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# Worst Case Scenarios in Soccer Training and Competition: Analysis of Playing Position, Congested Periods, and Substitutes

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**ABSTRACT**

**Aim**: To understand mean ($WCS_{mean}$) and peak ($WCS_{peak}$) worst case scenarios within training and game play in male professional soccer. **Methods**: Thirty-one ($n = 31$) first team players were monitored across 37 matches and 14 MD-3 sessions. Playing status was distinguished, football drills analyzed, and performance explored in long-period: >6 days, moderate-period: 5–6 days, and congested-period: ≤4 days. Relative total distance (TD), high-speed running distance (HSRD, >19.8 km·h$^{-1}$), sprint distance (SD, >25.2 km·h$^{-1}$), accelerations/decelerations (A+D, >3 m·s$^{-2}$), accelerations (Acc, >3 m·s$^{-2}$), and decelerations (Dec, >–3 m·s$^{-2}$) were measured as well as Maximum acceleration (Max Acc; m·s$^{-2}$) and deceleration (Max Dec; m·s$^{-2}$). **Results**: Analysis of variance found differences between matches and training in $WCS_{mean}$ for TD, HSRD, SD, and Max Dec in all positions ($p < .001$; partial $\eta^2 > .275$). Fullbacks displayed differences between match and training in Max Acc (moderate ESs; $p < .001$), while center backs and central midfielders in Max Dec (large ESs; $p > .05$). Main effects of playing status were discovered for all metrics except Max Dec ($p < .001$; partial $\eta^2 > .124$). Analysis showed differences between long- and congested-period for A+D and Dec (large ESs; $p \leq .05$). **Conclusions**: Findings provide more insights into short peak intensity demands of soccer showing that the maximum high velocity action of acceleration and deceleration is not being replicated in training. Nonstarters lack maximum intensity exposure in matches ($WCS_{peak}$) increasing the gap between training and competition even higher during congested fixture periods.

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Congested periods; soccer; substitutes; WCS

Wearable technology has been accepted as a valid and reliable tool to track absolute and relative distances in different speed zones, average speed, and changes in speed (accelerations and decelerations) in various team sports, including football (US: soccer) (Scott et al., 2016). Technical-tactical and physical analysis of modern match play informs the training process by making a comparison between competition and training prescription in all aspects (Harper et al., 2019; Wass et al., 2019). Thus, coaches can better understand the required intensity of certain football-specific drills and comprehend each player's activity profile to a higher extent (Carling et al., 2008; Delaney et al., 2018). The main goal of comparing game physical demands to training is to ensure players receive optimal physical stimulus relative to competition and positional demands to maximize their physical performance and reduce injury risk (Novak et al., 2021; Riboli, Esposito et al., 2021).

It is crucial to understand how match physical metrics are presented, not only to describe the volume of activity over the full, half, and/or quarter of the game, but to truly reflect intensity over shorter duration windows (Delaney et al., 2018; Novak et al., 2021). To depict intensity during different moments of the game and assess worst-case scenarios (WCS), data can be analyzed during attacking/defending phases, in ball possession (ball-in-play), using shorter periods of predetermined durations, and applying a rolling average during different time windows (e.g., 1 to 15 min) (Novak et al., 2021; Weaving et al., 2022). Football is unpredictable; events and actions happen randomly and do not usually occur during predetermined phases (Delaney et al., 2018). Hence, using fixed durations to assess WCS lacks sensitivity and might underestimate true running demands up to ~ 25% (Fereday et al., 2020). Rolling averages compared to fixed time epochs across different durations could be more accurate and appropriate to calculate locomotor load during peak match demands in professional football (Fereday et al., 2020; Martín-García et al., 2018; Riboli, Esposito et al., 2021; Riboli, Semeria et al. 2021). The moving average approach considers the intermittent nature of football and the natural variability within the game (Whitehead et al., 2018). These WCS are often characterized by high-intensity actions, occurring at intermittent moments, often impacted by contextual and situational factors (Oliva-Lozano et al., 2020). Varying durations of WCS have been analyzed in soccer, and shorter periods have been shown to produce the highest physical outputs (Martín-García et al., 2018).

The multifactorial WCS concept has recently been questioned due to its instability and difficulty to be applied in

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practical settings (Novak et al., 2021). Despite new findings about match peak demands distribution (Riboli, Esposito et al., 2021), our knowledge about what happens during these peak intensity passages with regards to technical-tactical activities as well as physiological adaptations (internal response) is scarce (Novak et al., 2021). Such research could enable coaches and practitioners to integrate physical and tactical aspects in training design to best prepare athletes for the position-specific high-intensity periods within a modern game (Bortnik et al., 2022). Regrettably, the current literature focuses on how to design and deliver WCS training merely based on one physical metric (i.e., total distance per minute), which has been considered a limitation since the high physical stress players are exposed to during these peak phases would not be fully reflected (Martín-García et al., 2018). Importantly, WCS, although maximal in matches, might not truly represent players' maximal aerobic capacity nor speed, and therefore should never be used by practitioners as a substitute for running drills based on physiological markers (e.g., $VO_{2max}$ and lactate threshold), commonly used as intensity indicators in physical preparation training in football (Weaving et al., 2022).

It has been reported that different WCS time epochs appear far greater than the soccer match mean values, especially for high-velocity activities and sprinting actions (Riboli, Semeria et al., 2021). Logically, mean values include periods of inactivity and all stoppages, which severely underestimates the locomotor and mechanical intensity of competition (Martín-García et al., 2019). A recent study found that most distances covered at various speed zones, and acceleration/deceleration efforts were performed at an intensity above the average 90-min demands (Riboli et al., 2021). This shows how important it is to apply high-intensity work in training, and use regular mechanical exposure to high speed and specific conditioning drills to reduce injury risk and prepare players physically for specific demands (Novak et al., 2021; Riboli, Esposito et al., 2021). Differences across various playing positions during the most physically demanding passages in soccer have also been reported, and thus positions should always be considered in the WCS concept (Martín-García et al., 2018; Riboli, Semeria et al., 2021). Moreover, future studies should provide better understanding of players' status differences (starting vs. substitute players) as well as analyze differences between congested and noncongested periods during peak intensity periods in soccer (Jiménez et al., 2022; Novak et al., 2021). This information would be considered important for coaches and practitioners for optimal top-up session design as well as adequate workload application and recovery strategy during the weekly microcycle (Novak et al., 2021; Riboli, Semeria et al., 2021).

It has been shown in soccer that central sessions of the microcycle, such as match day minus three (MD-3), have been the most demanding days of the week (Morgans et al., 2023). We refer to it as the "football conditioning day." Coaches seek to replicate and/or overload different physical metrics (distances in various speed zones, sprint, accelerations, and decelerations) on that day by using small-sided (SSGs), medium-sided, and large-sided games (LSGs); possession; and transitional games; and pressing activities, which all reflect high specificity (Oliva-Lozano et al., 2022). Recently, the WCS between training and match play in elite soccer was compared and significant differences were discovered in all physical metrics (total distance, high-speed running, and sprint distance) across all days of the week, including MD-3 (Oliva-Lozano et al., 2022). Different game formats have also been compared to match day peak intensity blocks across different time epochs. In fact, SSGs exposed players to lower locomotor load compared to competition, while overloading the mechanical load (accelerations and decelerations) (Lacome et al., 2018). This suggests that players might not be conditioned appropriately to meet the demands placed on them during match play and, in particular, the physical stresses imposed during WCS.

