

High speed movement and change-of-direction demands in modern elite soccer

GRIGOR GUTEV

Department “Track &Field”, National Sports Academy “Vassil Levski”, BULGARIA

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Abstract:

This study examined the high-speed running and change-of-direction (COD) demands of elite professional football players during official matches using GNSS/GPS-based monitoring. Twenty-four male outfield players competing at the highest level of Bulgarian football were analyzed across 103 full-match performances, with external load variables including total distance, distance covered across five speed zones, high-speed and sprint distances, maximal running speed, sprint count, accelerations, decelerations, directional changes, and high metabolic load distance (HMLD). Descriptive statistics were used to assess distributional characteristics and variability, while Pearson's correlation coefficients evaluated relationships between total distance and speed-zone metrics. The results indicated that total distance covered (mean $\approx$ 9.8 km) exhibited low variability, confirming its reliability as a global indicator of external load.

Keywords: Elite football; High-speed running; Change-of-direction; External load monitoring; Match demands; GNSS/GPS analysis

Introduction

Modern elite soccer is characterized by increasing physical and tactical demands, with high-speed sprints and change-of-direction (COD) movements now essential for both performance and player safety, a trend observed in both players and referees (Kirkendall, 2011; Kabakov, 2021; Ivanov, 2022; Gadev & Peev, 2022). The frequency and intensity of sprints, accelerations, decelerations, and rapid directional changes have increased, driven by evolving tactical strategies and the need for players to execute complex maneuvers under pressure. Traditional analyses that focus only on quantitative sprint data are insufficient; therefore, coaches should adopt a more integrated, position-specific approach that accounts for the tactical and biomechanical context of these actions (Filter et al., 2023). These factors not only influence match outcomes but also increase the risk of injuries, particularly non-contact lower-limb injuries such as ACL tears. Therefore, understanding the multifaceted nature of high-speed movement and COD is crucial for improving performance, developing effective training programs, and reducing injury risk (Hill-Haas et al., 2010; Zago et al., 2016; Loturco et al., 2018; Ivanov, 2024, 2025; Zlatev & Andonov, 2025)

Literature review:

COD performance in elite soccer is a complex, multifaceted trait that is not fully captured by traditional speed or power metrics because it is influenced by biomechanical technique, neuromuscular control, anthropometrics, and position-specific demands (Reilly et al., 2000; Guteva et al., 2015; Zago et al., 2016; Bizati, 2016; Loturco et al., 2018; Freitas et al., 2019; Harper et al., 2019; Granero-Gil et al., 2020; Morgan et al., 2022).

COD performance in elite soccer players is influenced by a combination of anthropometric and neuromuscular factors including strength, power, height, and body composition (Chaouachi et al., 2012). Multidirectional speed in soccer represents a complex motor ability that integrates acceleration, deceleration, change of direction, and agility, and therefore requires a structured, long-term development approach tailored to players (McBurnie, 2022). Importantly, it does not improve proportionally with age and general physical development, underscoring the need for targeted COD training despite increases in strength, speed, and power (Loturco et al., 2019).

Despite advances in football performance research, important gaps remain in understanding match demands. Many studies continue to emphasize total distance covered, which does not adequately capture the critical high-speed, sprinting, and COD actions that are essential for both performance and injury risk assessment, leading to an underrepresentation of the qualitative aspects of match play. Maintaining a high number of actions per min during the game is also of great importance (Verheijen, 2014). Furthermore, COD demands are frequently investigated in isolated or controlled settings, limiting ecological validity. There is a clear lack of comprehensive, match-based analyses that simultaneously assess linear high-speed running and multidirectional loads [including accelerations, decelerations, turning actions, and high metabolic load distance (HMLD)] during official competitions in elite male football.

Additionally, data on the variability, distribution, and interrelationships of high-intensity running metrics across multiple full-match observations in elite squads remain limited. Evidence from Eastern European elite football, particularly Bulgarian top-tier competitions, is especially scarce. These gaps highlight the need for comprehensive, ecologically valid studies of high-speed and COD demands during elite match play to inform training protocols and load management.

