support surfaces**					
CFP Tracking Test (center of foot pressure)	✓	✓	✓				✓								
Community Balance and Mobility Scale (CB&M)	✓	✓	✓	✓	✓	✓	✓				✓			✓	
drop jump - Mohammadi	✓	✓	✓				✓				✓				
drop jump - Niu	✓	✓	✓				✓				✓				
drop landing - de ridder & falk	✓	✓	✓				✓				✓				
Dynamic Balance Assessment		✓							✓	✓	✓			✓	
Dynamic Balance Board Test (DBBT)		✓						✓			✓				
Dynamic balance measuring track (Kirkendall 1987)			✓					✓							
Dynamic Gait Index		✓			✓	✓	✓				✓	✓			
Dynamic Gait Index (brazilian version)		✓			✓	✓	✓				✓	✓			

Balance Task	Role of Task						Environmental Variation				Object interaction	Obstacle negotiation	External forces	Dual tasking	Moving people or objects
	multicomponent?	static body stability	dynamic body stability	transfers	gait	transfers & gait	No variation	variation of support surfaces	variation of visual conditions	Variation of support surfaces					
Figure of 8 walking					✓										
Forward bending of trunk	✓	✓	✓	✓			✓				✓				
forward lunge test (FL)	✓	✓	✓		✓		✓								
Forward reach test	✓	✓	✓				✓								
Four Square Step Test		✓			✓		✓					✓			
Functional mobility test					✓										
Functional reach	✓	✓	✓				✓								
gait initiation		✓	✓		✓		✓					✓			
Gait Speed test (walking)		✓			✓		✓								
get up from chair, sit, stand	✓	✓		✓			✓				✓				
Golf swing	✓	✓	✓	✓			✓				✓				
Head Shake Sensory Organisation Test	✓	✓	✓				✓	✓			✓		✓	✓	
Heel Raise		✓	✓				✓	✓			✓		✓	✓	

Balance Task	Role of Task						Environmental Variation				Object interaction	Obstacle negotiation	External forces	Dual tasking	Moving people or objects
	multicomponent?	static body stability	dynamic body stability	transfers	gait	transfers & gait	No variation	variation of support surfaces	variation of visual conditions	Variation of support surfaces					
hopping	✓	✓	✓				✓	✓			✓	✓	✓	✓	
jump landing task - de Ridder	✓	✓	✓				✓					✓			
jump landing task - Meardon	✓	✓	✓				✓								
jump landing task - Menayo	✓	✓	✓				✓				✓				
jump landing task - Steib	✓	✓	✓				✓				✓				
jump landing task- Wikstrom 2006 ⍰ 2	✓	✓	✓				✓				✓				
jump landing task Wikstrom 2007	✓	✓	✓				✓				✓				
jump landing task Wikstrom 2008	✓	✓	✓				✓				✓				
jump landing task Wikstrom 2005	✓	✓	✓				✓				✓				
Locomotor Sensory Organisation Test		✓			✓		✓		✓	✓	✓		✓		✓
LOS - on a Balance Master	✓	✓	✓				✓				✓				✓
LOS - on an Equitest	✓	✓	✓				✓				✓				✓

Balance Task	Role of Task						Environmental Variation				Object interaction	Obstacle negotiation	External forces	Dual tasking	Moving people or objects
	multicomponent?	static body stability	dynamic body stability	transfers	gait	transfers & gait	No variation	variation of support surfaces	variation of visual conditions	Variation of support surfaces					
LOS - on a Biorescue	✓	✓	✓				✓				✓				✓
LOS - on a Force Plate	✓	✓	✓				✓				✓				✓
75% LOS	✓	✓	✓				✓								✓
LQ-YBT			✓				✓	✓			✓				
mini-BESTest			✓		✓			✓			✓	✓		✓	
Modified Bass Test		✓	✓				✓								
Modified Rivermead Mobility Index MRMI	✓	✓					✓								
Motor Coordination Test (MCT).		✓					✓	✓			✓		✓		
Motor control test		✓						✓			✓		✓		
Motor control test with auditory task		✓						✓			✓		✓	✓	
move COP to target			✓					✓			✓				
mSEBT	✓	✓	✓				✓								
multi hop	✓	✓	✓				✓				✓	✓			

Balance Task	Role of Task						Environmental Variation				Object interaction	Obstacle negotiation	External forces	Dual tasking	Moving people or objects
	multicomponent?	static body stability	dynamic body stability	transfers	gait	transfers & gait	No variation	variation of support surfaces	variation of visual conditions	Variation of support surfaces					
Multi-Directional Dynamic Stability (MDDS) Protocol		✓	✓		✓		✓				✓	✓			
Multiple hop test	✓	✓	✓				✓				✓				
Narrow Ridge Balance Test (NRBT)		✓	✓					✓			✓				
object transport tasks (upper body movement task)	✓	✓					✓				✓			✓	✓
obstacle crossing - Chen		✓	✓		✓		✓				✓	✓		✓	
obstacle crossing - Forte / Kim		✓	✓		✓		✓				✓	✓			
One leg hop test	✓	✓	✓				✓								
Papcsy-DePaepe Test					✓			✓			✓				
Pediatric Balance Scale		✓	✓				✓		✓		✓				
Pediatric Reach Test	✓	✓	✓				✓								
perturbed stance															
perturbed treadmill gait					✓			✓			✓		✓		
pulling task	✓	✓	✓				✓				✓				

Balance Task				Role of Task			Environmental Variation				Object interaction	Obstacle negotiation	External forces	Dual tasking	Moving people or objects
	multicomponent?	static body stability	dynamic body stability	transfers	gait	transfers & gait	No variation	variation of support surfaces	variation of visual conditions	Variation of support surfaces					
reach task	✓	✓	✓				✓				✓				
Rhythmic weight shift		✓	✓				✓								
risk & balance		✓	✓	✓	✓	✓	✓	✓							
seated reach test		✓	✓				✓				✓				
SEBT		✓	✓				✓				✓				
Sensory Organisation Test (SOT)		✓								✓	✓		✓		✓
single leg hop			✓												
single leg landing task		✓	✓				✓				✓				
single leg stance - Hatzitaki		✓	✓				✓								
single leg stance - Heinbaugh		✓							✓						
single leg stance - Nyland		✓								✓	✓				
single leg stance - Tsang		✓					✓						✓		
Sit to stand				✓			✓				✓				
sit to walk				✓			✓				✓				
Sitting pivot transfers				✓			✓				✓				

