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ORIGINAL ARTICLE

Utilisation of transitional clusters exhibited within soccer game play to inform training design: Are we meeting the required demands?

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ABSTRACT

The aims of this study were to investigate the effect of 15min blocks on physical metrics during transitions, analyse frequency, type, duration, and recovery period between clusters of transitional activities (CTA) in elite football. During ten official matches 23 elite footballers were tracked using GPS devices. Metrics per minute ($m \cdot min^{-1}$) as well as absolute variables: total distance (TD), high-speed running distance (HSRD > 19.8 $km \cdot h^{-1}$), sprint distance (SD > 25.2 $km \cdot h^{-1}$), relative high-speed running distance (VelB4), relative sprint distance (VelB5), acceleration distance (AccB3 Dist, distance with variations in running speed > 3 $m \cdot s^{-2}$), the number of high-intensity accelerations (HI Acc > 3 $m \cdot s^{-2}$) and decelerations (HI Dec > 3 $m \cdot s^{-2}$) were quantified. Significant effects of 15min blocks were found for TD (m) (p < .001; ES = .078), TD ($m \cdot min^{-1}$) (p = .047; ES = .036), HSRD (m) (p = .033; ES = .039), VelB4 (m) (p < .001; ES = .132), and HI Dec ($n \cdot min^{-1}$) (p = .002; ES = .059). Transitional activities recovery period was found to be 108.5 ± 26.2 s, CTA recovery period was 25.7 ± 3.6 s, while CTA peak duration reached 53.3 ± 18.2 s. This study indicates that physical metrics decrease in the last 15min blocks during transitions and high-pressure activities in games. In conclusion, repeated high intensity / high velocity activities frequently occur during contextualized peak intensity periods (transitions) in football, which should be reflected in modern training design.

Keywords: Performance analysis of sport, Soccer, Transitions, Counterattack, High pressure, Peak demands, Repeated activities.

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INTRODUCTION

Modern soccer match play has been described as an intermittent sport where both aerobic and anaerobic energy systems are stimulated during intense activities (accelerations, decelerations, changes of direction and sprints), which are usually combined with football-specific technical actions (tackles, passes, headings, and shots) (Oliva-Lozano et al., 2020a). It has been shown that both physical and technical demands have increased within contemporary soccer, thus emphasizing the need to reflect these changes in training design and integrate physical conditioning with technical-tactical aspects to better prepare soccer players for the modern demands of match play (Barnes et al., 2014; Nassis et al., 2020). Previous work has shown the importance of the match physical output analysis to better inform coaches and performance staff and optimally prescribe training load for each playing position (Harper et al., 2019; Wass et al., 2019). For this very purpose, valid and reliable wearable technology has been extensively used in research and practice to measure and track different absolute and relative physical metrics in training and official competitions (Scott et al., 2016). However, most of the research has paid attention to total and average match physical metrics, which merely reflect the volume of activity, yet neglecting fluctuations in physical and technical-tactical intensity, which could underestimate the intensity of the most demanding passages of football match play (Martin-Garcia et al., 2018, Bortnik et al., 2022).

To overcome this issue in elite football, there has been an increased focus on peak match demands, also referred to as worst-case-scenarios (WCS) (Riboli et al., 2021; Riboli et al., 2022). Different WCS durations have been investigated, and shorter duration peak demands were shown to generate higher intensity in soccer, which posts a question whether modern training design bests prepares athletes for these short and specific high-intensity periods (Martin-Garcia et al., 2018; Bortnik et al., 2022). Still there is more information needed regarding the football context behind these peak intensity blocks as well as their pattern of occurrence within a modern match play (Novak et al., 2021; Bortnik et al., 2023). This knowledge would enable coaches and practitioners to design, implement, and apply conditioning drills integrating football-specific and tactical aspects (small-sided games, tactical and positional drills, transition games, etc.) to better replicate true match demands for each playing position (Novak et al., 2021; Riboli et al., 2022).

Recent work that analysed the physical demands during transitional activities (TA's) in elite football, found greater high velocity demands compared to the 90-minute averages (Bortnik et al., 2022). Although, this body of work analysed phases in isolation. Offensive (defence-to-attack) and defensive (attack-to-defence) transitions have been identified as the key match phases when goals are conceived and many risks undertaken (Tenga et al., 2010; Wass et al., 2020). Accordingly, high-pressure activities were shown to be effective in scoring goals and creating goal-scoring opportunities as well as impose high mechanical (accel/decel) demands on offensive players, emphasizing the need to be physically fit (Tenga et al., 2010; Bortnik et al., 2022). In fact, transitional activities occur when a team is in possession of the ball during an offensive collective team activity and/or out of possession trying to collectively win the ball back (defensive activity) (Bortnik et al., 2023). Thus, representing a high context within a modern football game. The increased body of knowledge on these specific match phases (clusters) might be crucial in modern physical preparation of football players potentially having a direct impact on their match performance as well as reducing the risk of injury.