Despite the growing body of research on external load demands in elite football, current evidence remains limited in its integrated analysis of high-speed running and COD movements during official matches. Previous studies have often focused on isolated locomotor variables, such as total distance or sprinting, or have relied on testing conditions that do not fully capture the complex, context-dependent nature of competitive play. Moreover, the multidirectional demands of modern football, which are characterized by frequent accelerations, decelerations, and rapid directional changes performed at high velocities, have not been sufficiently quantified alongside traditional speed-zone metrics, particularly through the use of high-frequency GPS systems in elite competitions. Addressing this gap is essential because high-speed and COD actions are closely related to decisive performance moments and an increased risk of injury. Therefore, a comprehensive, match-based analysis that simultaneously captures high-speed movement characteristics and high-velocity directional changes is necessary to provide a more ecologically valid understanding of contemporary elite football demands and to enhance training planning, load monitoring, and injury prevention strategies.

The purpose of this study is to examine high-speed movement characteristics and high-velocity changes of direction in elite professional football players during official matches. Specifically, it aims to quantify external load parameters associated with high-intensity activity, including distance covered across different speed zones, sprint activity, maximal running speed, accelerations, decelerations, and HMLD, using GNSS/GPS-based tracking systems. In addition, the study seeks to analyze the frequency and distribution of high-speed directional changes as a key component of modern football performance. By providing an objective assessment of these locomotor demands in elite competition, the findings aim to support improved training planning, load monitoring, and performance management in professional football.

Materials and methods

The study used a descriptive observational design to examine external load indicators in elite professional football players during official competitive matches, with match-related locomotor and COD data collected and analyzed retrospectively. The sample consisted of 24 male professional players competing at the highest level of Bulgarian football, all representing the professional club Levski Sofia. Only outfield players who completed the full duration of official matches (two 45-min halves plus standard additional time) were included in the analysis, while goalkeepers were excluded owing to their specific activity profile (Modena et al., 2021).

A total of 103 full-match observations were analyzed, with all players being medically fit and free from injury at the time of data collection. The study adhered to established ethical standards for research involving human participants, and all data were anonymized prior to analysis. Player movement was monitored using the Barin GPS tracking system, operating at a 56 Hz sampling frequency, which is consistent with current practices in elite football performance analysis. The system provided measures of distance, speed, acceleration, deceleration, and directional changes, and previous research has demonstrated acceptable validity and reliability of such technology for assessing high-speed running and movement demands in football.

Each player wore the same tracking device across all recorded matches to minimize inter-unit variability. The devices were fitted in a custom-made vest positioned between the scapulae. Recording began prior to kick-off and ended immediately after the final whistle.

Matches were conducted in accordance with official competition regulations on standard-sized pitches, with no restrictions placed on tactical systems, playing positions, or match conditions, thereby preserving ecological validity.

The following external load variables were extracted for analysis:

- Total distance covered (m)
- Distance covered across five speed zones:
 - Speed zone 1: 0–7.2 km·h⁻¹ (m)
 - Speed zone 2: 7.2–14.4 km·h⁻¹ (m)
 - Speed zone 3: 14.4–21 km·h⁻¹ (m)
 - Speed zone 4: 21–24 km·h⁻¹ (m)
 - Speed zone 5: >24 km·h⁻¹ (m)
- High-speed running distance (zones 3–5) (m)
- Very high-speed and sprinting distance (zones 4–5) (m)
- Sprint distance (m) and sprint count
- Maximum running speed (km·h⁻¹)
- Number of accelerations and decelerations
- Directional changes (left and right turns)
- High metabolic load distance (HMLD)

Speed zone thresholds were defined based on widely recognized standards in elite football research. Descriptive statistics were calculated for all variables, including mean (X), standard deviation (S), minimum (Min), maximum (Max), range (R), coefficient of variation (V%), skewness (As), and kurtosis (Ex), to assess distributional characteristics and variability.

Pearson's correlation coefficients (r) were used to examine the relationships between total distance and distance covered across different speed zones. Statistical significance was set at $p < 0.01$ (two-tailed).

All statistical analyses were performed using standard statistical software. The selected methods and significance level were appropriate for the scale and distribution of the data.

