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A coding system to quantify powerful actions in soccer match play: a pilot study

A CODING SYSTEM TO QUANTIFY POWERFUL ACTIONS IN SOCCER MATCH PLAY: A PILOT STUDY

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Keywords: Locomotion, pediatric exercise, movement components, biomechanics.

Abstract

Purpose: The powerful activity profile of elite soccer match play has not been documented appropriately to inform specific maximal power assessment and development criteria. The aims of the current study were to develop a soccer specific powerful action (SSPA) notational analysis coding system that could be used to compare frequency and durations of powerful actions during elite youth soccer match play. **Methods:** Sixteen elite male English Premier League (EPL) Academy players (19±1 yrs) were recorded by an individual camera during sixteen competitive EPL U18 and U21 games. Video footage was analyzed using performance analysis software and SSPAs were coded according to the following categories: initial acceleration, leading acceleration, sprint, unilateral jump and bilateral jump. **Results:** The SSPA coding system demonstrated very good inter- and intra-rater objectivity (kappa coefficients ≥0.827). Elite youth EPL soccer players undertook significantly more initial (31±9) and leading (37±12) accelerations than sprints (8±3; p=0.014, d=1.7, and p<0.001, d=1.7, respectively) and jumps (6±5; p=0.002, d=1.7 and p<0.001, d=1.7, respectively). Players performed a significantly greater number of initial and leading accelerations with action durations below 1.5s compared to above 1.5s (p=0.001, d=1.6, and p=0.002, d=1.4), respectively. **Conclusions:** Our SSPA coding system provides an objective observational instrument for quantifying the frequency and duration of powerful actions performed during elite soccer match play. In our sample of elite youth soccer players, horizontal accelerations of short duration (<1.5s) from different starting speeds appear the most dominant powerful action in elite youth soccer match play.

Keywords: Locomotion, pediatric exercise, movement components, biomechanics.

An analysis of movement is important for understanding the physiological demands of a sport (Carling, Bloomfield, Nelsen, & Reilly, 2008). Evaluating the specific movements provides the basis for categorizing the types of actions that may be important for performance. Sport specific actions can be described as powerful when the athlete attempts to generate the greatest possible velocity at take-off, release or impact (Cormie, McGuigan, & Newton, 2011). Understanding the specific nature of the powerful actions performed during elite soccer match play can help inform assessments of muscular power and training strategies in this domain (Issurin, 2013; Maulder & Cronin, 2005).

Much of the available data on the performance of powerful actions within soccer come from studies that have used automated time motion analysis systems, which have classified maximal accelerations (Bradley, Di Mascio, Peart, Olsen, & Sheldon, 2010; Varley & Aughey, 2013) and sprint (Di Salvo et al., 2010) efforts as actions that require the player to complete both accelerations and running velocities over pre-determined thresholds [i.e. maximal acceleration threshold: >2.78 $m.s^{-2}$ (Varley & Aughey, 2013); Sprint threshold: >25.2 $km.hr^{-1}$ (Di Salvo et al., 2010)]. However, during linear speed testing protocols (Stolen, Chamari, Castagna, & Wisloff, 2005) and competitive games (Bradley et al., 2009), elite soccer players present a range of individual capabilities in terms of accelerations and maximal running speeds. As a consequence, the classification of accelerations and sprints as maximal could be misleading as these arbitrary speed thresholds may incorrectly classify movements that are not truly indicative of a maximal action for a specific individual player (Dogramac, Watsford, &

Murphy, 2011). The accuracy and objectivity of time motion analyses systems are frequently compromised at such higher speed ranges, and in actions that require both greater rates of acceleration and during efforts involving a change of direction (Akenhead, French, Thompson, & Hayes, 2014; Jennings, Cormack, Coutts, Boyd, & Aughey, 2010). Automated time motion analyses systems also often fail to report the vertical jump demands of soccer. Subsequently, considering these limitations, studies using automated time motion analysis systems may not characterize the powerful activity in elite soccer match play in sufficient detail to inform the specificity of soccer-associated muscular power assessment and development protocols.

Notational analysis systems have been proven as reliable and valid method of tracking player movements where short distances, frequent changes in direction (Dogramac et al., 2011) and vertical jumps (Faude, Koch, & Meyer, 2012; Mohr, Krustrup, & Bangsbo, 2003) are observed. Unlike automated time motion analyses systems, this method offers more flexibility for the identification of powerful actions based on the circumstances, during which the action is performed (i.e. during a situation when two players from opposite teams are accelerating in a race to get to an area of the pitch, or to a free soccer ball, this would suggest that the acceleration is performed as rapidly as possible, and can therefore be described as a powerful action). Notational analysis may therefore provide a more accurate description of the frequency and duration of the complex powerful actions performed by individual players during soccer match play (Dogramac et al., 2011).

