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Season-long worst-case scenario analysis of peak high-intensity locomotor demands in English League One professional soccer players

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ABSTRACT

This study examined positional differences, match-to-match variability, and seasonal exposure to peak locomotor demands in professional soccer players. Global positioning system (GPS) data were collected from 24 outfield players across 46 matches (600 player – match observations). Peak high-speed distance (HSD), sprint distance (SD), and acceleration – deceleration density (AD) were quantified using fixed 1-minute worst-case scenarios (WCS), expressed as absolute values and relative to each player's individual seasonal maximum (%iWCS). Peak HSD and AD differed by position ($p < 0.05$), with central midfielders exceeding centre-backs by +10.49 m·min^{-1} for HSD, while strikers demonstrated greater AD (+0.48 AU·min^{-1}). No positional differences were observed for SD ($p = 0.357$). Within-player variability ranged from 22–28% (HSD), 45–62% (SD), and 23–42% (AD). Mean relative exposure remained below individual maxima across positions (HSD: 63–69%; SD: 41–49%; AD: 45–60% iWCS), with near-maximal exposures (≥85% iWCS) occurring in only 5–20% of observations. Peak locomotor demands were largely independent of match outcome and location. These findings indicate that worst-case scenario demands are position-specific, highly variable, and infrequently reach near-maximal levels during competition. Practitioners should consider both absolute and relative measures when interpreting peak match demands and ensure that training exposes players to the upper range of observed intensities.

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Peak intensity; load monitoring; match analysis; peak demands; sprint distance

1. Introduction

High-intensity locomotor actions (HILAs), including high-speed running, sprinting, and rapid accelerations and decelerations, play a decisive role in match-defining moments in professional soccer. These actions frequently occur during transitional and pressing phases and underpin goal-scoring opportunities, defensive recoveries, and momentum-shifting sequences (Daly et al., 2025; Martínez-Hernández et al., 2023). In addition to their

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performance relevance, HILAs contribute substantially to neuromuscular fatigue and mechanically induced tissue stress, with implications for recovery and injury risk (Dupont et al., 2010; Nédélec et al., 2012). As such, the systematic quantification of these actions is essential to inform training prescription, optimise recovery strategies, and reduce injury risk in professional soccer.

In applied settings, practitioners commonly quantify match demands using whole-match average locomotor metrics. For example, players typically cover approximately 150–250 m of sprint distance during a match (Bradley et al., 2009; Di Salvo et al., 2010). However, these average values may underestimate the most demanding passages of play, which are more relevant for training design, return-to-play processes, and injury risk management. To address this limitation, worst-case scenario (WCS) approaches are widely used to identify the highest physical outputs observed within short time periods during match play (McGrath et al., 2026; Allen et al., 2024; Núñez-Sánchez et al., 2023; Whitehead et al., 2018). These time windows typically range from 1 to 10 minutes, with shorter epochs (e.g. 1 minute) capturing transient peak intensities and longer epochs (e.g. 3-, 5-, and 10-minute periods) reflecting more sustained high-demand passages (Suárez-Arrones et al., 2021). Importantly, WCS values represent absolute peak outputs rather than averaged values. This distinction is critical, as reliance on averaged locomotor metrics may underestimate the most demanding passages of play and potentially lead to under-preparation in training prescription (Mandorino & Lacome, 2024a, 2024b).

Previous research has demonstrated that WCS demands vary according to playing position, reflecting the tactical and spatial requirements of different roles (Lobo-Triviño et al., 2025; Morgans et al., 2025; Bortnik et al., 2024; Whitehead et al., 2018). For example, central midfielders and full-backs consistently demonstrate greater high-speed running WCS demands due to their involvement across both attacking and defensive phases, whereas strikers and wide players may exhibit greater sprinting or acceleration-based peak demands during high-intensity passages (Lobo-Triviño et al., 2025; Morgans et al., 2025). However, much of this work has been conducted over short competitive periods or limited match samples, restricting understanding of how stable these peak demands are across an entire season.

In addition to positional differences, peak locomotor demands may be influenced by contextual variables such as match outcome and match location. These factors have been shown to influence whole-match physical outputs, with higher running demands sometimes observed in losing or away conditions (Castellano et al., 2025; Filter et al., 2023). However, their influence on short-duration peak demands remains less clear. Understanding whether contextual variables meaningfully affect WCS is important for determining whether peak demands can be anticipated based on match conditions or whether they should be considered inherently variable and unpredictable.

