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From the lab to the field: Correlations between in-match running metrics and performance testing in elite male soccer

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Abstract

This study aimed to investigate the relationship between standardized linear sprint test performance and in-match running metrics in elite soccer players. Forty-seven national-level male youth soccer players (aged 17–23 years) completed a standardized 30-m sprint test with 5- and 10-m split times. Their in-match running performance was then monitored across six games, recording total distance covered, sprinting activity, and peak running speed using wearable tracking devices. The findings indicated moderate to large correlations (r = −0.63 to −0.40) between sprint test performance and match-related peak speeds. Conversely, no substantial correlations were identified between sprint performance and metrics such as sprint count or total distance, likely indicative of the impact of tactics and match context. No significant variations in positional characteristics were identified. The findings provide support for the use of linear sprint testing, particularly over distances of 30 m, as a valid tool for the assessment of sprint capacity in the context of soccer. It is recommended that coaches undertake regular testing of sprint performance in order to monitor speed development and to adapt training programs accordingly.

Keywords

Acceleration, association football, deceleration, linear sprint, playing position, speed

Introduction

Success in soccer is contingent upon the disruption of the opponent's system of play with a view to creating opportunities for scoring, whilst concurrently preserving one's own defensive integrity.[1,2] This dual challenge necessitates not only technical and tactical proficiency,[1,2] but also optimal physical conditioning.[3] Research indicates that the majority of scoring plays (83%) in elite soccer are preceded by high-intensity power and speed actions, with linear sprinting being particularly prominent.[4] The ability to rapidly accelerate and decelerate enables players to evade opponents, gain positional advantages, and generate offensive opportunities.[4,5] It is evident that nearly half of all goals (45%) are preceded by a linear sprint from the scoring player, typically without ball involvement and in open space. This observation underscores the dominant role of linear sprinting over curved or multidirectional actions.[4,6,7] The duration of these sprints is reported to range from 2 to 4 s, occurring at approximately 90-s intervals during

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a match.[8] The number of sprints per match varies depending on the position and playing style of the athletes, with values ranging from 17 to 81 sprint actions.[9–11] The majority of these sprints cover distances of less than 30 m, with a significant proportion falling within the 0-to-10-m range.[9–12] It has been demonstrated that elite players attain peak sprint velocities of 31 to 35 $km \cdot h^{-1}$, thus emphasizing the significance of both speed and power in elite-level soccer.[13–15] The considerable impact of linear sprint performance is substantiated by numerous studies, which have demonstrated considerable variability in sprint performances, ranging from 10 to 40 m, depending on performance level.[10,16] It has been demonstrated that elite players demonstrate superior sprint performance when compared to sub-elite counterparts.[17–19] Consequently, the development of sprinting ability, which is achieved through strength, plyometric and speed training, has become a central focus of research.[20–22] Linear sprint testing has become a standard component of performance assessments in soccer.[3,23] Despite the evidence that controlled sprint testing improves performance, its transferability to actual match situations remains limited. In one particular study on professional soccer players, strong correlations were observed between 30-m sprint times and peak match speeds ($r = -0.74$ to -0.86) but weak correlations with sprint counts ($r = -0.24$ to 0.34) across ten matches.[24] However, data concerning youth soccer are deficient, with existing findings primarily derived from other sports such as ice hockey and Gaelic football.[25,26]

The present study sought to (1) examine the relationship between standardized linear sprint performance and training, as well as in-match running metrics using global navigation satellite system (GNSS) tracking and internal measurement units (IMU), and (2) assess positional differences in match running demands among elite youth soccer players.

Method

Research design

A cross-sectional study was conducted to investigate the extent to which standardized linear sprint tests correlate with in-match performance metrics in youth elite soccer (Figure 1). A total of 73 elite youth soccer players (17–23 years old) were examined for linear sprint performance (with 5-, 10-, and 30-m times). Additionally, running performance data from the first six official matches, which took place during the first half of the season were collected using wearable sensory devices (GNSS and IMU) to record total distance, total sprint distance, top speed, sprint count, as well as accelerations and decelerations.

The participants were familiar with linear sprint diagnostics, which formed part of their semi-annual assessments. On the day preceding the designated test day, no training sessions were conducted, and the participants were instructed to abstain from strenuous activities. On the test day, participants were advised to refrain from any training prior to the linear sprint diagnostic. Throughout the tests, researchers provided strong verbal encouragement to ensure participants exerted maximal effort. To minimize potential confounding factors, participants were instructed to maintain their regular dietary habits and fluid intakes. The analysis was only conducted on field players who had accumulated a minimum playing time of 45 min across a minimum of four out of the six matches included in the study. This resulted in a total minimum play time of 180 min.