To date, previous soccer notational systems coded sprints but not accelerations (Bloomfield, Polman, & O'Donoghue, 2007; Faude et al., 2012), failed to report action duration (Faude et al., 2012), and only reported the frequency of powerful actions preceding goals (Faude et al., 2012) and during isolated random fifteen-minute periods of games (Bloomfield et al., 2007). No study has provided a comprehensive description of the powerful actions performed over the duration of a competitive soccer match. Consequently, there is currently limited information available to inform the specific detail of soccer-associated power assessment and training intervention protocols.

The primary aim of our study was to develop an objective soccer specific powerful action (SSPA) notational analysis coding system that could assess and compare the frequency and durations of various powerful actions during elite youth soccer match play. We also aimed to use this SSPA notational analysis coding system to describe the powerful activity profile of a sample of elite soccer players during youth English Premier League (EPL) soccer match play.

Method

Participants

Sixteen elite male soccer players registered to an EPL football academy provided consent to participate in the study. The study was approved by the (deleted for reviewing purposes) and complied with the Declaration of Helsinki (Ethics protocol number: P13/SPS/033; approved 31/10/13). Soccer players were considered elite if they had competed regularly (played over 12 competitive games in the previous 6 months) for one of the highest ranked (Category One) soccer academies in England, according to the Elite Player Performance Plan (Premier-League, 2011) audit criteria (only 24 out of 86 English soccer academies were awarded Category One status). Our entire sample of elite soccer players competed regularly in Division One of the Premier League 2 (the league for U23 Category One English academies). Furthermore, 12 of the participants were also members of their respective youth national teams, while three players had previously represented their senior national team. Players' age, height, body mass, sum of seven skinfold sites (taken at the biceps, triceps, subscapular, supraspinale, abdominal, mid-thigh, and calf) and estimated % body fat were (mean ± SD) 18.5 ± 1.0 years, 1.81 ± 0.07 m, 74.9 ± 8.6 kg, 44.3 ± 7.1 mm and 7.9 ± 1.2 %. The sample of players included three central defenders, three full backs, three central midfielders, three wide midfielders and four center forwards. Three of the players were substituted at various time-points during the second half. Therefore, their first-half performance data were reported but removed from the statistical analyses.

Equipment and Software

Individual player footage was filmed using digital video camera (Canon XM2, Amstelveen, Netherlands) mounted on a stationary tripod (Libec, Arizona, USA). Video footage was transferred to a desktop computer (Apple iMac, California, USA) and then analyzed using performance analysis software (Sportscode Gamebreaker Plus, Sportscode, NSW, Australia), operating at a frequency of 25 Hz. Speed testing (10 m and 30 m sprint) was performed using a photocell timing system (Brower Timing System, Salt Lake City, UT, USA). Seven of the players wore 10 Hz global position system (GPS) technology (STATSports, Newry, Northern Ireland) for complete 90 min matches.

Experimental Design

Firstly, a SSPA coding system was developed. Once the contents validity evidence, intra-observer and inter-observer objectivity of the SSPA coding system were established, sixteen players were filmed with an individual camera and the SSPA coding system was used to analyze the powerful activity profile performed by each player.

Soccer Specific Powerful Action Coding System

A video based player tracking notational analysis SSPA coding system was developed during five sequential stages (Brewer & Jones, 2002). Considering the limitations of previous soccer coding systems, it seemed appropriate initially to clearly define what actions can be considered powerful and hence could be incorporated into a notation system. A powerful action was defined as an effort that was performed as (or nearly as) explosively as possible. The identification of powerful actions was therefore based on the researcher recognizing circumstances in which the player performed an explosive effort. For example, accelerations and sprints were considered powerful actions in situations when the player was perceived to be aiming to travel to a specific area of the pitch as quickly as possible. Such actions were generally performed under circumstances which required the player to advance towards the ball before an oncoming opponent, move away from an advancing opponent, or travel to a specific area of the pitch in an attempt to gain possession of the ball from an opponent. Vertical jumps were considered powerful actions when it was assumed that the player was attempting to meet the ball at its highest point and therefore, jumping as high as possible.