Given the limited number of articles on the peak intensity periods in elite soccer, more work is required for both training and game scenarios to answer many questions and better inform training prescriptions regarding the WCS concept. Specifically, research has mainly studied time epochs of durations from 1 to 10 min (Weaving et al., 2022) and, knowing that elite soccer teams perform high-tempo attacking actions below 20 sec, and peak durations of crucial attacking/defending activities (transitions) last between 20 and 30 sec (Bortnik et al., 2022), more focus should be paid to shorter duration epochs (e.g., 30 sec). These short periods could offer more football-specific ways to expose players to maximum physical outputs they achieve in competition (Bortnik et al., 2022). Also, short running-based exercises (short high-intensity intervals and repeated sprints) have been commonplace in soccer training and associated with better sprinting performance (Nobari et al., 2023). Thus, it could be reasonable to suggest that regular mechanical exposure to high-velocity activities in training might offer many benefits linked to improved football performance, increased readiness to play, and potentially lower risk of injury (Bortnik et al., 2022). Moreover, coaches and practitioners are limited today to basic and commonly used physical variables (locomotor and mechanical) to reflect match demands in training during short maximum intensity periods (Bortnik et al., 2022; Riboli, Semeria et al., 2021). Additional metrics comparing match play and training intensity should be explored. Our study is unique and novel since it includes additional physical data (Max Acc and Max Dec) and, for the first time, analyses physical match and training performance during 30-sec maximum intensity periods in different situational and contextual scenarios, which could potentially add more practical value to soccer training design. Therefore, the current study aims to (a) compare 90-min demands to mean and peak 30-sec WCS in different metrics per minute; (b) investigate physical outputs in WCS during selected football-specific drills and assess positional differences between MD-3 and competition; (c) explore differences between starters and nonstarters during WCS; and (d) measure the impact of different recovery periods between games (long vs. moderate vs. congested period) on match day WCS.

## Materials and methods

### Participants

Thirty-one ($n = 31$) Israel Premier League male outfield players from a top three team in the country were monitored in 37 ($n = 37$) competitive matches across two consecutive seasons: 2021–2022 and 2022–2023 from February to October. Players were classified according to playing positions: center backs ($n = 4$), fullbacks ($n = 5$), central midfielders ($n = 10$), wingers ($n = 6$), and attackers ($n = 6$). Both starters ($n = 3,063$ individual observations) and nonstarters ($n = 846$ individual observations) were included in the study and their outputs compared. Starters completed minimum 60 min, while nonstarters (subs) entered the game in the 2nd half and played minimum 5 min (i.e., including stoppage time) and maximum 45 min (Hills et al., 2022). Players needed to participate in MD-3, MD-2, and MD-1 sessions and match play to be included in the study. Only comparisons between match and training performance were made with players who participated in an official match; other players were excluded from analysis. The study was approved by the Ethics Committee of the University of Central Lancashire. All participants provided written and verbal informed consent for the use of their GPS data in accordance with the Declaration of Helsinki.

### Procedures and experimental design

A total of 37 ($n = 37$) competitive games were analyzed. Both match day (MD) and match day minus three (MD-3) physical data were collected during this period. A total of $n = 3,909$ individual observations were extracted from all matches. To compare match to training performance, 13 MD ($n = 13$) played in the late evening (between 19:00 and 21:00) and 14 MD-3 ($n = 14$) sessions conducted in the morning (between 9:00 and 10:00) were investigated, giving a total of $n = 1,533$ match observations and $n = 1,860$ training observations. The comparisons were averaged across all training sessions and matches for each playing position. Training sessions are commonly categorized according to days prior a match (MD minus (-)) and postmatch (MD plus (+)) (Morgans et al., 2023). Our study analyzed only a conditioning day in the coaches' weekly schedule (MD-3). This day integrated technical, tactical, and physical components and aimed to overload different physical outputs in relation to individual match physical demands. In addition, tagging 30-sec periods for each participant (explained below) was labor extensive; hence, only MD-3 was included in our study. The following number of observations per positions were recorded: center backs ($n = 701$), fullbacks ($n = 421$), central midfielders ($n = 1223$), wingers ($n = 525$), and attackers ($n = 325$). Matches were categorized according to number of recovery days between matches: (a) long-period: >6 days ($n = 12$); (b) moderate-period: 5–6 days ($n = 10$); and (c) congested-period: ≤4 days ($n = 15$) (Djaoui et al., 2022). Physical performance data were captured using portable MEMS (10 Hz; Vector X7, Catapult Sports, Melbourne, Australia), which were worn between players' scapulae under a playing/training jersey in a custom-designed vest. This reflected routine monitoring strategies in the club and all players were familiar with it. Each subject wore the same device throughout the study to avoid interunit variation. The MEMS units were turned on at least 15 min prior to the start of session warmups to ensure acceptable satellite coverage. As previously suggested, the data were checked for satellite coverage and horizontal dilution of precision (HDOP) using an inclusion criterion of > 6 satellites and ≤ 1.0, respectively (Malone et al., 2017). The validity and reliability of this system have been reported previously, indicating excellent intraunit reliability (Scott et al., 2016). ICC values varied between 0.77 (95% CI: 0.62–0.89) (very large) to 1.0 (95% CI: 0.99–1.0) (nearly perfect) for the measurement of physical outputs such as distances at different velocity bands (Nicolella et al., 2018). For mechanical load, these devices have shown acceptable reliability for accelerations (CV = 1.4 ± 1.5% to 4.2 ± 1.5%), and acceptable to poor reliability for decelerations (CV = 2.5 ± 1.5% to 10.9 ± 1.5%) (Thornton et al., 2019).

Variables studied were previously used by others (Bortnik et al., 2022; Riboli, Semeria et al., 2021; Wass et al., 2019) and represented the following metrics covered per minute ($m \cdot min^{-1}$): total distance (TD), high-speed running distance (HSRD, >19.8 $km \cdot h^{-1}$), and sprint distance (SD, >25.2 $km \cdot h^{-1}$). In addition, number of the following actions were quantified: accelerations and decelerations (A+D, >3 $m \cdot s^{-2}$; $n \cdot min^{-1}$), accelerations (Acc, >3 $m \cdot s^{-2}$; $n \cdot min^{-1}$), and decelerations (Dec, <−3 $m \cdot s^{-2}$; $n \cdot min^{-1}$). Also, the value of maximum acceleration (Max Acc; $m \cdot s^{-2}$) and deceleration (Max Dec; $m \cdot s^{-2}$) was analyzed.

Once the session (training and game) had concluded, the data were transferred to the manufacturer's software package (*Openfield*, version 3.7.3) to extract training and 90-min match data. Extra time was excluded from analysis. The software used rolling moving average to calculate the most demanding 30-sec period (WCS—worst case scenario) of each participant for total distance—TD ($m \cdot min^{-1}$). To include all above metrics for analysis, 30-sec periods/tags were manually created on top of these individual peak intensity passages by the club's analysis department. In contrast to the generally adopted technique to analyze different metrics in isolation during WCS, this strategy allows us to observe locomotor demands in conjunction with accelerations and decelerations during the maximum intensity intervals in soccer match play (Novak et al., 2021; Sydney et al., 2023). For match day minus three (MD-3), 30-sec WCS were named after a drill they occurred in and were used to analyze and compare peak intensity periods between different exercises utilized in training. Finally, data were exported into Microsoft Excel (Microsoft Corporation, USA) to make additional calculations for all peak intensity periods. The mean 30-sec period ($WCS_{mean}$) for selected variables was calculated as the sum total of all observations, divided by their number. To compute the peak 30-sec period ($WCS_{peak}$), the highest values for all metrics in each game were found, and their average was calculated as the sum of all peak values, divided by their number.

### Statistical analysis

The study used descriptive analysis, and the results are depicted as mean ± standard deviation (SD). Between-matches coefficient of variation (CV) values were calculated for 30-sec blocks during different recovery periods for all metrics.

