Original Article

Physical demands of playing position within English Premier League academy soccer

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ABSTRACT

Physical demands of soccer competition vary between playing positions. Previous research investigated total, and high-speed distances, with limited research into acceleration demands of competition. Research investigating speed and acceleration demands have utilised arbitrary thresholds, overlooking the individual nature of athlete locomotion. The current investigation was the first utilising individual speed and acceleration thresholds, investigating the relative intensity of activities. Relationship between match outcome and physical outputs were also investigated. GPS data from 44 professional matches was collected using 10-Hz GPS and 100-Hz accelerometer devices. 343 observations were divided by playing position, and match result, with differences in GPS metrics analysed. Central midfielders produced the highest total distances, and moderate-intensity acceleration distances ($p<0.01$). Wide defenders and attackers produced the highest very high-speed running, sprinting, and high-intensity acceleration distances ($p<0.01$). Central defenders produced the lowest values for all metrics ($p<0.01$). No significant differences were found between GPS metrics for differing match outcomes ($p>0.05$). In addition to differing tactical and technical roles, soccer playing positions have specific physical demands associated. Current results allow overload of individual training intensities relative to competition. No relationships were evident between GPS metrics and match outcome, suggesting soccer success is the result of superior technical and tactical strategies. **Key words:** TEAM SPORTS, COMPETITION, GPS, ACCELERATION, SPRINTING.

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INTRODUCTION

Extensive research has focused upon quantifying the physical demands of soccer competition (Bangsbo et al., 2006; Molinos, 2013). Despite constituting only 12% of distance travelled, high-speed locomotion has received significant attention when analysing competitive performance (Bradley et al., 2009; Di Salvo et al., 2010). Rationale is that high-speed actions occur during the most significant moments of competition (Barnes et al., 2014; Di Salvo et al., 2009). Adding to the importance of high-speed actions, Faude et al (2012) state straight-line sprinting is the most dominant action during goal scoring. Despite the importance, previous research investigating high-speed demands of soccer have utilised arbitrary speed thresholds (Di Salvo et al., 2010). Considering the highly individual nature of athlete locomotion, there is potential for training load error when using arbitrary speed thresholds for athletes (Abt & Lovell, 2009). To improve accuracy when identifying the high-speed demands of soccer, Lovell and Abt (2013) have recommended individualised speed thresholds.

The physical demands of soccer cannot be characterised solely by high-speed GPS metrics. Osgnach et al (2009) suggest accelerations are of greater energy cost than constant speed movements. In addition, an athlete's ability to accelerate is suggested to contribute to on-field performance (Delaney et al., 2017). Focusing specifically upon high-speed metrics would result in accelerations occurring at low absolute speeds not being quantified (Akenhead et al., 2013; Guadino et al., 2010). The majority of research investigating physical demands of soccer competition have analysed total distance, and high-speed distances, but not considered acceleration activities (Bradley et al., 2009; Dellal et al., 2011, Di Salvo et al., 2010). Accelerations are highly fatiguing in nature, and with muscular fatigue responsible for a large proportion of injuries within soccer, consideration of accelerations are vital when assessing training load (Dalen et al., 2016; Ingebrigtsen et al., 2015). Of the limited research including acceleration analysis, arbitrary thresholds were utilised to determine acceleration intensity (Dalen et al., 2016; Ingebrigtsen et al., 2015). Similar to arbitrary speed thresholds, arbitrary acceleration thresholds fail to account for individual factors such as maturation status, or maximal capabilities. Consequently, the intensity at which individual athletes are operating cannot be calculated, an important aspect of monitoring training load (Hunter et al., 2015). To obtain vital information upon individual high-speed and acceleration demands during soccer competition, further investigation is necessary.