The researcher initially filmed pilot video footage of four different players and observed this pilot video footage in real time, and in slow motion, and developed a broad categorisation of SSPAs by identifying discrete movements that were perceived as being performed as (or nearly as) explosively as possible. The SSPA coding system is detailed in Tables 1 and 2. As acceleration (10 m linear speed assessment time) and sprint (30 m linear speed assessment time) capabilities are independent attributes in soccer players (Little & Williams, 2005), it was thought to be important to ensure that the SSPA coding system included specific criteria to allow the frequency of both of these types of powerful actions to be coded. The average 10 m linear speed assessment times for the elite youth academy players recruited for the current study was 1.72 ± 0.07 s. As these 10 m sprint times were similar to those previously reported in sample of Premier League footballers that also included international players (1.69 ± 0.08 s; this cohort included 14 players with 6 internationals; Cotte & Chatard, 2011), we believed it was an accurate representation of the acceleration capabilities within this cohort. Therefore, when the player had accelerated as (or nearly as) explosively as possible for more than 1.72 s, it can be assumed that they have progressed through the acceleration phase and now transitioned into performing a sprint action.

xxxxxxxxxxxx Table 1 and 2 near here xxxxxxxxxxxx

The contents validity of the SSPA coding system was established via interactions with an expert panel (n=5) that included one experienced applied football researcher, practitioner and university professor, one video analyst and two sport scientists, all currently employed by English Premier League Clubs. These specialists were invited to review and validate the coding system. This process consisted of the author explaining and demonstrating the coding classification system and receiving verbal feedback on it during a series of meetings. Following these discussions, all the specialists agreed with the SSPA coding system categories and rules. As a consequence, the SSPA coding system was deemed a valid measuring tool for recording the most frequent and important powerful actions performed during soccer match play.

Having established contents validity evidence for the SSPA coding system, the intra-observer objectivity was then investigated to establish if the test-retest objectivity for the principle researcher using the system was acceptable. Similarly, inter-observer objectivity was investigated to establish whether the author, and an inexperienced observer who had no previous experience of notational analysis methods, could record the same movements, at the same time points, during the same game. The process for investigating the intra- and inter-observer objectivity of the SSPA coding system is illustrated in Figure 1.

To investigate the intra-observer objectivity, the researcher initially viewed the individual player video footage of a single full competitive game and coded the powerful actions based on the criteria of the SSPA coding system being assessed. Twelve days later, the same researcher then repeated this analysis process again, coding the powerful actions during the same individual player video footage. Game codes were extrapolated to timelines with a recording scale of 0.5 s (with the exception of vertical jump actions, removing actions <0.5 s duration). The two timelines were matched.

During the inter-observer objectivity procedure, an in-experienced observer was required to view the same individual player video footage of a full competitive game and code the powerful actions based on the criteria of the SSPA coding system being assessed. The game codes were extrapolated and the observer timeline (recording scale 0.5) was matched with the corresponding timeline from the same individual player video footage coded by the researcher during the intra- objectivity analysis.

The level of agreement between matched timelines was analyzed for intra- and inter-observer objectivity using kappa statistics (Figure 1). During the development of the SSPA coding system the intra- and inter-observer objectivity assessments were completed on three and two occasions, respectively (Figure 1).

xxxxxxxxxxxx Figure 1 near here xxxxxxxxxxxx

The comprehensive development of the SSPA coding system indicated that the tool was an objective observational instrument for the coding of SSPAs. Following this evaluation, the data collection procedures commenced in conjunction with GPS-derived acceleration data, which were collected simultaneously with our SSPA data. This enabled us to compare our SSPA system with technology that is commonly used to quantify powerful actions in the applied field. The GPS-derived accelerations were recorded using wearable 10 Hz global position system (GPS) technology (STATSports, Newry, Northern Ireland). Seven players wore the trunk-mounted GPS unit, positioned in the mid scapula region as per manufacturer guidelines in a STATSports vest (Newry, Northern Ireland), for complete 90 min matches (the same as coded using our SSPA system). An acceleration was registered when the change in GPS speed increased for at least half a second, with a maximal acceleration of over 3 ms^{-2}. We compared the total number of accelerations throughout the game measured using GPS technology with the total number of powerful accelerations (initial and leading accelerations) coded using our SSPA coding system.

Procedure

Filming was conducted during sixteen competitive EPL Academy Youth League soccer matches (thirteen U21 and three U18 League Games) in the 2013-2014, and 2014-2015 season. All games were played on a grass surface and filmed using a digital video camera (Canon XM2, Amstelveen, Netherlands) mounted on a stationary tripod (Libec, Arizona, USA). Individual players were recorded and tracked by an individual camera, which was zoomed to provide clear, unobstructed and close images of the specific player in question from an elevated position.