Balance Task	Role of Task						Environmental Variation				Object interaction	Obstacle negotiation	External forces	Dual tasking	Moving people or objects
	multicomponent?	static body stability	dynamic body stability	transfers	gait	transfers & gait	No variation	variation of support surfaces	variation of visual conditions	Variation of support surfaces					
split squat on JOINFIT balance dome			✓					✓			✓				
stance															
step quick turn test (SQT)					✓		✓								
Step Test			✓				✓				✓				
step up and over test (SUO)			✓				✓	✓			✓				
step ups			✓				✓				✓				
Stepping in place test					✓		✓		✓						
stepping onto unstable surface (gait)					✓			✓			✓				
Stepping Test					✓		✓								
Stroop walking gait					✓		✓							✓	
tandem gait					✓		✓								
TGUG					✓		✓								
timed figure 8 run					✓		✓								
treadmill gait Falk / Vistamehr 2016					✓		✓				✓				

Balance Task	Role of Task						Environmental Variation				Object interaction	Obstacle negotiation	External forces	Dual tasking	Moving people or objects
	multicomponent?	static body stability	dynamic body stability	transfers	gait	transfers & gait	No variation	variation of support surfaces	variation of visual conditions	Variation of support surfaces					
treadmill gait Vistamehr 2014					✓			✓			✓				
trunk bending			✓				✓		✓						
TUG				✓	✓		✓				✓				
modified TUG				✓	✓		✓				✓				
TURN180					✓		✓								
unipedal step-down test				✓			✓				✓				
UQ-YBT			✓				✓								
Vertical jump			✓				✓				✓				
walking gait															
Weight shift - Groter			✓				✓				virtual				virtual
Weight shift - Lee			✓				✓								
whole body dynamic balancing task															
single leg jump landing															
Karateka Moves	✓	✓	✓	✓			✓								

Appendix F: All classified dynamic balance tests with new taxonomy

Balance Task	PE	D	P	A
30s chair stand test (sit to stand)	PE16	D2	P1	A1
5 times sit to stand	PE16	D2	P1	A1
6MWT	PE14	D1	P1	A1
75% LOS	PE2	D3, D5	P1	A1
8 foot up and go				
1. stand from chair	PE16	D2	P1	A1
2. walk	PE14	D1	P1	A1
3. sit	PE16	D2	P1	A1
10m walking gait	T14	D1	P1	A1
anterior, lateral, and medial jump				
two foot take off and land anterior jump	PE12	D2, D5	P1	A1
ltwo foot take off and land ateral jump	PE12	D2, D3	P1	A1
two foot take off and land medial jump	PE12	D2, D3	P1	A1
Ascend and descend stairs	PE14	D12	P1	A1
Bachman ladder task	PE17	D1	P1	A1
Balancing on fitball				
sitting, isolated upper extremities (Buddha osn)	PE1	D1	P1	A1
sitting, free moving hands	PE1	D1	P1	A1
sitting, hands on hips	PE1	D1	P1	A1
standing on knees, isolated upper extremities (Buddha osn)	PE2	D1	P1	A1
standing on knees, free moving hands	PE2	D1	P1	A1

Balance Task	PE	D	P	A
Balancing on fitball				
standing on knees, hands on hips	PE2	D1	P1	A1
standing on fitball, isolated upper extremities (Buddha osn)	PE2	D1	P1	A1
standing on fitball, free moving hands	PE2	D1	P1	A1
standing on fitball, hands on hips	PE2	D1	P1	A1
Balance beam				
70: narrow support (wooden beam, 10 cm wide, 20 cm high, 6 m long) The subjects had to walk as fast as possible on the beam.	PE14	D1	P1	A1
123: six tasks: walking forward on a 4-, 3-, and 2-in. wide beam and walking backward on a 4-, 3 - , and 2-in, wide beam for 12 ft., which was supported 6 inches from the floor	PE14	D1	P1	A1
181: walk slowly down beam, hands on hips, step over stick held knee high by examiner without touching it and continue to end of beam	PE14	D2	P1	A1
241: walking a 5.08-cm. balance beam and performing two balance items at points approximately one-third and two-thirds of the distance (284.48 cm.) across the beam. At the first 121.92-cm. mark the subjects were asked to bend down and touch one knee to the beam. At the second point, 182.88 an., the subjects were asked to perform a 360' turn, in whichever direction they preferred	PE14	D2, D4	P1	A1
381: balance beams width 4inches, 3 inches & 2 inches, 12 in in length and 1ft off floor. four tasks -1. walk forward, 2. walk backward,3. touch one knee to beam and stand, 4. stoop, turn 360 degrees and stand	PE14	D2, D4	P1	A1
1132: four balance beams widths 2.25 inches, 1.5 inches 3/4 inches and 3/8 inches. 10 feet long, four inches high. walk the beams starting on wides progress to narrowest with heel to toe	PE14	D1	P1	A1

Balance Task	PE	D	P	A
Balance beam				
479: 8ft beams with walking surfaces of 2,4 & 6in (actual width 1 7/8in, 3 7/8in and 5 7/8in) walking surface marked with 96 one inch zones. sturdy supports permitted placement of beams at three different elevations 12in, 24in & 36in.	PE14	D1	P1	A1
748: 2,5cm wide line taped to floor, 2 balance beams of widths 9.9cm & 4.5cm, raised 1 foot from floor. All 365.8m long. child asked to step onto beginning of line or mount beam and walk entire length forward and backward.	PE14	D1	P1	A1
921: walk forwards and backwards as quickly as possible across 2.5m long, 9cm wide, 5cm thick wooden plank barefooted. walk to marked 0.5m long mid area of plank turn 180 degrees and walked backwards to opposite end of plank. immediately repeated back in other direction	PE14	D4	P1	A1
balance beam speed test 1	PE14	D1	P1	A1
balance beam speed test 2	PE14	D1	P1	A1
BESS				
Single leg stance (SL),	PE1	D1	P1	A1
tandem stance (T),	PE2	D1	P1	A1
single leg stance on medium density foam (SLF),	PE1	D1	P1	A1
tandem stance on medium density foam (TF)	PE2	D1	P1	A1
Berg Balance Scale				
1. sit to stand	PE16	D1	P1	A1
2. standing unsupported,	PE2	D1	P1	A1
3. sitting usupported,	PE3	D1	P1	A1

