Sprint and High-Speed Running in Soccer: Should We Use Absolute or Normalized Thresholds?

by
Ricardo Pimenta [1,2,3,4,], Hugo Antunes [3], Filipe Maia [1,2], João Ribeiro [1,5], Fábio Yuzo Nakamura [1,4]*

The present study compared absolute (ABS) and normalized (expressed as a percentage of maximum speed, %MS) high-speed running (HSR) and sprinting (SPR) thresholds in soccer matches, while also assessing positional differences both among and within playing positions. Twenty-four elite youth male soccer players (age: 19.4 ± 0.9 years, body mass: 75.6 ± 6.8 kg, body height: 1.8 ± 0.06 m) participated in this study. Normalized thresholds were defined for high-speed running as 55–70% MS, 60–75% MS, 70–85% MS, and 75–90% MS, while sprinting was categorized as >90 % MS and >95% MS. For absolute thresholds, ABS-HSR was defined as distances covered at speed >19.8 km/h, whereas ABS-SPR corresponded to distances covered at speeds >25.2 km/h. Significant differences were observed between ABS-HSR and ABS-SPR and all normalized HSR and sprint thresholds ($p < 0.001$). Both between- and within-position comparisons revealed significant differences in distance covered between ABS and %MS speed bands. Midfielders (MFs) covered greater distances in the 55–70% MS speed interval (601.2 ± 294.7 m; $p < 0.001$; $d = -0.27$) compared to ABS-HSR. Interestingly, fullbacks (FBs) and wingers (WGs) demonstrated similar HSR patterns. Moreover, strikers (STs) did not cover distances >95% MS. This research highlights how the normalization approach to quantifying running demands differs significantly from the use of absolute metrics. Additionally, MFs were the only playing position to cover greater distances within a normalized HSR threshold. Furthermore, similar HSR patterns were observed between WGs and FBs.

***Keywords**: load management; monitoring; soccer; GPS; metrics*

Introduction

Soccer is a team sport characterized by intermittent physical exertion, with various high-intensity bouts interspersed with longer periods of low activity (Stølen et al., 2005; Tomazoli et al., 2020; Varley and Aughey, 2013). These high-intensity bouts are considered to be associated with decisive moments of the game (Lepschy et al., 2020) as previous studies have shown that high-speed running (HSR) actions, such as linear sprints, often precede goal-scoring moments (Asian-Clemente et al., 2024; Martínez-Hernández et al., 2023; Schulze et al., 2022). In male soccer players, high-speed running (HSR) and sprinting (SPR) have been typically defined as running actions of speed intensities exceeding 19.8 km/h and 25.2 km/h, respectively (Gualtieri et al., 2023), with each accounting for 7–11% (911–1063 m) and 1–3% (223–307 m) of the total distance covered during a soccer game (Barnes et al., 2014; Lago-Peñas et al., 2023; Reynolds et al., 2021). The volume of these actions has increased by 24% and

[1] *Research Center in Sports Sciences, Health Sciences and Human Development (CIDESD), University of Maia, Maia, Portugal.*
[2] *Research Center of the Polytechnic Institute of Maia (N2i), Maia Polytechnic Institute (IPMAIA), Castêlo da Maia, Maia, Portugal.*
[3] *Department of Rehabilitation and Performance Optimization (DROP), Futebol Clube Famalicão—Futebol SAD, Famalicão, Portugal.*
[4] *FSI Lab, Football Science Institute, Granada, Spain.*
[5] *Department of Performance Optimization (GOD), Sporting Clube de Braga SAD, Braga, Portugal.*
* Correspondence: rjl.pimenta@gmail.com

35% for HSR and SPR, respectively, over the last decade (Bush et al., 2015).

The quantification of HSR and sprint performance metrics has been facilitated by advances in GPS technology, which is widely used in soccer (Asian-Clemente et al., 2025; Bowen et al., 2017; Cummins et al., 2013; Gabbett, 2016) to provide valid and reliable information on high-speed running performance, provided that basic data extraction requirements are met. However, only a proper analysis of GPS data allows for an accurate interpretation of HSR and sprint performance (Pimenta et al., 2025a, 2025b). Unfortunately, many authors in scientific research have relied on absolute running threshold data, disregarding the individual capacity of each athlete. As a result, the interpretation of an athlete's running performance is likely to misrepresent the actual external load based on their true running capacities. For instance, for a player with a peak speed of 35 km/h, the typical absolute sprint threshold of 25.2 km/h represents only 72% of their peak speed capacity (Oliva-Lozano et al., 2023), an intensity previously associated with a striding rather than a sprinting pattern, which is observed at approximately 90% peak speed intensity (Freeman et al., 2023). Indeed, the practical and methodological considerations regarding normalization to maximal speed, as compared to absolute thresholds, have been increasingly discussed for both sprinting (Pimenta et al., 2025b) and HSR (Pimenta et al., 2025a).

Adding to this issue, the volume and intensity of HSR and sprint actions have increased over the years (Bradley et al., 2016; Bush et al., 2015). If in the past, the external load produced by soccer players was already misinterpreted, and now they exhibit greater volumes and intensities of HSR and sprint actions, it is highly likely that non-normalized approaches remain—and are even more—unsuitable for quantifying HSR and sprint efforts. Nevertheless, there are various ways to normalize running thresholds, as evidenced in a previous study that examined three different normalization methods (Tomazoli et al., 2020). Regardless of the method used, normalization is superior to absolute running thresholds, since HSR efforts tend to be overestimated in slower players (Gabbett, 2015; Murray et al., 2018), while faster players experience efforts at a relatively lower percentage of their maximum capacity (Murray et al., 2018). Even so, accumulated distance at high intensities has been reported to vary between 3 and 5% of the total distance covered, depending on the threshold applied (Gabbett, 2015; Murray et al., 2018; Reardon et al., 2015).

Although some authors have normalized values according to different reference points, these values are physiologically situated above the critical speed threshold. Therefore, athletes are assessed at an intensity that compromises their ability to sustain the activity (Jones and Vanhatalo, 2017). Additionally, as speed increases, the running pattern undergoes kinematic changes associated with heightened neuromuscular activity (Cerone et al., 2023) and mechanical stress (Chumanov et al., 2011; Schache et al., 2013), culminating in maximal values during sprinting. Consequently, this suggests that HSR encompasses a relatively broad range of speed intensities, incorporating slightly different running patterns (Freeman et al., 2023). As a consequence of relying on absolute running threshold values, load monitoring may be severely compromised throughout the entire competitive season, potentially contributing to decreased performance and higher fatigue levels. Moreover, the characterization and comparison of external load metrics, such as HSR distance covered, between different field positions often involves the utilization of absolute HSR thresholds, which consequently results in an erroneous interpretation of these comparisons.