The video footage of each game was transferred to a desktop computer (Apple iMac, California, USA) and then analyzed using performance analysis software (Sportscode Gamebreaker Plus, Sportscode, NSW, Australia), operating at a frequency of 25 Hz. Only actions when the circumstances would suggest that the player had to perform an effort as (or nearly as) explosively as possible were coded according to the categorisation criteria detailed in Table 1. The start and end points of powerful actions were coded to provide frequency counts and action duration outcomes. The video footage could be played back frame-by-frame, or in slow motion, to allow specific start and end points to be identified. Specific criteria used to identify these time points are illustrated in Table 2.

Data Analysis

Due to the relatively low number of observations for both unilateral and bilateral jumps, these actions were grouped together as one category (vertical jumps) for analyzing differences within and between powerful actions. The whole dataset was checked for normality and the frequency data for vertical jumps were not normally distributed. Therefore, a Friedman's test was used to determine if there were differences between the total frequencies of different powerful actions performed during the whole game (initial accelerations, leading accelerations, sprints, vertical jumps). Pairwise comparisons were performed with a Bonferroni correction to determine specific differences between the different powerful actions. Wilcoxon signed ranked tests were used to detect differences between the same powerful actions performed during the first half compared to the second half. Wilcoxon signed ranked tests were also used to detect differences between the number of powerful actions performed in the two duration categories (0.5 - 1.49 s and ≥1.5 s; these categories were chosen as 1.49 s is below 1.72 s, which is the average 10 m maximal sprint time for this group of players. This gives the practitioner a reference for the number of maximal accelerations performed over a distance of less than 10 m) and the number of unilateral compared to bilateral vertical jumps performed during the whole game. Simple effect size, estimated from the ratio of the mean difference to the pooled SD, was also calculated. Effect size ranges of <0.20, 0.21–0.60, and 0.61–1.20, 1.21–2.00, and >2.00 were considered to represent trivial, small, moderate large, and very large differences, respectively. To assess the level of agreement between SSPA and GPS methods regarding frequency of (maximal/near maximal) accelerations for the seven players, who wore the GPS unit for complete 90 min matches, we performed a Student's paired T-test and also calculated the coefficient of variation, a two-way random effect with absolute agreement intra-class correlation coefficient, and ratio limits of agreement (Nevill & Atkinson, 1997). All statistical analyses were completed using SPSS version 21 (SPSS Inc., Chicago, IL), and statistical significance was set at $p < 0.05$. All data are expressed as mean ± SD.

Results

Comparing The Frequencies of Powerful Actions

During a competitive soccer match, elite youth soccer players performed a total of 81 ± 18 powerful actions. There were significant differences between the frequency of actions performed during the match ($\chi^2(4) = 48.043$, $p < 0.001$). Pairwise comparisons revealed that players performed a significantly greater number of initial accelerations and leading accelerations than vertical jumps during the whole game (p = 0.002 and $p < 0.001$, respectively; Table 3), with these differences associated with large effect sizes (d = 1.7 and d = 1.7, respectively). Similarly, a significantly greater number of initial accelerations and leading accelerations were performed compared to sprints during the whole game (p = 0.014 and $p < 0.001$, respectively; Table 3), with these differences associated with large effect sizes (d = 1.7 and d = 1.7, respectively). There was no difference in the number of vertical jumps performed compared to sprints during the entire match (p = 1.000; Table 3), which was also associated with a small effect size (d = 0.4). Likewise, players performed a similar number of initial and leading accelerations during the whole game (p = 1.000; Table 3), which was also associated with a small effect size (d = 0.6).

Temporal Pattern of Maximal Actions

A significantly higher total number of powerful actions were performed during the first compared to the second half of matches (45 ± 10 vs. 37 ± 10; Z = -2.944, p = 0.003), with this difference associated with a moderate effect size (d = 0.7). More specifically, players performed a significantly greater number of initial accelerations in the first half (Z = -1.959; p = 0.050; Table 3), with this difference associated with only a small effect size (d = 0.6). A higher number of leading accelerations (Z = -1.889; p = 0.059; Table 3) was observed during the first, compared to the second half of the matches though this difference was not significant, and this differences was associated with a small effect size (d = 0.5). There was no difference between the numbers of sprints (Z = -0.158, p = 0.874; Table 3) or vertical jumps (Z = -1.437, p = 0.151; Table 3) performed during either half, with such comparisons also associated with trivial (d = 0.1) and small effect sizes (d = 0.4), respectively.

Duration of Powerful Actions

There were significantly greater number of initial accelerations (Z = -3.189, p = 0.001; Table 3), leading accelerations (Z = -3.115, p = 0.002; Table 3), and sprints (Z = -2.325, p = 0.020; Table 3), performed that lasted for durations between 0.5-1.49 s compared to the number of these activities performed for more than 1.5 s. These differences in the number of initial accelerations, leading accelerations, and sprints, were associated with large (d = 1.6), large (d = 1.4) and moderate (d = 0.7) effect sizes, respectively.