4. standing to sitting	PE16	D1	P1	A1
5. transfer from chair to chair,	PE14, PE16	D1	P1	A1
6. standing eyes closed,	PE2	D1	P1	A1
7. standing feet together,	PE2	D1	P1	A1
8. reaching forward outreached arms,	PE2	D1	P1	A1
9. retrieving object from floor,	PE2	D1	P1	A1
10. turning to look behind.	PE2	D14, D15	P1	A1
11. turning 360 degrees,	PE14	D4	P1	A1
12. placing alternate foot on stool,	PE14	D12, D33	P1	A1
13. standing one foot in front,	PE2	D23	P1	A1
14. standing on one foot.	PE1	D23	P1	A1
Community Balance and Mobility Scale (CB&M)				
unilateral stance up to 45 sec,	PE1	D23	P1	A1
tandem walking - 7 consecutive steps	PE14	D23	P1	A1
180 degree tandem pivot - lifting heels pivot around to opposite direction without stopping,	PE2	D4	P1	A1
lateral foot scooting - defned as alternately pivoting on the heel and toe of one foot while moving sideways.	PE1	D4	P1	A1
Hopping forward - Hop twice straight along this line to pass the 1m mark with your heel. Maintain your balance on your right/left leg at the finish.	PE11	D2, D3, D5	P1	A1
crouch & walk - Walk forward and, without stopping, bend to pick up the bean bag and then continue walking down the line.	PE14	D2	P1	A1
lateral dodging - Patient moves laterally back and forth along the line, between the 2m and 4m marks by repetitively crossing one foot over and in front of the other	PE4	D23	P1	A1
double leg balance on clever balance board	PE2	D27	P1	A1
drop jump	PE7	D2	P1	A1

drop landing				
365: step down from a 40-cm high box to control drop height and land onto the force plate	PE7	D2	P1	A1
429: standing on one leg drop off and landed with dominant leg onto force plate from height of 0.31m, hands on hips, stabilise as quickly as possible and remain standing for 6s	PE11	D2	P1	A1
844: bare-footed participants were instructed to start and terminate the landing movement in a standing position, to take off and touch-down with both feet, to lean forward with the body at take-off, to make a half-squat with the foot contact, and finally to brake the fall smoothly. The drop heights were designed as three grades: low (0.32 m), medium (0.52 m), and high (0.72 m	PE12	D2	P1	A1
Dynamic Balance Assessment				
Quiet standing on a firm surface with eyes open.	PE2	D1	P1	A1
Quiet standing on a firm surface with eyes closed	PE2	D1	P1	A1
Standing on a firm surface and performing Cyclic, rhythmic, left and right head rotation to visual targets placed 120 degrees apart. Large letter Ts clearly visible to all participants were used as the visual targets,	PE2	D15	P1	A1
Standing while performing a cyclic, rhythmic arm lifting and lowering task and while bolding on to a 50-cni lightweight wooden pole, 1.91 cm in diameter, with both bands kept shoulder width apart and elbows extended. The pole was raised to shoulder level and then lowered to the legs.	PE2	D9	P1	A1
Standing while performing cyclic. rythmic horizontal trunk rotations to 45 degrees in each direction.	PE2	D14	P1	A1
Standing while performing cyclic, rhythmic forward trunk bending and extension to return to the upright (erect) standing position. The amplitude of the trunk bending was about 30 degrees	PE2	D13	P1	A1

Dynamic balance measuring track (Kirkendall 1987)				
1. From the starting point, the athlete will perform a jump on one leg, on the mark 1	PE11	D2, D5	P1	A1
2. After he arrived on mark 1, the athlete will balance himself, then he will lift himself on his soles, and after finding his balance, he will try to keep it for 5 seconds;	PE1	D23	P1	A1
Dynamic Gait Index				
1. walk normally;	PE14	D1	P1	A1
2. walk fast;	PE14	D1	P1	A1
3. walk slowly;	PE14	D1	P1	A1
4. walk with head turns from side to side;	PE14	D15	P1	A1
5. then neck flexion/extension;	PE14	D16	P1	A1
6. walk and then pivot turn and stop;	PE14	D4	P1	A1
7. walk and step over a shoebox and 'slalom' around two cones.	PE14	D3, D33	P1	A1
8. walking up and down stairs.	PE14	D2, D24	P1	A1
Dynamic Gait Index/Functional gait assessment scoring form				
1. ambulate on level surface	PE14	D1	P1	A1
2. ambulating while changing speeds	PE14	D5	P1	A1
3. ambulating with horizontal head turns	PE14	D15	P1	A1
4. ambulating with vertical head turns	PE14	D16	P1	A1
5. ambulating with pivot turns	PE14	D4	P1	A1
6. stepping over obstacles	PE14	D33	P1	A1
7. ambuating with a narow BOS	PE14	D23	P1	A1
8. ambulating with eyes closed	PE14	D1	P3	A1
9. ambulating backwards	PE14	D1	P1	A1
10. walking up and down stairs.	PE14	D2	P1	A1

dynamic postural balance test	PE2	D3	P1	A1
dynamic sitting task	PE2	D1	P1	A1
Forward bending of trunk and reaching	PE2	D7, D14	P1	A1
forward lunge test (FL)	PE14	D2, D5	P1	A1
Four square step test	PE14	D3, D5, D33	P1	A1
Functional Mobility Test	PE14	D3, D5, D30	P1	A1
Functional reach				
raise arm, reach forward as far as possible	PE2	D7, D9, D13	P1	A1
tested in three conditions of forward reach and lateral reach (with right and left hand), both in and out of brace, reach forward and lateral as far as possible and displace a moveable marker on the yardstick	PE2	D7, D9, D13	P1	A1
functional reaching test	PE2	D7, D9, D13	P1	A1
functional stability boundary	PE2	D5	P1	A1
gait and pick up object test	PE14	D31	P1	A1
gait initiation				
quiet standing to walk	PE14	D1	P1	A1
Gait initiation was evaluated in four different conditions: stepping 45° medially by crossing the swing leg over the stance leg (M45); stepping forward (FWD); stepping laterally 45° (L45); and stepping 90° laterally (L90)	PE14	D1	P1	A1
Gait speed test	PE14	D1	P1	A1
gait speed, max & preferred	PE14	D1	P1	A1