Another limitation of current approaches is the reliance on absolute WCS values, which may obscure meaningful inter-individual differences. Players may achieve similar absolute peak outputs while operating at different relative intensities. Expressing peak demands relative to an individual's seasonal maximum (%iWCS) may therefore provide additional insight into how frequently players operate near their highest observed match intensities (Castellano et al., 2025; Filter et al., 2023; Oliva-Lozano et al., 2023; Silva et al., 2025). This approach may help practitioners distinguish between routine and truly demanding match exposures and provide a more individualised interpretation of peak load.

Despite growing interest in WCS approaches, within-player match-to-match variability and the frequency of exposure to near-maximal peak demands across a full competitive season remain poorly understood (Núñez-Sánchez et al., 2023; Polglaze et al., 2020). From an applied perspective, understanding both the magnitude and variability of peak demands is critical for informing training design and load management. Without this information, practitioners may risk over- or under-prescribing high-intensity training stimuli.

Therefore, the aims of this study were to: (1) quantify absolute 1-minute WCS demands for high-speed distance, sprint distance, and acceleration – deceleration density across playing positions during match play; (2) express these demands relative to each player's individual seasonal maximum (%iWCS); and (3) characterise within-player match-to-match variability and the frequency of exposure to near-maximal WCS demands across a full competitive season, including the influence of match outcome and location. It was hypothesised that peak demands would differ by position, demonstrate substantial within-player variability, and occur infrequently at near-maximal levels during match play. In addition, contextual variables such as match outcome and match location may influence peak demands, although their effects on short-duration WCS remain unclear.

2. Methods

2.1. Study design

A retrospective observational design was used to examine peak locomotor demands during match play across a full competitive season. Data were collected from 46 English Football League One matches during the 2024–2025 competitive season involving a single professional team. Match locomotor data were segmented into fixed, non-overlapping 1-minute epochs, with the highest value per match retained as the WCS, consistent with previous applied research (Delaney et al., 2018; Díez et al., 2025). Fixed epochs were selected in line with applied performance workflows and the structure of exported GPS data within the club environment. While rolling-average methods may capture higher peak values (Núñez-Sánchez et al., 2023), fixed epochs provide a consistent and practically interpretable approach for practitioners, supporting ecological validity in applied settings.

2.2. Participants

Twenty-four male outfield players from a professional English Football League One team participated (age: 25.8 ± 4.2 years; height: 181.2 ± 6.5 cm; body mass: 77.3 ± 8.9 kg; professional experience: 5.1 ± 2.7 years), contributing 600 player – match observations. Positional distribution was: centre backs (CB, $n = 5$), full-backs (FB, $n = 5$), central midfielders (CM, $n = 7$), wide midfielders (WM, $n = 5$), and strikers (ST, $n = 2$). Observations were included where players completed ≥ 15 minutes of match play and contributed ≥ 5 eligible matches across the season. The ≥ 15-minute threshold was applied to ensure sufficient exposure for players to reach representative peak locomotor values, as shorter playing durations may reduce the likelihood of attaining maximal outputs. However, it is acknowledged that peak values are inherently influenced by exposure duration, and this criterion may bias the sample towards players with greater match involvement. Goalkeepers were excluded due to their distinct positional demands. The team primarily competed in a 4–3-3 formation, providing contextual relevance for positional interpretation. Data were collected as part of routine performance monitoring, anonymised prior to analysis, and approved for research use by the club. Ethical approval was granted by the University of Lancashire Research Ethics Committee (Ref: HEALTH 01147).

2.3. Procedures

2.3.1. Data collection

Locomotor data were collected using 10-Hz Catapult Vector S7 global positioning system (GPS) units with integrated 100-Hz triaxial accelerometers (Catapult Sports, Melbourne, Australia). These systems demonstrate acceptable validity and inter-unit reliability for quantifying high-speed running, sprinting, and acceleration-based demands in professional soccer (Akyildiz et al., 2024; Delaney et al., 2015; Scott et al., 2016). Where possible, players wore the same device across matches, which was achieved in approximately 85–90% of observations, reflecting a high level of consistency in unit allocation. In instances where this was not feasible, standardised allocation procedures were applied in accordance with club practice to minimise inter-unit variability. Data were downloaded post-match using Catapult OpenField software (v2.5.3) and exported as fixed, non-overlapping 1-minute epochs. All match data, including regulation and stoppage time, were included in the analysis. Files were retained if mean satellite count was ≥ 10. Data were visually inspected for signal dropouts and implausible spikes, with particular scrutiny of epochs contributing to WCS values, in line with recommended quality-control procedures (Shergill et al., 2021).