Previous investigations have explored match average physical outputs taking into account different contextual factors (match half, match location, match outcome) (Oliva-Lozano et al., 2020b; Rhodes at al., 2021). Nevertheless, the effect of different contextual variables on the most demanding match passages has not been widely researched (Riboli et al., 2021; Oliva-Lozano et al., 2021; Bortnik et al., 2023). To the authors best knowledge there is no study investigating the effect of 15-minute blocks (intervals) on physical metrics during transitions in elite football. From a practical standpoint, comparing and knowing physical outputs in the first and last minutes of the match, might significantly influence the training drill design, potentially reduce a detrimental impact of fatigue on match performance and minimize risk of injury. In addition, there are no studies investigating frequency, type, duration, and recovery period between offensive/defensive repeated short high-intensity efforts (clusters) during transitional play in soccer (Aranda et al., 2019).

It is noteworthy that the ability to work intermittently and repeatedly produce high-intensity efforts collectively as a team over 90 minutes have been found a crucial aspect of successful performance in modern football (Carling et al., 2012; Ju et al., 2022). This knowledge about the number of repeated efforts and the rest interval between them would enhance training drill design for team collective tactical training and potentially improve football performance during key match phases (Bortnik et al., 2023). Therefore, the current study aims to 1) analyse the effect of 15min blocks (B1: 1'-15'; B2: 15'-30'; B3: 30'-45'; B4: 45'-60'; B5: 60'-75'; B6: 75'-90') on different absolute and relative physical metrics during TA's; 2) investigate clusters of transitional activities (CTA) in elite football; 3) explore the recovery period between clusters.

MATERIALS AND METHODS

Participants

Data were collected on all twenty-three elite outfield players (n = 23) during 2020-2021 1st Polish Division (Ekstraklasa) season. Players were categorized into the following playing positions: centre backs (n = 4), full backs (n = 5), central defensive midfielders (n = 2), central attacking midfielders (n = 2), central midfielders (n = 2), wingers (n = 5), and attackers (n = 3). Only starting players who completed minimum 60 min were analysed. Substitution players were not included in this study because they might produce higher physical outputs than starters due to pacing strategies (Wass et al., 2020). All subjects provided written and verbal informed consent for the use of their GPS data, in accordance with the Helsinki Declaration. To ensure player confidentiality, all data was anonymised. Ethical approval was provided by the University of Central Lancashire.

Procedures & experimental design

One UEFA CL qualifier and nine Polish domestic leagues (Ekstraklasa) between August and November of 2020 were investigated giving a total of ten games analysed (6 wins, 1 draw, and 3 losses). Analysis included 1164 offensive transitions, 1269 defensive transitions, 1120 fast attacks, and 696 high pressure activities, giving a total number of 4249 individual observations. The following number of observations per position were recorded: centre backs (n = 884), full backs (n = 972), central defensive midfielders (n = 236), central attacking midfielders (n = 270), central midfielders (n = 578), wingers (n = 778), and attackers (n = 531). During each match, all players wore portable MEMS (10 Hz; Vector S7, Catapult Sports, Melbourne, Australia) located between the scapulae in a custom-made vest underneath their playing shirt. All subjects were accustomed to the entire procedure since they used GPS devices daily as part of their routine monitoring strategy. All GPS units were turned on 15 mins before the start of the match to ensure satellite connection. The data was screened for satellite coverage and horizontal dilution of precision (HDOP) using an inclusion criterion of > 6 satellites and ≤ 1.0 respectively, to ensure acceptable GPS coverage as previously recommended (Malone et al., 2017). Each subject used the same GPS device for the entire period of investigation to avoid inter-unit error. The validity and reliability of these wearables have been shown previously (Johnston et al., 2014; Scott et al., 2016).

All analysed metrics were previously used in other studies (Wass et al., 2020; Riboli et al., 2021; Bortnik et al, 2022). They represented absolute distances covered per minute ($m \cdot min^{-1}$) in the following categories: total distance (TD), high-speed running distance (HSRD, > 19.8 $km \cdot h^{-1}$), sprint distance (SD, > 25.2 $km \cdot h^{-1}$), as well as the number of high-intensity accelerations and decelerations (A+D, > 3 $m \cdot s^{-2}$; $n \cdot min^{-1}$). In addition, the metrics depicted absolute distanced covered in the following categories: total distance (TD), high-speed running distance (HSRD), sprint distance (SD), the number of high-intensity accelerations (HI Acc, > 3 $m \cdot s^{-2}$), the number of high-intensity decelerations (HI Dec, > 3 $m \cdot s^{-2}$), and acceleration distance (AccB3 Dist, distance with variations in running speed > 3 $m \cdot s^{-2}$). Moreover, these variables reflected total relative high-speed running distance (VelB4) and relative sprint distance (VelB5), which have been claimed to represent the functional limits of endurance and sprint locomotor capacities (Mendez-Villanueva et al., 2012). As previously recommended, relative high-speed running distance (VelB4) and relative sprint distance (VelB5) was set as 100% maximal aerobic speed (MAS) – 30% (anaerobic speed reserve) ASR, and above MAS + 30% ASR, respectively (Mendez-Villanueva et al., 2012). An incremental running treadmill test was conducted by the club physiologist to measure VO_{2max} and MAS. The test was performed in the gym environment with a normal ambient temperature and took place on a mechanical treadmill (Technogym, Italy). It began with an initial speed of 10 km/h^{-1} and each stage was increases by 1.5 km/h−1. Five stages were set. Each stage lasted 4 minutes and it was separated by 1 minute passive break. The inclination was set at 1.5%. Polar heart rate monitors (Polar, Norway) and Polar M400 are used to record HR data. Expired gases were analysed breath-by-breath using an online automated gas analysis system (MetaLyzer® 3b-R2; Cortex Biophysik Gmbh, Leipzig, Germany) and accompanying software (MetaSoft® 3). Maximum oxygen uptake (VO_{2max}) was defined as the highest 15-s average oxygen uptake. Velocity (km/h^{-1}) during the maximum oxygen uptake (VO_{2max}) was recorded and set as the MAS.