The physical demand elicited upon athletes during soccer competition differs significantly dependent upon playing position (Molinos, 2013). For total distance, previous research concluded central defenders and strikers produced the lowest distances, whilst central midfield players produced the highest (Dellal et al., 2012; Guadino et al., 2010). For high-speed activities, wide players (both attacking and defending) produced the highest distances for sprinting and high-intensity running, whilst players operating in central areas produce the lowest (Carling, 2013). Number of accelerations produced by playing positions followed a similar pattern, with wide players accelerating significantly more than central players (Dalen et al., 2016; Ingebrigtsen et al, 2015). Research is yet to combine these GPS metrics into a collaborative investigation, determining the exact physical demands elicited upon soccer playing positions in an elite population. Alongside the physical demands of soccer playing positions, another area of interest to practitioners is the relationship between physical outputs and match outcome. Previous research investigating this relationship has proved equivocal. Mohr et al (2003) found top class soccer players produce higher physical outputs when compared to moderate professional players. More recently, researchers have concluded that successful teams demonstrate lower physical outputs in comparison to unsuccessful teams (Carling, 2013). Others cite no significant differences between teams of differing levels of success (Castellano et al., 2014).

To increase the probability of success, a large emphasis of soccer training is focused upon developing the physical attributes of athletes (Bowen et al., 2016). Training sessions are guided by competition, and aim to replicate or exceed the physiological demands encountered during matches. A high occurrence of specific activities may overload muscle groups, and have implications for conditioning athletes (Bloomfield et al., 2007). Consequently, it is vital for the training prescription process that competitive demands are accurately identified. The aim of the investigation was to identify the physical demands placed upon soccer playing positions using an individualised approach to monitoring. Previous research investigating the positional demands of competition utilised arbitrary speed and acceleration thresholds, overlooking the relative intensity of activities. The current investigation was the first to incorporate individual speed and acceleration thresholds, providing an accurate representation of intensity for playing positions. The investigation also aimed to examine the effect of physical outputs upon match outcome.

MATERIALS AND METHODOLOGY

Participants

Thirty-seven, male, full-time professional soccer players from an U23 Premier League academy (19.9 $\pm$ 1.4 years, height 180.3 $\pm$ 8.0 cm, weight 78.9 $\pm$ 8.4 kg) participated in the investigation. Participants were assigned an outfield playing position by the head technical coach. Playing positions were central defenders (CD, n = 7) wide defenders (WD, n = 7), central midfielders (CM, n = 8), wide attackers (WA, n = 8), and strikers (ST, n = 7). Each participant only featured in one playing position. All participants were briefed with a detailed explanation of the aims and requirements of the investigation, as well as potential risks. All participants provided written consent for their involvement. For participants under the age of 18, parental or guardian consent was provided. Participants were free to withdraw at any time, without any repercussions. The investigation was conducted with full approval from the ethical review board at the institution prior to commencing. The investigation conformed to the requirements stipulated by the Declaration of Helsinki, and all health and safety procedures were complied with.

Procedures

GPS match data was collected for 44 competitive matches using 10-Hz GPS and 100-Hz accelerometer devices (OptimEye S5B, Version 7.18; Catapult Innovations, Melbourne, Australia). Data collection spanned two seasons, during which matches were played once per week. Prior to the commencement of both competitive seasons, participants completed a six-week pre-season consisting of physical and technical training sessions, and friendly matches. Competitive matches within the investigation were comprised of Premier League 2 matches. Prior to competition, participants completed a standardised warm up, ensuring adequate preparation for competition. For each match, participants wore a portable GPS device in a designated tight-fitting vest located between the scapulae. GPS devices were switched on 15 minutes prior to the warm up, in accordance with manufacturer's instructions, and switched off immediately following competition. Participants wore the same GPS device for each match, avoiding inter-device error.

Prior to the data collection periods, participants completed maximum sprint speed (MSS), and maximum aerobic speed (MAS) protocols previously utilised by Mendez-Villanueva et al (2013) and Hunter et al (2015) to determine anaerobic and aerobic locomotor capabilities respectively. The MSS protocol required participants complete three maximal 40-metre linear sprints, with maximal rest between repetitions. MSS was defined as the fastest speed recorded over any 10m sector, and measured using electronic light gates (Brower TC Timing System) to the nearest 0.01s. The MAS protocol was a modified version of the University of Montreal Track Test (Leger & Boucher, 1980), previously used by Mendez-Villanueva et al (2013). The test began with an initial running speed of 8 $km.h^{-1}$, with the speed increasing by 0.5 $km.h^{-1}$ each minute.