The study did not account for playing position, match outcome, opposition strength, or tactical formations, all of which may influence locomotor demands. Additionally, internal load measures (e.g., heart rate) were not included.

Despite these limitations, the study provides a valid and ecologically sound representation of match demands in elite football.

Results

Table 1 shows descriptive statistics for total distance covered and distance accumulated across five predefined speed zones for field players who completed full football matches, with 103 observations recorded for each variable to ensure consistency and comparability across performance indicators. The mean total distance covered was 9,834 m, ranging from 6,947 to 12,343 m, with a standard deviation of 977 m, reflecting moderate inter-individual variability typical of match-play data influenced by positional roles and tactical demands. The distribution of total distance was approximately normal, as indicated by low skewness (As = 0.324) and kurtosis (Ex = 0.143), suggesting that most players' performances clustered around the mean with no significant deviation from normality (Figure 1).

In speed zone 1 (0–7.2 km·h⁻¹), players covered the greatest absolute distance (mean = 3,740 m), highlighting the predominance of low-intensity activities such as walking and standing during match play. However, this variable exhibited significant distributional irregularities, with very high skewness (As = 4.806) and kurtosis (Ex = 28.922), indicating a highly asymmetric and leptokurtic distribution. This suggests that while most players accumulated moderate, low-speed distances, a small subset displayed exceptionally high values, likely influenced by positional roles or tactical demands.

Distance covered in speed zone 2 (7.2–14.4 km·h⁻¹) averaged 4,107 m, representing a substantial portion of total match load. The distribution was moderately negatively skewed (As = -0.821), indicating that higher distances were more common than lower ones, while the kurtosis (Ex = 2.588) reflects a more peaked distribution than normal, suggesting relatively consistent engagement in moderate-intensity running across players. In speed zone 3 (14.4–21 km·h⁻¹), the mean distance was 1,560 m, with a standard deviation of 505 m, reflecting greater inter-individual variability as running intensity increased. The distribution exhibited positive skewness (As = 0.855) and mild leptokurtosis (Ex = 1.395), indicating that most players covered moderate distances at this intensity, while fewer players achieved exceptionally high values.

High-intensity running in speed zone 4 (21–24 km·h⁻¹) was significantly lower, with an average distance of 251 m. Despite the smaller absolute values, variability remained considerable (S = 103 m). Skewness (As = 0.713) and low kurtosis (Ex = 0.339) indicate a slightly asymmetric yet relatively stable distribution, reflecting limited but consistent exposure to high-speed actions.

Finally, speed zone 5 (>24 km·h⁻¹) accounted for the smallest share of total distance, with a mean of 177 m. The minimum value of 0 m indicates that some players did not reach this speed during the match. The distribution was slightly positively skewed (As = 0.378) and exhibited negative kurtosis (Ex = -0.670), indicating a flatter distribution and greater variability in sprinting activity among players.

Collectively, the data demonstrate a clear inverse relationship between running intensity and distance covered, with the majority of match distance accumulated at low to moderate speeds. As running speed increased, both total distance and the frequency of occurrences decreased, while relative variability increased. Distributional patterns indicate that lower-speed zones are more influenced by tactical and positional factors, whereas higher-speed zones primarily reflect individual physical capacities and the specific demands of each match.

Table 1. Descriptive statistics of distance and speed variables for outfield players (who completed full matches of two 45-min halves, including standard added time)

Index	N	R	Min.	Max.	X	S	As	Ex
Total distance	103	5396	6947	12343	9834	977	0.324	0.143
Speed zone 1 (0–7.2 km/h)	103	5877	2767	8644	3740	739	4.806	28.922
Speed zone 2 (7.2–14.4 km/h)	103	3964	1500	5464	4107	692	-0.821	2.588
Speed zone 3 (14.4–21 km/h)	103	3105	373	3478	1560	505	0.855	1.395
Speed zone 4 (21–24 km/h)	103	494	78	572	251	103	0.713	0.339
Speed zone 5 (over 24 km/h)	103	400	0	400	177	94	0.378	-0.670