Jump Type Frequency

There was no difference in the total number of unilateral compared to bilateral jumps performed during the matches (3 ± 3 vs. 3 ± 3; Z = -3.180, p = 0.437). The range of total vertical jumps performed, however, was large (Total vertical jumps: 2 – 18).

xxxxxxxxxxxx Table 3 near here xxxxxxxxxxxx

Comparing frequency of accelerations measured with SSPA and GPS methods

The frequency of "maximal" accelerations determined via GPS (49.6 ± 25.0) was lower than the number of total accelerations determined by SSPA (68.3 ± 19.7, t_6 = -3.45, p = 0.014). The intraclass correlation coefficient between the two methods was 0.755 (95% CI: 0.111 – 0.969; p = 0.009), and the coefficient of variation was 27.5%. The ratio limits of agreement were 1.478 (*/ ÷ 1.838). The bias ratio (1.478) implies that SSPA coded the frequency of maximal (or near maximal) accelerations on average 47.8% higher than those quantified using GPS, while the agreement ratio (*/ ÷ 1.838) indicates that 95% of the agreement ratios lay within 83.8% above or below the mean bias ratio. Thus, we can state that the agreement between the two methods for quantifying frequency of maximal (or near maximal) accelerations was poor.

Discussion

Our study aimed to develop a notational analysis coding system that could characterize the powerful activity profiles of elite youth soccer players in sufficient detail to inform the detail of maximal power assessment and development protocols. The main finding was that our SSPA coding system provides a highly objective observational instrument for quantifying the frequency and duration of powerful actions performed during elite soccer match play. In the sample of elite youth soccer players subsequently analyzed using the SSPA coding system, we show that over the course of a competitive game, EPL youth players performed a significantly greater (associated with a large effect size) number of initial and leading accelerations compared to both sprints and vertical jumps. Action duration data showed that the majority of initial accelerations (large effect size), leading accelerations (large effect size) and sprints (moderate effect size) performed over the course of a game lasted less than 1.5 seconds. Our findings suggest that accelerations of short duration (<1.5 seconds), from different starting speeds that are oriented in the horizontal direction, are the most dominant powerful action in elite youth soccer match play. This information suggests that soccer-associated maximal power assessment and development protocols could specifically focus on evaluating and enhancing the ability to perform horizontal, rather than vertical, powerful actions.

If a video based player tracking notational analysis coding system is to be used to provide information to inform the prescription of assessment and training strategies for elite soccer players, it is imperative that the coding system has been validated and shown to be objective for observers using the instrument. By consulting a range of experts in the field in series of meetings we have also provided very good content validity evidence that the SSPA coding system is representative of the powerful actions performed during soccer match play. The large kappa coefficients (≥ 0.827) calculated in the intra- and inter-observer objectivity analyses procedures demonstrates that the SSPA coding system is objective for both the researcher, and an inexperienced observer. Our findings therefore show that the SSPA coding system developed can be used with a high level of objectivity by other researchers in future studies to quantify the frequency and duration of powerful actions performed during soccer match play. As such detailed information is lacking in the current body of literature, we believe the SSPA coding system can serve as a platform for innovative future research that could provide the applied practitioner with detailed information to inform maximal power assessment and development processes in a soccer specific context.

Considering automated time motion analysis systems, utilizing GPS technology, have been commonly used to quantify "high intensity" aspects of a soccer match, we decided to compare the frequency of "maximal" accelerations identified via our SSPA method with that identified via GPS. Although the intraclass correlation coefficient was moderate, the large confidence intervals, the extremely wide ratio limits of agreement and high coefficient of variation showed there was poor agreement between the SSPA and GPS derived maximal (or near maximal) accelerations. Given that the objectivity and validity of 10 Hz GPS for measuring accelerations is compromised for those over 4 ms^{-2} (Akenhead et al., 2014), it is clear that the 10 Hz wearable GPS units are not suitable for accurately assessing the number of soccer-specific high intensity activities. Moreover, the speed and acceleration capabilities of our elite youth soccer players varied (range in 10 m sprint performance substantially: 1.53 – 1.75 s; range in 20 m sprint performance: 2.72 – 3.02 s), thus implying that some players surpassed the generic maximal acceleration threshold when eliciting only submaximal efforts, whereas other players may not have surpassed this generic threshold even when performing maximal/or near maximal accelerations. Considering these two factors, it is therefore not surprising that we found a discrepancy in the number of powerful accelerations when comparing the results from an automated time motion analysis system (with compromised validity and objectivity), with our SSPA coding system, which has been shown to have very good intra- and inter-observer objectivity. Our work further illustrates the limitations of using automated time motion analysis systems for describing the powerful activity profile in elite soccer. The discrepancy in results signifies the importance of our study for providing an accurate and objective representation of the powerful activity demands of youth soccer.