get up from chair, sit, stand	PE16	D2	P1	A1
golf swing	PE2	D4, D31	P1	A1
Head Shake Sensory Organisation Test				
1. SOT cond 2: eyes closed, firm surface while performing rythmic head movements in yaw	PE2	D15	P3, P5	A1
2. SOT cond 2: eyes closed, firm surface while performing rythmic head movements in pitch	PE2	D16	P3, P5	A1
3. SOT cond 2: eyes closed, firm surface while performing rythmic head movements in roll	PE2	D15, D16	P3, P5	A1
4.SOT cond 5: eyes closed on a sway-referenced support surface while performing rythmic head movements in yaw	PE2	D15, D19	P3, P5	A1
5. SOT cond 5: eyes closed on a sway-referenced support surface while performing rythmic head movements in yaw	PE2	D16, D19	P3, P5	A1
6.SOT cond 5: eyes closed on a sway-referenced support surface while performing rythmic head movements in yaw	PE2	D15, D16, D19	P3, P5	A1
hopping	PE11	D2	P1	A1
induced forward stepping	PE2	D31	P1	A1
jump landing				
two foot to one foot. Forward and to one side over hurdle.	PE7	D2, D3, D5, D33	P1	A1
two foot to one foot. Forward over hurdle	PE7	D2, D5, D33	P1	A1
two foot to one foot, forward from 90cm away	PE7	D2, D5	P1	A1
two foot to one foot, forward from 40% max jump height away or 70cm away, over hurdle	PE7	D2, D5	P1	A1
648: jump down from box, 2 heights, land on both feet	PE12	D2	P1	A1
673, 674 841, 842, 879, 1025, 1026, 1027, 1029, 1051: two feet to one, jump forward 50% max vertica and 70cm from FP	PE7	D2, D5	P1	A1

920, 1082: two foot to one foot jump diagonally 45% right and left	PE7	D2, D5	P1	A1
763: one foot to one foot, down from box, forward and diagonal	PE11	D2, D3, D5	P1	A1
1028: two feet to one foot, 70cm from FP, jump to 50% max vertical (A) Right limb lateral jump, (B) right limb diagonal jump, (C) right and left limb forward jump, (D) left limb diagonal jump, and (E) left limb lateral jump	PE7	D2, D3, D5	P1	A1
Karateka moves				
(i) left zenkutsu-dachi (advancement position with flexed lower left limb) and contemporary low block with the left arm (ghedan-barai).Forward displacement executing right oi-tsuki (long punch) and subsequent left punch (gyaku-tsuki) (steps 0–3)	PE14	D5, D8,	P1	A1
(ii) 45 backward displacement on the right performing left zenkutsu-dachi and left uchi-uke (block with the internal side of the forearm), left kizami-tsuki (punch corresponding to the advanced lower limb) and right gyaku-tsuki (steps 4–7);	PE14	D5, D8,	P1	A1
(iii) 45 forward advancement on the left putting the right foot next to the left (tsugi-ashi), then executing a circular kick with the left leg (mae-ashi mawashi-geri) and concluding with right gyakutsuki after left foot landing (steps 8–10).	PE14	SP11	P1	A1
Locomotor Sensory Organisation Test				
(1) Normal walking condition: both the speed of the virtual corridor and the treadmill speed are matched with the preferred walking speed (PWS).	PE14	D1	P2	A1
(2) Reduced visual condition: no VR is presented, the treadmill speed is matched with the PWS, and the subjects wear vision-reduced goggles.	PE14	D1	P4	A1
(3) Perturbed visual condition: achieved by manipulating the optic flow speed.	PE14	D1	P4	A1

(4) Perturbed somatosensory condition: achieved by manipulating the treadmill speed.	PE14	D1	P1	A1
(5) Reduced visual and perturbed somatosensory condition: achieved by reducing vision and manipulating the treadmill speed.	PE14	D1	P2	A1
(6) Perturbed visual and somatosensory condition: achieved by manipulating optic flow and treadmill speed.	PE14	D1	P4	A1
LOS				
Balance Master: 17, 34, 53, 177, 178, 322, 393, 726, 741, 944, 1004: move a cursor on the monitor and follow the rhythmic motion of a moving target while projecting their center of gravity toward 8 targets located on the computer screen at intervals of 45°. hld cursor in place for 10s	PE2	D3, D5	P1	A1
Equitest: 57, 753: moved the COP in 8 directions (left, right, front, back, left front, left back, right front, and right back) to the furthest possible extent	PE2	D3, D5	P1	A1
Biorescue: 695: moved the COP in 8 directions (left, right, front, back, left front, left back, right front, and right back) to the furthest possible extent while they stood on the support	PE2	D3, D5	P1	A1
NedSVE/IBV posturography system: 744: 8 seconds the subject had to move and try to keep the centre of gravity within each target on screen in 8 directions (anterior, anterior-right, right, posteriorright, posterior, posterior-left, left, and anterior-left)	PE2	D3, D5	P1	A1
force plate: 814: lean forward and backward, and then side-to-side, as far as they could	PE2	D3, D5	P1	A1
force plate: LOS tested with eyes open and eyes closed. no screen with marker	PE2	D3, D5	P1	A1
LQ-YBT	PE1	D2, D10	P1	A1
maximum speed walking gait	PE14	D1	P1	A1
mini-BESTest				

