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External and internal maximal intensity periods of elite youth male soccer matches

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Abstract

Understanding the maximal intensity periods (MIP) of soccer matches can optimise training prescription. The aim was to establish differences between positions and other contextual factors (match location, match outcome, playing formation and score line) for both external and internal MIP variables, and to investigate the differences in the match start time between MIP variables. Maximal moving averages (1 to 10 min) for average speed, high-speed running (5.5-7 $m \cdot s^{-1}$), sprinting (> 7 $m \cdot s^{-1}$; all $m \cdot min^{-1}$), average acceleration/deceleration ($m \cdot s^{-2}$) and heart rate (bpm, % maximal) were calculated from 24 professional youth players across 31 matches. Linear mixed models determined differences in MIP variables between positions, contextual factors and in the match start time of MIPs. *Trivial* to *large* positional differences existed in maximal external intensities while central defenders presented the lowest heart rate. It was *unclear* whether maximal intensities were influenced by contextual factors. MIPs for average speed, acceleration/deceleration and heart rate tend to occur concurrently (ES = *trivial*) within the first 30 min, while high-speed running and sprinting are likely to occur concurrently (ES = *trivial*) throughout a whole match. Practitioners could target maximising average speed and average acceleration/deceleration in technical-tactical based training to maximise heart rate responses.

Introduction

Time-motion characteristics are commonly used in soccer to measure and evaluate the intensity of match play (Akenhead & Nassis, 2016). This can inform the training process by identifying key physiological determinants and the evaluation of technical-tactical focused training prescription which is a frequent training mode in soccer (Barrett et al., 2020; Weaving et al., 2022). Given the intermittent and stochastic nature of the intensity construct in soccer, multiple external and internal measurements are used to operationalise the construct. External intensity refers to the rate of activities (e.g., speed) completed by players and is typically measured via wearable technology using a variety of measures such as average speed, distance covered in various speed thresholds (high-speed running and sprinting) and changes in speed (i.e. acceleration and deceleration) (Akenhead & Nassis, 2016; Delaney et al., 2018; Duthie et al., 2018; Riboli et al., 2021). Internal intensity refers to the rate of psycho-physiological response to the external intensity (Staunton et al., 2022) and is typically assessed via heart rate (HR), blood lactate concentration or rating of perceived exertion (Hill-Haas et al., 2011).

There have been attempts to quantify the external intensity of youth soccer match play (Abbott et al., 2018; Castellano et al., 2020; Doncaster et al., 2020; Duthie et al., 2018). Abbott et al. (2018) reported whole match average speed and high-speed running (HSR; 5.5 to 7 $m \cdot s^{-1}$) of U23 academy players to be >129 $m \cdot min^{-1}$ and >7.2 $m \cdot min^{-1}$, respectively. Although useful, as the intensity frequently changes, averaging across the whole match likely provides an under-representation of intensity. Segmental approaches, which average data across pre-defined segments (e.g., 0 to 5, 5 to 10, 10 to 15 min) are also used but as the maximal intensity of match may fall between two successive blocks (Bradley et al., 2009; Di Salvo et al., 2009) a maximal moving average approach provides a more valid method to capture the maximal intensity experienced by players for a given duration for a given match (maximal intensity period [MIP]; Varley, Elias, et al., 2012). In male senior players, MIP for average speed across 1- and 3-min were 10% and 8% greater with a moving average than a segmental approach (190 vs. 173 and 145 vs. 135 $m \cdot min^{-1}$, respectively; Fereday et al., 2020). Differences were greater at higher speeds (i.e., HSR) and longer durations (e.g., 11% and 20% differences for 1- and 3-min duration). Findings are consistent within youth (U23) populations (Doncaster et al., 2020; Duthie et al., 2018). However, limited data is available for the internal intensity (e.g., HR). For example, only a whole match average approach has been used for HR, ranging from 150 to 180 bpm (80 to 90% of maximal HR [$\%HR_{max}$]) across senior and youth populations, with the highest reached as ~98$\%HR_{max}$ (Bangsbo et al., 2006; Billows et al., 2005; Rohde and Espersen

1988; Stølen et al., 2005). Given the limitations of a whole match average, adopting a maximal moving average for internal intensity measures would enable practitioners to understand the maximal internal intensity players experience during match play. Similarly, research is needed to better understand maximal intensities measured via acceleration and deceleration, which are not captured by velocity-based variables (Harper et al., 2019).