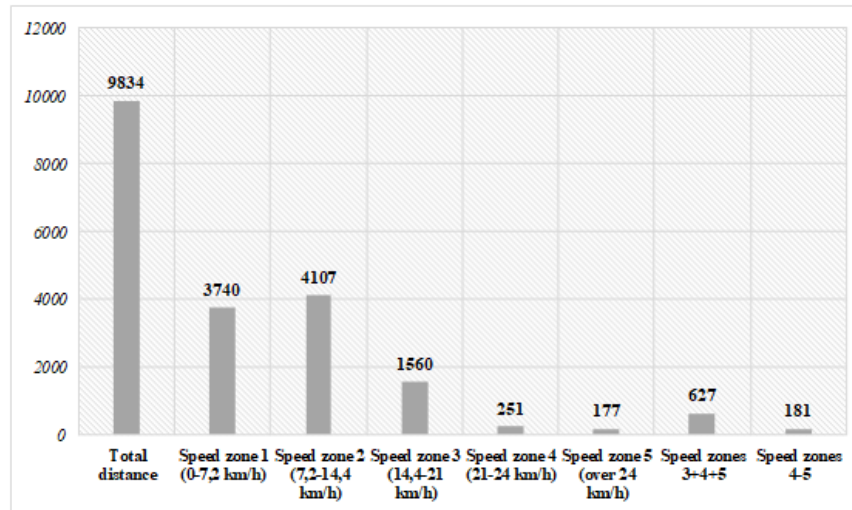


Figure 1. Mean distances (m) covered in different speed zones by outfield players (who played the full match, consisting of two 45-min halves including standard added time)

The coefficient of variation (CV) values presented in Figure 2 describe the match-to-match variability of total distance and distance covered across different speed zones during official football matches. Overall, the results demonstrate a clear increase in variability as running speed increases.

Total distance covered exhibited a low coefficient of variation (9.94%), reflecting consistent performance across matches. This suggests that total distance is a reliable external load metric, largely unaffected by situational or contextual factors such as match status or tactical strategy.

Distance covered in low-speed activities (speed zone 1: 0–7.2 km·h⁻¹) displayed a moderate CV of 19.75%, reflecting relatively consistent walking and standing behavior across matches. Similarly, speed zone 2 (7.2–14.4 km·h⁻¹) showed a CV of 16.84%, indicating low-to-moderate variability in jogging and low-intensity running, which represent fundamental components of match play. A progressive increase in variability was observed for moderate- to high-speed running, with distance covered in speed zone 3 (14.4–21 km·h⁻¹) showing a CV of 32.38% and speed zone 4 (21–24 km·h⁻¹) reaching a CV of 41.00%. These results suggest that higher-intensity running is increasingly influenced by match-specific demands, tactical decisions, and the quality of the opponents.

The highest variability was observed in speed zone 5 (>24 km·h⁻¹), with a CV of 53.14%, reflecting substantial match-to-match fluctuations in sprinting distance. This underscores the sporadic and context-dependent nature of sprints in football, which are often triggered by critical moments such as counterattacks, defensive recoveries, or goal-scoring opportunities. When speed zones were combined, high-speed running (zones 3–5) exhibited a CV of 31.56%, while very high-speed and sprinting distance (zones 4–5) showed a CV of 42.35%. These results indicate that, although combining zones reduces variability compared to isolated sprints, high-intensity running remains much less stable than total distance measures.

In summary, the data indicate that total distance covered is the most reliable locomotor metric, whereas high-speed and sprinting distances demonstrate substantial variability across matches. These findings highlight the need for cautious interpretation of high-intensity running metrics when assessing match demands and emphasize their sensitivity to contextual and tactical factors in official football competitions.