postural adjustments - sit to stand	PE16	D2	P1	A1
postural adjustments - rise to toes	PE2	D23	P1	A1
postural adjustments - stand on one leg	PE1	D23	P1	A1
postural adjustments - alternate stair touching	PE14	D1	P1	A1
postural adjustments - standing arm raise	PE2	D9	P1	A1
gait stability - gait	PE14	D1	P1	A1
gait stability - change in speed	PE14	D5	P1	A1
gait stability - walk with head turns	PE14	D15	P1	A1
gait stability - walk with pivot turns	PE14	D4	P1	A1
gait stability - step over obstacles	PE14	D33	P1	A1
TUG	PE16, 14	D2	P1	A1
TUG & cognitive dual task	PE16, 14	D2	P1	A1
Modified Bass Test	PE4	D2, D3, D5	P1	A1
Modified Rivermead Mobility Index MRMI	PE1	D1	P1	A1
modified version of the Springfield Beam-Walking Test (dynamic balance-Seashore 1951)	PE14	D1	P1	A1
motor control test protocol				
Equitest: assesses the automatic postural reactions in response to small (2.8 /s), medium (6 /s) and large (8 /s) platform translations in forward and backward directions.	PE2	D19	P1	A1
Equitest: with auditory task	PE2	D19	P14	A1
move COP to target				
force plate - 119: move COP to track a target on screen - forward and back postural sway	PE2	D3	P1	A1
posturographic platform - 752: screen with a point showing a vertical projection of the centre of body pressure. task involved keeping the posture so that the point C displayed on the screen was placed one by one in specific areas	PE2	D3, D5	P1	A1

stabilometer - 795: alternately shifted COP within two circles as fast as possibe	PE2	D3, D5	P1	A1
Promed Posturograph - 911: subject was required to move her body's centre of gravity (COG), so that its projection was maintained at all times in a square appearing on the monitor, which constantly moved in eight directions	PE2	D3, D5	P1	A1
KAT2000 stabilometer - 917: the cursor on the computer screen makes a circular movement with a speed of 360° every 10sec. task of superimposing the cross on the moving cursor	PE2	D3, D5	P1	A1
Good Balance - 921, 1023: . 8 targets, shown in circle on monitor - move COP through targets as quickly and accurately as possible. If the COP reached the target box, the next target box was displayed on the computer monitor	PE2	D3, D5	P1	A1
AccuGAIT - 943: participants practiced a postural tracking task along the antero-posterior (AP)and the medio-lateral (ML) axes, twice in each direction.	PE2	D3, D5	P1	A1
force plate - 1009: regulate their balance and to keep their CP within the moving box. While performing the postural task, they performed a secondary probe reaction time (RT) task. They responded vocally ("top") as rapidly as possible to an unpredictable auditory stimulus	PE2	D3, D5	P1	A1
mSEBT	PE1	D2, D10	P1	A1
Mulitple hop test	PE11	D2	P1	A1
multi hop (Wikstrom et al., 2005)	PE14, 11	D2, D3, D5, D33	P1	A1
Multi-Directional Dynamic Stability (MDDS) Protocol	PE11	D2, D3, D5	P1	A1
multi-directional reach	PE2	D2, D5, D7	P1	A1
Narrow Ridge Balance Test (NRBT)	PE1	D23	P1	A1
obstacle crossing				
215: Ten obstacles, (80 cm * 8 cm). There were two different test conditions: a single task (obstacle crossing alone) and a dual-task (obstacle crossing plus hand button pressing tasks).	PE14	D33	P15	A1

768: walk at their usual (selfselected) pace from the start to the end of the walkway, crossing the obstacle in the center as they proceeded involved crossing a 10-cm hurdle	PE14	D33	P1	A1
obstacle negotiation	PE14	D33	P1	A1
one leg hop	PE7	D1	P1	A1
Papcsy-DePaepe Test	PE14	D23	P1	A1
Pediatric Balance Scale			P1	A1
1. sit to stand,	PE16	D2	P1	A1
2. stand to sit,	PE16	D2	P1	A1
3. transfers,	PE16	D3	P1	A1
4. standing unsupported,	PE2	D1	P1	A1
5. siting unsupported,	PE3	D1	P1	A1
6. standing eyes closed,	PE2	D1	P3	A1
7. standing feet together,	PE2	D23	P1	A1
8. standing one foot in front,	PE2	D23	P1	A1
9. standing on one foot,	PE1	D1	P1	A1
10. turning 360 degrees,	PE14	D4	P1	A1
11. turning to look behind,	PE2	D14, D15	P1	A1
12. retrieving object from floor,	PE2	D2	P1	A1
13. placing alternate foot on stool,	PE14	D1	P1	A1
14. reaching forward with outstretched arm.	PE2	D7	P1	A1
Pediatric Reach Test	PE2	D3, D5	P1	A1
Periodic postural sway	PE2	D3, D5	P1	A1
perturbed single leg stance	PE1	D19	P1	A1
perturbed stance internal	PE1, PE2	D1, D3, D5, D11, D19, D31	P1	A1
perturbed treadmill gait	PE14	D19	P1	A1
preferred and max gait speed	PE14	D1	P1	A1
pulling task	PE2	D31	P1	A1

reach task				
217: erect standing posture, with arms comfortably placed against the side of the body, standing barefoot on the 0.5-m RSSCAN pressure mat The subjects were then asked to pick up the target placed in the center of the sagittal plane at two horizontal plane distances	PE2	D7	P1	A1
968: push the sliding hand plate with the first knuckles (the metacarpophalangeal joints) as far as possible in the specified direction without taking a step could raise their heels if they desired. Upward reach 50 degree incline and forward reach	PE2	D6	P1	A1
1020: six task conditions chosen to displace the COP position in three different directions (forward, to the side, and mid-way between the forward and side directions) and to two different extents (arm's length reach, a non-leaningtask, and maximum reach, a task allowing bendingat the hips and ankles). reach toward the target but was unable to touch or grasp it	PE2	D3, D5, D7	P1	A1
rhythm-direction control of movement	PE2	D3, D5	P1	A1
risk and balance	PE14, PE19, PE1	D4 D12	P1	A1
rythhmic weight shift	PE2	D3, D5	P1	A1
seated reach test	PE3	D7	P1	A1
SEBT	PE1	D2, D10	P1	A1
Sensory Organisation Test (SOT)				
1.Eyes open on firm surface,	PE2	D1	P1	A1
2.Eyes closed on firm surface	PE2	D1	P3	A1
3.Eyes open with sway referenced visual surround,	PE2	D1	P2	A1
4.Eyes open on sway referenced support surface,	PE2	D19	P1	A1
5.Eyes closed on sway referenced support surface,	PE2	D19	P3	A1
6.Eyes open on sway referenced support surface and surround	PE2	D19	P2	A1
Sharpened Romberg Test	PE2	D23		