2.4. Study variables

2.4.1. Worst-case scenario (WCS)

WCS values were defined as the highest locomotor output observed within any 1-minute epoch for a given player during a match. Three WCS variables were extracted:

- *High-speed distance (HSD; $m{\cdot}min^{-1}$)*: distance covered at speeds between 5.5–7.0 $m{\cdot}s^{-1}$
- *Sprint distance (SD; $m{\cdot}min^{-1}$)*: distance covered at speeds > 7.0 $m{\cdot}s^{-1}$
- *Acceleration – deceleration density (AD; $AU{\cdot}min^{-1}$)*: average absolute acceleration per minute

Speed thresholds were selected in accordance with previous literature (Gualtieri et al., 2023). Acceleration – deceleration density was calculated from all locomotor acceleration and deceleration efforts exceeding ±2 $m{\cdot}s^{-2}$ with a minimum dwell time of 0.5 s, ensuring that only sustained locomotor actions were captured and not transient spikes or collision-related artefacts, reflecting overall speed-change intensity during peak passages (Moreno-Azze et al., 2025).

2.4.2. Relative worst-case scenario (%iWCS)

Individual worst-case scenario (iWCS) was defined as the highest match-derived WCS value achieved by each player across the season for each variable. All %iWCS values were calculated at the individual player level prior to aggregation, ensuring consistency in relative exposure calculations across positional and contextual analyses. Match-level WCS values were then expressed relative to this individual maximum (%iWCS):

$$\%iWCS = \frac{\text{matchWCS}}{\text{individual seasonal maximum}} \times 100$$

This approach provides an individualised measure of relative intensity, enabling comparison of match demands relative to each player's peak observed capacity (Castellano et al., 2025; Filter et al., 2023; Oliva-Lozano et al., 2023; Silva et al., 2025). However, as iWCS is derived from a single maximal value, it may be sensitive to outliers and should be interpreted with this limitation in mind as it is derived from a single maximal observation.

2.4.3. Near-maximal exposure

Near-maximal exposure was defined as match observations in which WCS values reached ≥ 85% of iWCS. This threshold was used to identify instances where players were exposed to demands approaching their highest observed match-derived intensities. The proportion of observations exceeding this threshold was calculated for each variable.

2.4.4. Contextual variables

Contextual variables included:

- *Playing position*: CB, FB, CM, WM, ST
- *Match outcome*: win, draw, loss
- *Match location*: home vs away

These variables were included to examine potential contextual influences on peak locomotor demands (Castellano et al., 2025; Filter et al., 2023).

2.5. Statistical analysis

All statistical analyses were conducted using jamovi (version 2.7.18; The Jamovi Project), with linear mixed-effects models fitted using the GAMLj module.

2.5.1. Positional differences

Linear mixed-effects models were used to examine positional differences in absolute WCS locomotor demands (HSD, SD, AD). Playing position (centre-back, full-back, central midfielder, wide midfielder, striker) was included as a fixed effect, with player identity specified as a random intercept to account for repeated observations and unbalanced data. Estimated marginal means and 95% confidence intervals (CI) were calculated, with pairwise comparisons conducted where appropriate. Effect sizes (Hedges' g) were calculated to quantify the magnitude of between-group differences and interpreted as trivial (<0.2), small (0.2–0.6), moderate (0.6–1.2), and large (>1.2).

2.5.2. Contextual analyses

Separate linear mixed-effects models were conducted to examine the influence of match outcome (win, draw, loss) and match location (home vs away) on WCS variables. Each contextual variable was included as a fixed effect, with player identity retained as a random intercept. These models were conducted independently to avoid overparameterisation given the sample size and structure of the dataset.

2.5.3. Model diagnostics

Model assumptions were assessed via visual inspection of residual plots. No substantial violations of normality or homoscedasticity were observed.

2.5.4. Within-player variability

Within-player match-to-match variability was quantified using coefficients of variation (CV%), calculated for each player across all eligible matches as:

$$CV\% = \left(\frac{\text{standard deviation}}{\text{mean}}\right) \times 100$$

Individual CV% values were then averaged within positional groups for descriptive comparison.

2.5.5. Relative exposure

Relative WCS exposure (%iWCS) was calculated for all player – match observations. The proportion of observations exceeding the ≥85% iWCS threshold was calculated for each variable and expressed descriptively. Statistical significance was set at $p < 0.05$. In line with contemporary recommendations, interpretation prioritised effect sizes and confidence intervals rather than p-values alone.

3. Results

3.1. Absolute worst-case scenario (WCS) demands by playing position

Mean absolute 1-minute WCS values for high-speed distance (HSD), sprint distance (SD), and acceleration – deceleration density (AD) by playing position are presented in Table 1.