MAS was estimated as the speed of final stage completed by the participant. Using MSS and MAS values, each participant's anaerobic speed reserve (ASR) was calculated. ASR was defined as the difference between the MSS and MAS score and reported in $m.s^{-1}$. MSS, MAS and ASR values were used to determine each participant's speed thresholds, and consequent values for very high-speed running and sprinting GPS metrics. During the MSS protocol, the maximum rate of acceleration was calculated for each sprint using 10-Hz portable GPS devices (OptimEye S5B, Version 7.18; Catapult Innovations, Melbourne, Australia). The highest acceleration value was recorded for each participant. Each participant's maximal accelerative capacity value was used to determine their individual acceleration thresholds. This method had previously been utilised by Sonderegger et al (2016) to assess maximal accelerative capacity of athletes, and individualize acceleration thresholds.

Data Analysis

10-Hz GPS devices have demonstrated an acceptable level of accuracy and reliability when assessing the speed of movement within intermittent exercise (Varley et al., 2011). Mean number of satellites during data collection was 14.7 ± 1.8, and the mean horizontal dilution of position was 0.8 ± 0.1. Following each match recording, GPS devices were downloaded to a PC and analysed using Catapult Sprint software (Catapult Sprint 5.1.5, Catapult Innovations, Melbourne, Australia). Speed was calculated using measurements of the Doppler shift of signals received, distance was measured using positional differentiation. To allow direct comparisons in data, only participants completing 90-minutes were included within the analysis process. Once downloaded, each data set was edited and split into two 45-minute halves. Extra time at the end of each half was excluded to ensure comparison between matches. A total of 343 observations were collected from 44 matches, the mean number of observations per participant was 8.7 ± 1.9 matches. Speed-related GPS metrics recorded were maximal speed achieved, very high-speed running distance, and sprinting distance. Very-high speed running, and sprinting distances were characterised as the distances travelled between 100% MAS – 30% ASR, and >30% ASR respectively (Hunter et al., 2015; Mendez-Villanueva et al., 2013). Acceleration-related GPS metrics recorded were moderate-intensity (MI) acceleration, and high-intensity (HI) acceleration distances. These were characterised as distances travelled accelerating between 50-75% and >75% of an individual's maximal accelerative capacity respectively (Sonderegger et al., 2016). The total distance travelled during competition was also recorded (Molinos, 2013; Guadino et al., 2010). Mean values for GPS metrics were calculated for each playing position, and match outcome.

Statistical Analysis

Descriptive analyses were conducted on the data set, with normality values in the form of Kolmogorov-Smirnov and Shapiro-Wilk tests. Significance values < 0.05 indicated data was evenly distributed. Skewness and kurtosis values were assessed, with standard error between -2 and +2 indicating the data was evenly distributed. To investigate differences and interactions between match outcome and playing position, in the GPS metrics produced during competition, a two-way between subjects ANOVA was used. Bonferroni tests were used post-hoc to assess where differences occurred, with Cohen's *d* tests used to calculate effect sizes. The level of statistical significance was set at $p < 0.05$. All statistical analyses were performed using the software IBM SPSS statistics (version 22; SPSS, Inc., Chicago, IL, USA).

RESULTS

Two-way ANOVA results showed no significant differences in GPS metrics between different match outcomes ($p < 0.05$). For the purpose of clarity, these results have not been presented below. Two-way ANOVA results showed significant differences between playing positions for all GPS metrics ($p < 0.05$). The following sections discuss the follow up analysis, and detail between which playing positions differences in GPS metrics occurred.