Previous studies have reported that whole match physical performance is influenced by a variety of match-related factors such as playing position (Bradley et al., 2011), match location (Aquino et al., 2017; Lago et al., 2010), match outcome (Aquino et al., 2017; Lago et al., 2010), score line (Redwood-Brown et al., 2018), and playing formation (Bradley et al., 2011). More recently, research analysed MIP taking into consideration different contextual factors. For example, the effect of playing position across senior and youth players was evident: 1-min maximal average speed was greater for central midfielders than central defenders (202 vs. 188 $m \cdot min^{-1}$; Duthie et al., 2018), and wide players showed greater maximal intensities for HSR (72 to 78 $m \cdot min^{-1}$) than central players (52 to 54 $m \cdot min^{-1}$) (Oliva-Lozano et al., 2020). Whereas the effect of match location was unclear, either external intensities were higher at away games (Oliva-Lozano et al., 2020), or no difference reported (Connor et al., 2022). Meanwhile, research on the effects of match outcome and score line on maximal intensities is limited. Recently, it was highlighted that MIP may vary based on starting status (starter vs. substitute), and/or the start time of MIP in a match (minutes since the beginning of a match) (Novak et al., 2021). Furthermore, current MIP methods reflect an intensity for a single variable during match play and it is unknown whether the MIP for different variables occur at similar periods within the match. While the use of MIP to inform training prescription has become more common, the information of match-related factors and internal intensities has not been clarified or investigated. Therefore, the aims of this study were to establish the positional maximal external and internal intensities across different durations and to assess the effects of match location (home vs away), match outcome (win vs draw vs loss), playing formation and score line on maximal external and internal intensities across different durations within professional youth soccer matches. A secondary aim was to investigate the differences in the match start time of MIPs between/within intensity measures.

Methods

Design and subjects

An observational research design was conducted in which microtechnology, HR and video data were collected over 31 matches from 24 male outfield players from an English Football League Championship Academy (age [mean ± SD]: 17.6 ± 0.6 yrs; body mass: 69.8 ± 8 kg; height: 180.4 ± 7.3 cm; maximum HR: 203 ± 4.9 bpm). Both league and cup competitions were included (n = 21 and 10, respectively). Playing positions were central defenders (CD, n = 4), wide defenders (WD, n = 5), central midfielders (CM, n = 8), wide midfielders (WM, n = 5) and strikers (ST, n = 2). Players substituted onto the pitch (SUB) were separately categorised as the effect of starting status on the MIP was previously reported (Novak et al., 2021). Players substituted off the pitch were included into their assigned playing position. 338 individual match observations (mean ± SD = 14 ± 6.4 per player) were collected across each position: CD (n = 52; 4 ± 3.7, [range = 4 to 15]), WD (n = 54; 5 ± 4.4, [range = 1 to 17]), CM (n = 89; 7 ± 4.7, [range = 2 to 16]), WM (n = 54; 7 ± 4.8, [range = 2 to 17]), ST (n = 28; 9 ± 7.8, [range = 4 to 18]) and SUB (n = 61; 4 ± 2.9, [range = 1 to 10]). If players changed their position during a match, the position they played while the maximal intensity occurred were considered for the positional observation. Ethical approval was granted from University's Ethics Committee (approval number: 84521) and players provided written consent (or parental/guardian consent if participants were under 18).

Data collection

External intensity was measured using a micro-electro-mechanical system (MEMS) (Vector S7, Catapult Innovations, Melbourne, Australia) containing a 10 Hz Global Positioning System (GPS), Global Navigation Satellite System (GNSS) and 100 Hz tri-axial accelerometer worn inside a manufacturer supplied vest. HR was recorded using a Polar H10 (Polar Electro Oy, Kempele, Finland) placed tightly around the chest. All data was extracted through the manufacturer's software (Catapult OpenField, v3.4.1, Catapult Innovations, Melbourne, Australia). Players wore the same device for each match to avoid inter-unit reliability issues (Buchheit et al., 2014; Jennings et al., 2010). 10 Hz GPS has demonstrated an acceptable level of accuracy and reliability for measuring linear and multidirectional soccer activities (coefficient of variation = 2.0 to 5.3%; (Varley, Fairweather, et al., 2012). To represent external intensity, average speed ($m \cdot min^{-1}$), HSR ($m \cdot min^{-1}$; 5.5 to 7 $m \cdot s^{-1}$), sprinting ($m \cdot min^{-1}$; >7 $m \cdot s^{-1}$) and average acceleration/deceleration (AveAcc; $m \cdot s^{-2}$) were chosen. To represent internal intensity, HR expressed as average HR (HR_{ave}; bpm) and percentage of individual maximal HR ($\%HR_{max}$). The average acceleration/deceleration method takes the absolute value of all acceleration/deceleration data and averages over the duration of the defined period (Delaney et al., 2016). This has been suggested as indicative of combined acceleration and deceleration intensity of the activity as a valid and reliable method (CV = 1.2%; Delaney et al., 2016). It is also important to consider the match-to-match variability of the measures which have been reported as 6.9-7.3%, 20.6-29.8% and 5.4-5.8% for average speed, HSR and sprinting and average acceleration MIPs in elite soccer (Novak et al., 2021; Thoseby et al., 2022). However, maximal HR match-to-match variability has yet to be established.

Determination of external and internal maximal intensity periods and their timing within the match

Speed data was recorded every 0.1s (Doppler shift method) and HR data was recorded every 5s and were exported for each player and each match. To time synchronise exported data to the start time of each match half, a sync point was established by visually comparing the movement of players at match kick off using video to plotted longitudinal and latitudinal positional data from the microtechnology data in Catapult OpenField. This allowed the match file to correspond to the start duration of each half.