The normalization approach to the categorization of running intensities aligns with the principle of individualization in training, which is considered a fundamental concept in training prescription, allowing coaches to properly quantify the external load produced by each athlete (Djaoui et al., 2017). Therefore, it is likely that coaches would favor the normalization method for prescribing running intensities rather than relying on absolute threshold values, as it helps improve decision-making. However, before adopting this approach, it is necessary to determine whether decision-making processes differ when sports scientists analyze absolute versus normalized values. Accordingly, the present study aimed to (i) compare the use of normalized versus absolute running threshold methods across several official matches in elite youth soccer, and (ii) characterize and compare the external load across positions in this context. We hypothesized that (i) significant differences would be observed between absolute and normalized thresholds, particularly at higher normalized intensities in both HSR and SPR, (ii) heterogeneous patterns were expected to be observed across different positions with different thresholds due to the constraints of the game.

Methods

Participants

Twenty-four elite youth male soccer players (age: 19.4 ± 0.9 years, body mass: 75.6 ± 6.8 kg, body height: 1.8 ± 0.06 m) from the Under-23 Portuguese National Championship (highest national division for the specific age group) were invited to participate in this study. Players were classified as elite because 14 of them played in the Youth Champions League (Tier 4), while the remaining players were categorized as Tier 3 (national level) (McKay et al., 2022). The study was conducted following the principles of the Declaration of Helsinki, and approved by the institutional review board of the University of Maia, Maia, Portugal (protocol code: #210/2024; approval date: 28 May 2024).

Measures

For each game, only players who participated for at least 60 minutes were included in the analysis. The external match load was tracked with a portable 10-Hz global positioning system (GPS) device (Catapult Vector S7, Catapult Sports, Melbourne, Australia), which holds FIFA certification (certification number: 1003407) and has been validated for measuring maximum speeds (Cormier et al., 2023). To enhance data reliability and minimize inter-unit variability, the same GPS unit was assigned to each player for all data collection sessions. The GPS data were then extracted using the manufacturer's software (Catapult Openfield, version 3.10; Firmware 8.1).

Design and Procedures

The external load data after 14 championship qualification matches were selected not only for comparing absolute versus normalized values. For normalized thresholds, the distance covered at each threshold was calculated by normalizing it to each player's maximum speed (MS). The thresholds were defined as high-speed running at 55–70% MS, 60–75% MS, 70–85% MS, and 75–90% MS. Moreover, for sprinting, thresholds were set at >90% MS and >95% MS. The thresholds used were based on the rationale built from previous studies (unpublished opinion article). Briefly, for HSR, the lowest value of 55–60% was chosen since it is close to the critical speed in soccer players (Lord et al., 2020). For sprinting, the lowest cut-off value (90%) was selected based on the running kinematic pattern (Freeman et al., 2023) and the full activation of the hamstrings (McNally et al., 2023). Regarding the absolute thresholds, they were defined as absolute high-speed running (ABS-HSR, distance above >19.8 km/h) and the absolute sprint (ABS-SPR, distance above >25.2 km/h). The position designations were attributed considering the team's tactical formation and designations described in previous studies (Baptista et al., 2018; Dalen et al., 2016; Schuth et al., 2016) as follows: a centre back (CB), a full-back (FB), a midfielder (MF), a winger (WG) and a striker (ST).

Statistical Analysis

Statistical analyses were performed using IBM SPSS version 29 (IBM Corp, USA). To compare overall and within-playing-position differences in distances covered between absolute and normalized thresholds, paired samples *t*-tests were conducted. The influence of the playing position on the analyzed variables was assessed using one-way ANOVA, with Bonferroni post-hoc tests applied to examine pairwise differences. Effect sizes for one-way ANOVA were calculated using eta-squared (η^2) and interpreted as follows: small (0.01), medium (0.06), and large (0.14). Effect sizes for pairwise comparisons (Cohen's *d*) were calculated and interpreted as negligible (< 0.20), small (0.20–0.49), moderate (0.50–0.79), and large (≥ 0.80). Additionally, Pearson correlation analyses (r) were conducted to explore associations between the absolute and normalized thresholds. Correlation values were interpreted as negligible (0.00–0.10), weak (0.10–0.39), moderate (0.40–0.69), strong (0.70–0.89), and very strong (0.90–1.00) correlation (Schober et al., 2018). Positive values indicated a direct relationship, whereas negative values indicated an inverse relationship. Statistical significance was established at $p < 0.05$.

Results

Overall Players Comparison

The average MS of all players was 32.7 ± 0.95 km/h (ranging between 30.5 and 34.7 km/h).

Descriptive statistics for MS are presented in Table 1. Regarding HSR, significant differences were detected between ABS-HSR and all percentages of maximum speed. Specifically, differences were found between ABS-HSR (568.9 ± 225.4 m) and 55–70% MS (491.9 ± 330 m; $p < 0.001$; $d = 0.30$), 60–75% MS (300.8 ± 210.5 m; $p < 0.001$; $d = 1.73$), 70–85% MS (168.7 ± 95.9 m; $p < 0.001$; $d = 2.30$), and 75–90% MS (83.9 ± 71.2 m; $p < 0.001$; $d = 2.39$). Considering sprinting thresholds, significant differences were observed between ABS-SPR (108.1 ± 69.8 m) and 90% MS (6.6 ± 13.1 m; $p < 0.001$; d =1.58) as well as 95% MS (1.1 ± 4.1 m; $p < 0.001$; d =1.56).

Within-Playing-Positions Comparison

Comparisons between absolute and normalized values within playing positions are presented in Figure 2. For CBs, significant differences were observed when comparing ABS-HSR (353.4 ± 135.7 m) with 55–70% MS (278.6 ± 173.2 m; $p < 0.001$; $d = 0.55$), 60–75% MS (156 ± 115.5 m; $p < 0.001$; $d = 2.28$), 70–85% MS (106.0 ± 58.4 m; $p < 0.001$; $d = 2.42$), and 75–90% MS (57.8 ± 54.4 m; $p < 0.001$; $d = 3.05$). Significant differences were also found between ABS-SPR (74.1 ± 52.1 m) and >90% MS, (3.4 ± 9.0 m; $p < 0.001$; $d = 1.53$) as well as >95%MS (0.8 ± 3.6; $p < 0.001$; $d = 1.47$).

Regarding FBs, significant differences were observed when comparing ABS-HSR (619.3 ± 171.1 m) with 55–70% MS (449.9 ± 242.4 m; $p < 0.001$; $d = 0.67$), 60–75% MS (332.5 ± 187.7 m; $p < 0.001$; $d = 2.18$), 70–85% MS (184.7 ± 95.9 m; $p < 0.001$; $d = 3.67$), and 75–90% MS (63.8 ± 61.6 m; $p < 0.001$; $d = 3.07$). Moreover, significant differences were also recorded between ABS-SPR (133.5 ± 79.5 m) and >90%MS (10.2 ± 16.2 m; $p < 0.001$; $d = 1.79$) as well as >95%MS (2.5 ± 5.9 m; $p < 0.001$; $d = 1.69$).