Results for total distance demonstrated significant differences between playing position ($F_{(4,338)}$ = 187.898; *p* <0.001), with mean total distances shown in Table 1. CM produced significantly higher total distances when compared to all playing positions (*p* < 0.001). WD and WA produced similar total distances for competition, significantly higher than distances produced by ST and CD (*p* <0.001). ST produced significantly higher total distances in comparison to CD, but significantly lower than all other playing positions (*p* <0.001). CD produced the lowest total distance, significantly lower than all other playing positions (*p* <0.001). Table 1 demonstrates the significant differences in maximum speed achieved by playing positions during competition ($F_{(4,338)}$ = 173.999; *p* <0.001). WD and WA achieved similar maximum speeds during competition, significantly higher than CD, CM, and ST (*p* <0.001). There were no significant differences in maximum speed when comparing WD and WA, or comparing CD, CM, and ST.

Table 1. Differences in total distance, and maximum speeds achieved by soccer playing positions during competition.

	Playing Position				
	CD	WD	CM	WA	ST
Total distance (m)	9,830 ± 428	10,747 ± 420	11,570 ± 469	10,918 ± 353	10,320 ± 420
Significant differences present (p <0.05)	Sig. less than: WD (*d* =2.1) CM (*d* =3.9) WA (*d* =2.8) ST (*d* =1.1)	Sig. more than: CD (*d* =2.1) ST (*d* =1.0) Sig less than: CM (*d* =1.8)	Sig. more than: CD (*d* =3.9) WD (*d* =1.8) WA (*d* =1.6) ST (*d* =2.8)	Sig more than: CD (*d* =2.8) ST (*d* =1.5) Sig less than: CM (*d* =1.6)	Sig more than: CD (*d* =1.1) Sig less than: WD (*d* =1.0) CM (*d* =2.8) WA (*d* =1.5)
Maximum speed ($m.s^{-1}$)	7.4 ± 0.3	8.4 ± 0.4	7.5 ± 0.3	8.6 ± 0.4	7.6 ± 0.5
Significant differences present (p <0.05)	Sig less than: WD (*d* =2.8) WA (*d* =3.4)	Sig more than: CD (*d* =2.8) CM (*d* =2.5) ST (*d* =1.8)	Sig less than: WD (*d* =2.5) WA (*d* =3.1)	Sig more than: CD (*d* =3.4) CM (d =3.1) ST (*d* =2.2)	Sig less than: WD (*d* =1.8) WA (*d* =2.2)

NOTE: CD = Central Defenders, WD = Wide Defenders, CM = Central Midfielders, WA = Wide Attackers, ST = Strikers.

Figure 1 demonstrates the very high-speed running and sprinting distances produced by soccer playing positions during competition. Significant differences were identified between playing positions for both very-high speed running ($F_{(4,338)}$ = 684.486; *p* <0.001), and sprinting distances ($F_{(4,338)}$ = 200.446; *p* <0.001). When focusing upon very high-speed running distances, WD and WA produced the highest distances, with CD, CM, and ST producing significantly lower distances in comparison (*p* <0.001). ST produced significantly higher very-high speed running distances when compared to CD and CM (*p* <0.001). CD produced significantly lower very-high speed running distances when compared to all other playing positions (*p* <0.001). The same significant differences were seen between playing positions for sprinting distances, with one exception. There was no significant difference in sprinting distances produced by CM and ST.