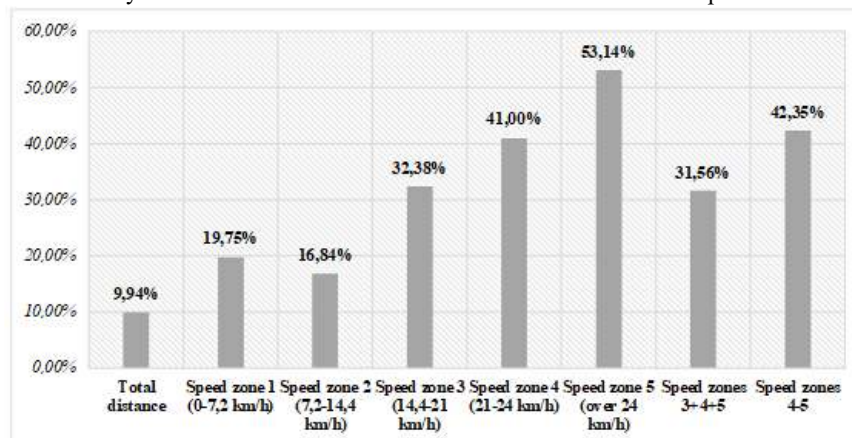


Figure 2. Coefficient of variation (V%) for distance and speed variables

Table 2 presents descriptive statistics for high-speed running activities performed by outfield players who completed the full duration of official matches. A total of 103 match observations were analyzed for each high-speed index, providing a robust sample for assessing distributional characteristics and variability.

For combined high-speed running distance (speed zones 3–5), the mean distance covered was 1,987 m, with a standard deviation of 627 m, reflecting significant variation around the mean. Recorded values ranged from 472 to 3,957 m, yielding a total range of 3,485 m. The CV (31.56%) indicates moderate-to-high match-to-match variability, emphasizing the substantial influence of tactical structure, positional demands, and situational factors on high-speed running volume. Positive skewness ($As = 0.645$) reflects a right-skewed distribution, with extremely high values being less frequent but exerting a significant effect on the overall distribution. The kurtosis value ($Ex = 0.657$) suggests a slightly leptokurtic distribution, indicating a modestly higher concentration of observations around the mean compared to a normal distribution.

For very high-speed running and sprinting distances (speed zones 4–5), the mean distance covered was 427 m, with a standard deviation of 181 m, reflecting substantial variability between matches. Distances ranged from 88 to 956 m, giving a total span of 868 m. The CV (42.35%) was significantly higher than that observed for the broader high-speed category, indicating that sprint-related activities are highly inconsistent across matches. This increased variability underscores the intermittent and context-dependent nature of sprint actions in football. Skewness ($As = 0.484$) indicates a moderately right-skewed distribution, while the near-zero kurtosis ($Ex = -0.011$) suggests an approximately mesokurtic distribution, closely resembling normality in terms of peakedness. Collectively, these findings indicate that although combining speed zones (3–5) reduces relative variability compared with sprinting distance alone (zones 4–5), high-intensity running metrics remain significantly less stable than global measures such as total distance covered. The pronounced variability and non-normal distribution of high-speed and sprinting distances highlight their sensitivity to match context, tactical demands, and transient game events, emphasizing the need for careful interpretation when using these metrics for performance monitoring and load management in elite football.

Table 2. Descriptive statistics of high-speed activities performed by outfield players (who completed full matches of two 45-min halves, including standard added time)

Index	N	R	Min.	Max.	X	S	V%	As	Ex
Speed zones 3–5	103	3485	472	3957	1987	627	31.56%	0.645	0.657
Speed zones 4–5	103	868	88	956	427	181	42.35%	0.484	-0.011

Table 3 presents descriptive statistics on rapid directional changes among outfield players who completed full matches (two 45-min halves plus standard added time). The analysis is based on a sample of 103 observations for each variable, ensuring consistency and comparability across indices.

The HMLD index, representing the highest overall workload, had a mean value (X) of 1,623 and a wide range ($R = 1,842$), spanning from 795 to 2,637. The relatively large standard deviation ($S = 391$) and coefficient of variation ($V\% = 24.12\%$) indicate substantial inter-individual variability in high-movement directional load among players. Positive skewness ($As = 0.579$) reflects a moderately right-skewed distribution, with higher HMLD values occurring more frequently in a smaller subset of players. The low positive kurtosis ($Ex = 0.143$) suggests a distribution close to normal, exhibiting only slight peakedness.

In terms of accelerations, players averaged 91 actions per match, with values ranging from 34 to 134. Variability was moderate, reflected by a standard deviation of 19 and a coefficient of variation of 21.32%. Slightly negative skewness ($As = -0.253$) indicates a tendency toward higher frequencies of acceleration, with fewer players performing very low counts, while low kurtosis ($Ex = 0.238$) suggests a relatively even distribution without pronounced clustering.