3.2. High-speed distance

Peak high-speed running demands differed by playing position ($p = 0.022$). Compared with centre-backs (CB), central midfielders (CM) demonstrated higher peak HSD (+10.49 m·min^{-1}, 95% CI 4.90–16.10, $p = 0.002$, g = 0.80 [moderate]). Full-backs (FB; +8.65 m·min^{-1}, 95% CI 2.64–14.70, $p = 0.010$, g = 0.60 [small – moderate]), strikers (ST; +8.27 m·min^{-1}, 95% CI 0.63–15.90, $p = 0.048$, g = 0.55 [small – moderate]), and wide midfielders (WM; +7.12 m·min^{-1}, 95% CI 1.16–13.10, $p = 0.030$, g = 0.50 [small]) also exhibited higher peak HSD than CB.

Table 1. Absolute and relative worst-case scenario (WCS) locomotor demands by playing position.

Position	No. of Players	Sample Size	WCS–HSD ($m{\cdot}min^{-1}$)	WCS–SD ($m{\cdot}min^{-1}$)	WCS–AD ($AU{\cdot}min^{-1}$)	HSD %iWCS (%)	SD %iWCS (%)	AD %iWCS (%)	≥85% iWCS–HSD (%)	≥85% iWCS–SD (%)	≥85% iWCS–AD (%)
CB	5	115	38.93 ± 9.40	23.73 ± 12.60	1.09 ± 0.24	67.7 ± 15.9	48.1 ± 25.1	60.1 ± 13.3	15.7	10.4	6.1
FB	5	110	47.55 ± 13.72*	32.21 ± 15.69	1.31 ± 0.43†	67.2 ± 18.5	49.0 ± 22.9	50.2 ± 16.3	20.0	6.4	5.5
CM	7	185	49.75 ± 14.24*	25.86 ± 16.13	1.23 ± 0.39	63.0 ± 18.1	40.5 ± 23.6	51.8 ± 17.1	11.9	7.0	4.9
WM	5	121	45.27 ± 13.58*	31.28 ± 18.55	1.39 ± 0.58*	63.5 ± 19.0	40.9 ± 23.7	48.1 ± 19.1	15.7	5.0	7.4
ST	2	69	47.32 ± 9.93*	32.57 ± 14.50	1.65 ± 0.77*	69.0 ± 14.7	45.3 ± 20.0	44.5 ± 19.3	14.5	5.8	7.2

Abbreviations: CB = centre backs; FB = full-backs; CM = central midfielders; WM = wide midfielders; ST = strikers; WCS = worst-case scenario; HSD = high-speed distance; SD = sprint distance; AD = acceleration–deceleration density; iWCS = individual worst-case scenario.

Notes: Sample size refers to player–match observations. Values are presented as mean ± SD. %iWCS represents relative exposure to each player's individual worst-case scenario.

Effect sizes are reported in the Results section.

3.3. Sprint distance

No effect of playing position was observed for peak sprint distance during WCS passages ($p = 0.357$), with substantial overlap in confidence intervals across all positional groups.

3.4. Acceleration–deceleration density

Peak acceleration – deceleration density differed by playing position ($p = 0.020$). Relative to CB, strikers demonstrated higher AD (+0.48 AU·min^{-1}, 95% CI 0.21–0.75, $p = 0.003$), while wide midfielders also exhibited higher values (+0.31 AU·min^{-1}, 95% CI 0.09–0.52, $p = 0.012$). Full-backs showed a borderline difference compared with CB (+0.23 AU·min^{-1}, 95% CI 0.01–0.45, $p = 0.050$), whereas no difference was observed for CM ($p = 0.180$).

3.5. Relative worst-case scenario (%iWCS)

Mean relative WCS exposure (%iWCS) across positions is presented in Table 1, with seasonal patterns illustrated in Figure 1.

Across all locomotor metrics, mean relative exposure during peak 1-minute passages remained below individual seasonal maxima. When examined by playing position (Table 1), mean values ranged from 63–69% for HSD, 41–49% for SD, and 45–60% for AD. Individual match observations approaching or reaching 100% iWCS were observed, although these occurred infrequently. Near-maximal exposure (≥85% iWCS) occurred in 12–20% of observations for HSD, 5–10% for SD, and 5–7%