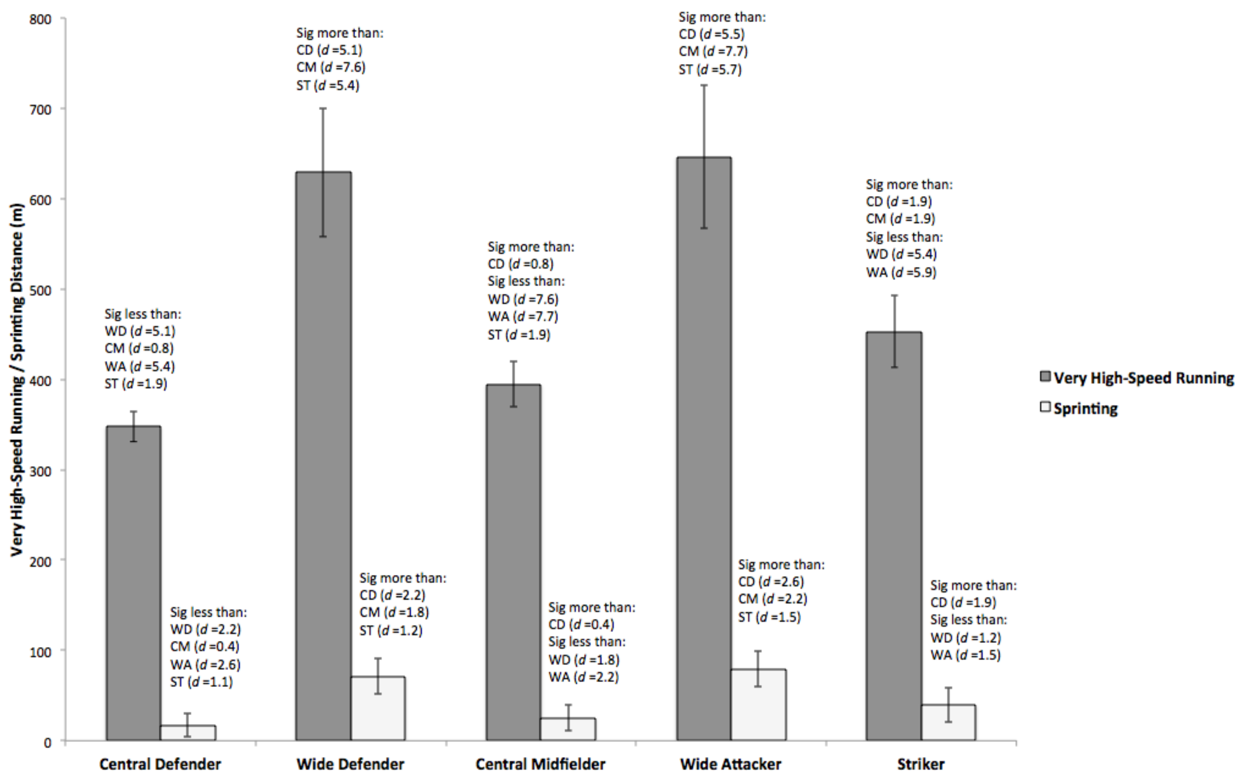

Figure 1. Differences very high-speed running and sprinting distances produced by soccer playing positions.

Figure 2 shows the MI, and HI acceleration distances produced by soccer playing positions during competition. Significant differences in MI ($F_{(4,338)}$ = 91.475; p <0.001), and HI acceleration distances ($F_{(4,338)}$ = 147.436; p <0.001) were demonstrated between playing positions. When focusing on MI acceleration distances, CM produced significantly higher distances than all other playing positions (p <0.001). WD, WA, and ST produced similar MI acceleration distances, with no significant differences between playing positions. CD produced significantly lower MI acceleration distances compared to all other playing positions (p <0.001). Results for HI acceleration distances differed to MI acceleration distances. WD and WA produced significantly higher HI acceleration distances compared to CD, CM, and ST (p <0.001). CD, CM, and ST produced similar HI acceleration distances, with no significant differences in distances produced.