Unlike previous notational analysis coding systems (Bloomfield et al., 2007; Faude et al., 2012), our SSPA coding system documented the number and type (initial or leading) of powerful accelerations performed throughout the duration of a whole game [as opposed to just before goals scored (Faude et al., 2012), or during isolated 15-minute periods (Bloomfield et al., 2007)]. Moreover, unlike previous notational analysis coding systems (Bloomfield et al., 2007; Faude et al., 2012), we also included the action duration, which gives valuable information for the practitioner that may inform the rep duration of speed/agility or conditioning drills, and the specificity power development protocols. By also being the first study to include the type of jump action (unilateral or bilateral), we provide innovative information that may be used to inform soccer specific power assessment and development protocols. We believe the information provided in our study provides the most objective and comprehensive available description of the detail of powerful actions performed over the duration of a competitive soccer match.

Using the SSPA coding system to analyse a sample of elite youth soccer players during youth EPL match play, we show that these players undertook 8~fold more horizontal accelerations than sprints (~68 vs. 8, respectively), thus suggesting horizontal acceleration is a more dominant action (Table 3). We also show that elite EPL youth soccer players performed 11~fold more horizontal accelerations (initial and leading accelerations combined) than vertical jumps (~68 vs. 6, respectively) during a competitive match. Subsequently, our data suggests that powerful efforts oriented in the anterior-posterior and mediolateral directions are performed more frequently during elite EPL youth soccer match play than efforts oriented the vertical direction. Considering it has been previously documented that unilateral jump capabilities in different directions are independent qualities that require different muscle activation profiles (Murtagh et al., 2017) and should be assessed and developed separately (Meylan, Nosaka, Green, & Cronin, 2010), our data in this sample of EPL players suggests that future soccer specific power assessment and development protocols should prioritize anterior-posterior and mediolateral power production. More specifically, our findings suggest that horizontal jump assessments (rather than vertical jumps which are the most common assessment employed currently at elite soccer clubs), should be prioritized in elite soccer assessment protocols. However, the range in vertical jump frequency in the current study (2-18) may also suggest that this capacity is more important for some positions than others, or perhaps dependent on the type of game and opposition. Our innovative data therefore makes the soccer practitioner aware that certain EPL youth players may be required to jump in the vertical direction more frequently. Subsequently, vertical power training may be prescribed on an individual basis depending on how often the player is required to jump vertical in a game.

To optimize muscular power assessment and development programmes for soccer players, knowledge of the detail of these actions is important. The majority of horizontal accelerations and sprints were performed for durations of less than 1.5 s (Table 3). This information suggests that short duration explosive horizontal efforts are the most dominant powerful action during elite youth EPL soccer match play. These findings are in agreement with Cometti and Colleagues (2001) and, as acceleration performance has been associated with horizontal-forward jump performance (Dobbs, Gill, Smart, & McGuigan, 2015), these findings may further support the inclusion of this assessment in elite soccer talent identification protocols. In addition, this data from our sample of EPL players also suggests that the most frequent action included in soccer specific speed, and soccer speed endurance development drills, should be explosive short duration maximal accelerations (<1.5 s).

Our study is the first to categorize accelerations as initial or leading, based on the inertia that the player is required to overcome before initiating the acceleration. As there was no difference (and small effect size) in the number of initial and leading accelerations completed by EPL youth soccer players (Table 3), our results show that both of these actions are should be developed simultaneously during soccer training interventions.

Analyzing the effect of time on the frequency of powerful actions may also provide useful information for the prescription of soccer conditioning programmes. Elite EPL youth soccer players performed fewer maximal actions in the second half in comparison to the first half. More specifically, significantly fewer initial accelerations, and a tendency for fewer leading accelerations, were performed in the second half, thus suggesting that powerful horizontal actions were reduced as a function of time. However, these differences between halves for initial and leading accelerations were associated with small effect sizes. Due to the complexity of factors that could influence the reduction in running performance during soccer match play (Paul, Bradley, & Nassis, 2015), the significance of these findings is not yet known from a practical or theoretical perspective. Nevertheless, our data may suggest that soccer practitioners could aim to apply specific conditioning interventions to help players perform initial accelerations more frequently during the second half of competitive matches. Such interventions could include high intensity conditioning drills that include the performance of maximal accelerations, from static or walking starts, in the latter stages of the session when a certain level of fatigue has been accumulated.