After each match, transitional activities (TA's) were manually selected and tagged by the club's analysis team in the Catapult Vision video analysis system (Catapult Sports Ltd, Melbourne, Australia). Analysts used the observational methodology REOFUT theoretical framework to identify these periods (Collins et al., 2006), which was part of the club's analysis protocols utilized daily by the analysis team. Good to high intra- and inter-observer reliability of the current analysis method was previously shown (Tenga et al., 2010; Aranda et al., 2019; González-Rodenas et at., 2020). Data from the Catapult vision software were then downloaded and integrated into the manufacturer's software package (Openfield, version 3.2.0) and finally exported into Microsoft Excel (Microsoft Corporation, USA) to make additional calculations for each transitional play, clusters, and recovery periods. Clusters (CTA) were defined as two or more transitional activities that occurred within a period shorter than 61 secs as previously recommended (Buchheit et al., 2010; Carling et al., 2012, Bortnik et al., 2023). The transition mean count average for selected variables and clusters frequencies were calculated as the sum total of all TA's, divided by their number. To get the clusters' peak duration, the highest values in 10 games were found, and their average was calculated as the sum of all peak duration values during clusters, divided by their number. Transitions were categorized into the following activities: positive transition (PT), negative transition (NT), fast attack (FA), and high pressure (HP), which were previously investigated by other authors (Tenga et al., 2010; González-Rodenas et at., 2020; Bortnik et al., 2022). In addition, the game was divided into six 15min blocks: B1 (1'-15'), B2 (15'-30'), B3 (30'-45'), B4 (45'-60') B5 (60'-75') B6 (75'-90') to determine the effect of time on physical metrics during TA's.

Statistical analysis

The study used a descriptive analysis, and the results are depicted as mean ± standard deviation (SD). Between-matches, between-halves, and between 15-min blocks coefficient of variation (CV) values were calculated for transitions for selected metrics per minute.

Statistical analyses was performed using IBM Statistical Package for the Social Sciences (SPSS, Version 27.0, IBM Corporations, New York, USA) with the statistical significance accepted at the 0.05 level. A univariate analysis of variance (ANOVA) was conducted to quantify main effects for games, transition type, and time (15min blocks). Interaction effects were also quantified, and any significant main effects associated with games, transitions, and time were investigated using post hoc pairwise comparisons. The assumptions associated with the statistical model were assessed to ensure model adequacy. To assess residual normality for each dependent variable, q-q plots were generated using stacked standardised residuals. Scatterplots of the stacked unstandardized and standardised residuals were also utilised to assess the error of variance associated with the residuals. Mauchly's test of sphericity was also completed for all dependent variables, with a Greenhouse Geisser correction applied if the test was significant. Partial eta squared (η^2) were calculated to estimate effect sizes for all significant main effects and interactions. Partial eta squared was classified as small (0.01–0.059), moderate (0.06–0.137), and large (>0.138), as previously suggested (Cohen, 1988).

