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EMERY, Jim <http://orcid.org/0000-0002-4272-1610>, DRISCOLL, Heather F, BARNES, Andrew <http://orcid.org/0000-0001-8262-5132> and JAMES, David M. <http://orcid.org/0000-0002-1135-626X>

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A method for characterizing high acceleration movements in small-sided football

Jim Emery[a*], Heather F. Driscoll[b], Andrew Barnes[c], David M. James[a]

[a]*Centre for Sports Engineering Research, Sheffield Hallam University, Sheffield, S10 2BP, UK*
[b]*School of Engineering, Manchester Metropolitan University, Manchester, M1 5GD, UK*
[c] *Academy of Sport and Physical Activity, Sheffield Hallam University, Sheffield, S10 2BP, UK*

Abstract

Small sided football is the most popular area of adult football in the UK, with an estimated 1.5m adults playing every week. Matches are played on smaller pitches using different rules to the 11-a-side game; this results in less stoppage time and a higher volume of ball activity per player. Despite these established differences in playing style and the increase in participation, the types and frequencies of movements performed are not fully understood due to the time consuming nature of current notational analysis methods.
Understanding movements is of particular interest to researchers and developers seeking task representative protocols and products for small sided football. The importance of movement type, specifically those with high horizontal plane accelerations, has been demonstrated by recent findings linking traction and shoe stiffness to injury and performance in a number of team sports.
In this paper we introduce a new motion analysis technique that uses a combination of inertial sensors and manual notational analysis to describe high acceleration movements in a repeatable and more time effective manner than previously published. A recreational 5-a-side team (mean ± SD: age 17.8 ± 0.26 years, body height 1.77 ± 0.05 m, body mass 74.23 ± 16.25 kg) were observed during one season at a commercial football centre. Player mounted sensors were used to identify 1824 high acceleration movements from three players in seven matches. These movements were then classified using operational definitions adapted from notational analysis literature.
This paper outlines a high acceleration movement analysis technique, provides normative high acceleration movement profiles for three individual 5-a-side players, and suggests comparisons to published 11-a-side data. These movement profiles provide a foundation for footwear researchers and product designers to re-align their current practice or products from the 11-a-side game to this more popular style of football.

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1. Introduction

According to Sport England's Active People Survey [1] approximately 58% of adult footballers play small sided football compared to 34% playing it's more traditional 11-a-side equivalent. Small sided games include 5, 6 and 7-a-side matches played on smaller pitches with different rules to the 11-a-side game; no balls are allowed above head height, rebounds from walls keep the ball in play and unlimited rolling substitutions allow players to rest off the pitch. It is generally accepted that small sided football is played at a higher intensity with more dribbles, shots and tackles and a greater number of ball contacts per individual than the 11-a-side game [2,3], as a result, it has been recommended as a development tool for skill acquisition and physical

* Corresponding author. j.emery@shu.ac.uk

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conditioning [4]. While the physiological and tactical demands of the game have been studied in elite populations, to date there has been no detailed characterization of the types and frequencies of movements performed.

Recent player centred footwear tests have shown links between traction and performance using individual or linked high acceleration movements designed to push the shoe-surface combination to their limit [5–7]. In studded footwear, Schrier et al. [5] used lab based tests to determine that mechanically tested traction affected quick 180° turning movements but had little or no effect on straight sprint times. Similarly, Sterzing et al. [8] used a field based test comprising a linear sprint and a series of 11 linked turns (ten 72° and one 180°) to conclude that a 3% difference in performance could be achieved by appropriately matching footwear to surface. Both these studies highlight the link between performance and footwear yet provide little or no rationale for the movement tasks used in the research. This is likely due to the lack of detailed movement profiles currently available for small sided football and the labour intensive nature of notational analysis.

There are a growing number of methods for tracking player movements in team sports which may be split into two categories; 1) automated or 2) manual. Automated methods include GPS tracking, automated camera tracking, and local position measurement. They offer very quick and relatively accurate (< .3 m error) player position data and are often used by tacticians and strength and conditioning coaches to better understand the games' physical demands. Currently these automated systems cannot distinguish between movement types, for example; between a side-cut and crossover-cut. Such a level of detail is essential for designing more task representative footwear test courses. A number of manual movement classification methods exist, from relatively simple real-time [3,9], to more time consuming and highly detailed post match analysis systems [10,11]

A commonly cited method is the Bloomfield Movement Classification scheme [11]. It offers high levels of detail but takes analysts one hour to analyze one minute of footage [12]. Although this might be considered prohibitive, the movement detail could be instrumental for informing movement demands in team sports. Such a comprehensive understanding of movements would in turn facilitate the design of task representative footwear test courses for small sided football. If a more time effective method existed, it would be easier to characterize the movement demands of small sided football. Therefore, the aim of this research was to develop a reliable and time effective method for characterizing high acceleration movements in small sided football. We also sought to provide normative movement profiles of 3 individual players.