Although our cohort included 12 international standard players from six different countries, a limitation of our study was that all 16 elite youth players, who participated in this study, represented the same English Premier League Academy at U18/U21 level. Thus, our results may not be indicative of soccer powerful activity profiles in other age groups or in teams competing in other leagues in different countries. Moreover, as we only included 16 elite youth players, our study should be repeated with a larger sample size to confirm our findings are representative of EPL youth soccer match play. Future research could therefore recruit larger cohorts and focus on using our SSPA coding system to compare the powerful action demands at different age groups and in elite soccer clubs playing in different countries

In conclusion, the current study developed a video-based player tracking notational analysis coding system that could be used to provide a highly objective account of the powerful actions performed during elite soccer match play. In our sample of elite EPL youth soccer players analysed, vertical jumps and sprints were performed less frequently than both initial and leading horizontal accelerations. The results showed that initial and leading horizontal accelerations of short duration (< 1.5 s) are the most frequently performed powerful actions during elite youth soccer match play. In comparison to the first half, EPL youth soccer players performed significantly fewer initial accelerations during the second half.

What Does This Article Add?

Our study provides evidence that a notational analysis coding system can be used to provide soccer practitioners with an insight into the powerful action demands of EPL youth soccer match play. The detail that the SSPA coding system describes such powerful actions may be used to inform the specificity of soccer specific physical assessment and development protocols. As the most dominant action performed by the sample of elite youth EPL soccer players in our study were horizontal accelerations from different starting speeds, our data suggests the assessment and development of the ability to produce horizontal impulse from static or walking speeds, but also from moving speeds, should be prioritized within the athletic development protocols applied at elite youth soccer clubs. We also show that elite youth soccer players are required to perform powerful vertical jump and sprint actions, and whilst these capabilities may also be important to assess and develop, they should not be prioritized over the ability to perform short duration horizontal accelerations. The vertical jump requirements of EPL youth soccer match play were varied (range between 2-18) and therefore, the ability to produce vertical power may be more important for specific players. Analyzing the temporal patterns of powerful actions shows that the specific action that was performed less frequently during the second half was the initial acceleration.

Practitioners may aim to improve the ability to perform this action in conditioning programmes tailored towards improving second half physical performance.

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Table 1. Soccer specific powerful action (SSPA) coding system categories and definitions.

Category	Definition
Initial acceleration	Very high-intensity horizontal acceleration where the player propels their body in the forward or sideways direction whilst initiating the first propulsion when either static, walking, or after changing direction.
Leading acceleration	Very high-intensity horizontal acceleration where the player propels their body in the forward or sideways direction whilst initiating the first propulsion when performing a movement that cannot be defined as static, walking or changing direction.
Sprint	If the player is perceived to continue to perform the very high intensity acceleration effort for over 1.72 s, the acceleration now turns into a sprint action. At this time point the acceleration terminates and a sprint action will begin.
Bilateral jump	Very high-intensity propulsion of body off two legs in a primary vertical direction with only partial horizontal direction. This must have a clear identifiable take off and flight phase.
Unilateral jump	Very high-intensity propulsion of body off one leg in a primary vertical direction with only partial horizontal direction. This must have a clear identifiable take off and flight phase. This category can include actions such as jumping to control the ball and does not necessarily have to be a jump for a header.

Table 2. Criteria for defining start and end point of all powerful actions.

Start point of powerful actions:

- The beginning of all powerful actions was defined as the moment that the players' foot first made contact with the ground immediately before initiation of the first explosive propulsion of the movement.
- On the rare occasion that the player initiated the powerful action from a static stance with both feet in contact with the ground, the action began at the instance (time frame before) marked by the first noticeable extension of ankle, knee or hip.

End point of powerful actions

- All powerful actions ended one-time frame before the first ground contact of the deceleration or landing phase.
- The deceleration phase of horizontal actions began when the player's stride pattern changed and his landing foot contacted the ground in front of his center of mass acting to slow him down.
- This was often marked by a heel strike when the foot initially made ground contact.

Table 3. Absolute frequencies of powerful actions during elite youth soccer match play (n=16); mean ± SD.