Inferential statistical analyses were performed using the 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 30-sec period, position, players' status (starters and nonstarters), and recovery period (long-, moderate-, and congested-period). Interaction effects were also quantified, and any significant main effects associated with periods, positions, status, and recovery periods were investigated using Bonferroni 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 standardized residuals. Scatterplots of the stacked unstandardized and standardized residuals were also utilized 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 ($\eta^2$) 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

Displayed in Table 1 are the mean, standard deviations, and 95% confidence intervals (CI) for TD (m·min$^{-1}$), HSRD (m·min$^{-1}$), SD (m·min$^{-1}$), A+D (n·min$^{-1}$), Acc (n·min$^{-1}$), Dec (m·min$^{-1}$), Max Acc (m·s$^{-2}$), and Max Dec (m·s$^{-2}$) for $WCS_{mean}$ and $WCS_{peak}$, respectively, and 90-minute averages for each of the listed metrics.

Table 2 highlights drills performed on match day minus three (MD-3), their level of specificity, area size, and characteristics. Comparisons between $WCS_{peak}$ in training and competition for TD (m·min$^{-1}$), HSRD (m·min$^{-1}$), SD (m·min$^{-1}$), A+D (n·min$^{-1}$), Acc (n·min$^{-1}$), Dec (m·min$^{-1}$), Max Acc (m·s$^{-2}$), and Max Dec (m·s$^{-2}$) for different playing positions can be seen in Figure 1. Figure 2 shows differences between $WCS_{mean}$ in drills, match day as well as 90-min averages for selected physical metrics.

Comparison between starters and nonstarters in match day $WCS_{mean}$ and $WCS_{peak}$ for TD (m·min$^{-1}$), HSRD (m·min$^{-1}$), SD (m·min$^{-1}$), Acc (n·min$^{-1}$), and Dec (m·min$^{-1}$) is displayed in Figure 3.

**Table 1.** Team mean ± SD and 95% confidence intervals for total distance: TD (m·min$^{-1}$), high speed running distance: HSRD (m·min$^{-1}$), sprint distance: SD (m·min$^{-1}$), number of accelerations and decelerations: A+D (n·min$^{-1}$), number of accelerations: Acc (n·min$^{-1}$), number of decelerations: Dec (n·min$^{-1}$), maximum acceleration: Max Acc (m·s$^{-2}$), maximum deceleration: Max Dec (m·s$^{-2}$), and differences (%) between whole-match (90-min), mean and peak 30sec WCS across 37 official matches.

| | 90-min | | $WCS_{mean}$ | | $WCS_{peak}$ | | Percentage (%) | |
|---|---|---|---|---|---|---|---|---|
| | Mean ± SD | 95%CI | Mean ± SD | 95%CI | Mean ± SD | 95%CI | 90-min vs $WCS_{mean}$ | 90-min vs $WCS_{peak}$ |
| TD (m) | 101.4 ± 4.3 | 100.0 to 102.8 | 174.3 ± 8.0 | 171.3 to 177.0 | 203.8 ± 12.0 | 199.8 to 207.8 | 58.2 | 49.8 |
| HSRD (m) | 5.7 ± 1.1 | 5.3 to 6.1 | 29.7 ± 6.4 | 27.6 to 31.8 | 54.6 ± 8.9 | 51.6 to 57.6 | 19.2 | 10.4 |
| SD (m) | 1.1 ± 0.3 | 1.0 to 1.2 | 7.7 ± 2.9 | 6.7 to 8.7 | 21.4 ± 7.2 | 19.0 to 23.8 | 14.3 | 5.1 |
| A+D (n) | 2.4 ± 0.3 | 2.3 to 2.5 | 4.1 ± 0.4 | 4.0 to 3.9 | 6.3 ± 1.2 | 5.9 to 6.7 | 58.5 | 38.1 |
| Acc (n) | 1.2 ± 0.1 | 1.16 to 1.24 | 2.0 ± 0.2 | 1.9 to 2.1 | 3.3 ± 0.6 | 3.1 to 3.5 | 60.0 | 36.4 |
| Dec (n) | 1.2 ± 0.1 | 1.15 to 1.25 | 2.0 ± 0.2 | 1.9 to 2.1 | 3.3 ± 0.6 | 3.1 to 3.5 | 60.0 | 36.4 |
| Max Acc | 5.1 ± 0.6 | 4.9 to 5.3 | 3.8 ± 0.2 | 3.7 to 3.9 | 4.7 ± 0.4 | 4.6 to 4.8 | 134.2 | 108.5 |
| Max Dec | −6.5 ± 0.6 | −6.7 to −6.3 | −4.5 ± 0.3 | −4.6 to −4.4 | −6.0 ± 0.6 | −6.2 to −5.8 | 144.4 | 108.3 |

**Table 2.** Selected drills performed on MD-3 (match day minus three), their technical-tactical level of specificity, area size, content, and characteristics.

| Drills | Exercise mode | Level of technical-tactical specificity (Chena et al., 2022) | Area size | Content and characteristics of each drill | Duration range | Bouts range |
|---|---|---|---|---|---|---|
| 10v10 Medium | Large-sided game | High specificity | 170–200 m2 medium space | 10v10 training games continously played on a medium space with two keepers. Players keep their positions and normal game rules apply. | 8–20 min | 2 to 3 |
| 10v10 Transitions | Large-sided tactical game | | 200–250 m2 medium—large space | 10v10 training intermittent games played on a large space with two keepers. Players keep a ball possession in a small-medium space and attempt to exploit a free space behind the defense line to quickly get into the opposition box. Five players attack and three players defend. | 3–6 min | 4 to 6 |
| 5v5 | Small-sided game | Moderate—high specificity | 128–160 m2 small—medium space | 5v5 games continously played on a small-medium space with two keepers. Players are not assigned to playing positions. All balls are distributed by keepers. | 3–5 min | 3 to 4 |
| 4v4 | | | 120–160 m2 small—medium space | 4v4 games continously played on a small-medium space with two keepers. Players are not assigned to playing positions. All balls are distributed by keepers. | 3–4 min | 4 to 5 |
| Extra | Top-ups—high velocity runing with changes of direction | Minimum specificity | box to box – 75 meters | Box-to-box (around 75 m) runs alternated with box-to-half pitch-to-box (around 38 m) runs. Each effort lasts between 12 and 15 seconds and it is interspersed with 24- to 30-second recovery period (1:2 work to rest ratio) | 12–15 sec | 8 to 12 |
| Submax runs | High velocity shuttles | | 50 meters | 50-meter straight-line shuttles lasting 7–8 seconds (22–25 km/h) interspersed with 22-second recovery period (1:3 work to rest ratio) | 7–8 sec | 8 to 10 |