Subjects

Power analyses were conducted in G*Power 3.1 (Universität Düsseldorf, Düsseldorf, Germany) to determine the sample size requirements. Separate global-effects MANOVAs (each with five groups [playing positions], $\alpha = 0.05$, $1-\beta = 0.80$, and assuming a medium effect size [$f^2 = 0.15$]) were conducted. The first MONOVA on linear sprint times and peak speed, the second on total distance covered, mean sprint distance, mean sprint count, acceleration count, and deceleration count, the third on peak speeds in Training an d match. Each analyses indicated a required sample size of up to 55 participants. A similar calculation indicates that for a Pearson correlation test with $r = 0.5$, an alpha level of 0.05, and 80% power, the required sample size is approximately 52 participants, suggesting a comparable sample size requirement. Therefore, this study recruited a total of 73 national-level male youth soccer players (Tier 3),[27] representing approximately 30% more than the maximum estimated requirement (55 participants), to ensure sufficient power after applying inclusion and exclusion criteria. Participants were recruited from three elite youth soccer academies and represented teams competing in the highest German junior divisions (U17, U19 Bundesliga) or U23 fourth highest senior league (Regionalliga). The sample included 11 athletes from national teams (U17, U19, U21), including Germany, Kosovo, Italy, Albania, Turkey, Croatia or South Korea. This placed them in the category of elite athletes.[28] Throughout the 6-week study period, the training volume comprised four weekly soccer sessions (approx. 90–105 min each), incorporating both team-based and position-specific drills. In addition, the programme involved two weekly strength and athletic conditioning sessions (approx. 60 min each) and one weekly recovery session (approx. 60 min). On occasion, an additional 30-min massage treatment was also administered. All participants engaged in weekend competitions with their respective teams during the season. Prior to participation, all individuals, and for those under the age of 18, also their parents, were informed of the experimental risks associated with the research and provided written informed consent to participate in the present study. None of the included

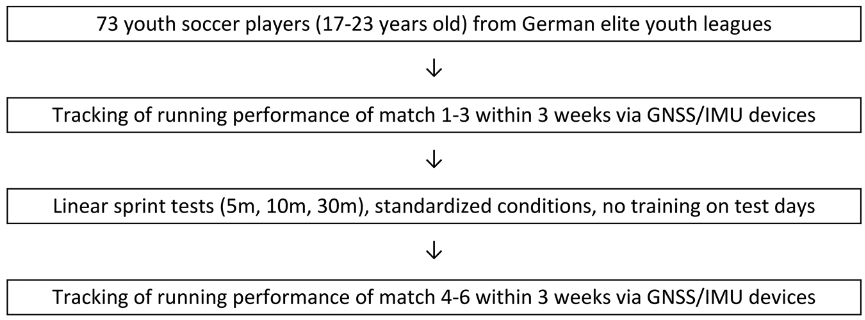

Figure 1. Study design.

participants reported any injuries at the time of testing. 26 participants were excluded from the data analysis due to insufficient playing time. However, these participants were still able to continue with the training and matches without any disadvantages. The group characteristics, presented as mean ± standard deviation, were as follows: height, 1.82 ± 0.06 m; body mass, 75.3 ± 7.3 kg; and age, 18.8 ± 3.5 (range:17–23) years old. Ethical approval for the study was granted by the institutional review board at the German University of Health and Sport (DHGS-EK-2024-009). All procedures were conducted in accordance with the Helsinki Declaration.

In-match sprint performance

Match running performance was recorded using 10-Hz GNSS and IMU technology (Catapult Vector S7, Catapult Sports, Melbourne, Australia), worn in a specially designed vest provided by the manufacturer positioning the sensors in a vertical position between the scapulae.[29] In order to minimize measurement variability, the sensors were activated 15 min prior to the commencement of each match or training. This allowed sufficient time for successful satellite connection. Additionally, each sensor remained assigned to the same player for the entire study period (training and match). Furthermore, the participants were accustomed to the equipment through regular use during training and matches over the course of several seasons. The Catapult Vector S7 system has been documented as a valid and reliable device for accurately measuring running performance metrics in sports under various conditions (Intraclass Correlation Coefficient [ICC] = 0.84–0.99, Coefficient of Variation [CV] = 0.01 to 3.9%), with typical measurement errors for the specific system ranging between 1% and 2.5%.[29–32] The data were subsequently downloaded and analyzed using the manufacturer's custom software (OpenField Operator Console – Version 3.13.0).