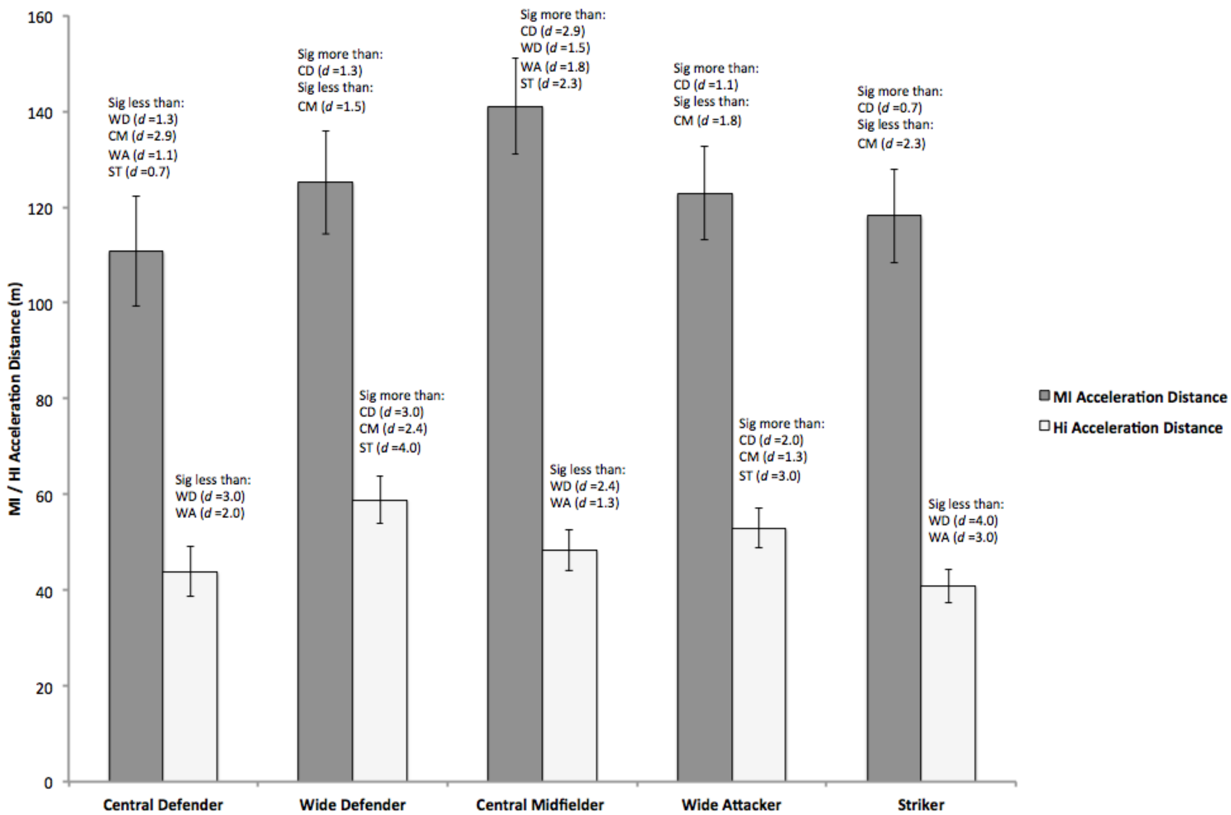

Figure 2. Differences in MI and HI acceleration distances produced by soccer playing positions.

DISCUSSION

The aim of the investigation was to identify differences in physical outputs produced by soccer playing positions, and between match outcomes. Total distance, maximum speed, high-speed distances, and moderate- and high-intensity acceleration metrics were recorded to identify global physical demands placed upon playing positions. The investigation was the first to individualise speed and acceleration thresholds to quantify the individual intensity of activities.

Current results demonstrated CD produced the lowest total, very high-speed running, and sprinting distances, as previously reported by Dellal et al (2011) and Guadino et al (2010). Despite being the least physically demanding position, CD are highlighted as an important position tactically, operating as the last line of defence (Bangsbo et al., 2006). CM produced the highest total distances, complimenting research by Bradley et al (2009) and O'Donoghue et al (2005). High total distances produced by CM are related to the positional role of linking defence and attack, often requiring involvement in both phases of play. These results were in contrast to research conducted by Carling (2013), finding that WA produced the highest total distances. Differences in results could be attributed to the varying tactical roles of WA between research investigations.