2. Method

2.1 Data collection and processing

Following institutional ethical approval, a recreational under 21s five-a-side team was observed during eight league matches (mean ± SD: age 17.8 ± 0.26 years, body height 1.77 ± 0.05 m, body mass 74.23 ± 16.25 kg) throughout their 2014/15 season. Matches were captured using two digital video cameras (GoPro 3 Black Edition, GoPro, Inc. USA) mounted above the Goals at either end of the pitch. Players were instrumented with inertial sensors (Opal sensors by APDM, Inc. USA) fitted between the scapula in tight vests (miCoach Team Elite vests by adidas AG, Germany). The inertial sensors recorded accelerometer, rate gyroscope and magnetometer readings at a 40Hz sampling frequency. Both systems were synchronized via a clapping movement which provided an acceleration peak along with an audible and visual cue on the video footage. Once synchronized with the inertial sensors the cameras recorded the entire match. Automated post processing inertial sensor data used a bespoke algorithm (Mathworks, USA). Body centered coordinates were converted to a global reference frame. The resultant of the global horizontal acceleration components was filtered using a 2nd order zero phase lag Butterworth filter. Optimal cut off frequency was determined using residual analysis and defined as the frequency at which the second derivative of the residual with respect to cut off frequency (Δ = 0.5 Hz) became larger than a threshold of 0.2 m.s-2/Hz2 [13]. A horizontal acceleration threshold which minimized inclusion of non-high acceleration activities such as walking and jogging was set at the 99.8th percentile of a player's maximum horizontal acceleration for that match. The time signature of each identified peak was converted in to a video frame number and a single trained operator characterized the movements using a bespoke notational analysis structure.

Development of the video coding structure began with a review of current movement classification schemes [3,9–11,14] followed by an unstructured observational analysis. The Bloomfield Movement Classification System [11] provided the highest level of movement detail and was used as a template. Adaptations to the Bloomfield system were implemented after one full match had been analyzed. Movement categories or modifiers were removed where a strong theoretical justification could be made; for instance, the walk and stand categories did not occur simultaneously with high horizontal acceleration. On the ball activities were also removed and described in terms of player movement to match the studies aims.

The movement classification scheme includes 14 primary movements which, during pilot testing, were found to occur simultaneously with high horizontal accelerations. These primary movements were described in greater detail using 28 modifiers. The 14 primary movements and their operational definitions can be found in table 1.

Table 1. Primary movement definitions and their operational definitions

Primary movement	Definition
Sprint	Maximal effort, rapid motion
Run	Manifest purpose and effort, usually when gaining distance
Shuffle	Moving with a very short stride length, e.g. readjusting footwork, stumbling, or when braking heavily from a sprint
Skip	Moving with small bound like movements (one footed take off)
Fall	Descending to the ground
Get up	Getting up from the ground
Jump	Spring free from the ground or other base by the muscular action of both left and right feet and legs
Land	Entered after jump when contact with the ground is made
Stop	To brake suddenly
Imapct	Any contact made with another player
Swerve	to rapidly change direction in one movement without turning the body
Turn/twist	to rotate on the spot about a planeted foot
Side cut	Side cut using the outside leg to change direction
Crossover cut	Side cut using the inside leg to change direction

Presentation of a movement profile carries an assumption that a 'normative profile' has been reached [15]. In this study a profile was considered normative when the cumulative means of the five most prevalent movements stabilized to within 5% variation of the previous matches' entry.

2.2 Reliability

To establish inter-observer and intra-observer agreement, a group of experienced analysts (minimum 1 year experience) were recruited. They used the method outlined above to analyze a five-a-side university intra-mural league match (age 20±3 years). Training consisted of; a brief project overview and details of data collection (10 minutes), an introduction to the coding structure (10 minutes), two video examples of every primary movement (30 minutes) and a discursive group coding session to familiarize them with video viewing software and the spreadsheet entry system (30minutes). For intra-observer agreement, the match was re-analyzed by one observer one month later.

The Kappa statistic was used to quantify the agreement within (intra) and between (inter) observers [16]. A Kappa value of 1 indicates perfect agreement, > 0.6 represents a substantial strength of agreement, 0.4 to 0.6 is moderate, 0.2 to 0.4 is a fair strength of agreement, 0 to 0.2 is a poor agreement, and a kappa of 0 indicates agreement equivalent to chance [17].