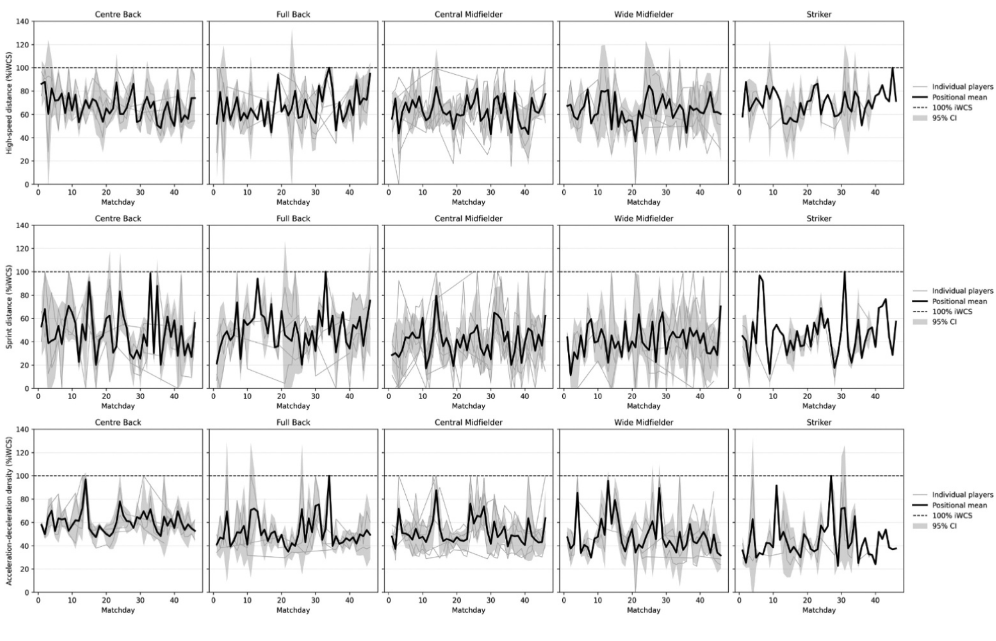

Figure 1. Match-to-match variation in relative locomotor demands (%iWCS) across positions. High-speed distance (top), sprint distance (middle), and acceleration–deceleration density (bottom) are shown across matchdays. Grey lines represent individual players, the black line the positional mean, shaded areas the 95% CI, and the dashed line 100% iWCS.

for AD. These exposures were distributed intermittently across the season, with no clear clustering within specific phases. Visual inspection of Figure 1 indicated considerable descriptive overlap in relative exposure between positional groups; however, no formal inferential analysis was conducted for %iWCS.

3.6. Contextual influences on WCS demands

Peak locomotor demands according to match outcome and match location are presented in Table 2.

Absolute WCS values for HSD, SD, and AD were comparable across match outcomes (win, draw, loss), with only trivial differences observed between conditions. Linear mixed-effects modelling revealed no significant effect of match outcome on any locomotor variable (all $p > 0.05$), with negligible variance explained (marginal $R^2 \leq 0.003$). Similarly, peak locomotor demands were comparable between home and away matches. Higher mean values for HSD and SD were observed in away fixtures; however, considerable overlap in variability across conditions suggests that these differences were small and not statistically meaningful. No significant effect of match location was observed for any locomotor variable (all $p > 0.05$).

The %iWCS values presented in Table 2 were carefully rechecked and confirmed to be correct. The higher values observed relative to Table 1 reflect differences in data aggregation rather than inconsistencies in calculation. Specifically, Table 1 presents positional averages, where %iWCS values are first calculated at the individual player level and then summarised within positional groups. In contrast, Table 2 is based on pooled player – match observations across contextual conditions (match outcome and location), irrespective of position. This pooled approach results in different weighting of observations, whereby players with higher relative exposures or greater match involvement may contribute more strongly to the overall mean. Consequently, higher %iWCS values may emerge in Table 2 despite being derived from the same dataset.

Table 2. Peak worst-case scenario (WCS) locomotor demands according to match outcome and location.

Context	n	WCS–HSD ($m\cdot min^{-1}$)	WCS–SD ($m\cdot min^{-1}$)	WCS–AD ($AU\cdot min^{-1}$)	HSD %iWCS (%)	SD %iWCS (%)	AD %iWCS (%)
Outcome							
Win	307	46.75 ± 13.32	32.44 ± 18.35	1.33 ± 0.43	71.5 ± 15.8	63.0 ± 17.6	59.8 ± 16.5
Draw	77	46.14 ± 13.33	31.91 ± 18.67	1.31 ± 0.42	70.8 ± 16.4	61.5 ± 19.2	58.9 ± 17.1
Loss	216	45.13 ± 13.18	31.88 ± 18.08	1.33 ± 0.44	70.2 ± 16.2	61.9 ± 18.4	59.2 ± 16.8
Location							
Home	298	44.74 ± 13.91	30.75 ± 18.42	1.32 ± 0.44	69.5 ± 16.7	60.9 ± 18.4	58.7 ± 17.0
Away	302	47.43 ± 12.49	33.27 ± 17.99	1.33 ± 0.42	71.7 ± 15.4	63.3 ± 17.9	60.1 ± 16.2

Abbreviations: WCS = worst-case scenario; HSD = high-speed distance; SD = sprint distance; AD = acceleration–deceleration density; iWCS = individual worst-case scenario.