The MF position presented significant differences when comparing ABS-HSR (526.0 ± 167.3 m) with 55–70% MS (601.2 ± 294.7 m; $p < 0.001$; $d = -0.27$), 60–75% MS (318.4 ± 185.0 m; $p < 0.001$; $d = 1.31$), 70–85% MS (161.6 ± 79.7 m; $p < 0.001$; $d = 2.57$), and 75–90% MS (91.9 ± 56.3 m; $p < 0.001$; $d = 2.63$). Additionally, significant differences were also observed between ABS-SPR (74.5 ± 42.1 m) and >90%MS (5.1 ± 8.1 m; $p < 0.001$; $d = 1.65$) as well as >95%MS (0.8 ± 3.6 m; $p < 0.001$; $d = 1.76$).

The WG position revealed differences when comparing ABS-HSR (686.7 ± 204.1 m) with 55–70% MS (478.7 ± 256.8 m; $p < 0.001$; $d = 0.84$), 60–75% MS (291.4 ± 178.5 m; $p < 0.001$; $d = 2.97$), 70–85% MS (185.3 ± 84.4 m; $p < 0.001$; $d = 2.89$), and 75–90% MS (71.2 ± 58.1 m; $p < 0.001$; $d = 3.14$). Furthermore, significant differences were also observed between ABS-SPR (130.9 ± 66.3 m) and >90% MS (5.1 ± 14.8 m; $p < 0.001$; $d = 1.96$) as well as >95% MS (1.2 ± 5.2 m; $p < 0.001$; $d = 1.99$).

Finally, similar findings were observed for STs between ABS-HSR (771.7 ± 251.1 m) and 55–70% MS (676.0 ± 386.0 m; $p < 0.001$; $d = 0.38$), 60–75% MS (454.6 ± 305.5 m; $p < 0.001$; $d = 1.87$); 70–85% MS (237.1 ± 129.5 m; $p < 0.001$; $d = 2.68$), and 75–90% MS (157.9 ± 100.4 m; $p < 0.001$; $d = 3.41$). Additionally, significant differences were observed for ABS-SPR (166 ± 67.1 m) compared to >90%MS (11.4 ± 17.3 m; $p < 0.001$; $d = 2.56$) and >95%MS (0.0 ± 0.0 m; $p < 0.001$; $d = 2.47$). Correlations using all players and within-playing-positions are presented in Table 1.

Between-Playing-Positions Comparison

Regarding the comparison of MS, no significant differences were found between positions ($p = 0.24$; $\eta^2 = 0.25$). Even so, for descriptive purposes, the values were as follows: CB: 33.0 ± 0.9 km/h, FB: 33.4 ± 0.3 km/h, MF: 32.2 ± 1.0 km/h, WG: 32.9 ± 1.3 km/h, ST: 32.4 ± 0.4 km/h.

Comparisons between absolute and normalized values across positions for HSR and SPR are presented in Table 2. Concerning HSR (Figure 3A), for all between-positions comparisons, significant differences were detected for 19.8 km/h ($p < 0.001$; $\eta^2 = 0.4$), 55–70% MS ($p < 0.001$; $\eta^2 = 0.20$), 60–75% MS ($p < 0.001$; $\eta^2 = 0.17$), 70–85% MS ($p < 0.001$; $\eta^2 = 0.17$), and 75–90% MS ($p < 0.001$; $\eta^2 = 0.19$). Post-hoc analysis revealed significant differences in various speed thresholds. For ABS-HSR, significant differences were observed between the pairs CB-FB ($p < 0.001$; $d = 1.7$), CB-MF ($p < 0.001$; $d = 1.1$), CB-WG ($p < 0.001$; $d = 1.9$), CB-ST ($p < 0.001$; $d = 2.1$), FB-MF ($p = 0.045$; $d = 0.6$), FB-ST ($p = 0.002$; $d = 0.7$), MF-WG ($p < 0.001$; $d = 0.9$), and MF-ST ($p = 0.002$; $d = 0.7$). Further differences were observed in 55–70% MS between CB-FB ($p = 0.012$; $d = 0.8$), CB-MF ($p < 0.001$; $d = 1.3$), CB-WG ($p = 0.004$; $d = 0.9$), CB-ST ($p < 0.001$; $d = 1.3$), FB-MF ($p = 0.020$; $d = 0.6$), FB-ST ($p = 0.002$; $d = 0.7$), and WG-ST ($p = 0.018$; $d = 0.6$). Additionally, the pairs CB-FB ($p < 0.001$; $d = 1.1$), CB-MF ($p < 0.001$; $d = 1.1$), CB-WG ($p = 0.007$; $d = 0.9$), CB-ST ($p < 0.001$; $d = 1.3$), FB-ST ($p = 0.045$; $d = 0.5$), MF-ST ($p = 0.009$;

d = 0.5), and WG-ST (p = 0.003; d = 0.7) revealed significant differences at 60–70% MS. Furthermore, in the 70–85% MS threshold, significant differences were recorded between the pairs CB-FB ($p < 0.001$; d = 1), CB-MF (p = 0.006; d = 0.8), CB-WG ($p < 0.001$; d = 1.1), CB-ST ($p < 0.001$; d = 1.3), and MF-ST ($p < 0.001$; d = 0.7). At the last normalized HSR threshold, 75–90%MS, the pairs CB-MF (p = 0.036; d = 0.6), FB-ST ($p < 0.001$; d = 1.1), MF-ST ($p < 0.001$; d = 0.8), and WG-ST ($p < 0.001$; d =1.1) showed significant differences.

Regarding SPR (Figure 3B), significant differences were observed between positions only for the ABS-SPR threshold ($p < 0.001$; $\eta^2 = 0.25$) and non-significant effects for >90%MS (p = 0.010; η^2 = 0.05) and >95%MS (p = 0.047; η^2 = 0.04). Post-hoc analysis showed significant differences between the pairs CB-FB ($p < 0.001$; d = 0.9), CB-WG ($p < 0.001$; d = 1.0), CB-ST ($p < 0.001$; d = 1.5), FB-MF ($p < 0.001$; d = 0.9), MF-WG ($p < 0.001$; d = 1.0), and MF-ST ($p < 0.001$; d = 1.6).