A similar pattern was observed for decelerations, with a mean of 107 actions per match and a range of 58–160. Deceleration showed slightly lower relative variability ($V\% = 18.70\%$), indicating greater consistency among players in braking actions. Negative skewness ($As = -0.238$) again reflects a higher occurrence of high counts, and kurtosis ($Ex = 0.008$) indicates an almost perfectly normal distribution.

For directional turns, right and left turns had similar mean values ($X = 53$ for both), indicating a balanced workload during match play. Right turns showed slightly higher variability ($V\% = 32.62\%$) compared to left turns ($V\% = 30.98\%$), suggesting less consistency among players when performing rightward directional changes. Both variables exhibited positive skewness ($As = 0.582$ for right turns and $As = 0.712$ for left turns), indicating that most players performed a moderate number of turns, while a smaller subset displayed substantially higher counts. Kurtosis values differed between directions: left turns had a higher Ex value (0.567), reflecting a more peaked distribution and greater concentration of observations around the mean.

Overall, the results indicate that rapid changes of direction are a frequent and highly variable component of match demands. The HMLD index demonstrates the highest absolute and relative variability, reflecting differences in individual movement strategies or positional roles on the pitch. Accelerations and decelerations are more evenly distributed among players, whereas turning actions exhibit greater variability and asymmetry. These findings underscore the importance of personalized load monitoring and position-specific conditioning strategies to adequately prepare players for the multidirectional demands of competitive match play.

Table 3. Descriptive statistics of rapid directional changes among outfield players (who completed full matches of two 45-min halves, including standard added time)

Index	N	R	Min.	Max.	X	S	V%	As	Ex
HMLD	103	1842	795	2637	1623	391	24.12%	0.579	0.143
Acceleration	103	100	34	134	91	19	21.32%	-0.253	0.238
Deceleration	103	102	58	160	107	20	18.70%	-0.238	0.008
Right turn	103	84	21	105	53	17	32.62%	0.582	0.235
Left turn	103	78	24	102	53	17	30.98%	0.712	0.567

Table 4 presents descriptive statistics for the maximum speed of outfield players who completed full matches (two 45-min halves plus standard added time). The variables analyzed include sprint distance, sprint count, and maximum running speed, reflecting different aspects of high-speed performance during match play.

The sprint distance (m) variable exhibits very high variability among players. Although the mean sprint distance is relatively low ($X = 35$ m), values range widely from 0 to 158 m ($R = 158$). The large standard deviation ($S = 391$) and extremely high coefficient of variation ($V\% = 1126\%$) reflect substantial inter-individual differences, indicating that sprinting distance is highly inconsistent and largely dependent on match context, positional role, or tactical demands. Strong positive skewness ($As = 1.134$) shows that most players covered minimal sprint distances, while a smaller subset achieved significantly higher values. The low positive kurtosis ($Ex = 0.291$) indicates a moderately flat distribution, with minimal clustering around the mean.

The sprint count variable further highlights the irregular nature of sprinting actions during matches. Players averaged 5 sprints per match, with values ranging from 0 to 11, indicating that sprint frequency is limited for most individuals. The coefficient of variation is extremely high ($V\% = 401\%$), reflecting substantial differences in sprint involvement across the sample. Slight positive skewness ($As = 0.495$) suggests a tendency toward lower sprint counts, with relatively few players performing higher numbers of sprints. Negative kurtosis ($Ex = -0.407$) indicates a flatter-than-normal distribution, consistent with a wide dispersion of sprint counts rather than clustering around the mean.

In contrast, maximal speed (km/h) displays markedly different statistical characteristics. The mean maximal speed during matches was high ($X = 28.69$ km/h), with values ranging from 6.41 to 34.88 km/h ($R = 28.47$). Compared to sprint distance and sprint count, maximal speed shows much lower variability, as indicated by a standard deviation of 2.86 km/h and a low coefficient of variation ($V\% = 9.98\%$), suggesting a relatively uniform ability among players to reach high running velocities during match play. Strongly negative skewness ($As = -2.209$) indicates that most players achieved speeds near the upper end of the distribution, with very low maximal speeds occurring rarely. The extremely high kurtosis ($Ex = 13.666$) reflects a sharply peaked distribution, showing strong clustering of maximal speed values around the mean and limited dispersion.