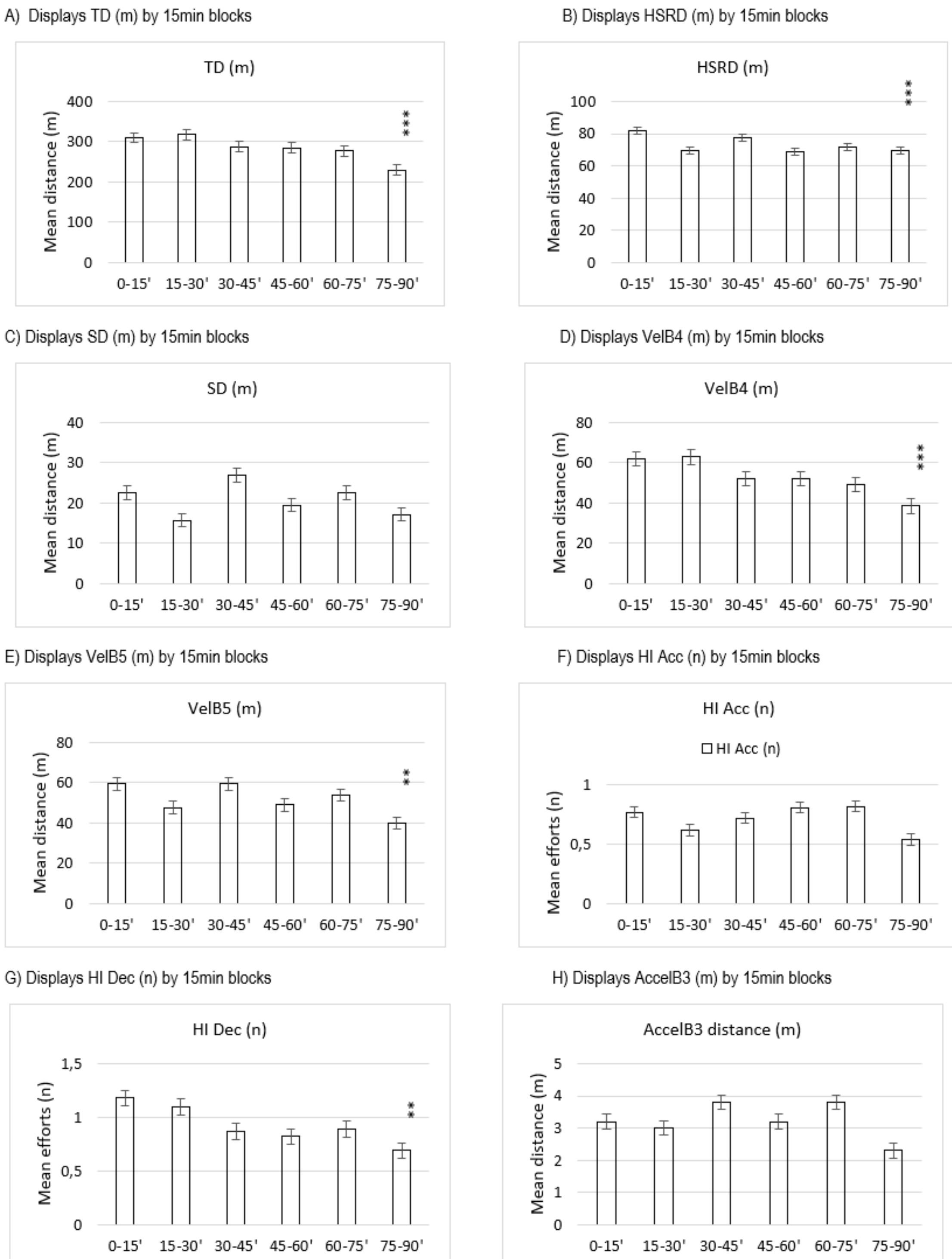
RESULTS

TD (m) analysis showed significant effects for game (F = 4.590, p < .001, partial η^2 = .071) and a transition type (F = 17.097, p < .001, partial η^2 = .109). Also, analysis of HSRD (m), SD (m), VelB4 (m), and VelB5 (m) identified significant effects for a transition type (HSRD: F = 15.298, p < .001, partial η^2 = .099; SD: F = 9.916, p < .001, partial η^2 = .066; VelB4: F = 15.471, p < .001, partial η^2 = .100; VelB5: F = 12.614, p < .001, partial η^2 = .083). In addition, TD (m·min^{-1}), HSRD (m·min^{-1}), SD (m·min^{-1}), and A+D (n·min^{-1}) analysis revealed significant effects for a transition type (TD: F = 29.754, p < .001, partial η^2 = .176; HSRD: F = 14.441, p < .001, partial η^2 = .094; SD: F = 6.248, p < .001, partial η^2 = .043; A+D: F = 4.453, p = .004, partial η^2 = .031). Moreover, a game x time interaction for HI Acc (n) (F = 3.511, p = .001, partial η^2 = .055) and A+D (n·min^{-1}) (F = 2.178, p = .035, partial η^2 = .035) was discovered. Interactions of game, transition type, and time were nor found for TD (m), TD (m·min^{-1}), HSRD (m), HSRD (m·min^{-1}), SD (m), SD (m·min^{-1}), VelB4 (m), VelB5 (m), HI Dec (n), and AccB3 distance (m) (p > .05).