Total distance (distance per minute: distance covered based on changes in position), peak running speed (maximum instantaneous speed based on changes in position and time), sprint count (number of instances in sprint speed zone [>23.0 km·h^{-1}] more than a distance of 5 m), total sprint distance [Dwell Time: >0.1](distance per minute: distance covered in sprint speed zone based on changes in position), as well as the number of accelerations and decelerations [(±) 2–3 m/s^2 |(±) 3–4 m/s^2 | (±) >4 m/s^2], based on changes in speed and time, were analyzed in three matches prior to and three matches following the linear sprint testing. The variables were normalized based on the number of minutes played and extrapolated to a 90-min performance. In addition to the matches, players wore the Catapult system during every training session within this period. This allowed for the recording of the highest speeds achieved during both training sessions and matches. The maximum values from all training sessions during the study period were included in the analysis.

Linear sprint performance

A 30-m linear sprint measurement was conducted to assess participants' acceleration and linear sprint ability. Tests were performed on new-generation artificial turf, reflecting the surface on which the players predominantly train and compete, alongside natural grass fields. The participants wore soccer boots to simulate match conditions. After a standardized warm-up consisting of low-intensity jogging at a self-selected pace, following running drills, dynamic stretching, and acceleration runs, participants performed two maximal sprints, separated by 3-min rest intervals. Sprint times were recorded via four double-light barriers (Witty Time Kit, Microgate, Bolzano, Italy). Split times at 5-m, 10-m, and flying sprint (10-m to 30-m) were collected.[33] The start line was positioned 0.75 m behind the first light gate to standardize the initial momentum and avoid premature triggering of the system by hand movement or a tilted upper body position.[34–36] Participants were granted autonomy in initiating the timing sequence upon activating the barriers. Additionally, the players wore the Catapult system during the linear sprints to record the highest speed achieved within the 30-m distance. The test-retest reliability is reported to have an intraclass correlation coefficient (ICC) = 0.94–0.97.[35] The fastest 30-m sprint time achieved by each participant was used for data analysis.

Statistical analysis

Statistical analyses were conducted using SPSS software, version 29 (IBM, Ehningen, Germany). Visualizations of scatterplots and heatmaps were created in R (version 4.3.1, R Foundation for Statistical Computing, Vienna, Austria) using the ggplot2 package. Data are reported as mean ± SD. The significance level for all statistical tests was set at 0.05. Normality was assessed using the Shapiro-Wilk test. Reliability was calculated using the ICC, CV, Mean Absolute Error (MAE), and Mean Absolute Percentage Error (MAPE). Reliability statistics were derived from two trials conducted on the test day. Homogeneity or heterogeneity of variance was assessed using Levene's test for equality of variances, while the homogeneity of covariances was evaluated using Box's test. Three separate one-way MANOVA analyses were conducted to examine differences between playing positions: one for sprint test performance, one for mean match running data and another for peak training and match speed. When MANOVA indicated significant results, post-hoc univariate ANOVAs were performed for each dependent variable. For omnibus comparisons, partial eta-squared values (η^2) were calculated as an indicator of effect size, with values of 0.01–0.06 considered small, 0.07–0.13 medium, and ≥0.14 large. Relationships between sprint test results and match running performance were analyzed using Pearson's correlation coefficient. According to Cohen,[37] the suggested effect size thresholds for correlation coefficients are as follows: trivial ($r \leq 0.10$), small ($0.10 < r \leq 0.30$), moderate ($0.30 < r \leq 0.50$), and large ($r > 0.50$). In this study, these thresholds (effect sizes) will be considered in the interpretation and evaluation of the correlation results, taking into account the specific research context and practical relevance.

Results

The linear sprint data, including split times, and the match data exhibited a normal distribution. The results of the linear sprint performance are presented in Table 1. The reliability of the linear sprint test was confirmed by an ICC of 0.913 for the 5 m split time (CV = 2.1%; MAE = 0.03 s; MAPE = 2.85%), an ICC of 0.953 for the 10 m split time (CV = 1.0%; MAE = 0.02 s ; MAPE = 1.35%), and an ICC of 0.983 for the 30 m time (CV = 0.4%; MAE = 0.02 s ; MAPE = 0.52%).