Overall, the data reveal a clear distinction between sprint volume variables (sprint distance and sprint count) and sprint capacity variables (maximal speed). While the ability to reach high maximal speeds appears relatively consistent across players, the execution of sprinting actions during matches is highly variable and context-dependent. These findings indicate that maximal speed represents a stable physical capacity, whereas sprint-related match actions are strongly influenced by tactical role, playing position, and situational factors. Therefore, performance analysis and training interventions should differentiate between developing maximal speed capacity and managing match-specific sprint exposure.

Table 4. Descriptive statistics of maximum speed characteristics of outfield players (who completed full matches of two 45-min halves, including standard added time)

Index	N	R	Min.	Max.	X	S	V%	As	Ex
Sprint (m)	103	158	0	158	35	391	1126%	1.134	0.291
Sprint count	61	11	0	11	5	19	401%	0.495	-0.407
Maximal speed (km/h)	284	28.47	6.41	34.88	28.69	2.86	9.98%	-2.209	13.666

Table 5 presents the correlation analysis of distances covered across different speed zones by field players who completed full-match participation (two 45-min halves plus normal additional time). The correlation matrix provides insight into how total distance and distances in specific speed zones relate, revealing the structure of match-running demands.

Moderate to strong positive correlations were observed between total distance and distances covered in speed zone 2 (7.2–14.4 km/h; $r = 0.648$), speed zone 3 (14.4–21 km/h; $r = 0.772$), and speed zone 4 (21–24 km/h; $r = 0.570$). All correlations were statistically significant at the 0.01 level, indicating that increases in total match distance are primarily driven by greater volumes of low-to-moderate and high-speed running rather than very low-speed or maximal-speed activities. The strongest association with total distance was found in speed zone 3, suggesting that running at moderate-to-high intensities constitutes a key component of overall match load.

In contrast, total distance showed only weak correlations with speed zone 1 (0–7.2 km/h; $r = 0.094$) and speed zone 5 (>24 km/h; $r = 0.125$), suggesting that walking and very low-speed activities, as well as maximal-speed running, contribute relatively little to inter-individual differences in total distance covered during match play. Significant negative correlations were observed between speed zone 1 and all higher-intensity zones, including zone 2 ($r = -0.563$), zone 3 ($r = -0.391$), zone 4 ($r = -0.309$), and zone 5 ($r = -0.305$). These inverse relationships suggest a trade-off between low- and high-speed activities, whereby players who cover greater distances at higher speeds tend to spend less time in low-speed movement, reflecting differences in playing style, positional roles, or overall match involvement.

Positive, statistically significant correlations were observed between adjacent, progressively higher-speed zones. Specifically, speed zone 2 was positively correlated with zone 3 ($r = 0.628$) and zone 4 ($r = 0.356$), while speed zone 3 showed a strong association with zone 4 ($r = 0.735$). These findings indicate a coherent progression in running intensities, with players covering greater distances at moderate speeds also more likely to engage in higher-speed running. Additionally, speed zone 4 was strongly correlated with speed zone 5 ($r = 0.693$), suggesting that high-speed running (21–24 km/h) is a strong predictor of exposure to sprinting activities (>24 km/h).

In contrast, no significant relationship was found between speed zones 2 and 5 ($r = 0.037$), indicating that low-to-moderate running volume does not directly translate into maximal-speed efforts. This supports the notion that sprinting represents a distinct component of match performance, primarily influenced by tactical context and explosive actions rather than overall running volume.

Overall, the correlation structure indicates that total match distance is primarily associated with moderate- and high-speed running, while very low-speed and maximal-speed activities represent more independent aspects of performance. The strong associations between neighboring speed zones suggest a hierarchical organization of running intensities, whereas the weak relationships involving maximal-speed running underscore its situational and intermittent nature. These findings highlight the need for differentiated monitoring of speed zones in performance analysis and emphasize the importance of targeting specific running intensities in training design and load management strategies.