15-min blocks

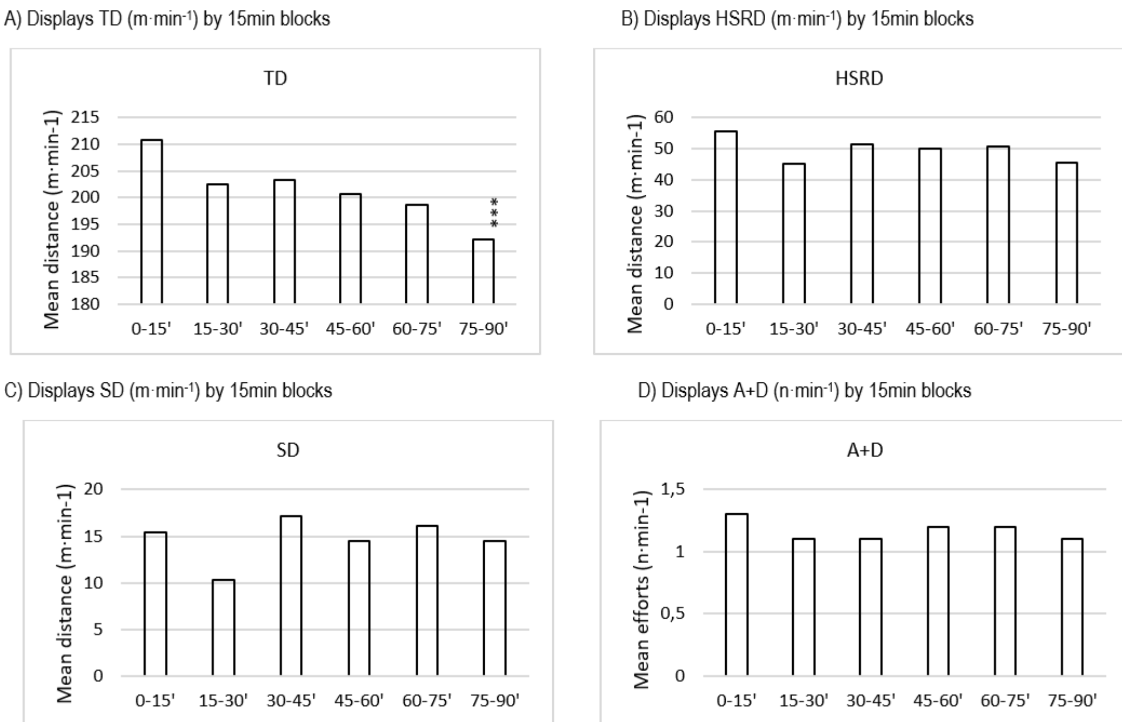
Analysis of TD (m), HSRD (m), SD (m), VelB4 (m), Vel B5 (m), HI accel (n), HI Dec (n) identified significant effects of game (TD: F = 3.865, p < .001, partial η^2 = .081; VelB5: F = 2.079, p = .046, partial η^2 = .046) and a transition type (TD: F = 16.361, p < .001, partial η^2 = .139; HSRD: F = 15.437, p < .001, partial η^2 = .132; SD: F = 7.766, p < .001, partial η^2 = .071; VelB4: F = 19.383, p < .001, partial η^2 = .160; VelB5: F = 12.041, p < .001, partial η^2 = .106; HI Accel: F = 3.009, p = .031, partial η^2 = .029; HI Dec: F = 2.998, p = .031, partial η^2 = .029). There was a game x time interaction (F = 1.536, p = .031, partial η^2 = .150) and a game x transition type x time interaction (F = 1.493, p = .018, partial η^2 = .218) for VelB4 (m). Also, a game x time interaction was found for HI Acc (n) (F = 2.580, p < .001, partial η^2 = .228) as well as a game x transition type x time interaction for HI Dec (n) (F = 1.493, p = .018, partial η^2 = .218). No interactions of game, transition type, and time were discovered for TD (m), HSRD (m), SD (m), VelB5 (m), AccB3 distance (m) (p > .05).

Additional analysis identified statistically significant effects of time (15min blocks) for TD (m), HSRD (m), Relative high-speed running distance (VelB4) (m), and high-intensity decelerations HI Dec (n·min^{-1}) (TD: F(5,305) = 5.195, p < .001, partial η^2 = .078; HSRD: F(5,305) = 2.263, p = .033, partial η^2 = .039; VelB4: F(5,305) = 9.303, p < .001, partial η^2 = .132; HI Dec: F(5,305) = 2.407, p = .002, partial η^2 = .0590). Further analysis of metrics per minute revealed only significant effects for TD (m·min^{-1}) (TD: F(5,305) = 2.277, p = .047, partial η^2 = .036).



*Note. Different from 0-15' * p < .05; ** p < .01; *** p < .001.*

Figure 1. Effects of time (0-15', 15-30', 30-45', 45-60', 60-75' and 75-90') on a) mean total distance (TD), b) mean high-speed running distance (HSRD), c) mean sprint distance (SD), d) mean relative high-speed running distance (RelV4), e) mean relative sprint distance (RelV5), f) mean number of high-intensity accelerations (HI Acc), g) mean number of high-intensity decelerations (HI Dec), and h) mean high-intensity acceleration distance (AccB3) during transitions and high pressure activities.



*Note. Different from 0-15' * p < .05; ** p < .01; *** p < .001.*

Figure 2. Effects of time (0-15', 15-30', 30-45', 45-60', 60-75' and 75-90') on a) mean TD (m·min^{-1}), b) mean HSRD (m·min^{-1}), c) mean SD (m·min^{-1}), and d) mean A+D (n·min^{-1}) during transitions and high pressure activities across 10 matches.

Figure 3 displays the match-to-match variability for transitions in 1st and 2nd half, transitions in 15min blocks, and all transitions.

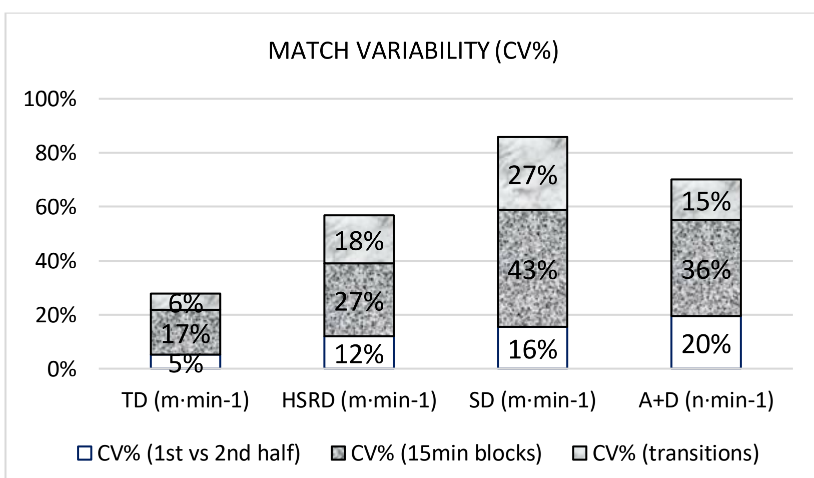


Figure 3. The match-to-match variability depicted as CV (%) for transitions in 1st vs. 2nd half (white), transitions in 15min blocks (granite), and all transitions (white marble) across 10 matches are shown for total distance – TD (m·min^{-1}), high-speed running distance – HSRD (m·min^{-1}), sprint distance – SD (m·min^{-1}), and number of accelerations/decelerations A+D (n·min^{-1}).