Table 1 presents the descriptive statistics for linear sprint performances. Levene's test indicated homogeneity of error variances for linear sprint performance, split times, and peak speed ($p = 0.084$–0.972). Additionally, Box's test confirmed the homogeneity of covariances ($p = 0.362$). A one-way MANOVA revealed no statistically significant differences between playing positions across the combined dependent variables ($F = 1.079$, $p = 0.382$, partial $\eta^2 = 0.098$, Wilk's $\Lambda = 0.663$).

The total playing time for the participants averaged 456 ± 82 min (range: 287–579 min) across the included matches, corresponding to an average of 85 ± 9 min per match. Mean match performances are presented in Table 2. The Levene's test indicated homogeneity of error variances for mean sprint distance, mean sprint count, acceleration count, and deceleration count ($p = 0.074$–0.526); however, mean distance exhibited heterogeneity ($p < 0.001$). Furthermore, the Box's test revealed heterogeneity of covariances ($p = 0.016$). A one-way MANOVA identified statistically significant differences between playing positions across the combined dependent variables ($F = 2.013$, $p = 0.006$, partial $\eta^2 = 0.213$, Wilk's $\Lambda = 0.383$). However, subsequent post-hoc ANOVAs did not attain statistical significance between positions ($F = 0.479$–2.108, $p = 0.097$–0.751, partial $\eta^2 = 0.044$–0.167).

Participants achieved, on average, 91 ± 5% (Range: 76–99%) of their highest recorded speed during each match. Descriptive statistics of peaks speeds are shown in Table 2. Levene's test indicated homogeneity of error variances for peak speeds in training and match ($p = 0.427$–0.436). Additionally, Box's test confirmed the homogeneity of covariances ($p = 0.102$). A one-way MANOVA identified no statistically significant differences between playing positions across the combined dependent variables ($F = 0.812$, $p = 0.594$, partial $\eta^2 = 0.073$, Wilk's $\Lambda = 0.859$).

As demonstrated in Figure 2, there is a moderate to strong correlation between linear sprint performance and peak speed metrics. As illustrated in Figure 3, these relationships were particularly robust for peak sprint speed during match play. In contrast, Figure 4 demonstrates that the correlations between linear sprint test performance and average running performance metrics during match play are generally negligible, with the majority failing to attain statistical significance.

Discussion

The present study investigated the relationship between standardized linear sprint tests and in-match running performance in elite youth soccer players. The findings indicated moderate to large correlations between sprint test performance and in-match peak speeds. However, the anticipated positional differences in sprint and match metrics were not statistically confirmed.

The observed running metrics were consistent with previous research, thereby supporting the validity of the collected data.[38,39] In accordance with the findings of previous

Table 1. Descriptive statistics of linear sprint performance over 30 m, including split intervals and maximal sprint velocity, in elite male youth soccer players grouped by position.

Position	n	5 m (s)	10 m (s)	30 m (s)	Peak speed (km·h^{-1})
Striker	9	0.99 ± 0.06	1.68 ± 0.07	4.00 ± 0.14	32.18 ± 1.09
Attacking Midfielder	9	0.97 ± 0.07	1.67 ± 0.08	4.04 ± 0.16	31.42 ± 0.89
Central Midfielder	11	1.01 ± 0.08	1.71 ± 0.09	4.06 ± 0.15	31.51 ± 1.49
Wing-Back / Winger	8	0.98 ± 0.08	1.67 ± 0.08	4.01 ± 0.16	31.96 ± 0.92
Center Back	10	1.00 ± 0.06	1.72 ± 0.08	4.05 ± 0.14	31.97 ± 0.74
Total	47	0.99 ± 0.07	1.69 ± 0.08	4.03 ± 0.15	31.80 ± 1.07

Table 2. Descriptive statistics of mean match running performance (extrapolated to 90 min), and peak speeds recorded during training and official matches over a six-match period, stratified by playing position in elite male youth soccer players.