Table 5. Correlation analysis of distance covered across different speed zones by outfield players (who completed full matches of two 45-min halves, including standard added time)

Total distance	Total distance	Speed zone 1 (0–7.2 km/h)	Speed zone 2 (7.2–14.4 km/h)	Speed zone 3 (14.4–21 km/h)	Speed zone 4 (21–24 km/h)	Speed zone 5 (over 24 km/h)
Speed zone 1 (0–7.2 km/h)	0.094					
Speed zone 2 (7.2–14.4 km/h)	0.648	–0.563				
Speed zone 3 (14.4–21 km/h)	0.772	–0.391	0.628			
Speed zone 4 (21–24 km/h)	0.57	–0.309	0.356	0.735		
Speed zone 5 (over 24 km/h)	0.125	–0.305	0.037	0.309	0.693	

Bold font indicates that the correlation is significant at the 0.01 level (two-tailed).

Discussion

This study provides a comprehensive assessment of high-speed running, sprinting, and COD demands during official match play in elite professional football. The results confirm that modern football is characterized by relatively stable overall running volumes but highly variable high-intensity and multidirectional actions, reflecting the complex and situational nature of match physical demands.

Total distance covered exhibited low variability and an approximately normal distribution, reinforcing its validity as a reliable indicator of overall match load. However, the findings demonstrate that total distance alone does not adequately capture the qualitative demands of match play. Distances covered at moderate and high running speeds (speed zones 2–4) were the primary contributors to total distance, whereas very low-speed and sprinting activities showed only weak associations, supporting previous evidence that critical match actions are not reflected in overall distance metrics.

High-speed running and sprinting distances exhibited progressively greater variability with increasing speed, underscoring their intermittent and context-dependent nature. Sprint distance and sprint count demonstrated very high coefficients of variation, whereas maximal speed showed low variability among players. This indicates that maximal speed represents a relatively stable physical capacity, while sprint exposure during matches is largely influenced by tactical role, positional demands, and situational factors. These findings

emphasize the importance of differentiating between sprint capacity and sprint volume when monitoring performance.

The COD analysis revealed that accelerations, decelerations, and turning actions are integral components of match play. Decelerations were slightly more consistent than accelerations, indicating relatively uniform braking demands across players. In contrast, HMLD and turning actions showed substantial inter-individual differences, reflecting variability in movement strategies and positional roles. Although left and right turns were balanced at the group level, their variability highlights the importance of individualized assessment of multidirectional load.

Correlation analysis demonstrated a structured relationship between adjacent speed zones, reflecting a hierarchical progression of running intensities. The absence of a significant association between moderate-speed running and sprinting underscores that sprinting is a distinct, situational component of performance. Negative correlations between low-speed activity and higher-speed zones further indicate a trade-off between passive and active movement profiles.

In conclusion, these findings highlight that elite football performance cannot be fully captured by total distance alone. High-speed running, sprinting, and COD actions are highly variable yet essential elements of match demands, supporting the adoption of personalized, speed-zone-specific, and multidirectional monitoring strategies to optimize training design, load management, and injury prevention in elite football.

Conclusions

This study demonstrates that the physical demands of elite football are characterized by stable overall running volumes but highly variable high-speed running, sprinting, and COD actions. While total distance covered remains a reliable indicator of overall match load, it does not fully reflect the critical, context-dependent actions that influence performance outcomes.

High-speed running and sprinting distances exhibited significant variability between matches, whereas maximal speed appeared to be a relatively consistent physical capacity. This distinction highlights the importance of differentiating between sprint capacity and match-specific sprint exposure when evaluating player performance. Furthermore, the frequent occurrence of accelerations, decelerations, and directional changes underscores the significant multidirectional demands placed on players during competition.

From a practical standpoint, these findings support the implementation of personalized monitoring strategies that extend beyond total distance metrics. Training programs should incorporate position-specific high-speed running and COD drills to better reflect match demands, while load management strategies should account for the high variability of sprinting and multidirectional actions to minimize injury risk. Overall, integrating detailed speed-zone and COD analyses into performance monitoring can improve training effectiveness and promote sustainable performance in elite football.

Conflicts of interest – There are no conflicts of interest to declare.

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