Post Hoc tests showed significant difference between the first and last 15min blocks for TD (m) and TD (m·min^{-1}), HSRD (m), relative high-speed running distance (VelB4) (m), relative sprint distance (VelB5) (m) (p < .001) as well as number of HI Dec (p = .006). Other metrics did not reveal any significant differences between 15min blocks (p > .05).

Figure 1 highlights the effects of time (15min blocks) on absolute physical metrics that occur during transitions, accompanied with significant difference between 0-15' and 75-90'. The effect of time (15min blocks) on metrics per minute in all transitions across the games analysed, accompanied with the p-value for 0-15' and 75-90' is displayed in Figure 2.

Table 1 depicts duration-related metrics including recovery periods for transitional activities (TA's) and clusters, accompanied by the mean, standard deviations, confidence interval (CI), min and max. Frequency of clusters' transitional activities shown as the mean, standard deviations, percent, min, and max are detailed in Table 2. Table 3 highlights the frequencies of transitional activities in clusters and matches expressed as the mean, standard deviations, confidence interval (CI), and percent.

Table 1. Mean ± SD, 95% confidence intervals and minimum/maximum duration-related metrics including recovery periods for transitional activities (TA's) and clusters across 10 official matches.

Duration	Mean ± SD	95%CI	Minimum	Maximum
TAs recovery period (s)	108.5 ± 26.2	89.8 – 127.2	72.0	164.0
Cluster TAs duration (s)	9.9 ± 1.0	9.2 – 10.6	9.0	12.0
Cluster total duration (s)	28.0 ± 5.8	23.9 – 32.1	23.0	42.0
Cluster TA recovery period (s)	25.7 ± 3.6	23.1 – 28.3	21.0	32.0
Cluster peak duration (s)	53.3 ± 18.2	40.0 – 66.3	29.0	94.0

Table 2. Frequency of clusters' transitional activities.

Transition	Mean count ± SD (cluster)	Percent (%)	Minimum count	Maximum count
NT	10.1 ± 3.7	31	4	17
PT	8.3 ± 3.6	25	5	17
FA	7.9 ± 4.0	24	3	15
HP	6.4 ± 5.1	20	1	15
Total	32.7 ± 11.5	100	16	52

Note. PT = Positive transition; NT = Negative transition; FA = Fast attack; HP = High pressure depicted as a count and percent of transitions in clusters expressed as a mean ± SD and minimum/maximum count across 10 official matches.

Table 3. Comparisons between clusters' transitional activities and match TA'a frequencies.

Transition	Mean count ± SD (cluster)	Mean count ± SD (match)	Percent (%)
NT	10.1 ± 3.7	15.2 ± 4.6	66
PT	8.3 ± 3.6	13.7 ± 4.2	61
FA	7.9 ± 4.0	13.0 ± 3.6	61
HP	6.4 ± 5.1	7.7 ± 6.5	83
Total	32.7 ± 11.5	50.0 ± 11.1	66

Note. PT = Positive transition; NT = Negative transition; FA = Fast attack; HP = High pressure depicted as a count and percent of transitions in clusters expressed as a mean ± SD and percent across 10 official matches.

DISCUSSION

The aims of the present study were to investigate the effect of 15min blocks on physical metrics during transitions, analyse clusters of transitional activities (CTA), and explore the recovery period between clusters in elite football. This is the first study investigating frequency, type, duration, and recovery period between repeated TA's defined as clusters. Main findings revealed that out of 50 transitions that occurred on average across ten games (Bortnik et al., 2022), 33 were repeated activities (CTA), with a range of 16 to 52. In fact, on average 66% of all transitional activities were clusters, which in practical terms means that more than 2 TA's occurred within 1 min (Buchheit et al., 2010; Bortnik et al., 2023). Repeated high-intensity / high-velocity efforts during short and contextualized blocks of activity might be more frequent in modern football match play than previously reported (Carling et al., 2012). Thus, posing a question whether coaches and practitioners adequately prepare players for modern match play demands. Further work is required to determine this by comparing transitional work completed in training to game output. Negative transitions (NT) reached highest number (31%), followed by positive transitions (PT), and fast attacks (25%, and 24% respectively). High-pressure activities (HP) were least frequent (20%). However, 83% of all HP activities were repeated revealing the importance and an integrative meaning of these defensive actions in modern match play.