Notes: Values are mean ± SD; *n* = player–match observations. No significant differences between contextual conditions (all $p > 0.05$). %iWCS values are pooled across conditions and therefore differ from positional averages in Table 1 due to aggregation.

3.7. Within-player match-to-match variability

Within-player match-to-match variability in WCS values, quantified using coefficients of variation (CV%), is presented in Figure 2.

Across positional groups, mean CV% ranged from:

- 22–28% for HSD
- 45–62% for SD
- 23–42% for AD

Sprint distance consistently demonstrated the greatest variability across all positions, indicating substantial fluctuations in peak sprint exposure between matches. High-speed distance exhibited comparatively lower variability, while acceleration – deceleration density demonstrated moderate-to-high variability across positions. Statistical comparisons were not conducted for Figure 2, as the aim was to provide a descriptive overview of within-player variability rather than to infer between-position differences.

4. Discussion

The aim of this study was to examine absolute and relative (%iWCS) 1-minute WCS locomotor demands, alongside within-player match-to-match variability, across a full competitive season in professional soccer players. The main findings were that: (i) absolute peak demands differed by playing position for high-speed distance and

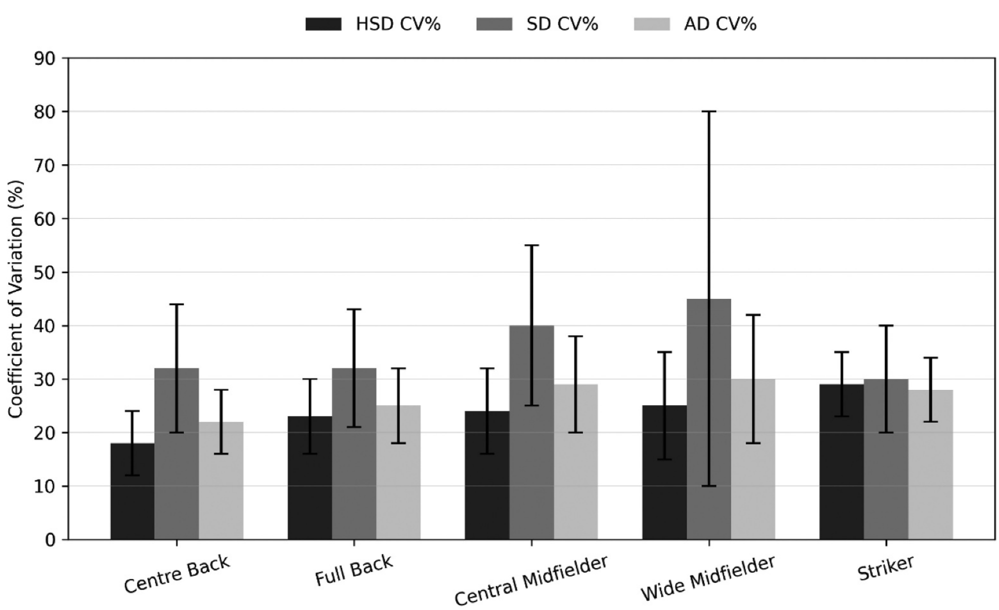

Figure 2. Within-player match-to-match variability (coefficient of variation, CV%) of worst-case scenario locomotor demands by playing position. High-speed distance (HSD), sprint distance (sd), and acceleration–deceleration density (ad) are presented as mean values for each positional group. Error bars represent ± standard deviation.

acceleration – deceleration density, but not sprint distance; (ii) peak demands were typically performed below individual seasonal maxima, with only intermittent exposure to near-maximal intensities; and (iii) substantial within-player variability was observed, particularly for sprint distance and acceleration-derived metrics. In addition, peak demands were largely independent of match outcome within the present dataset. Collectively, these findings indicate that WCS demands are position-specific, highly variable, and influenced by individual capacity rather than contextual match factors (García-Calvo et al., 2025).