3. Results

The results of the reliability study are shown in Table 2. For primary movements and modifiers both inter and intra observer agreement were 'substantial' [17], with intra-analyst having a slightly better level of agreement.

Table 2. Kappa reliability scores.

Agreement	Primary movement	Modifier
Inter-observer	0.603 (p<0.001), 95% CI (484, 0.722)	0.605 (p<0.001), 95% CI (0.477, 0.734)
Intra-observer	0.638 (p<0.001), 95% CI (0.529, 0.747)	0.612 (p<0.001), 95% CI (0.491, 0.734)

To establish normative profiles, three of most consistently attending players were selected for further analysis study. A total of 1824 high acceleration movements were observed in 450 minutes of match play. It took approximately two minutes to analyze each movement which equates to 8 minutes of analysis time per minute of match time. Figure 1 shows player one's cumulative sprint frequency over 8 matches with normative profile error limits. This criterion was applied to the top five most prevalent high acceleration movements for all players and normative profiles were reached after analysing 8 matches.

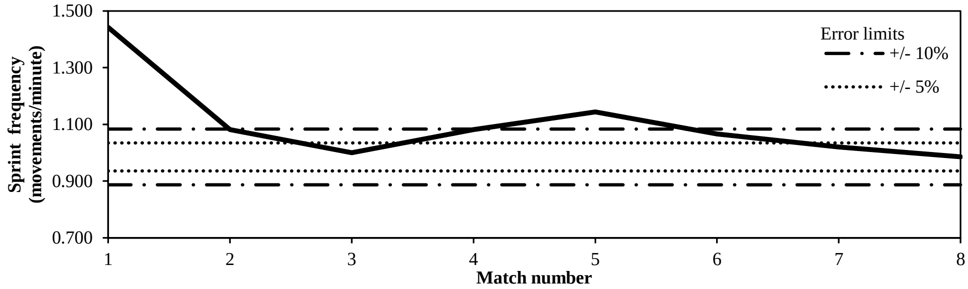

Figure 1. Player one's sprint cumulative sprint frequency with respect to 5% and 10% error limits.

The league rules allowed unlimited substitutions; the playing time for each player is shown in table 3. Despite having the shortest volume of playing time, player three exhibited a relatively high number of high acceleration movements, and therefore had the highest high acceleration movement frequency. Players 1 and 2 had very similar movement frequencies although player 1 spent more time on the pitch.

Table 3. Time spent on the pitch and movement number for all players and individuals

	Player 1	**Player 2**	**Player 3**	**All players**
Time (minutes)	173.5	160.25	115.5	449.25
Movements	660	605	559	1824
Frequency (movements/minute)	3.80	3.78	4.84	4.06

The prevalence of different types of high acceleration movements are shown in table 4. Movements are sorted in order of the percentage of total high acceleration movements from all players. None of the three individual players are accurately represented by the average of all players.

Table 4. Movement prevalence as a frequency (movements/minute) and as a percentage of total high acceleration movements

Primary movement	Player 1		Player 2		Player 3		All players	
	Frequency (move/min)	(%)	Frequency (move/min)	(%)	Frequency (move/min)	(%)	Frequency (move/min)	(%)
Sprint	0.46	11.97%	0.83	21.98%	1.10	23%	0.79	19%
Braking shuffle	0.77	20.30%	0.46	12.23%	0.61	13%	0.62	15%
Impact	0.51	13.48%	0.46	12.23%	0.65	13%	0.54	13%
Run	0.29	7.73%	0.47	12.56%	0.79	16%	0.52	12%
Side cut, 0 - 90°	0.35	9.24%	0.29	7.77%	0.31	6%	0.32	8%
Skip	0.34	8.94%	0.29	7.60%	0.29	6%	0.30	8%
Stop	0.34	8.94%	0.29	7.60%	0.23	5%	0.29	7%
Crossover cut, 0 - 90	0.18	4.70%	0.11	2.81%	0.21	4%	0.16	4%
Side cut, 90 - 180	0.06	1.52%	0.19	4.96%	0.17	4%	0.14	3%
Accelerating shuffle	0.07	1.97%	0.12	3.31%	0.18	4%	0.13	3%
Turn or twist	0.05	1.36%	0.09	2.31%	0.13	3%	0.09	2%
Fall	0.15	3.94%	0.05	1.32%	0.00	0%	0.07	2%
Jump	0.06	1.67%	0.05	1.32%	0.10	2%	0.07	2%
Land	0.06	1.52%	0.02	0.66%	0.04	1%	0.04	1%
Swerve	0.05	1.36%	0.04	0.99%	0.03	1%	0.04	1%
Crossover cut, 90 - 180	0.03	0.76%	0.01	0.33%	0.00	0%	0.01	0%
Get up	0.02	0.61%	0.00	0.00%	0.00	0%	0.01	0%