single leg hop				
1130: performed the single-leg hop test for distance, allowing the use of the arms to accelerate	PE11	D2, D5	P1	A1
976: jump as far as possible horizontally land on one leg	PE7	D2, D5	P1	A1
single leg hop stabilisation test	PE7	D2, D5	P1	A1
single leg jump landing task	PE7	D2, D5, D33	P1	A1
single leg stance	PE1	D1	P1	A1
Single limb stance	PE1	D1	P1	A1
Sit to stand	PE16	D2	P1	A1
sit to walk	PE17	D2	P1	A1
Sitting pivot transfers	PE18	D3, D4	P1	A1
six spot step test	PE14	D11, D32	P1	A1
split squat on JOINFIT balance dome	PE2	D2	P1	A1
step quick turn test (SQT)	PE14	D4	P1	A1
step test	PE14	D1	P1	A1
step up and over test	PE14	D35	P1	A1
step ups	PE14	D1	P1	A1
Stepping in place test	PE14	D1	P1	A1
stepping (gait)	PE14	D1	P1	A1
stepping test	PE14	D1	P1	A1
Stroop walking task	PE14	D1	P15	A1
Tandem Gait	PE14	D23	P1	A1
Tap test	PE14	D1	P1	A1
timed figure 8 run	PE14	D4	P1	A1
treadmill gait	PE14	D1	P1	A1
trunk bending	PE2	D13	P1	A1
TUG	PE17	D2	P1	A1
TUG & dual task	PE17	D2	P15	A1

TURN180	PE14	D4	P1	A1
turning task	PE14	D4	P1	A1
UQ-YBT	PE3	D10	P1	A1
usual speed walking gait	PE14	D1	P1	A1
virtual and real reaching and stepping	PE14	D7	P1	A1
visual push test	PE2	D1	P1	A1
voluntary sway	PE2	D3, D5	P1	A1
walking gait				
75, 155, 460, 1016: walk across forceplates/foot pressure sensors	PE14	D1	P1	A1
104: walk between 2 parallel lines using their normal gait and speed for 6m	PE14	D1	P1	A1
164: walk across a 2x6 inch board 8 feet in length, forwards and backwards	PE14	D1	P1	A1
191, 944: level walking along 10m walkway	PE14	D1	P1	A1
251: 1. walk as straight as poss 10, heel-toe arms across chest eyes open. 2. walk as straight as poss 10, heel-toe arms across chest eyes closed	PE14	D1	P1	A1
257: walk across an uneven terrain walkway	PE14	D1	P1	A1
259: walk along a 6m walkway while wearing three different insole conditions under normal or reduced vision conditions	PE14	D1	P1	A1
321: walk barefoot at their selfselected speed on a 25 foot carpeted path with and without 'dribble' glasses that blocked the subject's view of their feet	PE14	D1	P1	A1
431: taught to walk at 4.5 km/h±10% by immediate feedback on walking speed (normal walking), two different walking conditions: 1) normal walking and 2) walking on a white line marked on the floor across the force plates	PE14	D1	P1	A1
445: walkign over 10m 1. habitual and 2. max walking speeds, 3. max walking speed with walking width restricted to 15cm, 4. walk & name as many animals beginning with letter B or C, 5. walk then pick up teo hand	PE14	D1,D42	P1	A1

weights and continue walking, 6. walk carrying an empty box, 7. walk and stpe ver obstacles 890: walk along 8m walkway, randomly during 25% of trials signaled (audio buzzer) to terminate gait within the next two steps. The four experimental conditions were (midsole hardness as measured on a Shore A scale): (1) soft (A15); (2) standard (A33); (3) hard (A50); (4) barefoot	PE14	D1, D30	P1	A1
958: 3 m straight line on the ground. Participants, barefoot or in socks, must walk with one foot in front of another up to 10 steps without moving aside the line	PE14	D23	P1	A1
960: gait on a noncompliant and consistent surface with normal vision (NC), gait on a compliant and inconsistent surface (foam with embedded wooden blocks) with normal vision (C), gait on a noncompliant (linoleum) surface with vision obscured (NCVO), and gait on a compliant and inconsistent surface with vision obscured (CVO). obscured vision wore a lightweight foam-board collar that obscured visual reference to their feet	PE14	D1	P3	A1
962, 1103: walk at a self-selected comfortable speed from the start of a 2 m marking before the GAITRite walkway, to the end of the 2 m marking past the GAITRite walkway	PE14	D1	P1	A1
1041: walk across 10m walkway with and without a glass of water in their dominant hand	PE14	D1	P1	A1
1064: walk at self selected speed	PE14	D1	P1	A1
1108: walk down hallway and stop at 30m condns: barefoot, wearing habitual shoes and custome foot orthoses, wearing habitual shoes and prefabricated foot orthoses	PE14	D1	P1	A1
1109: walk: single-primary task (walking alone), single-secondary task (hand button pressing alone), and dual-task (walking plus hand button pressing tasks)	PE14	D1	P1	A1

Weight shift	PE2	D3, D5	P1	A1
Weight shifting task	PE2	D3, D5	P1	A1

Appendix G: New taxonomy glossary of terms

Postural Equilibrium

Static BOS: fixed position of area beneath an object or person that includes every point of contact that the object or person makes with the supporting surface. These points of contact may be body parts e.g., feet or hands, or they may include things like crutches or the chair a person is sitting in.

Non-static BOS: moving position of area beneath an object or person that includes every point of contact that the object or person makes with the supporting surface. These points of contact may be body parts e.g., feet or hands, or they may include things like crutches or the chair a person is sitting in support body parts in contact with the supporting surface.

Flight: movement that involves all supports to leave the reference surface at the same time

no flight: at least one support is in contact with the support surface at one time.

change in POS: change in point of support: change from support limb in contact with the reference surface at any point in the movement.