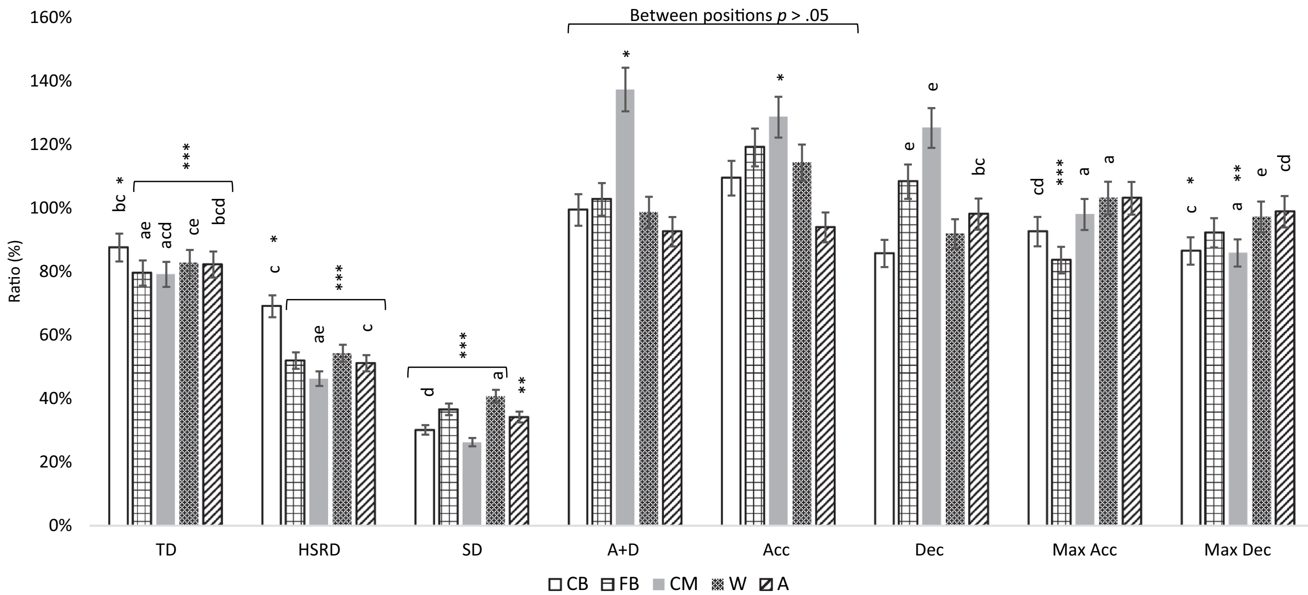


Figure 1. The ratio (%) of training (MD-3 $WCS_{peak}$) and competition (MD $WCS_{peak}$) for CB (Center Back), FB (Full Back), CM (Central Midfielder), W (Winger), and A (Attacker) in total distance: TD (m·min$^{-1}$), high-speed running distance: HSRD (m·min$^{-1}$), sprint distance: SD (m·min$^{-1}$), number of accelerations/decelerations: A+D (n·min$^{-1}$), number of accelerations: Acc (n·min$^{-1}$), number of decelerations: Dec (n·min$^{-1}$), maximum acceleration: Max Acc (m·s$^{-2}$), and maximum deceleration: Max Dec (m·s$^{-2}$). Note: Significant differences [a] CB, [b] FB, [c] CM, [d] W, and [e] A ($p < .05$). Different from MD * $p < .05$; ** $p < .01$; *** $p < .001$. MD-3 is match day minus three; MD is match day; $WCS_{peak}$ is peak 30-secperiod (worst case scenario).

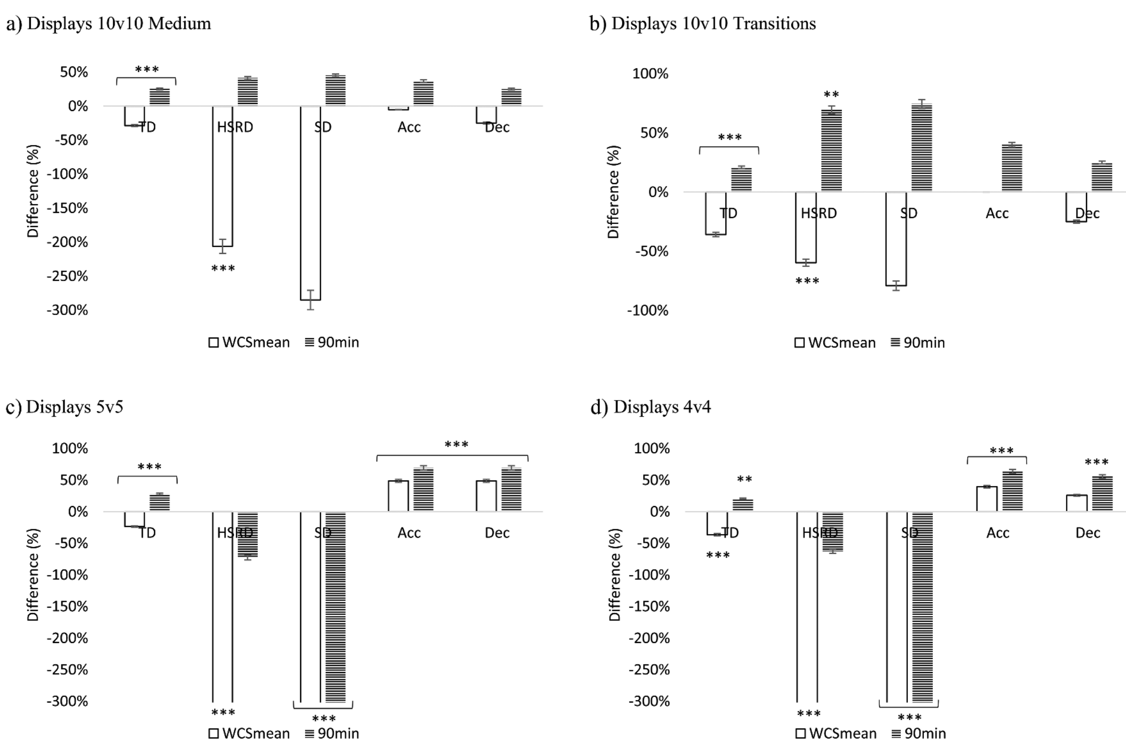


Figure 2a. Differences (%) between drill $WCS_{mean}$ vs match day $WCS_{mean}$ (white bar) and drill $WCS_{mean}$ vs 90-min average demands (horizontal stripes bar) in total distance: TD (m·min$^{-1}$), high-speed running distance: HSRD (m·min$^{-1}$), sprint distance: SD (m·min$^{-1}$), number of accelerations: Acc (n·min$^{-1}$), and number of decelerations: Dec (n·min$^{-1}$). Note: Significant differences from drill $WCS_{mean}$ * $p < .05$; ** $p < .01$; *** $p < .001$ Drills were performed on match day minus three (MD-3).

Table 3 depicts all analyzed physical metrics for match day $WCS_{mean}$ in long-period (>6 days), moderate-period (5–6 days), and congested-period (≤4 days), accompanied by the mean, standard deviations, confidence interval (CI), and match-to-match variability of the listed physical variables.

### *90-min versus $WCS_{mean}$ vs $WCS_{peak}$*

Significant effects of period ($WCS_{mean}$, $WCS_{peak}$, 90-min) were found for all analyzed metrics: TD (m·min$^{-1}$), HSRD (m·min$^{-1}$), SD (m·min$^{-1}$), A+D (n·min$^{-1}$), Acc (n·min$^{-1}$), Dec (m·min$^{-1}$), Max Acc (m·s$^{-2}$), and Max Dec (m·s$^{-2}$) (large ESs; $p \leq .001$).