Each match file was then exported in an Excel spreadsheet and analysed in R Studio (v 2022.02.0, R Foundation for Statistical Computing, Vienna, Austria) using a custom-built script to compute the maximal moving average for 1 to 10 min for each variable and its start time within the match. Microtechnology inclusion criteria (e.g., number of connected satellites ≥10, horizontal dilution of precision (HDOP) ≤1, velocity ≤10 $m \cdot s^{-2}$, acceleration ≤±6 $m \cdot s^{-2}$; (Malone et al., 2017) was applied to each sampling point to remove erroneous data. HR data was excluded when >15% of the whole data points were missed during match play, and a total number of 80 observations out of 338 were removed. To model the relationship between moving average durations for each intensity measure for each player observation, a power law relationship was evaluated using the formula; $y = cx^n$ (Katz & Katz, 1999; Katz & Katz, 1994), where c is the intercept and n the slope of the relationship.

Match contextual factors

Contextual factors were analysed to examine the influence of match location, match outcome, playing formation and score line on maximal external and internal intensities. Match location was classified as home (n = 21) or away (n = 10), and match outcome as win (n = 7) or loss (n = 23). The respective club used either 4-3-3 (n = 15), 4-2-3-1 (n = 10), or 3-4-3 (n = 6) formation. Score line was the final score by the end of each match and classified into small (≤1 goal differential; n = 9), medium (2 goal differential; n = 6), and large (≥3 goals differential; n = 16) (Redwood-Brown et al., 2018).

The match start time of maximal intensity periods

As each match file included data from the official start of each match, the start time of MIP in a match was established. As the MEMS device collected speed data at 10 Hz, if the 1-min MIP for average speed occurred at data point 600, the start time would be 1st minute of a match. The regular time of match was used to determine the start time of MIPs, indicating each half was set as 45 min duration (0 to 45 for 1st and 45 to 90 for 2nd) and the duration of the half-time break was removed. If the start time of MIP was outside of regular time (e.g., 45.2 min or 91 min) that time point was included as the last minute of each half (i.e., 45 and 90 min, respectively). This occurred for 11 observations during 1-min MIP.

Statistical analysis

Data were visually inspected for normality and distributions using histograms and Q–Q plots, and non-normal distributions were identified. Therefore, data were log-transformed prior to analysis to reduce error arising from non-uniform residuals (Hopkins et al., 2009). Presence of outliers were investigated for values falling outside of 2.2 multiplied by the interquartile range (IQR; n = 5). Descriptive data were summarised as median and lower (25%) and upper (75%) IQR.

Model 1 & 2 (The effects of position and contextual factors on external and internal MIP)

Linear mixed models (*lme4* package in R; Kuznetsova et al., 2017) were used to overcome the assumption of independence and also to account for the altering sample sizes between groups with repeated measures (Field, 2013). This model determined the magnitude of differences between positional groups and contextual factors for the dependent variables. A power law relationship existed between running intensity and duration (r = 0.89-0.93 ± 0.05). Therefore, dependent variables were the intercept and slope of external and internal intensity measures (average speed, HSR, sprinting, AveAcc, HR) across 1 to 10 min durations (Delaney et al., 2018), while fixed effects were positional group (CD, WD, CM, WM, ST and SUB) and contextual factors (match location, match outcome, formation and score line). Player and match identity were included as random effects to account for repeated measures and variability between matches and players.

Model 3 & 4 (The differences in the match start time of MIP between intensity measures for a given duration and between durations for each intensity measure)

To investigate the differences in the start time of MIP in a match between external and internal intensity variables for a given duration, and between different time durations within each intensity measure, a separate linear mixed model analysis was used. As the start time of MIP showed weak relationships with moving average duration across all variables ($r = 0.33$ to 0.51 ± 0.47 to 0.56), a power law was deemed inappropriate to represent the match start time. Therefore, three durations (1-, 5-, and 10-min) for each variable were selected to investigate the difference in the start time between intensity variables within short (1-min), medium (5-min) and long (10-min) timeframes. The start time of each MIP was included as a dependent variable (i.e., 19:15 or 71:47), and the intensity measures (average speed, HSR, sprinting, AveAcc HR) and durations (1-, 5-, and 10-min) were included as fixed effects in this model. Identification number of individual players was included as random effects.

To assess model fit across all models, the models were each compared against a null model (with only random effects included), using the Akaike Information Criterion (AIC) (with lower the AIC indicating better model fit). The magnitude and direction of difference (effect sizes [ES] ± 95% confidence intervals [CI]) as well as significance (p-value) were determined for comparisons. For the current study, ES was classified as *trivial* (< 0.2), *small* (0.2 - 0.59), *moderate* (0.6 - 1.19), *large* (1.2 - 2.0) and *very large* (> 2.0) (Hopkins, 2010). All statistical analyses were conducted using R Studio with alpha level set at $p < 0.05$ for all comparisons.

Results

Positional differences

Table 1 provides median and interquartile range for the maximal intensity modelling (slope and intercept) for each position. The model improved the AIC over the null model for all intensity measures: average speed (-869.3 vs. null = -863.8), HSR (44.8 vs. null = 55.9), sprinting (643.2 vs. null = 650.7), AveAcc (-1321.5 vs. null = -1335.5), and HR_{ave} (-1151.6 vs. null = -1106.5). Therefore, ES (± 95% CI) comparisons between positions for each intensity variable are illustrated in Figure 1. Descriptive data for each maximal intensities for each position for the individual time duration is illustrated in Supplementary Figure 1.