When investigating positional differences in very high-speed running and sprinting distances, current results emulated previous research, finding WA produced the highest distances for very high-speed running, and sprinting (Bradley et al., 2010; Ingebrigtsen et al., 2015). Similar results were identified for maximum speeds achieved during competition, as previously demonstrated by Bradley et al. (2009). High-speed running and sprinting distances produced by WD were similar to WA, the result of operating on the flanks of the pitch.

Wide areas are less congested when compared to central areas, resulting in increased opportunities to achieve high speeds unopposed. Significantly lower very high-speed running, and sprinting distances produced by CD and CM owe to operating in congested, central areas of the pitch (Di Salvo et al., 2007).

When investigating positional differences in acceleration, Ingebrigtsen et al (2015) reported a higher frequency of accelerations in wide players compared to central. Current results illustrate this for HI acceleration distances, with WA and WD producing the highest distances. Rationale is the frequent requirement of wide positions to reach high-speeds, with rapid acceleration necessary to achieve this. For MI accelerations, the current investigation found CM produced the highest distances. This complimented research by Bloomfield et al (2007), stating CM are involved in high volumes of moderate intensity activity. Differences in HI and MI acceleration distances produced by playing positions emphasise the importance of sub-dividing these maneuvers dependent upon intensity.

ST produced significantly lower total distances in comparison to WD, WA and CM, the result of limited involvement defensively, within the current formation. Operating in central areas, ST are required to produce stretched runs behind opposition defenders, explaining moderate very high-speed running, sprinting, and HI acceleration distances. When investigating the effects of physical outputs upon match outcome, no significant differences were identified for any GPS metric. This was contrary to previous research (Carling, 2013; Mohr et al., 2003), but complimented the suggestion by Castellano et al (2014) that soccer success is the result of superior technical and tactical strategies.

Considering the significant differences in physical demands placed upon playing positions, uniform training methods would be impractical. Specific playing positions require emphasis on distinct physical components relating to their competitive requirements (Dalen et al., 2016). CD has the least physical demand associated, allowing for a larger volume of tactical and technical training, cited as important for the position (Bangsbo et al., 2006). To overload competitive intensities, recommendations for total distance are >109 $m.min^{-1}$, with HI acceleration distances >0.5 $m.min^{-1}$.

WD and WA are characterised by large volumes of very high-speed running, sprinting, and HI accelerations. Specific training should incorporate linear speed production, rapid acceleration to maximal speeds, and the ability to repeat these actions. Overload intensities for very high-speed running, and sprinting are >7.2 $m.min^{-1}$, and >4.1 $m.min^{-1}$ respectively for WA, and >7.0 $m.min^{-1}$, and >3.9 $m.min^{-1}$ respectively for WD. To overload competitive HI acceleration distances, intensities should exceed >0.7 $m.min^{-1}$ for WA, and >0.6 $m.min^{-1}$ for WD.

Considering the physical demands elicited upon CM during competition, the training emphasis should differ from WD and WA. Specific training should involve high total distances, with frequent MI accelerations. To overload competitive intensities for total distance, training intensity of >129 $m.min^{-1}$ is required, with MI acceleration intensity >1.6 $m.min^{-1}$. For ST, demands were multifaceted, with no dominant physical activity. To overload competitive intensities, very-high speed running and sprinting intensities of >5.0 $m.min^{-1}$, and >2.8 $m.min^{-1}$ are required. Training intensities of >0.5 $m.min^{-1}$ are required to overload HI accelerations. The current investigation's training intensity recommendations are derived from mean positional intensities for competition. Gabbett et al (2016) warn that if the average demands of competition are focused upon, athletes may be underprepared for the most demanding passages of play. Consequently, further research is required to quantify the aforementioned most demanding passages.

CONCLUSION

The current investigation demonstrates the significant differences in physical demands elicited upon soccer playing positions during competition. In addition to differing tactical and technical roles, each playing position has a specific physical demand associated. Findings provide coaches with the information to accurately prescribe training intensities above those encountered during competition. Further individualisation can be achieved by prescribing training intensities to specific playing positions. Consequently, soccer training can be made specific to the individual, and physical activities overloaded improve competitive performance.

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