Position	Mean Distance (m)	Mean Sprint Distance (m)	Mean Sprint Count	Mean Acceleration Count	Mean Deceleration Count	Peak match/ training speed (km·h^{-1})	Peak match speed (km·h^{-1})
Striker	9070 ± 1086	221 ± 115	13 ± 6	85 ± 32	82 ± 30	33.43 ± 1.12	31.21 ± 1.42
Attacking Midfielder	9311 ± 2410	207 ± 96	11 ± 5	85 ± 39	87 ± 43	32.83 ± 0.67	30.25 ± 1.54
Central Midfielder	10238 ± 896	162 ± 118	11 ± 8	107 ± 34	107 ± 35	32.55 ± 1.21	30.58 ± 1.35
Wing-Back / Winger	9888 ± 573	268 ± 114	15 ± 7	108 ± 48	109 ± 48	32.99 ± 0.86	31.07 ± 0.97
Center Back	9432 ± 539	147 ± 44	10 ± 4	81 ± 22	81 ± 22	33.10 ± 0.86	30.86 ± 0.98
Total	9605 ± 1298	207 ± 96	11 ± 5	93 ± 39	93 ± 38	32.96 ± 1.00	30.78 ± 1.27

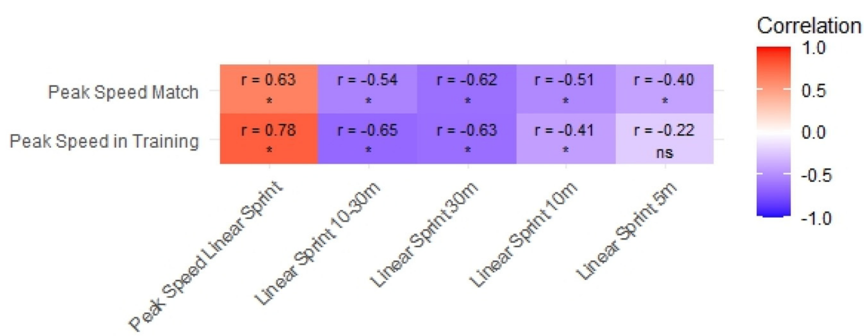

Figure 2. Correlations (r-values) between linear sprint performance variables and peak speeds recorded during training and match play over a six-match period in elite male youth soccer players.

research, which emphasized positional variations in match sprint demands,[9–11,40] the present study's MANOVA revealed a significant positional effect. Nevertheless, this effect was not substantiated by subsequent post-hoc ANOVAs. This discrepancy may result from differences in the analytical approaches: MANOVA considers the intercorrelations among dependent variables, potentially enhancing its sensitivity to detect subtle combined effects, whereas the subsequent univariate ANOVAs evaluate each variable independently without accounting for these correlations. Consequently, the positional effect might not have been robust enough to remain statistically significant when analyzed separately through ANOVAs. Accordingly, previous research suggests that age-related differences within the analyzed age groups are generally small.[38] From a practical perspective, it can also be argued that sprint performance plays a crucial role across all playing positions in modern soccer.[16] The tactical significance of sprint actions has evolved markedly, driven by diverse pressing structures (both high- and low-block systems), compact defensive shapes that often leave exploitable space once pressing lines are bypassed, immediate ball-chasing after turnovers regardless of field position and rapid transitions. Above all, enhanced positional fluidity, both within matches (e.g., full-backs covering half-spaces or attackers dropping into mid-field) or across a season (e.g., via rotations or injury cover). All of these factors likely underlie our non-significant post-hoc comparisons: players in nominally different