For average speed intercept, CD was significantly lower to a *small* to *moderate* extent than WD, CM and SUB but were not significantly lower than WM or ST. Generally, *small* effects were observed for all other positional comparisons. There were *small* differences in HSR intercept between positional groups. WD and WM showed significantly higher sprinting intercept than CD (ES = *small*), CM (ES = *small to moderate*) and SUB (ES = *small* to *moderate*). AveAcc intercept was significantly greater for WD than all other positions (ES = *moderate* to *large*) except CM (ES = *small*) while ST was significantly lower than other positions (ES = *small* to *large*). *Small to moderate* differences in slopes were observed between positions for all external and internal intensity measures.

Match contextual factors

Supplementary Table 2 presents median and interquartile range for the slopes and intercepts of external and intensity variables for different match contextual factors. The standardised differences (± 95% CI) in intercepts and slopes of maximal intensities based on match contextual factors are illustrated in Figure 2. There were improvements in the specified models against the null model for average speed for match location (-879.2), match outcome (-870.2) and scoreline (-868.6), where effects were *trivial* and non-significant. There was improvement for sprinting for match location (646.7 vs. null = 650.7), and the intercept was significantly greater in away games to a *small* extent than home games. There was not an improvement against the null model for other variables with match contextual factors and so these comparisons were not interpreted. However, the wide CIs limit the conclusions drawn.

The Match Start Time of Maximal Intensity Periods

Figure 3 provides ES (± 95% CI) in the match start time of MIP between different intensity measures for a given duration (1-, 5- and 10-min), and between durations (1-, 5- and 10-min) for a given intensity measure based on starting status (i.e., starters vs. substitute). The start time of MIP for each measure is presented in Supplementary Table 3 as median and interquartile range and Supplementary Figure 5 as a density plot over the timeline of a match.

Overall, differences in the start time for 1-min MIP were *small* between average speed, AveAcc and HR. HSR and sprinting showed *small* differences with average speed and AveAcc and *moderate* differences with HR. At 5- and 10-min durations, the start time of HR MIP showed *trivial* differences with MIP for average speed and AveAcc but *small/moderate/large* differences with HSR and sprinting. Regardless of duration, differences in the start time were *trivial* between average speed and AveAcc and *trivial* between HSR and sprinting.

For HR, the differences in the start time for 1-, 5- and 10-min period were *trivial.* For average speed and sprinting, the start time of 1-min was *moderately* different to 5- and 10-min but *trivial* between 5- and 10-min. For AveAcc, there were *small to moderate* differences in the start time for 1-, 5-, and 10-min MIP.

Discussion

The aim was to establish the (1) positional differences, (2) effects of contextual factors (match location, match outcome, playing formation and score line) and (3) differences in the match start time of MIP in external and internal variables across different durations within professional male youth soccer matches. The main findings were: (1) there are *trivial to large* positional differences in maximal external intensities, (2) CD presented the lowest maximal internal intensity, while the rate of decline was *small to moderately* greater in ST and SUB than WD, CM and WM, (3) it was *unclear* whether maximal intensities were influenced by match contextual factors given the uncertainty in the estimates and (4) MIPs for average speed, AveAcc and HR occur concurrently (ES = *trivial*) within the first 30 min of the first half, while HSR and sprinting occur concurrently (ES = *trivial*) yet throughout the match.

For external intensity, WD generally elicited the highest intercepts (average speed, HSR, SPR and AveAcc) across positions, although the differences in HSR and sprinting with WM were *trivial to small*, and in average speed with CM was *trivial*. Generally, CD showed lower intensities than other positions in average speed, HSR and sprinting by *moderate to large* extent but not AveAcc. ST showed the lowest AveAcc with *small to very large* differences to other positions. Substitutes generally demonstrated not only lower values of maximal intensities (ES = *small to moderate*) but also greater decline over time durations (ES = *small to moderate*) than other positions, except CD. Given it is likely that substantial fatigue wouldn't be present for substitutes across a 10-min period, it likely highlights the potential influence of contextual factors (e.g., stoppages when ball is not in play) on a substitutes' intensity during matches. Intercept and slope values are generally comparable to that reported by Delaney et al. (2018) in senior players. Although, HSR, sprinting (45 to 62 vs. 69 to 95 m·min^{-1}), and AveAcc (0.78 to 0.86 vs. 0.87 to 0.95 m·s^{-2}) appear higher in the current study. For the descriptive data reported for individual time durations (Supplementary Figure 1), average speed appears similar to that previously reported in the senior game across Spanish (1-min: 177-204 m·min^{-1}; 5-min: 131-150 m·min^{-1}; Casamichana et al., 2019; Martín-García et al., 2018) and Italian (1-min: 177-198 m·min^{-1}; 5-min: 129-145 m·min^{-1}; Riboli et al., 2021) leagues. Whereas HSR and sprinting appear ~12% and ~43% greater in the current study than those reported in senior levels (Casamichana et al., 2019; Martin-Gracia et al., 2018; Novak et al., 2021; Riboli et al., 2021). Such differences may highlight that maximal intensities are affected by multiple factors, such as different technical and tactical characteristics and playing styles between teams. Therefore, practitioners should develop team and individual specific references for maximal intensities to help evaluate technical-tactical training prescription for that team and individual.