Discussion

To the best of our knowledge, this is the first study to compare and correlate absolute and normalized thresholds across different intensity levels and apply them over multiple competitive matches. In accordance with our initial hypothesis, the findings of the present study demonstrated that ABS-HSR differed from all normalized values when analyzing all the players together, particularly at higher normalized intensities. Indeed, the effect size reached its lowest value (d = 0.30, small effect size) within the 55–70% MS range, suggesting that absolute values tended to converge within this interval. Given that this range spanned 15% and that the effect size of the subsequent range (60–75% MS) was classified as very strong and coincided with the highest correlation value (r = 0.75) in relation to ABS-HSR, it is plausible that high-speed running intensity falls within the 55–60% MS range. This study also demonstrated that, in sprinting, a threshold of 25.2 km/h was far from >90% of maximum speed for elite players. Furthermore, in relation to field positions, and in accordance with our initial hypothesis, a heterogeneous pattern across different thresholds was identified among the various positions, suggesting that absolute thresholds lacked the sensitivity required to detect variations in load intensity.

Table 1. Correlation between overall and within playing positions comparisons with absolute values and normalized values for high-speed running and sprinting.

Thresholds Correlations			Within Positions Correlations									
			CB		FB		MF		WG		ST	
Variables	r	*p*-value	r	*p*-value	r	*p*-value	r	*p*-value	r	*p*-value	r	*p*-value
ABS-HSR vs. 55–70%	0.54*	<0.001	0.63*	<0.001	0.29*	0.037	0.39*	<0.001	0.45	0.21	0.77*	<0.001
ABS-HSR vs. 60–75%	0.75*	<0.001	0.77*	<0.001	0.73*	<0.001	0.6*	<0.001	0.77*	<0.001	0.83*	<0.001
ABS-HSR vs. 70–85%	0.69*	<0.001	0.72*	<0.001	0.75*	<0.001	0.54*	<0.001	0.55*	<0.001	0.61*	<0.001
ABS-HSR vs. 75–90%	0.46*	<0.001	0.81*	<0.001	0.02	0.9	0.21	0.070	0.03	0.068	0.81*	<0.001
ABS-Sprint vs >90%	0.51*	<0.001	0.7*	<0.001	0.73*	<0.001	0.12	0.321	0.26	0.091	0.5*	<0.001
ABS-Sprint vs >95%	0.28*	<0.001	0.65*	<0.001	0.35	0.010	0.08	0.505	0.23	0.140	-	-

*Legend: CB (Center Back), FB (Fullback), MF (Midfielder), WG (Winger), ST (Striker); ABS-HSR, Absolute high speed running; 55–70% MS, 55–70% of maximal speed; 60–75% MS, 60–75% of maximal speed; 70–85% MS, 70–85% of maximal speed; 75–90% MS, 75–90% of maximal speed; ABS-Sprint, Absolute sprint; >90% MS, >90% of maximal speed; >95% of maximal speed; * statistically significant difference (p < 0.05)*

Table 2. Descriptive values (mean ± standard deviation) of distances covered across the various HSR and sprinting thresholds for all playing positions.

Variables	CB	FB	MF	WG	ST
ABS-HSR (m)	353.4 ± 135.6	619.3 ± 171.1	526 ± 167.3	686.7 ± 204.1	771.7 ± 251.1
55–70%MS (m)	278.6 ± 173.2	449.9 ± 242.4	601.2 ± 294.7	478.7 ± 256.8	676 ± 386.0
60–75%MS (m)	156 ± 115.5	332.5 ± 187.7	318.4 ± 185.0	291.4 ± 178.5	454.6 ± 305.5
70–85%MS (m)	106 ± 58.4	184.7 ± 95.9	161.6 ± 79.7	185.3 ± 84.4	237.1 ± 129.5
75–90%MS (m)	57.7 ± 54.4	63.8 ± 61.6	91.8 ± 56.3	71.2 ± 58.1	71.2 ± 58.1
ABS-Sprint (m)	74.1 ± 52.1	133.5 ± 79.5	74.5 ± 42.1	130.9 ± 66.3	166 ± 67.1
>90%MS (m)	3.4 ± 9.0	10.2 ± 16.2	5.1 ± 8.1	5.1 ± 14.8	11.4 ± 17.2
>95%MS (m)	0.8 ± 3.6	2.5 ± 5.8	0.7 ± 2.5	1.2 ± 5.2	0 ± 0

Legend: CB (Center Back), FB (Fullback), MF (Midfielder), WG (Winger), ST (Striker); ABS-HSR, Absolute high speed running; 55–70% MS, 55–70% of maximal speed; 60–75% MS, 60–75% of maximal speed; 70–85% MS, 70–85% of maximal speed; 75–90% MS, 75–90% of maximal speed; ABS-Sprint, Absolute sprint; >90% MS, >90% of maximal speed; >95% MS, >95% of maximal speed

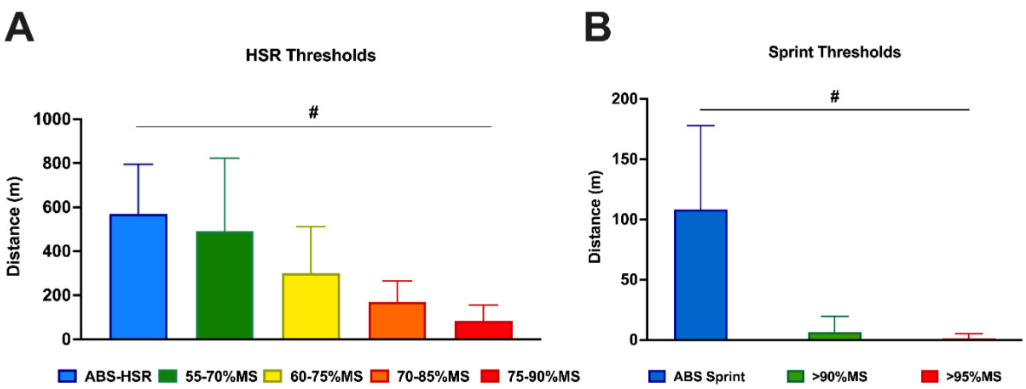

Figure 1. Comparison between absolute vs normalized values for (A) high-speed running and (B) sprinting. *Legend: ABS-HSR, Absolute high-speed running; 55–70% MS, 55–70% of maximal speed; 60–75% MS, 60–75% of maximal speed; 70–85% MS, 70–85% of maximal speed; 75–90% MS, 75–90% of maximal speed; ABS-SPR, Absolute sprint; >90% MS, >90% of maximal speed; >95% MS, >95% of maximal speed; # statistically significant difference between absolute thresholds and normalized thresholds (p < 0.001)*