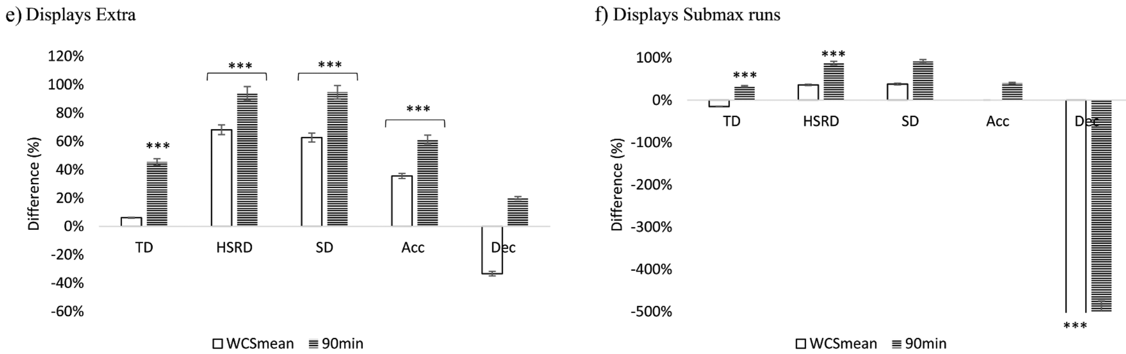


**Figure 2b.** (Continued).

## *Positional differences in $WCS_{peak}$ between training and competition (MD-3 vs. MD)*

Main effects of position were found on TD ($m{\cdot}min^{-1}$), HSRD ($m{\cdot}min^{-1}$), SD ($m{\cdot}min^{-1}$), A+D ($n{\cdot}min^{-1}$), Acc ($n{\cdot}min^{-1}$), Dec ($m{\cdot}min^{-1}$), Max Acc ($m{\cdot}s^{-2}$), and Max Dec ($m{\cdot}s^{-2}$) (TD: $F(4,124) = 13.663$, $p < .001$, partial $\eta^2 = .306$; HSRD: $F(4,124) = 4.834$, $p = .001$, partial $\eta^2 = .135$; SD: $F(4,124) = 3.724$, $p = .007$, partial $\eta^2 = .107$; Dec: $F(4,124) = 4.149$, $p = .003$, partial $\eta^2 = .118$; Max Acc: $F(4,124) = 3.986$, $p = .004$, partial $\eta^2 = .114$; Max Dec: $F(4,124) = 6.768$, $p < .001$, partial $\eta^2 = .179$). No main effects were found for A+D ($n{\cdot}min^{-1}$) and Acc ($n{\cdot}min^{-1}$) ($p > .05$). There was a game x time interaction for Max Acc ($m{\cdot}s^{-2}$) $F = 4{,}124$, $p = .013$, partial $\eta^2 = .096$). No interactions of position x session were discovered for TD ($m{\cdot}min^{-1}$), HSRD ($m{\cdot}min^{-1}$), SD ($m{\cdot}min^{-1}$), A+D ($n{\cdot}min^{-1}$), Acc ($n{\cdot}min^{-1}$), Dec ($n{\cdot}min^{-1}$), and Max Dec ($m{\cdot}s^{-2}$) ($p > .05$). Further analysis for all individual positions revealed significant differences between training and competition for TD ($m{\cdot}min^{-1}$), HSRD ($m{\cdot}min^{-1}$), and SD ($m{\cdot}min^{-1}$) ($p < .05$). No differences were detected in A+D ($n{\cdot}min^{-1}$), Acc ($n{\cdot}min^{-1}$), and Dec ($m{\cdot}min^{-1}$) for all positions ($p > .05$) except CM. Difference in Max Acc ($m{\cdot}s^{-2}$) between MD and MD-3 was only present for FB ($p < .001$), whereas CB and CM revealed significance in Max Dec ($m{\cdot}s^{-2}$) ($p > .05$).

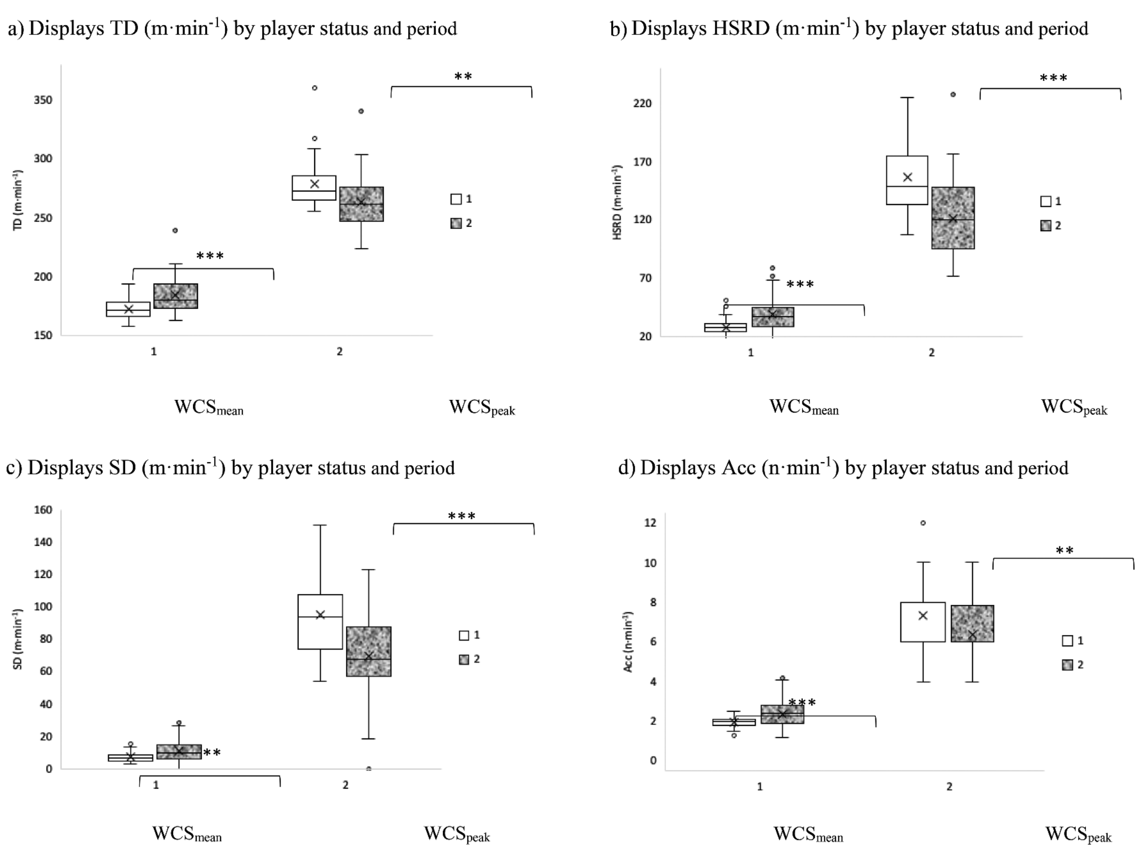


**Figure 3a.** Clustered boxplots with mean and outliers comparing Starters (1 - white) and Non-Starters (2 - granite) during MD $WCS_{mean}$ and MD $WCS_{peak}$ in a) total distance: TD ($m{\cdot}min^{-1}$), b) high-speed running distance: HSRD ($m{\cdot}min^{-1}$), c) sprint distance: SD ($m{\cdot}min^{-1}$), d) number of accelerations: Acc ($n{\cdot}min^{-1}$), and e) number of decelerations: Dec ($n{\cdot}min^{-1}$), f) maximum acceleration: Max Acc ($m{\cdot}s^{-2}$), and g) maximum deceleration: Max Dec ($m{\cdot}s^{-2}$) across 37 games. Note: Significant difference * $p < .05$; ** $p < .01$; *** $p < .001$. MD is match day; $WCS_{mean}$ is mean 30-secperiod; $WCS_{peak}$ is peak 30-secperiod.