	Initial acceleration	Leading acceleration	Sprint	Vertical jump
Total	31 ± 9 ^{cd}	37 ± 12 ^{cd}	8 ± 3 ^{ab}	6 ± 5 ^{ab}
1st Half	17 ± 5 $^{\#}$	20 ± 7	4 ± 2	3 ± 3
2nd half	14 ± 5	16 ± 6	4 ± 3	3 ± 2
Action duration 0.50-1.49 s	22 ± 6 $^{\&}$	25 ± 9 $^{\&}$	5 ± 2 $^{\&}$	N/A
Action duration > 1.50 s	9 ± 4	12 ± 4	3 ± 2	N/A

Post hoc tests: ^{a} Significantly different to the frequency of initial accelerations, ^{b} Significantly different to the frequency of leading accelerations, ^{c} Significantly different to the frequency of sprints, ^{d} Significantly different to the frequency of vertical jumps; $^{\#}$ Significantly different to the frequency of the same powerful action performed in the 2nd half; $^{\&}$ Significantly different to the frequency of the same powerful action performed for a duration > 1.50 s ($p < 0.05$).

Figure 1

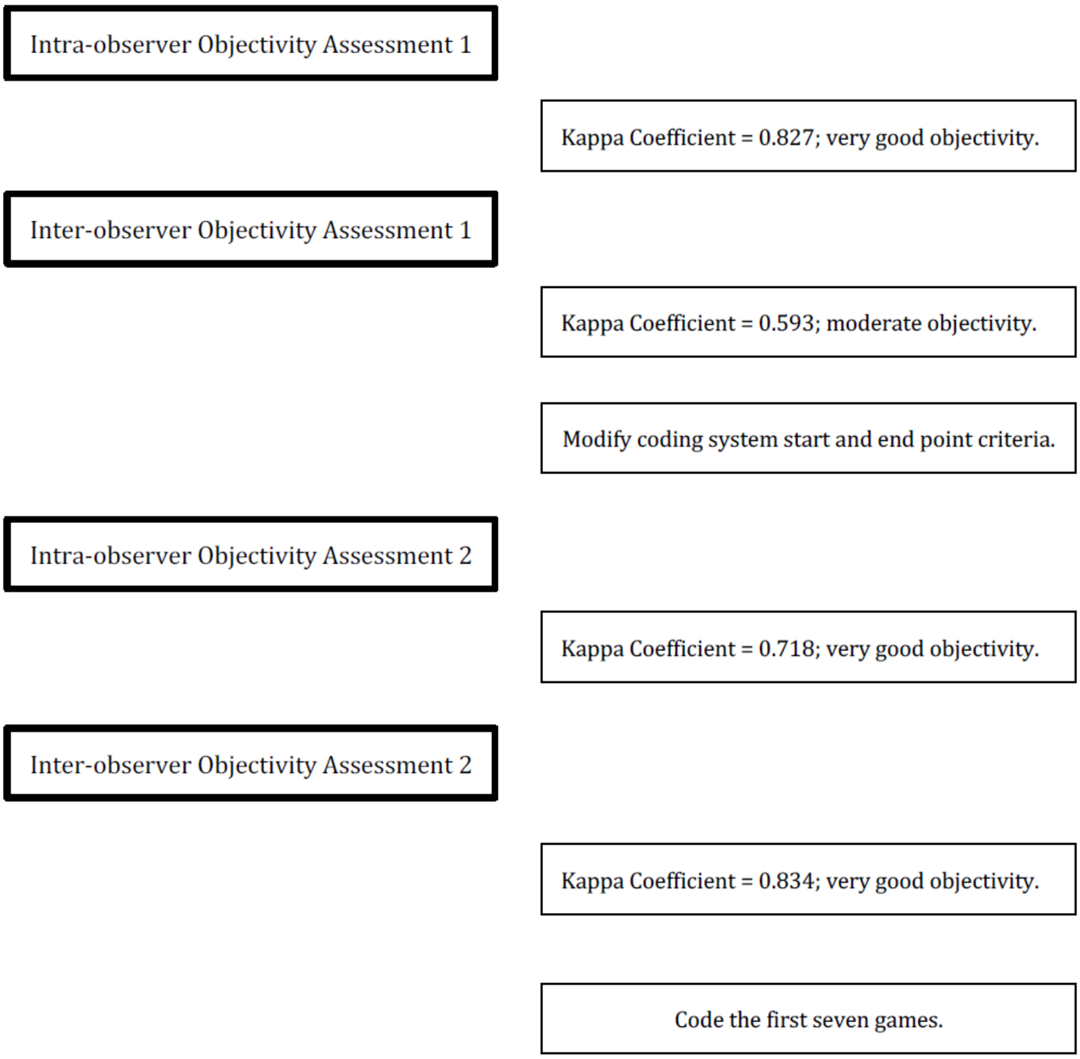

Figure. 1 An illustration of the intra- and inter- observer reliability (objectivity) process.