Destabilising challenge

reference surface: normal non-moving, flat, and level surface.

external forces: any externally applied force to the participant, not including those that come from a deviation from the reference surface.

variation of visual conditions: reference being eyes open, well-lit environment, unaltered visual field, and a non-moving visual surround.

object interaction: real any physical interaction with an object in the environment during a task that is not fixed to the environment.

object interaction: virtual presence of objects in the environment that provide feedback/simulation during a task moving people or objects, presence of moving people or objects in the environment excluding the support surface and virtual objects and where there is no direct interaction from the participant.

dual tasking: performance of a secondary task such as a manual or cognitive task while performing a primary balance task.

obstacle negotiation: negotiation of objects systematically placed in the environment.

Appendix H: Football movement questionnaire informed consent

Sheffield Hallam University

SAMPLE PARTICIPANT CONSENT FORM

TITLE OF RESEARCH STUDY: A questionnaire to determine football movements considered important for performance or related to injury

Please answer the following questions by ticking the response that applies

	YES	NO
1. I have read the Information Sheet for this study and have had details of the study explained to me.	☐	☐
2. My questions about the study have been answered to my satisfaction and I understand that I may ask further questions at any point.	☐	☐
3. I understand that I am free to withdraw from the study within the time limits outlined in the Information Sheet, without giving a reason for my withdrawal or to decline to answer any particular questions in the study without any consequences to my future treatment by the researcher.	☐	☐
4. I agree to provide information to the researchers under the conditions of confidentiality set out in the Information Sheet.	☐	☐
5. I wish to participate in the study under the conditions set out in the Information Sheet.	☐	☐
6. I consent to the information collected for the purposes of this research study, once anonymised (so that I cannot be identified), to be used for any other research purposes.	☐	☐

Participant's Signature: ______________________________ **Date:** __________

Participant's Name (Printed): ______________________________

Contact details: ____

____

Researcher's Name (Printed): LEONA BRAYNE______________

Researcher's Signature: [redacted]

Researcher's contact details:

[redacted]

Please keep your copy of the consent form and the information sheet together.

Appendix I: Football Movements Questionnaire

Sheffield Hallam University | Centre for Sports Engineering Research

Football Movements Questionnaire

Please fill in your details below:

Participant No (please leave blank)	
Football Club	
Position	
Years of experience	

Using the scale below, please enter the number that represents your expert opinion on how the movement (left column) relates to the performance (columns to the right). Please consider these movements as they would be used in a game scenario with the ball. A glossary of terms is provided on a separate page.

Disagree	Agree	Strongly agree
1	2	3

		Creating goal scoring opportunity	Defending around the box	Winning a tackle / regaining possession	Injury risk
1	Running in a straight line in any direction is important in...				
2	Running with a turn is important in...				
3	Running whilst rotating the trunk is important in...				
4	Running in an arc is important in...				
5	Running with a cutting/sidestepping movement is important in...				
6	Dribbling the ball is important in...				
7	A lunge forward is important in...				
8	A lunge backwards is important in...				
9	A lunge with outstretched leg is important in...				

Sheffield Hallam University | Centre for Sports Engineering Research

		Creating goal scoring opportunity	Defending around the box	Winning a tackle / regaining possession	Injury risk
10	A side lunge is important in…				
11	A squat is important in…				
12	A squat with outstretched leg is important in…				
13	Accelerating in a straight line is important in…				
14	Braking in any direction is important in…				
15	A two foot jump single leg landing is important in…				
16	A two foot jump single leg landing with whole body turn is important in…				
17	A two foot jump single leg landing with trunk rotation is important in…				
18	A two foot jump single leg landing with head rotation is important in…				
19	A two-foot jump two leg landing is important in…				
20	A two-foot jump two leg landing with whole body turn is important in…				
21	A two-foot jump two leg landing with trunk rotation is important in…				
22	A two-foot jump two leg landing with head rotation is important in…				
23	A hop single leg landing is important in…				
24	A hop single leg landing with whole body turn is important in…				
25	A hop single leg landing with trunk rotation is important in…				
26	A hop single leg landing with head rotation is important in…				
27	A hop two leg landing is important in…				
28	A hop two leg landing with whole body turn is important in…				
29	A hop two leg landing with trunk rotation is important in…				
30	A hop two leg landing with head rotation is important in…				
31	A single leg kick is important in…				

Sheffield Hallam University | Centre for Sports Engineering Research

		Creating goal scoring opportunity	Defending around the box	Winning a tackle / regaining possession	Injury risk
32	A standing volley is important in....				
33	A volley whilst running is important in...				
34	Single leg balance whilst manipulating the ball (skill/trick) is important in...				
35	Receiving a ball is important in...				
36	Heading with a jump is important in...				
37	Chesting is important in...				
38	Chesting with a jump is important in...				
39	Jockeying is important in...				
40	Jostling to win the ball is important in...				
41	Shielding the ball whilst jostling is important in...				
42	Shielding the ball is important in...				
43	A bicycle kick is important in...				
44	A scissor kick is important in...				
45	A side block tackle is important in...				
46	A sliding tackle is important in...				
47	A feint is important in...				
48	A shoulder barge while standing is important in...				
49	A shoulder barge whilst running is important in...				

Appendix J: Questionnaire glossary of terms

Football Movements Glossary

Term	Definition
Running	At a continuous speed
Running with a turn	Running with a sudden turn that changes the direction of the run and the direction the body is facing
Rotating the trunk	Legs facing in the direction of the run, with rotation of the upper body in any direction
Running in an arc	Player progressively changes path travelled while turning
Cutting/sidestepping	Moving to the side without rotating the body or changing the direction the body is facing
Single leg balance whilst manipulating the ball	Performing any kind of trick or skill whilst in possession of the ball that directly involved movement of the ball to manoeuvre past an opponent
Lunge	Any position of the body where one leg is positioned forward with knee bent and foot flat on the ground while the other leg is positioned behind or to the side
Squat	Any position of the body where both feet are on the ground and hips and both knees are bent
Accelerating	Where a player in a stationary position suddenly starts moving at a moderate or high intensity