Consistent with previous research, absolute WCS values for high-speed distance and acceleration – deceleration density demonstrated clear positional differentiation (Lobo-Triviño et al., 2025; Morgans et al., 2025; Whitehead et al., 2018). Central midfielders and full-backs exhibited greater peak high-speed running demands than centre-backs, likely reflecting their involvement across both attacking and defensive phases and the requirement to cover larger areas of the pitch at speed. In contrast, strikers and wide midfielders demonstrated higher peak acceleration – deceleration density, which may reflect frequent short, high-intensity actions such as pressing, directional changes, and explosive movements within confined spaces. These findings reinforce the importance of position-specific profiling of peak demands and support previous work highlighting the influence of tactical role on locomotor outputs (Lobo-Triviño et al., 2025; Morgans et al., 2025). However, the positional sample included only two strikers, and findings for this group should therefore be interpreted with caution. In contrast, no positional differences were observed for sprint distance, despite relatively high absolute values during peak passages. This supports the notion that sprinting actions are highly situational and influenced by transient match contexts, such as counterattacks, defensive recovery runs, or opposition behaviour, rather than being tightly coupled to positional role (Moreno-Azze et al., 2025; Myhill et al., 2025). From an applied perspective, this suggests that sprint-based WCS metrics may be less suitable as fixed positional benchmarks and may instead reflect stochastic exposure to match-specific scenarios. Accordingly, practitioners should exercise caution when using sprint-based WCS values in isolation to inform position-specific conditioning targets.

Expressing peak demands relative to each player's individual seasonal maximum (%iWCS) provided additional insight beyond absolute values. Across all metrics, mean relative exposure remained well below individual maxima, with the majority of observations performed below 85% iWCS. Notably, slightly higher relative exposure values were observed when data were aggregated across contextual variables, which likely reflects differences in grouping structure rather than true increases in peak intensity. Specifically, near-maximal exposures (≥85% iWCS) occurred in only 12–20% of observations for high-speed distance and less frequently for sprint distance (5–10%) and acceleration – deceleration density (5–7%). These findings align with previous research suggesting that players rarely operate at their highest match-derived intensities during competition (Oliva-Lozano et al., 2023; Silva et al., 2025). Importantly, players may achieve similar absolute WCS values while operating at different relative intensities, highlighting the limitation of relying solely on absolute metrics. Expressing demands relative to individual capacity therefore provides a more nuanced framework for interpreting peak exposure and may help inform decision-making in applied settings (Castellano et al., 2025; Filter et al., 2023). From an applied perspective, the infrequent attainment of ≥85% iWCS during match play suggests that competition alone may not consistently expose players to their highest observed locomotor demands. However, this study did not quantify training exposure or adaptive responses, and therefore this implication should be interpreted cautiously. Nonetheless, the findings support the inclusion of targeted training strategies to ensure that players are periodically exposed to high-intensity scenarios, particularly when preparing for the most demanding phases of match play or during return-to-play processes.

A key finding of the present study was the magnitude of within-player match-to-match variability in WCS values. Sprint distance demonstrated consistently high variability across all positions, while acceleration – deceleration density exhibited moderate-to-high variability. In contrast, high-speed distance showed comparatively lower, though still meaningful, variability. These differences likely reflect the underlying nature of each locomotor metric. Sprinting and acceleration-based actions are episodic and strongly influenced by tactical context, match state, and decision-making processes, whereas high-speed running may be more closely linked to sustained involvement in play. Similar variability patterns have been reported in previous research examining peak and whole-match locomotor outputs (Myhill et al., 2025; Polglaze et al., 2020). From a load-management perspective, these findings suggest that single WCS values may not adequately represent the range of demands experienced by players, and that variability should be considered when interpreting peak match data.

The contextual analyses indicated that peak locomotor demands were largely independent of match outcome. No significant differences were observed between wins, draws, and losses, suggesting that peak passages can occur regardless of match result. This is consistent with previous work demonstrating that high-intensity actions are often driven by transient phases of play rather than overall match outcome (Castellano et al., 2025). Similarly, match location had a limited influence on peak demands. Although slightly higher high-speed and sprint values were observed in away matches, these differences were small and accompanied by considerable overlap in variability. Taken together, these findings indicate that contextual factors such as outcome and location exert minimal influence on short-duration peak demands compared with positional role and the inherent variability of match play. The inclusion of acceleration – deceleration density extends the characterisation of WCS demands beyond traditional speed- and distance-based metrics. Acceleration and deceleration actions contribute substantially to mechanical load, neuromuscular fatigue, and tissue stress (Harper et al., 2019; Vanrenterghem et al., 2017), and are closely linked to decisive match events such as pressing and transitions (Daly et al., 2025; Varley & Aughey, 2013). In the present study, acceleration – deceleration density differentiated between positions and demonstrated considerable variability, supporting its sensitivity to the mechanical demands of peak passages. These findings reinforce the importance of incorporating acceleration-based metrics alongside traditional WCS measures to provide a more comprehensive representation of match demands (Rebollo-Mejía et al., 2025; Silva et al., 2024; Thoseby et al., 2023). Collectively, the present findings highlight that the value of WCS metrics lies not only in quantifying peak demand magnitude, but also in understanding how these demands vary across players and matches. Absolute WCS values provide useful positional benchmarks, while relative exposure (%iWCS) and variability metrics offer additional context for interpreting the significance of peak match demands. Integrating these approaches may provide a more ecologically valid framework for load monitoring and training prescription in professional soccer.