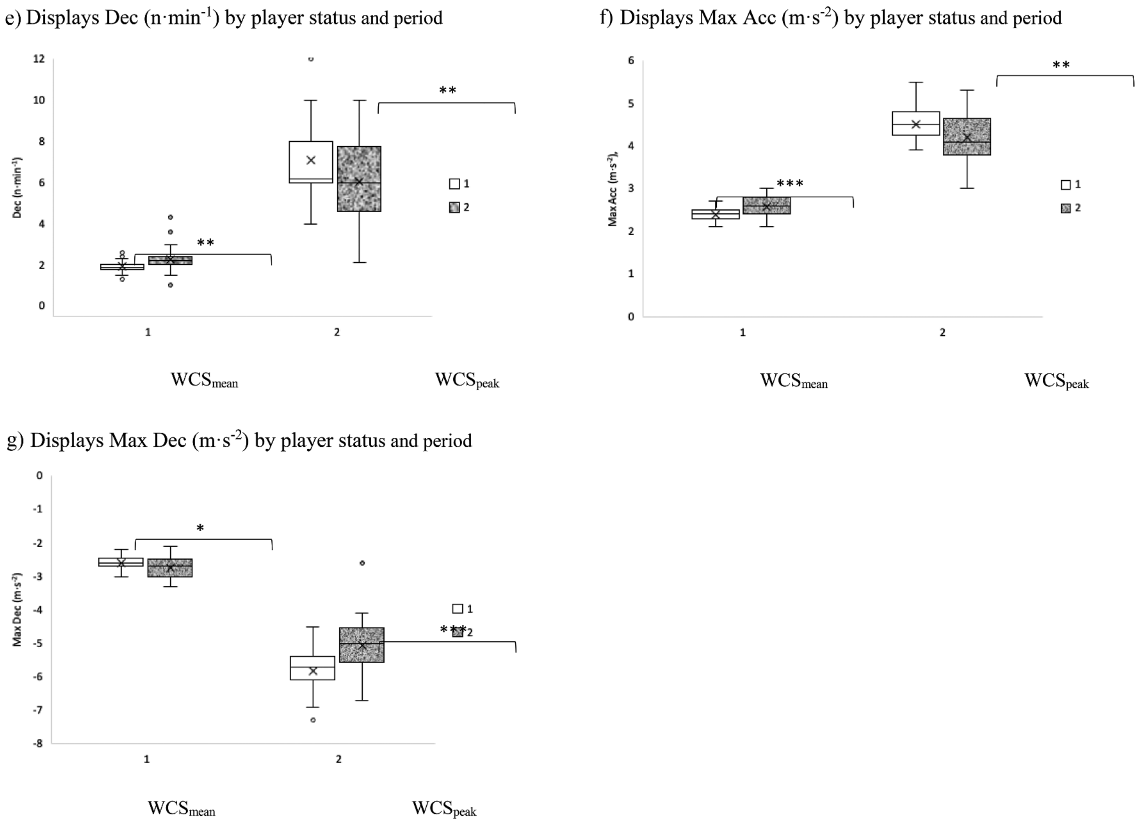


**Figure 3b.** (Continued).

**Table 3.** Team mean ± SD, 95% confidence intervals, and coefficient of variation: CV (%) in periods of long-period (>6days), moderate-period (5-6days), and congested-period (≤4days recovery) during mean 30sec WCS for for total distance: TD (m·min$^{-1}$), high speed running distance: HSRD (m·min$^{-1}$), sprint distance: SD (m·min$^{-1}$), number of accelerations and decelerations: A+D (n·min$^{-1}$), number of accelerations: Acc (n·min$^{-1}$), number of decelerations: Dec (n·min$^{-1}$), maximum acceleration: Max Acc (m·s$^{-2}$), maximum deceleration: Max Dec (m·s$^{-2}$) across 37 official matches.

| | $WCS_{mean}$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | LONG-PERIOD (>6 days) (*n* = 12) | | | MODERATE-PERIOD (5–6 days) (*n* = 10) | | | CONGESTED-PERIOD (≤4 days) (*n* = 15) | | |
| | Mean ± SD | 95%CI | CV (%) | Mean ± SD | 95%CI | CV (%) | Mean ± SD | 95%CI | CV (%) |
| TD (m) | 174.6 ± 10.6 | 170.1 to 179.1 | 6.1 | 176.0 ± 14.1 | 169.4 to 182.6 | 8.0 | 181.8 ± 16.8 | 175.6 to 188.1 | 9.2 |
| HSRD (m) | 30.0 ± 7.2 | 33.0 to 36.0 | 24.1 | 32.2 ± 10.7 | 27.2 to 37.2 | 33.2 | 36.6 ± 15.6 | 30.8 to 42.5 | 42.6 |
| SD (m) | 7.9 ± 3.3 | 6.5 to 9.3 | 41.3 | 7.9 ± 4.4 | 5.8 to 9.9 | 55.4 | 10.2 ± 6.7 | 7.7 to 12.7 | 65.8 |
| A+D (n) | 4.6 ± 1.2 | 4.2 to 5.0 | 25.8 | 4.2 ± 0.7 | 3.7 to 4.6 | 15.9 | 4.1 ± 0.9 | 3.8 to 4.4 | 20.8 |
| Acc (n) | 2.4 ± 0.6 | 2.1 to 2.6 | 26.7 | 2.1 ± 0.4 | 1.9 to 2.4 | 19.8 | 2.0 ± 0.5 | 1.9 to 2.3 | 26.3 |
| Dec (n) | 2.3 ± 0.6 | 2.1 to 2.5 | 27.2 | 2.0 ± 0.3 | 1.8 to 2.3 | 13.9 | 2.0 ± 0.4 | 1.8 to 2.2 | 22.0 |
| Max Acc | 2.5 ± 0.2 | 2.4 to 2.6 | 8.2 | 2.5 ± 0.2 | 2.4 to 2.6 | 9.0 | 2.4 ± 0.2 | 2.3 to 2.5 | 9.8 |
| Max Dec | −2.7 ± 0.3 | −2.8 to −2.6 | 9.7 | −2.7 ± 0.2 | −2.8 to −2.6 | 8.6 | −2.6 ± 0.3 | −2.7 to −2.5 | 9.9 |
| Overall | | | 22.8 | | | 20.5 | | | 25.8 |

*Note:* Significant differences from congested periods # ($p \leq .05$). Number of games are displayed as n.

### *Starters versus nonstarters ($WCS_{mean}$ and $WCS_{peak}$)*

Significant effects of player status (starters or nonstarters) were found in $WCS_{mean}$ for TD (m·min$^{-1}$), HSRD (m·min$^{-1}$), SD (m·min$^{-1}$), A+D (n·min$^{-1}$), Acc (n·min$^{-1}$), Dec (m·min$^{-1}$), Max Acc (m·s$^{-2}$) (large ESs; $p < .001$). Only Max Dec (m·s$^{-2}$) revealed moderate ESs; $p = .013$.

In addition, significant effects of player status were found in $WCS_{peak}$ for all analyzed metrics (moderate to large ESs; $p \leq .005$).

### *$WCS_{mean}$ in long-period versus moderate-period versus congested-period*

No main effects of recovery period between games were found on any metrics ($p > .05$). Post hoc tests showed significant differences between the long-period (>6 days) and congested-period (≤4 days recovery) for A+D (n·min$^{-1}$) and Dec (m·min$^{-1}$) ($p \leq .05$). Other metrics did not show any significant differences between recovery period ($p > .05$).

## Discussion

The main purpose of the present study was to analyze and explore 30-sec $WCS_{mean}$ and $WCS_{peak}$ in an elite soccer team. Rationale for selecting 30-sec periods for analysis was based on our recent studies, which revealed that transitions frequently occurred repeatedly as clusters (between 3 and 5 activities within 1 min) lasting on average around 30 sec (Bortnik, Bruce-Low et al., 2023; Bortnik, Burgerr et al., 2023). To the authors' knowledge, this is the first study to investigate and compare 30-sec peak training to match demands in soccer and introduce new metrics for analysis such as Max Acc and Max Dec ($m \cdot s^{-2}$). Main findings discovered that during these short time windows, football-specific drills used by coaches in conditioning sessions failed to replicate high-velocity and maximum deceleration actions relative to match peak demands across all playing positions. However, acceleration and deceleration demands were adequately imposed in training. Significantly higher metrics were discovered only in central midfielders for A+D, Acc, and Dec (137%, 129%, and 125%, respectively) between MD and MD-3. The findings highlight the importance of prescribing running-based drills for starting and nonstarting players in team conditioning, individual top-up, and return to play sessions. This exercise was found to be the only mode to overload high-speed running and sprinting metrics, which might better mechanically prepare players to sprint and cover distances at higher velocity in matches, potentially improving football performance and lowering the risk of injury (Ekstrand et al., 2023). Our study showed that during congested fixture periods, accelerations and decelerations should be closely monitored in training and games since these mechanical metrics were significantly lowered in peak intensity blocks in competition. This emphasizes the detrimental effect of fatigue on eccentric muscle abilities, effective breaking, and quality movement in tight spaces during congested periods in soccer (Djaoui et al., 2022; Rhodes et al., 2021).