To the authors knowledge, this is the first study investigating internal maximal intensities. It is not surprising that the values of maximal HR intensities reported were higher than average HR over 90 min (166 to 175 bpm; Helgerud et al., 2001; Stølen et al., 2005; Strøyer et al., 2004) across male senior and youth level players. Maximal HR intensities for the 1-min ranged from 185 to 200 bpm (92 to 95%HR_{max}) while for 10 min was from 171 to 184 bpm (85 to 90% HR_{max}). Similar to previously reported by Coelho et al. (2011), the position with the lowest (i.e., CD) and highest (i.e., CM) average speeds also concurrently presented the lowest (i.e., CD) and highest (i.e., CM) heart rate MIP regardless of duration. Given the current study findings, where CD experienced a lower maximal HR intensity during match play, practitioners should not consider that CD are exposed to similar internal intensities than other positions during match play. This could inform the training process by potentially allowing targeted training to occur to expose CD to such internal intensities during training (e.g., controlled conditioning drills). It is possible that this underexposure to heart rate intensity is also present in soccer specific training (e.g., technical-tactical drills, small-sided games). However, it is unclear how this potential underexposure in HR intensity during a match contributes to variability in physiological capacity in CDs and further work is needed. Such findings also highlight the practical importance of supporting the measurement of both external and internal intensities.

To the authors knowledge, this is the first study investigating the differences in the match start time of external and internal MIP variables. Although there were *small* differences in the match start time for 1-min durations, there were *trivial* differences between average speed, AveAcc and HR in 5- and 10-min durations. Within the external intensity measures, average speed and AveAcc MIP had similar match start time regardless of duration (ES = *trivial*) which was same for HSR and sprinting (ES = *trivial*). The match start time of MIP for average speed, AveAcc and heart rate predominantly occurred within the first 30-min of the first half (Supplementary Table 3) which was *moderately* different to the match start time for HSR and sprinting MIP.

Meanwhile, the start time of HSR and sprinting MIP varied throughout the 90-min (Supplementary Figure 5). HSR and sprinting actions have been reported to be highly variable between matches for whole match (coefficient of variation [CV] = 11 to 26%) (Carling et al., 2016) and for the MIP (CV = 21 to 31%) based analysis (Novak et al., 2021). Equally, the distance covered at higher speeds has also previously been reported to be maintained in the second half whilst total distance declines (Bradley & Noakes, 2013). This is logical, as HSR actions tend to occur as singular events often preceding decisive moments in the match. Additionally, average speed and acceleration-based measures can be considered more reflective of continuous movements during match play which could explain the greater coupling with MIP heart rate responses during the match. This could explain the differences in timing between HSR/sprinting and average speed/acceleration/heart rate in the current study. Taken all together, if the goal of a technical-tactical based training drill is to maximise heart rate responses, the findings of the current study suggest that technical-tactical drill constraints should be designed with a focus to expose players to the maximal intensities for average speed and AveAcc concurrently if the goal is to increase the internal intensity of the training drill.

This study is not without limitations. The present results indicate that maximal intensities did not differ between match contextual factors which is consistent with previous studies investigating the effects of match outcome and playing formation (Bradley et al., 2011; Oliva-Lozano et al., 2020). However, given the uncertainty in the estimates, that the model fit did not improve when considering match contextual factors and the small number of observations in some contextual factors (e.g., there was only 1 draw, so excluded from analysis), it is not possible to establish the presence or absence of an effect. In addition, findings are representative of a single soccer academy which may not be generalisable due to differences in the tactical approaches to match play or the physiological capacity of the players investigated. Therefore, future studies should look to build on these initial insights with multi-club analysis. This could allow deeper examination of the effect of contextual factors. For example, future studies should look to include a greater number of observations per contextual factor to better establish their effect and which would also allow positional specific comparisons within different formations to be made both within (e.g., 4-3-3 CD vs. 3-4-3 CD) and between (4-3-3 CD vs. 4-3-3 CM) positions. If practitioners are to design representative drills that balance physical and technical-tactical development, there is also a need to consider the technical-tactical actions completed within the MIPs which this study did not investigate. Such research would help coaches and sports science practitioners to collaborate to design game-based drills targeting multiple qualities (i.e., technical, tactical, and physical).

Conclusion

Positional differences in external and internal MIP exist in youth soccer matches. For 5- and 10-min durations, there were trivial differences in match start time between average speed, AveAcc and heart rate MIPs and their start time tends to occur within the first 30 min of the first half. Trivial differences in match start time between HSR and sprinting MIPs but the match start times varied throughout a match.

Practical Applications

To maximise heart rate for prolonged durations during technical-tactical training, practitioners could target the manipulation of constraints that focus on maximising average speed and average acceleration and deceleration activities. Based on the slope and intercept results of the current study detailed within Table 1, should a practitioner wish to prescribe a technical-tactical drill that equals the mean peak average speed ($y = 195 \text{ x } 3^{-0.18}$), average acceleration/deceleration and heart rate for WD (e.g., 3 min), a target intensity of 160 $\text{m}\cdot\text{min}^{-1}$, 0.76 $\text{m}\cdot\text{s}^{-2}$ and 185 bpm, respectively, could be targeted. Given their sporadic nature, HSR and sprinting could be prescribed separately outside of soccer-specific drills.