Several limitations should be acknowledged. First, fixed, non-overlapping 1-minute epochs were used to identify WCS, which may underestimate peak values compared with rolling-average approaches (Núñez-Sánchez et al., 2023). Second, iWCS was defined as the single highest match-derived value for each player, which may be sensitive to outliers and does not necessarily reflect a stable estimate of maximum capacity. Third, the ≥15-minute inclusion criterion may influence the likelihood of attaining peak values, potentially biasing results towards players with greater match exposure. Fourth, the study was conducted within a single team competing in English League One, which may limit the generalisability of the findings to other competitive levels or tactical contexts. Additionally, although the team primarily operated within a 4–3-3 system, no detailed analysis of tactical phases or playing styles was conducted, which may influence the occurrence of peak demands. The positional sample included only two strikers, which may limit the generalisability of findings for this position. As such, interpretations related to striker-specific demands should be made with caution given the small number of players in this position. Finally, only external load variables were examined; future research integrating internal load measures and tactical context may provide a more comprehensive understanding of the physiological and performance implications of WCS demands.

5. Conclusion

Peak 1-minute locomotor demands in this cohort of professional soccer players were position-specific and demonstrated substantial variability across a competitive season. While absolute WCS values differed between positions for high-speed distance and acceleration – deceleration density, sprint distance appeared less dependent on positional role and more influenced by situational match contexts. Across all metrics, peak match demands were typically performed below individual seasonal maxima, with near-maximal exposures (≥85% iWCS) occurring infrequently. These findings highlight the importance of considering relative measures of intensity (%iWCS), alongside absolute values, when interpreting peak match demands. In addition, the substantial within-player variability observed across matches suggests that single WCS values may not adequately represent the range of demands experienced during competition.

Within the context of a single English League One team, peak locomotor demands were largely independent of match outcome and only minimally influenced by match location, indicating that short-duration peak passages may be driven more by transient match dynamics than broader contextual factors. Overall, these findings support the use of a multidimensional approach to monitoring peak demands, incorporating absolute, relative, and variability-based metrics to better inform training design, load management, and return-to-play decision-making in professional soccer.

6. Practical applications

Practitioners should interpret WCS metrics as a range of demands rather than a single fixed value. Given the substantial match-to-match variability observed, training prescription should incorporate exposure to a spectrum of intensities, including both typical and peak scenarios, to better reflect the fluctuating demands of match play.

The infrequent occurrence of near-maximal exposures (≥85% iWCS) during matches suggests that competition alone may not consistently provide sufficient stimulus to prepare players for peak locomotor demands. Accordingly, practitioners may need to deliberately programme high-intensity drills within the weekly microcycle to ensure regular exposure to these demands, particularly for players with limited match minutes or during congested schedules.

Relative measures of peak intensity (%iWCS) can be used to contextualise individual match exposures and support decision-making in load monitoring and return-to-play processes. For example, practitioners may use %iWCS thresholds to assess whether players have been sufficiently exposed to high-intensity demands before progressing through rehabilitation stages or returning to full training.

Training design should also reflect positional and metric-specific demands. High-speed running and acceleration – deceleration demands demonstrated clear positional differences, suggesting that position-specific conditioning drills may be warranted. In contrast, sprint demands appeared highly variable and less position-dependent, indicating that sprint exposure may be better addressed through varied and scenario-based training rather than fixed positional targets.

Finally, given the limited influence of match outcome and location on peak demands, practitioners should not rely on contextual factors to drive exposure to high-intensity scenarios. Instead, deliberate planning of peak-demand exposures within training may be required to ensure consistent preparation for the most demanding phases of match play.

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P.M. designed the study, collected and analysed the data, and drafted the manuscript. D.H., J.A., and T.D. contributed to study design, interpretation of results, and manuscript revision. All authors approved the final manuscript.

Author contributions

CRediT: **Paul McGrath:** Writing – original draft; **Damian Harper:** Writing – review & editing; **Jill Alexander:** Writing – review & editing.

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Availability of data and material

Data are available from the corresponding author upon reasonable request.

Ethics approval

Ethical approval for this study was granted by the University of Lancashire Research Ethics Committee (Ref: HEALTH 01147).

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