The current body of work found that mean cluster transitional activity (CTA) duration was no different from other transitional activities and lasted around 10 secs (Gonzalez-Rodenas et al., 2020; Bortnik, et al., 2022). CTA mean total duration was nearly three times longer (28 secs), with CTA peak duration found to be 53 secs. In addition, the study showed that the mean rest interval between all transitional activities was over four times longer than mean CTA recovery period (108.5 sec vs. 25.7 sec). An important consideration in relation to work:rest ratios, when specifically conditioning players.

This work revealed a novel concept of clusters described as > 2 transitional activities occurring within 1 minute (Buchheit et al., 2010; Bortnik et al., 2023). Football is an intermittent sport, and the ability to perform repeated actions has been found an important component of success in elite soccer (Carling et al., 2012). Short recovery between phases of high-intensity efforts might have a detrimental effect on physical performance (Balsom et al., 1992) and hence, gaining knowledge surrounding repeated high-intensity efforts (CTA) within match play in relation to the frequency, tactical context, and recovery periods informs training design, thus potentially influencing match performance, and injury risk (Carling et al., 2012; Nassis et al., 2020). Future research should consider the positional differences during these intensified blocks of activity.

Interestingly, absolute and relative physical metrics during transitions decreased as the game progressed in time. Recently, it has been reported that players generated the highest number of high-intensity actions in the first 15min blocks of each half (Oliva-Lozano et al., 2023). Fatigue and/or insufficient rest might be the main reason of a declined physical performance and potentially a higher risk of injury (Rhodes et al., 2021). These findings are consistent with previous studies exploring fatigue effects in elite football revealing physical performance differences existing between both halves and separate 15-minute periods in male and female footballers (Datson et al., 2017; Barrera et al., 2021; Bortnik et al., 2023). This could be due to non-specific approach to physical performance analysis. Demands of the games are influenced by individual team approach, individual capacity, level of opponent, and playing philosophy (Rampinini et al., 2007). Consideration of cluster analysis would provide vital information for practitioners to inform the physical demands required for each player and the prescribed work:rest ratios needed within training design. It is acknowledged that these demands were quantified over 10 games and further work is needed over a greater number of games across different leagues and clubs in a season.

Findings within the present study revealed a significant reduction in absolute metrics of TD (m), HSRD (m), VelB4 (m), and the number of HI Dec during TA's, when comparing the first and last 15min blocks. The detrimental impact of fatigue on muscle function due to repeated high velocity actions has been well documented (Harper et al., 2019; Rhodes et al., 2019; Rhodes et al; 2020). Suggesting that the repeated actions experienced in the clusters presented in the current body of work, result in a decrease in physical performance of these metrics over time. This reduction in high velocity running has been associated with inadequate training or preparation (Vasquez et al. (2021). It is proposed that this is a result of decreased insight into the current demands of transitional play (Bortnik et al., 2023), and the present study provides a deeper analysis of the true physical demands of contemporary football. Recently, there has been an increased focus on acceleration and deceleration performance due to their high neuromuscular demand and impact on match outcome (Rhodes et al., 2021; Djaoui et al., 2022). It is important to note that despite low running speed in game play these high intensity actions are repeatedly required (Gaudino et al., 2013). Increasing knowledge of the peak demands of these actions, will inform training design, potentially reducing the resultant fatigue effects demonstrated in this body of work. It is noteworthy to state that we explored absolute and relative locomotor metrics, and future work should also use individual acceleration / deceleration thresholds to better reflect players' individual physical performance capacities (Carling et al., 2012).

Interestingly, the current study demonstrated that 88% of HP activities were performed in conjunction with other transitional actions. Evidence identifies that HP activities are an aggressive approach to winning the ball back and creating goal scoring chances (Vogelbain et al., 2014). Resulting in higher mechanical loads (Bortnik et al., 2022). Incorporation of defensive tasks aiming at rapidly closing down space and pressing opponents with other offensive activities in possession to either keep the ball and/or initiate a fast attack and/or counter-attack, would provide specificity in preparing players for game play. This would potentially increase fatigue tolerance of repeated high velocity actions that can occur at any time within a game (Oliva-Lozano et al., 2021). Cluster analysis related to transitional activity provides practitioners with greater detail with regards the intensity and frequency of the blocks of activity and it is essential that training design incorporates this notion (Bortnik et al., 2023). This would maximise physical performance and specifically condition players, potentially reducing injury risk.

Previous studies reported that the mean transition performance (m·min^{-1}) between official football games had around 16% match-to-match-variability (Rampinini et al., 2007; Riboli et al., 2021; Bortnik et al., 2022). Our findings showed lower variability between the first and second 45-min (13%), and higher between 15min blocks (31%). Hence, shorter high-intensity specific blocks of activity were revealing highest unpredictability within each game. Surprisingly, sprinting activities - SD (m·min^{-1}) were found to be much more consistent between halves (16% variability) in contrast to the match transitions sprinting demands (27% variability) and 15min blocks that had the highest variance (43%). Data demonstrated that not high-velocity activities (Rampinini et al., 2007; Gregson et al., 2010), but A+D (n·min^{-1}) represented the greatest unpredictability between both halves (20%). However, SD (m·min^{-1}) had the highest overall variability across all metrics, which is consistent with previous studies (Riboli et al., 2021; Bortnik et al., 2022). These results show high dynamics and unpredictability of the contemporary game and hence, inform how challenging it is to design training for elite footballers in practical settings (Gregson et al., 2010). Nevertheless, the physical and tactical workload players are exposed to during peak intensity blocks in contemporary match play is not only dependent on opponent / teammate's activities (Bradley et al., 2020), but also on many different contextual factors such as match location, match half, score-line, match outcome, playing formation, etc., and other (Gregson et al., 2010, Bortnik et al., 2023). These important match-related contextual variables were not included in our analysis and future studies should investigate the impact of these factors on the physical demands during transitions in football.