### *Peak demands in relation to 90-min averages*

Findings revealed that all periods ($WCS_{mean}$ vs $WCS_{peak}$ vs. 90-min) significantly differed in all physical metrics. The greatest discrepancies for $WCS_{peak}$ were present for HSRD ($m \cdot min^{-1}$) and SD ($m \cdot min^{-1}$), which constituted 10.4% and 5.1%, respectively, of the average match demands. TD ($m \cdot min^{-1}$) was around 50%, while A+D ($n \cdot min^{-1}$) was just below 40% of the whole-match mean. Interestingly, competition averages generated higher than $WCS_{mean}$ Max Acc and Dec by 34.2% and 44.4%, respectively, which could indicate that highest values of acceleration and deceleration occurred at other phases of the game. These findings are lower than the 1-min peak periods data reported by Riboli, Semeria et al. (2021) across different positions, but consistent with others who determined similar differences between 90 minaverage demands and the 1-min peak values for TD, HSRD, and SPD (~50%, ~10%, and ~ 5%, respectively) for all playing positions (Oliva-Lozano et al., 2023). Hence, how we analyze physical metrics guides whether players are meeting demands of the game (Bortnik et al., 2023; Martín-García et al., 2019). Indeed, a recent body of work revealed that during transitional activities players covered greater distances per minute than reported for $WCS_{peak}$ in our study: ~ 290 m versus 204 m (with ~165 m vs. 55 m considered to be high-speed running, and ~84 m vs. 21 m to be sprinting) and performed an equal number of accelerations and decelerations per min (~5) (Bortnik et al., 2022). In this regard, more studies answering "WHY" and not only "WHAT" should be conducted by investigating contextualized blocks of high-intensity activities to better inform/guide coaches and practitioners and integrate physical with technical-tactical aspects in contemporary training design (Ju et al., 2023).

### *Training in relation to competition*

All locomotor variables (TD, HSRD, SD) during training were insufficiently imposed on all playing positions, which is consistent with other research (Oliva-Lozano et al., 2022). Large discrepancies were identified for SD ($m \cdot min^{-1}$) across all positions in $WCS_{peak}$. Central midfielders received only 26%, center backs 30%, attackers 34%, fullbacks 37%, and wingers 41% of the competition sprint distance. A novel finding of the current investigation was that the Max Dec ($m \cdot s^{-2}$) value was also lower for all positions in training $WCS_{mean}$/$WCS_{peak}$, especially for center backs and central midfielders, reaching 86% of competition $WCS_{peak}$. Deficits between match play and training might potentially fatigue players to a greater extent and place these positional groups at higher risk of injury in matches if muscles are not adequately stressed and adapted to specific demands of competition in training (Ekstrand et al., 2023; Rhodes et al., 2021). Hence, it could be suggested to use collective high-intensity efforts in activities aiming to provide support to offensive players and then rapidly switch to recovery runs during defensive transitions (Ju et al., 2023). Special attention might be paid to center backs and central midfielders to expose them to maximum efforts during these transitions (Bortnik et al., 2024). Maximum Acc ($m \cdot s^{-2}$) on MD-3 was similar to the MD $WCS_{peak}$, with only fullbacks falling below to 84%. Again, this shows that training failed to provide an adequate amount of maximum acceleration actions in this positional group, which could possibly underprepare them for specific demands of competition and increase risk of injury (Bengtsson et al., 2018). Full backs have a unique tactical role to provide support by over/underlapping movements in possession while performing recovery runs out of possession, both occurring at high velocity (Bortnik et al., 2024; Ju et al., 2023). Therefore, these two tactical phases could be initiated by maximum acceleration movements to ensure this positional group receives adequate acceleration stimuli in training. In general, more attention could be paid for covering greater distances (TD, HSRD, SD; $m \cdot min^{-1}$) and including maximum deceleration actions in training across all positions. Regular mechanical exposure to high-velocity and high-intensity activities could better replicate match peak intensity and condition players for these demanding periods (Nobari et al., 2023). More work is required in this area.

### Drills in relation to competition

Coaches integrate technical-tactical and physical aspects in training usually by selecting football-specific modes of exercise (Barrett et al., 2020; Moniz et al., 2020; Oliva-Lozano et al., 2022), which could compromise and lower the physical outputs (Weaving et al., 2022) as it can be seen in our body of work. Our results reported that all high-intensity locomotor demands during all games were far lower than the match $WCS_{mean}$. Only 10v10 Transitions overloaded the whole-match average HSRD ($m{\cdot}min^{-1}$) by nearly 70%. Small-sided games (5v5 and 4v4) produced 30 to 50% higher Acc and Dec ($n{\cdot}min^{-1}$) relative to match $WCS_{mean}$, which is in accordance with other research (Lacome et al., 2018; Riboli et al., 2023). It has been recommended to use larger areas in different game formats, utilize transition games with large spaces, and complement football-specific drills with additional positional exercises and running-based activities to truly reflect HSRD and SD relative to the match play demands (Bortnik et al., 2022; Riboli et al., 2023). In fact, our study revealed "Extra" (top-up high-velocity action with changes of direction) and "Submax runs" being the only exercise modes that overloaded MD $WCS_{mean}$ high-velocity metrics (HSRD, SD) by ~ 60% and ~ 36%, respectively. Also, "Extra" elicited 35% and 61% higher than $WCS_{mean}$ and 90-min acceleration demands, respectively. Hence, it might be effectively used to increase mechanical stress on players when SSGs could not be performed. For instance, this mode could be utilized for subs and bench players right after competition to compensate match demands and overload locomotor and mechanical demands. Indeed, high-velocity actions and frequent exposure to higher speed have been linked to reduced likelihood of noncontact injuries and have been determined a key action leading to goal-scoring opportunities in soccer (Beato et al., 2021; Faude et al., 2012). Our study also found positional differences during various soccer-specific drills performed on MD-3 and, hence, an individualized approach would be best to replicate/overload individual WCS (Lacome et al., 2018). More work should be done in this area by investigating other exercise modes and comparing them to shorter WCS time epochs found in official matches.