Term	Definition
Braking	Where the player becomes stationary after moderate to high intensity movement
Two-foot jump single leg landing	Movement commences with two feet on the floor and ends with a landing on one foot
Two-foot jump two leg landing	Movement commences and ends with two feet in contact with the floor
Hop single leg landing	Movement commences and ends with one foot on the floor
Hop two leg landing	Movement commences with one foot on the floor and ends with two feet on the floor
Whole body turn	Upper and lower limbs rotate simultaneously to face a different direction
Trunk rotation	Upper body rotates to the left or right whilst the lower limbs stay facing the original direction
Head rotation	Head rotates whilst upper body and lower limbs stay facing original direction
Single leg kick	One stable leg, pass struck with the other leg and foot
Volley	striking the ball with the front of the foot, with the toes pointing downward, ankle locked, and the knee lifted, other leg stable
Single leg balance whilst manipulating the ball (skill/trick)	Using one leg or foot to move the ball in order to retain possession or beat an opponent

Term	Definition
Receiving the ball	Single leg stance whilst controlling the ball with other foot
Heading	Heading whilst both feet are in contact with the ground
Heading with a jump	Heading with both feet off the ground as a result of a jump
jockeying	A low position with both knees bent, turned slightly at an angle from the attacker allowing quick turns if needed
Jostling to win the ball	Running using upper and lower body strength to knock opponent away from the ball and regain
Shielding the ball whilst jostling	Using body to protect the ball when under direct pressure
Bicycle kick	Jumping and using leg to contact the ball over head
Scissor kick	Jumping and using both legs, one to propel motion and the other to contact the ball over head
Slide block tackle	Sliding along floor with a leg and foot up to block balls motion
Sliding tackle	Sliding along floor whilst using one or two legs to win the ball from an opponent
feint	Shifting a body part (Foot/knee etc) to disguise an action to throw opponent off balance
Shoulder barge	Running and using upper body strength and shoulder to win the ball

Appendix K: Differentiation of skill level informed Consent

Sheffield Hallam University

INFORMED CONSENT

TITLE OF RESEARCH STUDY: Differentiation of skill level of football players through dynamic balance testing

Please answer the following questions by ticking the response that applies

	YES	NO
1. I have read the Information Sheet for this study and have had details of the study explained to me.	☐	☐
2. My questions about the study have been answered to my satisfaction and I understand that I may ask further questions at any point.	☐	☐
3. I understand that I am free to withdraw from the study within the time limits outlined in the Information Sheet, without giving a reason for my withdrawal or to decline to answer any particular questions in the study without any consequences to my future treatment by the researcher.	☐	☐
4. I agree to provide information to the researchers under the conditions of confidentiality set out in the Information Sheet.	☐	☐
5. I wish to participate in the study under the conditions set out in the Information Sheet.	☐	☐
6. I consent to the information collected for the purposes of this research study, once anonymised (so that I cannot be identified), to be used for any other research purposes.	☐	☐

Participant's Signature: ______________________________________ **Date:** __________

Participant's Name (Printed): ____________________________________

Contact details: ____

____

Researcher's Name (Printed): ___________________________________

Researcher's Signature: _______________________________________

Researcher's contact details:
Leona Brayne
CSER, Sheffield Hallam University, Broomgrove Teaching Block, Broomgrove Road, Sheffield, S10 2BP
[redacted]

Please keep your copy of the consent form and the information sheet together.

Appendix L: Physical Activity Readiness Questionnaire

Sheffield Hallam University

Faculty of Health and Wellbeing Research Ethics Committee
Sport and Exercise Research Ethics Review Group

Pre-Test Medical Questionnaire

Name: ____

Date of Birth: _____________ Age: _______________Sex: ________________

Please answer the following questions by putting a circle round the appropriate response or filling in the blank.

1. How would you describe your present level of activity?
   Sedentary / Moderately active / Active / Highly active

2. How would you describe you present level of fitness?
   Unfit / Moderately fit / Trained / Highly trained

3. How would you consider your present body weight?
   Underweight / Ideal / Slightly over / Very overweight

4. Smoking Habits

Smoking Habits	Are you currently a smoker?	Yes / No
	How many do you smoke	.... per day
	Are you a previous smoker?	Yes / No
	How long is it since you stopped?	.... years
	Were you an occasional smoker?	Yes / No
		.... per day
	Were you a regular smoker?	Yes / No
		.... per day

5. Do you drink alcohol? Yes / No
   If you answered **Yes**, do you usually have?
   An occasional drink / a drink every day / more than one drink a day?

6. Have you had to consult your doctor within the last six months? Yes / No
   If you answered **Yes**, please give details.......................................
   ....
   ....

7. Are you presently taking any form of medication? Yes / No
   If you answered **Yes**, please give details.......................................
   ....
   ....

8. As far as you are aware, do you suffer or have you ever suffered from:

a Diabetes?	Yes / No	b Asthma?	Yes / No
c Epilepsy?	Yes / No	d Bronchitis?	Yes / No
e *Any form of heart complaint?	Yes / No	f Raynaud's Disease?	Yes / No
g *Marfan's Syndrome?	Yes / No	h *Aneurysm/embolism?	Yes / No
I Anaemia	Yes / No		

9. *Is there a history of heart disease in your family? Yes / No

10. *Do you currently have any form of muscle or joint injury? Yes / No
If you answered **Yes**, please give details.......................................
....
....

11. Have you had to suspend your normal training in the last two weeks? Yes / No
If the answer is Yes please give details...
....
....

If blood is not being taken from you please disregard Section 12. below.

12. * Please read the following questions:

a)	Are you suffering from any known serious infection?	Yes / No
b)	Have you had jaundice within the previous year?	Yes / No
c)	Have you ever had any form of hepatitis?	Yes / No
d)	Are you HIV antibody positive	Yes / No
e)	Have you had unprotected sexual intercourse with any person from an HIV high-risk population?	Yes / No
f)	Have you ever been involved in intravenous drug use?	Yes / No
g)	Are you hemophiliac?	Yes / No

13. As far as you are aware, is there anything that might prevent you from successfully completing the tests that have been outlined to you? Yes / No

---

IF THE ANSWER TO ANY OF THE ABOVE IS YES THEN:

a) **Discuss the nature of the problem with the Principal Investigator.**

b) **Questions indicated by (*) Allow your Doctor to fill out the ' Doctors Consent Form provided.**

As far as I am aware the information I have given is accurate.

Signature: ....

Signature of Parent or Guardian if the subject is under 18:

....

Date: ....../....../......