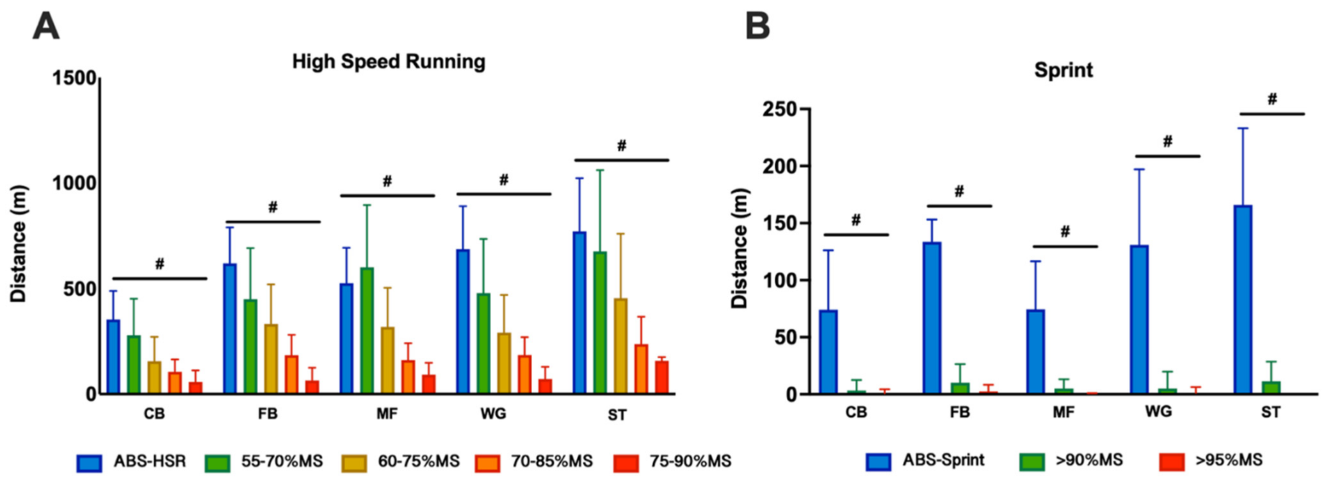

Figure 2. Comparison between absolute vs normalized values within positions for (A) high speed running and (B) sprinting.

Legend: CB, Centre Back; FB, Full Back; MF, Midfielder; ST, Striker; ABS-HSR, Absolute high-speed running; 55–70% MS, 55–70% of maximal speed; 60–75% MS, 60–75% of maximal speed; 70–85% MS, 70–85% of maximal speed; 75–90% MS, 75–90% of maximal speed; ABS-SPR, Absolute sprint; >90% MS, >90% of maximal speed; >95% MS, >95% of maximal speed; # statistically significant difference between absolute thresholds and normalized thresholds ($p < 0.001$)

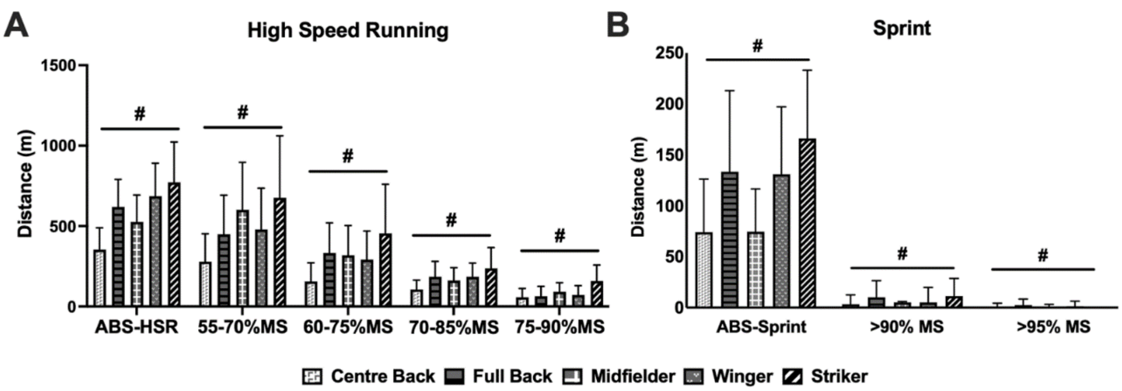

Figure 3. Comparison between absolute and normalized values between positions for (A) high speed running and (B) sprinting.

Legend: 55–70% MS, 55–70% of maximal speed; 60–75% MS, 60–75% of maximal speed; 70–85% MS, 70–85% of maximal speed; 75–90% MS, 75–90% of maximal speed; ABS-SPR, Absolute sprint; >90% MS, >90% of maximal speed; >95% MS, >95% of maximal speed; # statistically significant difference between absolute thresholds and normalized thresholds ($p < 0.001$)

It should be noted that the difference between 55–60% and 90%—typically defined in the literature as 90% of maximal speed—is a substantial gap. Therefore, incorporating a HSR profile with a stronger mechanical emphasis may be warranted. Indeed, the HSR pattern was reported to be better represented at speeds corresponding to 75% MS instead of the 19.8 km/h speed, as the latter was observed to more closely represent a jogging rather than a HSR pattern (Freeman et al., 2023). As reported in previous studies, the 55–60% MS values are closer to those described for critical speed (Lord et al., 2020). Since critical speed represents the maximal speed an athlete can sustain without excessive lactate accumulation leading to severe fatigue (de Lucas et al., 2012), it is debatable whether the observed values of 55–60% MS could be considered "high-speed" running. Therefore, it could be suggested to better identify HSR across different players' profiles to include two distinct HSR zones: one more related to the metabolic component (60–75% MS), where midfielders tend to accumulate a greater volume, and another more associated with mechanical demands (75–90%), where positions such as the FB and the WG tend to accumulate higher volumes.

Regarding sprinting, the absolute threshold (25.2 km/h) exhibits a substantial discrepancy when expressed as normalized values, with very large effect sizes and further emphasized by the lower level, albeit significant, correlations (90% MS; d = 2.56; r = 0.51; and 95%MS; d = 2.47; r = 0.28) in comparison to the correlations observed for HSR variables, indicating that >90% MS and >95% MS are much superior to ABS-SPR. Consequently, the characterization of sprinting is compromised, not only affecting training and match load management, but also influencing the development of physiological adaptations. Indeed, sprinting has been considered a vaccine for hamstring strain injury with exposure to intensities >95% MS being associated with lower injury occurrences (Buchheit et al., 2023). However, if coaches rely on the utilization of the ABS-SPR band, it is not possible to analyze how many efforts or how much distance an athlete covered at >95% MS, which has been reported essential to activate 100% the hamstrings (Higashihara et al., 2010). Consequently, an athlete may be under or overstimulated resulting in a lack or excessive sprint exposure, respectively, both of which are inappropriate as the first results in no adaptations to sprint training and the latter will induce excessive fatigue levels. This impact on data interpretation is illustrated in Figures 1 and 2. Indeed, the comparison between and within positions reveals that while players may accumulate similar loads above absolute thresholds, their patterns in relation to normalized values can be entirely distinct.