### Starting and substitute players

There has been a plethora of studies in soccer comparing 90-min external/internal load differences between starting and nonstarting players (Bradley & Noakes, 2013; Liu et al., 2020; Los Arcos et al., 2017). But research analyzing playing status during WCS in soccer is scarce (Fereday et al., 2020; Sydney et al., 2023). Our results showed nonstarters (subs) generating higher physical output in all metrics analyzed during $WCS_{mean}$ compared to starting players. These findings are consistent with others who reported greater TD ($m{\cdot}min^{-1}$) covered by nonstarters over shorter peak periods (1-, 2-min), and higher HSRD ($m{\cdot}min^{-1}$) in all time epochs (Delaney et al., 2018; Fereday et al., 2020). A feasible explanation for lower outputs detected in starters would be self-pacing strategy (conscious or subconscious) adopted to minimize the physical effort and preserve energy over the course of match play (Bradley & Noakes, 2013). In turn, subs have been shown to display more aggressive pacing behavior compared to starters due to their knowledge regarding exercise/match duration in which they have to make an impact on team performance by achieving a higher physical effort (Ferraz et al., 2018). Since substitutes are expected to bring about higher effort comparing to starters, the importance of high-intensity warmup preceding the match entry should be highlighted and emphasized. Previous investigations reported insufficient preparation or a decrease in body temperature post-warmup impacting physical performance of substitute players (Hills et al., 2021). Substitutes should be provided with optimal physical and tactical preparation preentry to make the best impact on the team performance (Hills et al., 2021). Our further and novel findings revealed nonstarters covering lower distances (TD, HSRD, SD: $m{\cdot}min^{-1}$), performing less high-intensity accelerations and decelerations (Acc, and Dec: $n{\cdot}min^{-1}$), and generating lower values of Max Acc and Dec ($m{\cdot}s^{-2}$) compared to starting players in $WCS_{peak}$. These results are consistent with Sydney et al. (2023), who also showed lower peak physical demands experiences in nonstarters. In fact, subs might not be subjected to the most demanding passages of match playand, hence, may have less opportunities to reach maximum intensity (running outputs), which was reported in the opening ~ 10 to 15 min postkickoff (Bradley & Noakes, 2013; Hills et al., 2022). Therefore, knowing maximum intensity periods of all players could help practitioners to design a more accurate training program (top-up conditioning sessions) and adequate recovery strategy, ensure optimal preparation/readiness for competition demands, have less discrepancies in total weekly load, and reduce risk of injury (Ekstrand et al., 2023; Hills et al., 2022). Both starting and substitute players should be frequently exposed to maximum intensity in training (speed, max accelerations, and decelerations) to be able to maintain a higher physical output (nonstarters) and withstand peak match demands (starters). Thus, it would be reasonable to suggest repeated sprint training: < 10 sec all-out short sprint sequences for starters and short high-intensity-interval training: < 45 sec submaximal efforts for nonstarters (Buchheit & Laursen, 2013; Nobari et al., 2023). Future work should determine and distinguish best exercise modes for these groups.

### Congested fixture period

Short recovery time between subsequent matches has been associated with high physical stress resulting in fatigue, decreased tactical behavior, and higher risk of muscle injury; hence, coaches should individualize load prescription and recovery, and use rotation strategy during congested periods (Ekstrand et al., 2023; Julian et al., 2021). Despite unchanged locomotor metrics across 90-min (Carling et al., 2012), it has been shown that accelerations/decelerations, and time spent accelerating/decelerating were significantly lowered during a congested fixture period in youth and elite soccer players (Djaoui et al., 2022; Rhodes et al., 2021). Research investigating peak match demands during congested periods in elite soccer is limited (Jiménez et al., 2022), so this work is paramount to add to the body of literature. Previous studies did not reveal significant differences in physical outputs during WCS between noncongested and congested periods, which might indicate that players pace their physical effort during 90 min to preserve their energy for peak intensity passages (Bradley & Noakes, 2013). Our findings showed that only accelerations/decelerations (A+D; n·min$^{-1}$) and Dec (n·min$^{-1}$) significantly decreased in $WCS_{mean}$ during congested periods, which is contradictory to previous WCS studies highlighted earlier, but consistent with literature analyzing the whole-match performance (Djaoui et al., 2022; Rhodes et al., 2021). Indeed, accelerations and decelerations alongside high-speed running and sprint distance have been recently perceived as important indicators of high intensity demands of soccer training and competition (Ju et al., 2023). It is worth noting that quick changes of direction, which produce high eccentric muscle actions, have been found more physically stressful than high-velocity activities (Delaney et al., 2018) and recommended as a reliable tool to assess match physical performance and fatigue in soccer (Djaoui et al., 2022; Mohr et al., 2016). Decelerations have also been shown to occur more frequently than accelerations in soccer competition regardless of match result (Harper et al., 2019; Rhodes et al., 2021). Since contemporary football imposes high-velocity actions and rapid changes of direction in small and tight areas, it is of paramount importance to monitor A+D performance and apply high-intensity decelerations in training. This might better prepare soccer players for competition demands and potentially reduce detrimental effect of fatigue on their abilities to fulfill their positional tasks and tactical responsibilities across the whole-match duration and peak intensity passages (Harper et al., 2019; Rhodes et al., 2021).

### *Match-to-match-variability*

Further novel findings of our body of work showed that match-to-match variability of locomotor variables (e.g., SD) during the congested-period was highest compared to long-, and moderate-periods (65.8% vs. 41.3% vs 55.4%, respectively). Our results are greater compared to previous studies reporting variability of physical performance during peak intensity periods in soccer for high-intensity metrics such as SD and A+D, but similar for TD and HSRD (Bortnik et al., 2022; Riboli, Semeria et al., 2021; Thoseby et al., 2022). This might be accounted for due to shorter duration WCS in our investigation, which could provide higher unpredictability in match play compared to longer time epochs and display the real challenge of modern soccer training design in practice (Gregson et al., 2010).

### *Limitations*

Only one team was analyzed in our study, no technical-tactical data were presented, nor was team formation reported. Future studies should include additional contextual factors such as game status (win, draw, loss), scoreline, match location (home, away), match half, and substitution timing, players' rotations, and recovery strategies. Deeper knowledge about contextual factors not included in our study would allow more holistic approach to verify physical performance during peak intensity periods in soccer. Other situational factors such as opponents' level/ranking could also be included. Moreover, internal load (RPE, HR) during peak match demands should be considered (Sydney et al., 2023). Furthermore, we explored only absolute metrics, and future studies should analyze relative locomotor and mechanical variables to describe individual physical capabilities more accurately, which might provide greater insight into injury incidence. Finally, our body of work analyzed only MD-3 sessions and other days of the week should also be explored in the future.

## Conclusions

In conclusion, it is of high importance that soccer coaches use not only data from 90-min averages to reflect match volume in training but also combine intensity footballers experience during peak intensity periods to better guide their training prescription, top-up conditioning and return-to-play sessions. This study is unique as it contributes to the existing body of knowledge in soccer about physical performance during WCS of shorter duration (30 sec), analyzing positional differences and assessing impact of different drills on physical performance during these phases. However, it also proposes additional metrics such as maximum acceleration and deceleration for more accurate training design. High discrepancies were identified between the match and training overload phase, highlighting a slightly different approach needed to take place to truly reflect and better prepare all positions for the high-intensity/velocity demands of competition, and minimize the risk of injury. We found starters were being exposed to maximum intensity ($WCS_{peak}$), whereas nonstarters were generating higher effort during the entire bout of activity ($WCS_{mean}$). This could suggest that the gap between training and match play for maximum intensity actions was even greater in substitute players. Finally, significant differences between the long-period and congested-period were determined for A+D and Dec. Our findings might serve high value to coaches, practitioners, and physical therapists in ensuring training demands better match playing demands, especially in periods of WCS.

## Practical applications

In football conditioning sessions, practitioners could pay more attention to total distances covered and high-velocity actions (HSRD, SD) regardless of playing position. They could include more activities generating maximum decelerations for center backs and central midfielders and expose fullbacks to maximum accelerations to truly reflect match play demands during short peak intensity blocks. This could be achieved by using rapid changes from offensive to defensive activities (transitions) in team/individual training prescription. Regarding the drill selection, in addition to football-specific exercises (SSGs) that adequately reflect/overload mechanical metrics during WCS, running-based drills could be utilized as an effective strategy to minimize discrepancies between training and match play peak demands, especially in terms of high-speed and sprinting exposure. Repeated sprint training: < 10 sec all-out short sprint sequences might be used for starters to reach peak intensity and short high-intensity-interval training: < 45 sec submaximal efforts for nonstarters to maintain high physical effort over short duration activities. Furthermore, the running-based drills with change of direction might be applied postmatch during a compensatory session for bench and substitute players. On MD-3, LSG could be utilized if coaches' objective was to overload 90-min total distance (running demands). However, if the goal was to surpass the whole-match high-velocity demands (HSRD and SD), then transitional LSGs could be selected. Accelerations and decelerations should be monitored during a weekly microcycle, especially during a period of congested fixture to assess potential fatigue, inability to recover between matches, and higher risk of muscle injury.

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