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Table 1. Intercept and slope values for estimating maximal intensities by duration for each position. Data are median ± Interquartile Range.

		Average Speed (m·min^{-1})	HSR (m·min^{-1})	Sprinting (m·min^{-1})	AveAcc (m·s^{-2})	HR (bpm)	%HRmax (%)
CD	Intercept	176 (172-184)	46.9 (38.9~53.1)	22.6 (18.1~30.5)	0.9 (0.85~0.93)	183 (176~189)	91.7 (89~95.5)
	Slope	-0.17 (-0.19~-0.14)	-0.7 (-0.75~-0.61)	-0.88 (-1~-0.76)	-0.18 (-0.2~-0.16)	-0.03 (-0.03~-0.02)	-0.03 (-0.03~-0.02)
WD	Intercept	195 (183~201)	56.2 (51.2~74)	31.2 (22.8~38)	0.95 (0.9~0.99)	189 (183~193)	93.1 (91.3~94.6)
	Slope	-0.18 (-0.2~-0.17)	-0.63 (-0.76~-0.57)	-0.88 (-0.99~-0.71)	-0.2 (-0.21~-0.18)	-0.02 (-0.03~-0.02)	-0.02 (-0.03~-0.02)
CM	Intercept	191 (180~199)	49 (40.7~57.5)	22.5 (16.8~28.9)	0.91 (0.88~0.96)	195 (190~199)	95.5 (94.2~96.4)
	Slope	-0.17 (-0.19~-0.15)	-0.66 (-0.77~-0.58)	-0.88 (-1~-0.78)	-0.19 (-0.21~0.17)	-0.02 (-0.03~-0.02)	-0.02 (-0.03~-0.02)
WM	Intercept	188 (177~196)	63.2 (51.4~71.6)	32.6 (23.4~41.7)	0.89 (0.85~0.93)	192 (188~195)	94.9 (93.2~95.5)
	Slope	-0.18 (-0.19~-0.16)	-0.66 (-0.72~-0.61)	-0.87 (-1~-0.75)	-0.2 (-0.22~-0.18)	-0.02 (-0.03~-0.02)	-0.02 (-0.03~-0.02)
ST	Intercept	188 (183~198)	59.3 (56.1~67.2)	28.9 (23.1~35.5)	0.87 (0.83~0.9)	192 (188~197)	94 (91.8~95.6)
	Slope	-0.19 (-0.21~-0.17)	-0.67 (-0.76~-0.61)	-0.91 (-1~-0.76)	-0.2 (-0.22~-0.18)	-0.03 (-0.03~-0.02)	-0.02 (-0.03~-0.02)
SUB	Intercept	186 (188~199)	51.4 (41.2~62.6)	25.8 (23.4~33.9)	0.9 (0.85~0.95)	191 (184~198)	93.2 (91~95.8)
	Slope	-0.18 (-0.21~-0.16)	-0.69 (-0.83~-0.63)	-0.95 (-1~-0.75)	-0.2 (-0.23~-0.18)	-0.03 (-0.04~-0.02)	-0.03 (-0.04~-0.02)

CD, central defender; WD, wide defender; CM, central midfielder; WM, wide midfielder; ST, striker, SUB, substitute; HSR, high-speed running (5.5-7 m·s^{-1}); Sprinting (> 7 m·s^{-1}); AveAcc, average acceleration/deceleration; HR, heart rate; %HRmax, percentage of maximal heart rate.