It is consistent with the observation of the higher accumulated distance in the absolute thresholds in HSR and SPR categories within all positions, with the only exception being the superior accumulated distance at 55–70% MS for MFs. The general pattern observed in the within-position comparison suggests that the majority of players accumulate higher distances in the ABS-HSR intensity, showing a strong correlation (r = 0.75) with distances covered at 60–75% MS. This level of correlation is somewhat expected as the 60–75% MS band represents speeds between 19.3 and 22.5 km/h which are proximal to the ABS-HSR band (19.8–25.2 km/h). However, for MFs, 55–70% MS represents the band in which they accumulate greater distances. The 55–70% MS range, based on a reference speed of 32.2 km/h observed as the mean maximal speed of MFs in the current sample, corresponds to speeds between 17.7 and 22.5 km/h. This range includes speeds below the HSR threshold and encompasses additional distances covered at speeds between 17.7 and 19.8 km/h. Notably, MFs tend to cover greater total distances than other positions; however, they have been reported to cover less HSR distance (>19.8 km/h) compared to defenders and forwards while exhibiting higher distances covered per minute on average (Modric et al., 2024; Perrotta et al., 2025). This reinforces the notion that MFs exhibit a running intensity profile characterized by a narrower amplitude, meaning they do not accumulate extensive distances at very high speeds nor at very low intensities. This could be attributed to their role in maintaining positional balance, engaging in constant movement in smaller spaces, and frequently adjusting their pace to meet tactical demands (Carril-Valdó et al., 2025). It could be interesting to apply the 55–70% MS range on previous studies' data to verify the possible distinctive intermittent running profile of midfielders relative to other positions. This warrants further investigation.

The disparity between absolute and normalized speeds within positions is even more pronounced in the sprint category, as all positions revealed notably lower distances covered at both normalized sprint intensities. This comparison provides valuable insights for load monitoring in sprinting activities. If we consider the 25.2 km/h intensity, it may lead us to believe that players covered significant sprinting distances. As mentioned earlier, this disparity in intensity references could lead to errors in training program designs, especially when reaching sprinting values is a target (Szymanek-Pilarczyk et al., 2024), both from a performance and injury prevention perspective.

The between-position comparisons provide soccer research with important data regarding players' HSR and SPR profiles for each position. CBs show a propensity to have lower accumulated distances across the majority of speed thresholds, reflecting their lower HSR demands relative to other positions, independent of the HSR definition used, except for the 75–90% range. Although CBs usually cover lower total distances relative to other positions, they are also required to execute high-intensity runs during duels with the offensive opposition, which are often deemed to be the fastest players (Dzhilkibaeva et al., 2024). Additionally, CBs display strong correlations between covered distances at ABS-HSR and both the 60–75% MS (r = 0.77) and 70–85% MS (r = 0.72) thresholds. Interestingly, CBs of the current sample can be considered fast relative to their field position, such that the 60–70% MS (19.8–24.8 km/h) band actually represents a range similar to that observed for ABS-HSR (19.8–25.2 km/h). FBs and WGs can be interpreted as positions with similar HSR demands over the various thresholds. This can be attributed to the interchangeable functions of FBs and WGs, which often compensate for each other in offensive and defensive actions along the corridor. Their HSR correlation matrices share a similar number of significant correlations, notably in the 60–75% MS (FB: r = 0.73; WG: r = 0.77) and 70–85% MS bands (FB: r = 0.75; WG: r = 0.55). However, compared to WGs, they show a stronger correlation in the 70–85% MS variable, thus substantiating a higher involvement in relatively higher intensities.

From a tactical perspective, this contributes to the more eclectic role of FBs in the current soccer tactical systems, which require FBs to be physically able to cope with offensive and defensive actions despite their natural defensive positioning on the field, often next to CBs. For this reason, when the team loses the ball in the offensive portions of the pitch, FBs must quickly recover their defensive positioning by increasing their running speed. On the contrary, WGs do not have to cover such long distances, as their natural position is situated in more offensive portions of the field. Furthermore, the longer distances that must be covered by FBs provide the affordance to reach higher speeds. It is notable how, as a position becomes more offensive, the HSR profile tends to be more intense. The CB position displays higher magnitude differences compared to all other positions. Conversely FB and WG positions demonstrate similar patterns, but they are substantially different from the HSR profile of STs, as are MFs compared to STs, though not as much as when compared to WGs or FBs. In STs, all HSR correlations are considered significant, proving the high-intensity nature of their running actions. STs perform roles such as they apply pressure on the opponents' defensive block when without possession, and they make off-the-ball runs with the aim of getting closer to the opponent's goal. These off-the-ball efforts may well consist of high-intensity runs, previously reported to be associated with goal-scoring moments.

The correlation calculations also demonstrate how the strength of the correlations abruptly decreases from >90% MS to >95% MS, especially for FBs and STs, with the latter not attaining speeds above 95% MS during the observed matches. Interestingly, FBs were the players who accumulated the greatest sprint distance at >95% of maximum speed. This may be explained by their greater ability to cover longer distances along the lateral corridor. Additionally, STs should have experienced a high sprinting demand during the matches. However, when normalizing values, the same STs revealed that they were not even able to reach 95% MS. This makes sense, since the 25.2 km/h threshold represents a lower % MS for faster players (usually STs or WGs) and therefore is a relatively lower speed intensity to reach when compared to slower players. This explains why STs can accumulate higher absolute sprinting distances but sometimes no sprinting distance at all when accounting for normalized speed.

The present study has some limitations that should be acknowledged. Firstly, the level of players involved, specifically U23, must be considered, as these threshold characteristics may be influenced by the physical profiles associated with each position. Nonetheless, we believe that our approach of normalizing the data provides a more robust framework for the control and monitoring of training loads. Secondly, the data were derived from match situations, where naturally, the playing style of both our team and the opposing teams may have influenced the metrics. Consequently, the findings should not be generalized to other age groups, competitive levels or sex.

Conclusions

This study shows significant differences between the use of normalized and absolute HSR and sprint thresholds. This was verified for all players overall and within-positions with the exception for MFs in the 55–70% MS range. Notably, ABS-SPR distances were far greater than both >90% MS and >95% MS distances, revealing that, in various studies, sprint distances have been overestimated, with probable subsequent consequences regarding load management and hamstring strain muscle injury risk. Although CBs covered less distances, their normalized HSR thresholds were significantly associated with ABS-HSR. MFs presented a distinctive HSR running pattern compared to all other positions, while FBs and WGs shared a similar pattern. Finally, data regarding HSR and sprinting distances covered by STs corroborate the high-intensity nature of efforts associated with their offensive functions and, interestingly, they were not able to reach >95% MS during the observed games, further supporting the notion that the use of absolute speed thresholds is inappropriate for load monitoring purposes. Based on the findings of the present study, absolute thresholds appear insufficiently sensitive to accurately detect variations in load intensity. Accordingly, it is proposed that HSR be subdivided into two distinct zones: a high-speed zone, defined as 60–75% MS, and a very high-speed zone, defined as 75–90% MS. Sprinting would then be characterized by efforts exceeding 90% MS. This refined classification may enhance the understanding of the specific running demands across different playing positions and inform the design of more individualized and effective training and load monitoring strategies.