Based on our main findings, transitional activities and transitional games in/out of possession (defence-to-offense transitions, offense-to-defence transitions, and fast attacks) could be considered a crucial component of a weekly training plan in modern training design (Ju et al., 2022b). Offensive transitions (counter-attacks) should be executed at maximum effort to surprise opponents and create chances to score a goal (Gonzalez-Rodenas, et al., 2020). From a practical standpoint, it would be important to add more space to reach near-maximum velocity while over/underlapping, running with ball, exploiting space, and breaking into penalty box (Riboli et al., 2020; Bortnik et al., 2022) since successful elite football teams were found to generate higher intensity during these activities (Ju et al., 2023). Offensive transitions have recently been found to significantly overload 90min sprinting demands and accumulate nearly half match sprint distance (Bortnik et al., 2022). These phases are full of technical-tactical context and a powerful ammunition to expose players to maximum velocity actions in training (Bortnik et al., 2022). Defensively, on the other hand, players should be able to react quickly, squeeze space, apply high pressure, cover, and perform a recovery run to stop the opposition attack (Gonzalez-Rodenas et al., 2020; Bortnik et al., 2022, Ju et al., 2022). Midweek sessions (MD-4 / MD-3) might offer an optimal timeframe to overload different locomotor and mechanical metrics and reflect the repeated high-intensity activity profile of modern match play (Martín-García et al., 2018; Martín-García et al., 2019; Vázquez et al., 2021; Oliva-Lozano et al., 2021).

Despite quite long mean recovery period between TA's found in our study (108 sec), the mean total duration of clusters and mean recovery periods between repeated transitional activities (CTA) indicated that speed endurance production mode could be effectively used with elite footballers integrating both physical and tactical aspects to improve performance during blocks of maximum intensity as previously reported in football (Mohr et al., 2016; 2017; Bradley et al., 2018). Repeated sprint training consisting of actions below 10 secs and sprint interval training using all-out efforts lasting around 20-30 secs might also be utilized to prepare players for CTA in competition (Hostrup et al., 2019). More research is needed to compare training to match transitional activities and determine if speed endurance training / sprint intervals positively impacts players physical performance during CTA.

CONCLUSIONS

It is highly important to understand the meaning of contextualized blocks of maximum intensity activities (transitions) within contemporary football match play. Modern football training design should move away from 90min averages and consider conditioning players for short blocks of repeated high intensity / high velocity activities that frequently occur together during transitional play in elite soccer. Such approach might counteract a detrimental impact of fatigue on team and individual physical / tactical performance in last stages of match play and potentially reduce the risk of injuries. This knowledge might prevent the mismatch between true match physical demands and training content during an overload weekly phase. Findings of this study could serve a high practical importance for coaches, practitioners, and physical therapists. It is important to note that any analysis of game demand and resultant training design is individually defined by the football philosophy of the club and coaching team.

Practical applications

Transitional activities in games expose players to repeated and intermittent high intensity / high velocity actions together. To reduce decline in physical output during contextualized blocks of maximum intensity at the end of match play, coaches and practitioners could apply different transitional games in and out of ball possession, tactical drills (offensive and defensive), and various sided games (pitch size, number of players, with/without goalkeepers) to adequately condition players for the modern physical demands of competition and potentially lower injury risk. During transitional games and tactical drills coaches might consider performing pressing high up in the opponent's half in conjunction with other transitional activities. For instance, pressing should be followed by a counterattack and/or fast attack within a short period of time. Additionally, speed endurance production, repeated sprints, and sprint intervals with appropriate work:rest ratios that integrate position-specific technical / tactical aspects might be considered during team / individual / return-to-play sessions to replicate the demands of clusters in training and optimally prepare players for the most physically demanding passages in games. It would be important in these sessions to create additional space to perform attacking actions and break into penalty box at high velocity. Finally, high-speed activities and high-intensity decelerations should be monitored closely during a weekly microcycle taking into a consideration position-specific needs in football to avoid over/underloading.

AUTHOR CONTRIBUTIONS

Conceptualization: Lukasz Bortnik and Dave Rhodes. Methodology: Lukasz Bortnik, Ryland Morgans, Dave Rhodes. Software: Joost Burger and Lukasz Bortnik. Validation: Lukasz Bortnik, Joost Burger and Dave Rhodes. Formal analysis: Lukasz Bortnik and Dave Rhodes. Investigation: Lukasz Bortnik, Joost Burger, Dave Rhodes. Resources: Lukasz Bortnik and Dave Rhodes. Data curation: Lukasz Bortnik and Dave Rhodes. Writing – original draft preparation: Lukasz Bortnik. Writing – review and editing: Dave Rhodes and Ryland Morgans.

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