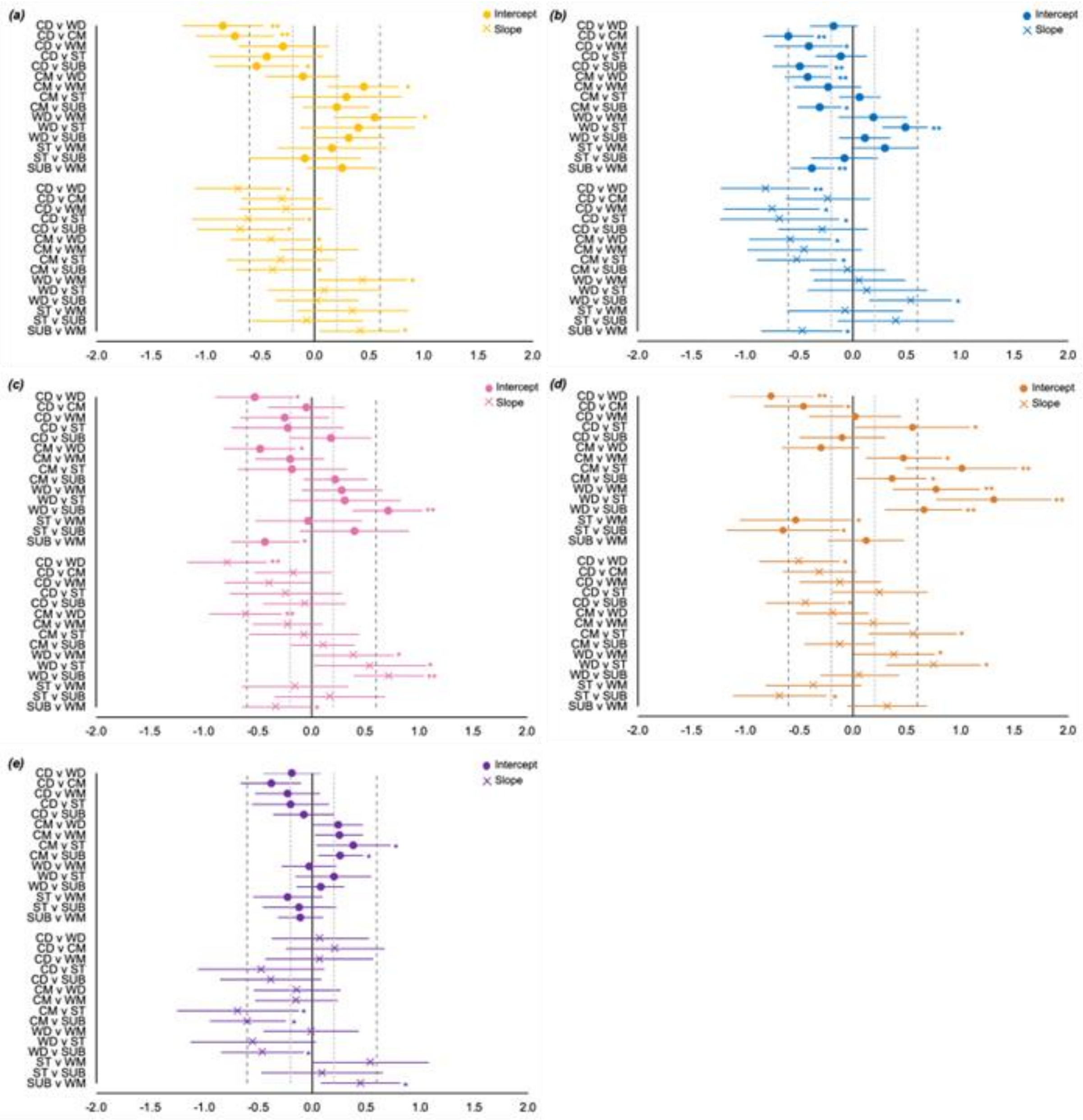

Figure 1. Standardised differences (effect size ± 95% confidence intervals) in intercepts and slopes of maximal intensities between positions for (a) average speed, (b) high-speed running (5.5-7 m·s^{-1}), (c) sprinting (> 7 m·s^{-1}), (d) average acceleration/deceleration and (e) heart rate. Dotted line represents the trivial and small differences between positions. Positive values mean the first position being greater than the latter position, and vice versa. * $p < 0.05$, ** $p < 0.001$. CD, central defender; WD, wide defender; CM, central midfielder; WM, wide midfielder; ST, striker, SUB, substitute.