Author Contributions: Conceptualization: R.P.; methodology: R.P.; software: R.P. and H.A.; validation: R.P., J.R. and F.Y.N.; formal analysis: R.P. and F.M.; investigation: R.P.; resources: R.P. and F.Y.N.; data curation: R.P. and H.A.; writing—original draft preparation: R.P.; writing—review & editing: R.P., H.A. and F.Y.N.; visualization: R.P. and H.A.; supervision: R.P. and F.Y.N.; project administration: R.P.; funding acquisition: F.Y.N. All authors have read and agreed to the published version of the manuscript.

ORCID iD:

Ricardo Pimenta: https://orcid.org/0000-0003-0134-5038

Hugo Antunes: https://orcid.org/0009-0005-3451-3079

João Ribeiro: https://orcid.org/ 0000-0002-7658-4837

Fábio Yuzo Nakamura: https://orcid.org/0000-0002-5336-3652

Funding Information: This work was funded by National Funds by FCT—Foundation for Science and Technology under the following project UID/04045: Research Center in Sports Sciences, Health Sciences, and Human Development.

Institutional Review Board Statement: This study was conducted following the principles of the Declaration of Helsinki, and approved by the institutional review board of the University of Maia, Maia, Portugal (protocol code: #210/2024; approval date: 28 May 2024).

Informed Consent: Informed consent was obtained from all participants included in the study.

Conflicts of Interest: The authors declare no conflict of interest.

Received: 17 February 2025

Accepted: 14 August 2025

References

Asian-Clemente, J. A., Asín-Izquierdo, I., Requena, B., Galiano, C. (2025). External and Internal Loads of Transition Games Are Affected by the Presence of an Opposing Team and Their Initial Positions. *Journal of Human Kinetics*, *97*, 115–126. https://doi.org/10.5114/jhk/191850

Asian-Clemente, J. A., Rabano-Muñoz, A., Suarez-Arrones, L., & Requena, B. (2024). Analysis of Differences in Running Demands between Official Matches and Transition Games of Young Professional Soccer Players according to the Playing Position. *Journal of Human Kinetics*, *92*, 121–131. https://doi.org/10.5114/jhk/175339

Baptista, I., Johansen, D., Seabra, A., & Pettersen, S. A. (2018). Position specific player load during match-play in a professional football club. *PloS One*, *13*(5), e0198115.

Barnes, C., Archer, D. T., Hogg, B., Bush, M., & Bradley, P. S. (2014). The evolution of physical and technical performance parameters in the English Premier League. *International Journal of Sports Medicine*, *35*(13), 1095–1100.

Bowen, L., Gross, A. S., Gimpel, M., & Li, F.-X. (2017). Accumulated workloads and the acute:chronic workload ratio relate to injury risk in elite youth football players. *British Journal of Sports Medicine*, *51*(5), 452–459.

Bradley, P. S., Archer, D. T., Hogg, B., Schuth, G., Bush, M., Carling, C., & Barnes, C. (2016). Tier-specific evolution of match performance characteristics in the English Premier League: it's getting tougher at the top. *Journal of Sports Sciences*, *34*(10), 980–987.

Buchheit, M., Settembre, M., Hader, K., & McHugh, D. (2023). Exposures to near-to-maximal speed running bouts during different turnarounds in elite football: association with match hamstring injuries. *Biology of Sport*, *40*(4), 1057–1067.

Bush, M., Barnes, C., Archer, D. T., Hogg, B., & Bradley, P. S. (2015). Evolution of match performance parameters for various playing positions in the English Premier League. *Human Movement Science*, *39*, 1–11.

Carril-Valdó, J. J., Ferrandis, J., Claver, F., Gil-Arias, A., & González-Rodenas, J. (2025). Comparison of physiological and physical demands between small-sided games and official matches in youth football players. *Sport Sciences for Health*, *21*, 1021–1028.

Cerone, G. L., Nicola, R., Caruso, M., Rossanigo, R., Cereatti, A., & Vieira, T. M. (2023). Running speed changes the distribution of excitation within the biceps femoris muscle in 80 m sprints. *Scandinavian Journal of Medicine & Science in Sports*, *33*(7), 1104–1115.

Chumanov, E. S., Heiderscheit, B. C., & Thelen, D. G. (2011). Hamstring musculotendon dynamics during stance and swing phases of high-speed running. *Medicine and Science in Sports and Exercise*, *43*(3), 525–532.

Cormier, P., Tsai, M.-C., Meylan, C., Agar-Newman, D., Epp-Stobbe, A., Kalthoff, Z., & Klimstra, M. (2023). Concurrent Validity and Reliability of Different Technologies for Sprint-Derived Horizontal Force-Velocity-Power Profiling. *Journal of Strength and Conditioning Research*, *37*(6), 1298–1305.

Cummins, C., Orr, R., O'Connor, H., & West, C. (2013). Global positioning systems (GPS) and microtechnology sensors in team sports: a systematic review. *Sports Medicine (Auckland, N.Z.)*, *43*(10), 1025–1042.

Dalen, T., Jørgen, I., Gertjan, E., Geir Havard, H., & Ulrik, W. (2016). Player Load, Acceleration, and Deceleration During Forty-Five Competitive Matches of Elite Soccer. *Journal of Strength & Conditioning Research*, *30*(2), 351–359.

de Lucas, R. D., Dittrich, N., Junior, R. B., de Souza, K. M., & Guglielmo, L. G. A. (2012). Is the critical running speed related to the intermittent maximal lactate steady state? *Journal of Sports Science & Medicine*, *11*(1), 89–94.

Djaoui, L., Chamari, K., Owen, A. L., & Dellal, A. (2017). Maximal Sprinting Speed of Elite Soccer Players During Training and Matches. *Journal of Strength and Conditioning Research*, *31*(6), 1509–1517.

Dzhilkibaeva, {natalya, Khomiakova, A., Kalinin, E., Kuzmichev, V., & Lunina}, A. (2024). Long-term analysis of the physical and technical performance of players in Russian Premier Liga football matches from 2015 to 2022. *Journal of Physical Education and Sport*, *24*(7), 1778–1787.

Freeman, B. W., Talpey, S. W., James, L. P., Opar, D. A., & Young, W. B. (2023). Common High-Speed Running Thresholds Likely Do Not Correspond to High-Speed Running in Field Sports. *Journal of Strength and Conditioning Research*, *37*(7), 1411–1418.

Gabbett, T. J. (2015). Use of Relative Speed Zones Increases the High-Speed Running Performed in Team Sport Match Play. *Journal of Strength and Conditioning Research*, *29*(12), 3353–3359.