4. Discussion

4.1. Reliability

One of the aims of this research was to develop a reliable and more time effective method for characterizing high acceleration movements during small sided football. Substantial agreement at both inter and intra-observer level was found for primary movement descriptors (0.603 ($p<0.001$) and 0.638 ($p<0.001$) respectively) and modifiers (0.605 ($p<0.001$) and 0.612 ($p<0.001$) respectively). Analysis of 450 minutes of match play took 60 hours in this study; approximately 14% of the 450 hours it would have taken to analyze using the Bloomfield Movement Classification system.

This high level of agreement was achieved using inertial sensors and a mathematical algorithm, rather than the human eye to determine high acceleration movements. The objective definition of high acceleration movements meant that an identical number of movements were selected for analysis by every observer and had implications on the type and limits of the reliability analysis. Consider a case where very similar numbers of movements were observed but they had little or no agreement between movements; if reliability was analyzed using correlation or percentage error it is theoretically possible for a 'good' outcome despite little or no agreement. Whereas, the Kappa statistic assesses each pair of observations against a chance corrected measure of agreement and would report 'poor' agreement in this hypothetical scenario. Therefore, in this study, the Kappa statistic was deemed highly appropriate. Furthermore, the fixed number of movements identified in this study is analogous to Altman's [17] study where radiographers agreed a fixed number of xeromammograms to be diagnosed This meant that Altman's reliability thresholds remain relevant to this study [18].

Precise operational definitions were adapted from Bloomfield's [11] detailed classification scheme which was also shown to have substantial levels of agreement ($k = 0.697$ to 0.789). Our findings show that the presented method is reliable, yet it yielded lower agreement than Bloomfield's time-motion analysis method. This result is somewhat unexpected as the fixed number of discreet movements analyzed, should theoretically increase levels of agreement when compared to a time-motion method. One possible cause for this is the reduced number of movement categories in this study. Cohen's Kappa increases as the number of classification codes increases [19]. In this study, several classification codes were removed from the Bloomfield movement classification system because those movements do not occur during periods of high horizontal plane acceleration. This highlights one of the challenges associated with using Cohen's kappa and the risk of attempting to make direct comparison between the reliability of analysis methods.

4.2. Movement profiles

This study described the high acceleration movements performed by a UK junior recreational team in their small sided football league. The results support previous suggestions that small sided football is played at a higher intensity. Bloomfield found that English Premier League players performed decelerations at a frequency of 0.60 movements per minute, in comparison to the 0.62 presented here. Similarly, the frequency of stops in the 11 a side game was 0.36 movements per minute vs. 0.29 in this study [20]. Whilst these frequencies are similar, it is important to note that Bloomfield's analysis was not restricted to high acceleration movements and the numbers they presented would be reduced if restricted to high accelerations. In light of this, it can be inferred that the number of stops and turning movements reported here would be greater than published elite 11-a-side findings.

The dominance of linear movements (sprint, braking shuffle and run) discovered here was also observed in 11-a-side studies [20,21]. Previous authors found that standing and walking accounted for 67.3% of the movements occurring before a turn [21]. These movements were not used in this coding structure because they did not occur during the observational analysis of high acceleration movements. It is safe to assume that standing and walking would be performed at a lower speed than a sprint. This suggests that higher intensity activity is performed with fewer turning movements relative to lower intensity; hence the higher proportion of sprints (18.59%) reported here compared to turns (7.89%).

The differences between player profiles can be seen in tables 3 and 4. All players spent different lengths of time on the pitch and players one and two had a lower high acceleration movement frequency than player 3. Player one has a different high acceleration movement rank (braking, impact, sprint, run) to players two and three (sprint, run, braking/impact), which was not evident in initial observations. These results provide initial data to support the movement profile associated with small sided football but are limited to a specific team in a specific recreational league. Future work should aim to conduct a more comprehensive movement analysis on a greater number of recreational players and matches. Such work could begin to explain how these confounding factors effect movement choices at player or team level and provide a more generalizable movement profile from which footwear researchers and manufacturers can re-align their current products or practices.

5. Conclusion

This study presents a new method to characterize the movements performed during recreational small sided football using a combination of inertial sensors and manual notational analysis. The method has been shown to be reliable, time effective and sensitive enough to observe differences in high acceleration playing style for recreational small sided footballers. This study also presents typical movement profiles for three individual small sided football players. The movement profiles offer researchers and developers the foundations to re-align their current products or practice for this more popular style of recreational football.

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