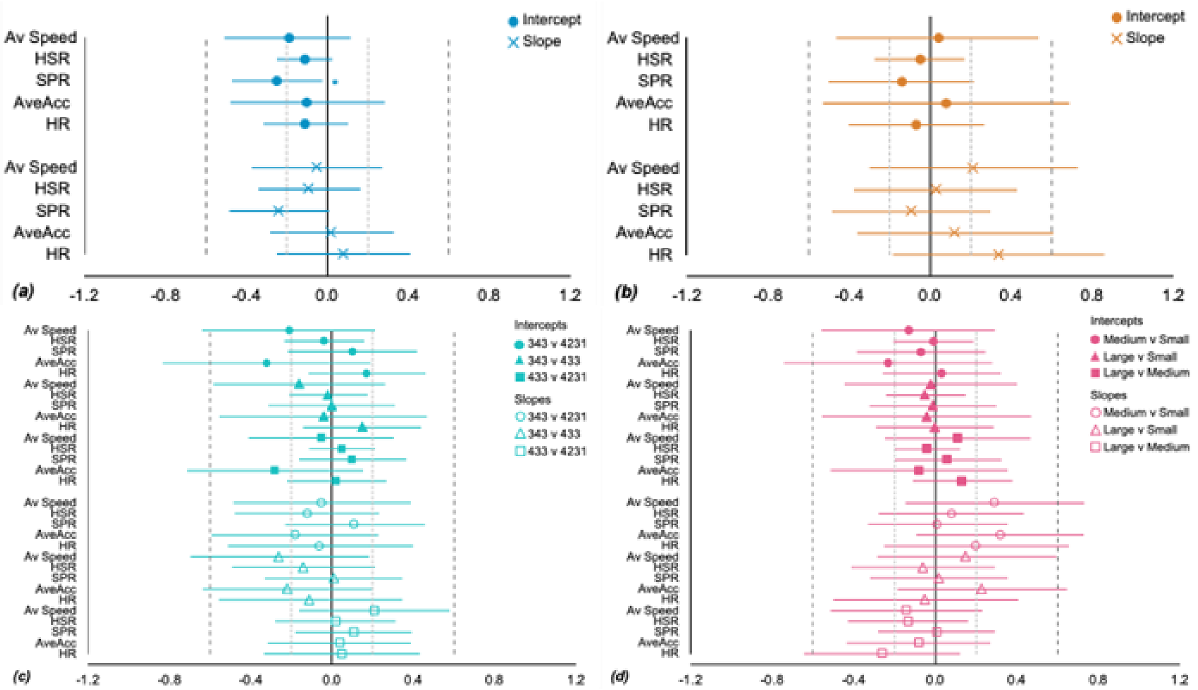

Figure 2. Standardised differences (effect size ± 95% confidence intervals) in intercepts and slopes of maximal intensities based on match contextual factors: (a) match location (home vs. away), (b) match outcome (win vs. loss), (c) playing formation (3-4-3 vs. 4-2-3-1 vs. 4-3-3) and (d) scoreline (small vs. medium vs. large). Dotted line represents the trivial and small differences between positions. Positive values mean the first position being greater than the latter position, and vice versa. * $p < 0.05$, ** $p < 0.001$. Av Speed, average speed; HSR, high-speed running (5.5-7 m·s^{-1}); SPR, Sprinting (> 7 m·s^{-1}); AveAcc, average acceleration/deceleration; HR, heart rate.

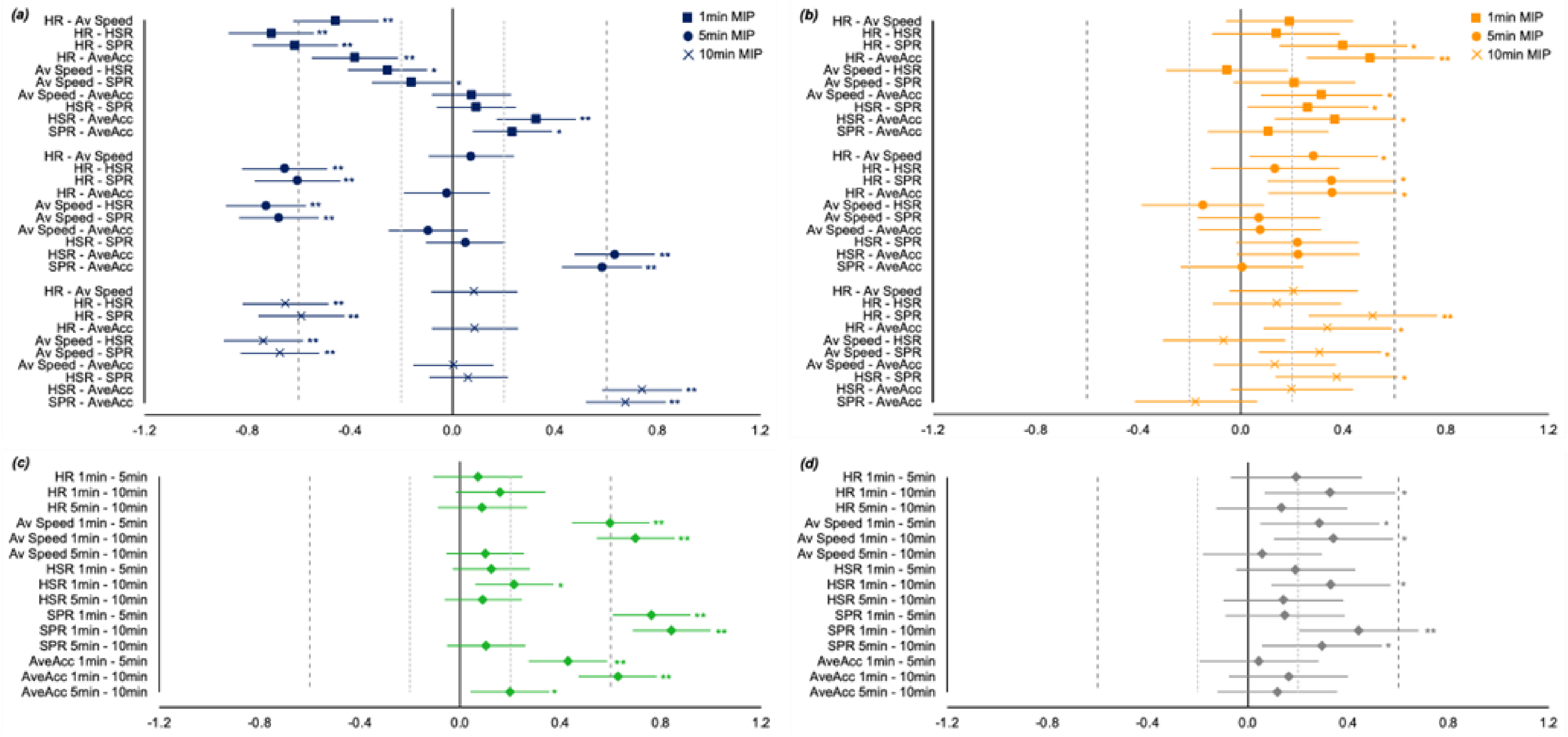

Figure 3. Standardised differences (effect size ± 95% confidence intervals) in the match start time of 1-, 5- and 10-min maximal intensity periods between intensity measures for (a) starters and (b) substitutes, and in the match start time of each intensity measure between durations for (c) starters and (d) substitutes. Dotted line represents the trivial and small differences between variables. Positive values mean the first variable being greater than the latter one, and vice versa. * $p < 0.05$, ** $p < 0.001$. Av Speed, average speed; HSR, high speed running (5.5-7 $m \cdot s^{-1}$); SPR, sprinting (> 7 $m \cdot s^{-1}$); AveAcc, average acceleration/deceleration; HR, heart rate.