Gabbett, T. J. (2016). The training-injury prevention paradox: should athletes be training smarter and harder? *British Journal of Sports Medicine*, *50*(5), 273–280.

Gualtieri, A., Rampinini, E., Dello Iacono, A., & Beato, M. (2023). High-speed running and sprinting in professional adult soccer: Current thresholds definition, match demands and training strategies. A systematic review. *Frontiers in Sports and Active Living*, *5*, 1116293.

Higashihara, A., Ono, T., Kubota, J., Okuwaki, T., & Fukubayashi, T. (2010). Functional differences in the activity of the hamstring muscles with increasing running speed. *Journal of Sports Sciences*, *28*(10), 1085–1092.

Jones, A. M., & Vanhatalo, A. (2017). The "Critical Power" Concept: Applications to Sports Performance with a Focus on Intermittent High-Intensity Exercise. *Sports Medicine (Auckland, N.Z.)*, *47*(Suppl 1), 65–78.

Lago-Peñas, C., Lorenzo-Martinez, M., López-Del Campo, R., Resta, R., & Rey, E. (2023). Evolution of physical and technical parameters in the Spanish 2012–2019. *Science & Medicine in Football*, *7*(1), 41–46.

Lepschy, H., Wäsche, H., & Woll, A. (2020). Success factors in football: an analysis of the German Bundesliga. *International Journal of Performance Analysis in Sport*, *20*(2), 150–164.

Lord, C., Blazevich, A. J., Abbiss, C. R., Drinkwater, E. J., & Ma'ayah, F. (2020). Comparing Maximal Mean and Critical Speed and Metabolic Powers in Elite and Sub-elite Soccer. *International Journal of Sports Medicine*, *41*(4), 219–226.

Martínez-Hernández, D., Quinn, M., & Jones, P. (2023). Linear advancing actions followed by deceleration and turn are the most common movements preceding goals in male professional soccer. *Science & Medicine in Football*, *7*(1), 25–33.

McKay, A. K. A., Stellingwerff, T., Smith, E. S., Martin, D. T., Mujika, I., Goosey-Tolfrey, V. L., Sheppard, J., & Burke, L. M. (2022). Defining training and performance caliber: A Participant Classification Framework. *International Journal of Sports Physiology and Performance*, *17*(2), 317–331.

McNally, T., Edwards, S., Halaki, M., O'Dwyer, N., Pizzari, T., & Blyton, S. (2023). Quantifying demands on the hamstrings during high-speed running: A systematic review and meta-analysis. *Scandinavian Journal of Medicine & Science in Sports*, *33*(12), 2423–2443.

Modric, T., Carling, C., Lago-Peñas, C., Sarmento, H., Veršić, S., Pajonková, F., & Sekulic, D. (2024). It is not (all) about running faster, opponent also plays; the effect of opposition team formation on running performance in professional soccer match-play. *International Journal of Performance Analysis in Sport*, *25*(4), 595–609. https://doi.org/10.1080/24748668.2024.2430099.

Murray, N. B., Gabbett, T. J., & Townshend, A. D. (2018). The Use of Relative Speed Zones in Australian Football: Are We Really Measuring What We Think We Are? *International Journal of Sports Physiology and Performance*, *13*(4), 442–451.

Oliva-Lozano, J. M., Fortes, V., López-Del Campo, R., Resta, R., & Muyor, J. M. (2023). When and how do professional soccer players experience maximal intensity sprints in LaLiga? *Science & Medicine in Football*, *7*(3), 288–296.

Perrotta, R., Ungureanu, A. N., Cherubini, D., Brustio, P. R., & Lupo, C. (2025). Technical, tactical, and time–motion match profiles of the forwards, midfielders, and defenders of a men's football Serie A team. *Sports*, *13*(2), 28.

Pimenta, R., Antunes, H., Ribeiro, J., & Nakamura, F. Y. (2025a). Should GPS data be normalized for performance and fatigue monitoring in soccer? A theoretical-practical discussion on high-speed running. *Frontiers in Sports and Active Living*, *7*, 1603767.

Pimenta, R., Antunes, H., Ribeiro, J., & Yuzo Nakamura, F. (2025b). Should GPS data be normalized for performance and fatigue monitoring in soccer? A theoretical-practical discussion on sprinting. *German Journal of Exercise and Sport Research*, Advanced online publication. https://doi.org/10.1007/s12662-025-01048-7.

Reardon, C., Tobin, D. P., & Delahunt, E. (2015). Application of Individualized Speed Thresholds to Interpret Position Specific Running Demands in Elite Professional Rugby Union: A GPS Study. *PloS One*, *10*(7), e0133410.

Reynolds, J., Connor, M., Jamil, M., & Beato, M. (2021). Quantifying and Comparing the Match Demands of U18, U23, and 1ST Team English Professional Soccer Players. *Frontiers in Physiology*, *12*, 706451.

Schache, A. G., Dorn, T. W., Wrigley, T. V., Brown, N. A. T., & Pandy, M. G. (2013). Stretch and activation of the human biarticular hamstrings across a range of running speeds. *European Journal of Applied Physiology*, *113*(11), 2813–2828.

Schober, P., Boer, C., & Schwarte, L. A. (2018). Correlation Coefficients: Appropriate Use and Interpretation. *Anesthesia and Analgesia*, *126*(5), 1763–1768.

Schulze, E., Julian, R., & Meyer, T. (2022). Exploring Factors Related to Goal Scoring Opportunities in Professional Football. *Science & Medicine in Football*, *6*(2), 181–188.

Schuth, G., Carr, G., Barnes, C., Carling, C., & Bradley, P. S. (2016). Positional interchanges influence the physical and technical match performance variables of elite soccer players. *Journal of Sports Sciences*, *34*(6), 501–508. https://doi.org/10.1080/02640414.2015.1127402

Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of soccer: an update. *Sports Medicine (Auckland, N.Z.)*, *35*(6), 501–536.

Szymanek-Pilarczyk, M., Nowak, M. J., Góra, T., Oleksy, Ł., Drozd, M., & Wąsik, J. (2024). The Evaluation of the Modified Wave Periodization Model Efficiency on the Example of Young Soccer Players' Sprint Tests. *Journal of Human Kinetics*, *94*, 215–226. https://doi.org/10.5114/jhk/191699

Tomazoli, G., Marques, J. B., Farooq, A., & Silva, J. R. (2020). Estimating Postmatch Fatigue in Soccer: The Effect of Individualization of Speed Thresholds on Perceived Recovery. *International Journal of Sports Physiology and Performance*, *15*(9), 1216–1222.

Varley, M. C., & Aughey, R. J. (2013). Acceleration profiles in elite Australian soccer. *International Journal of Sports Medicine*, *34*(1), 34–39.