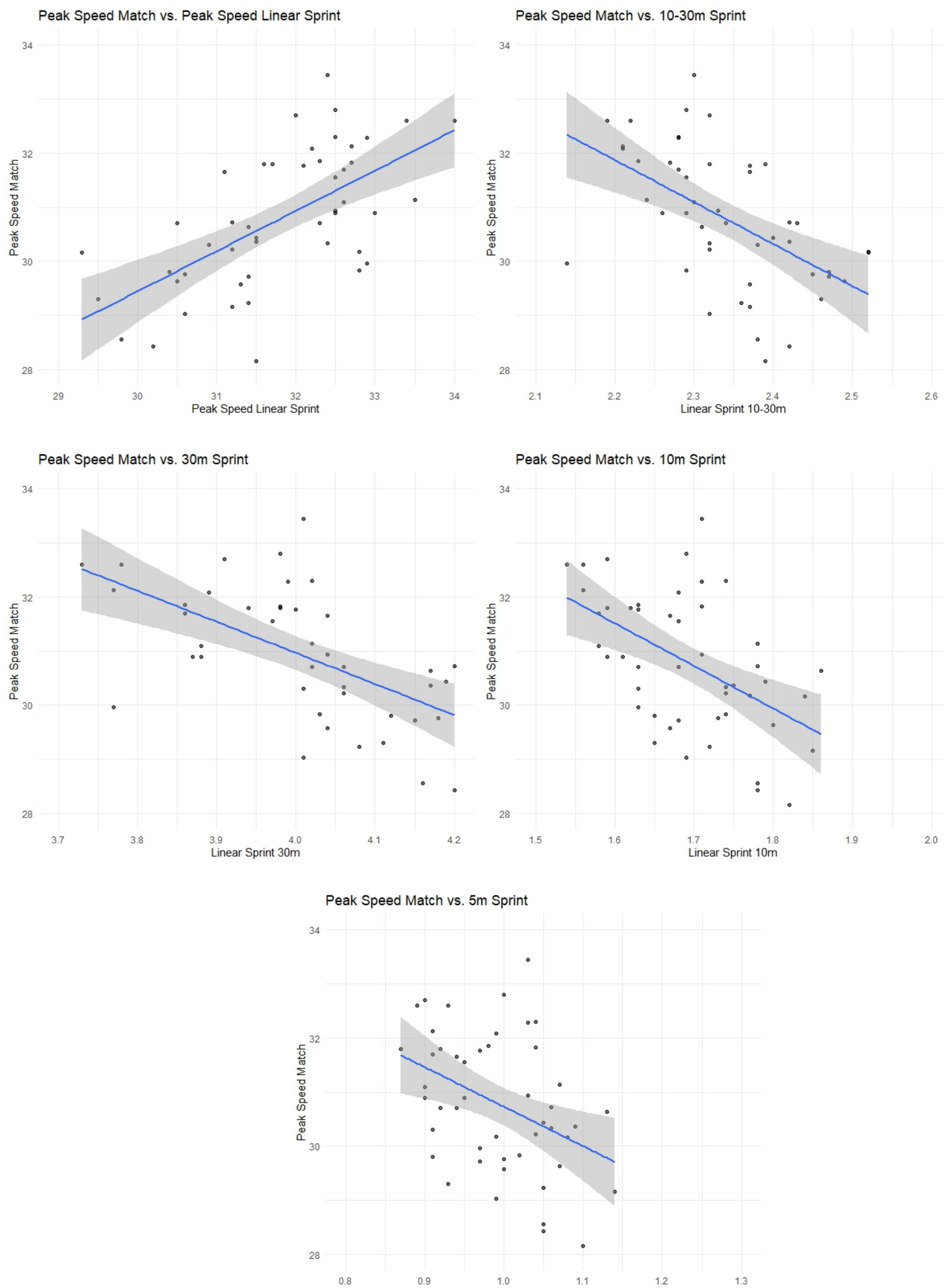

Figure 3. Scatter plots with linear regression lines and 95% confidence intervals illustrating the relationships between linear sprint performance variables and peak speeds recorded during training and match play across a six-match period in elite male youth soccer players.

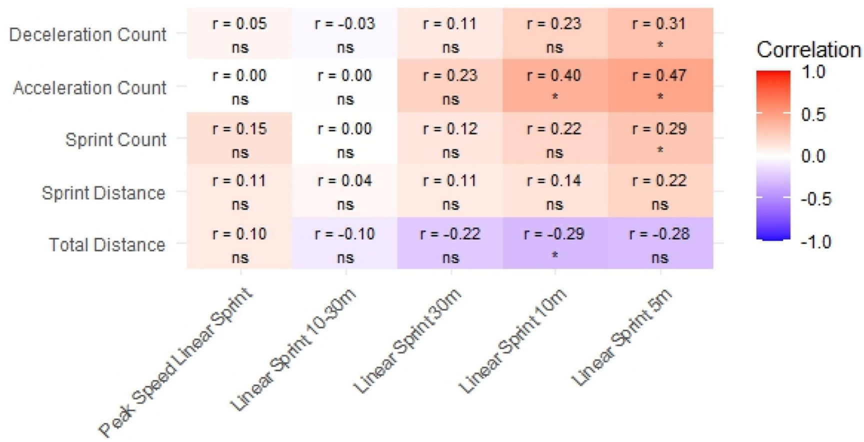

Figure 4. Correlations (r-values) between linear sprint performance variables and in-match running performance indicators, including sprint count, number of accelerations and decelerations as well as sprinting distance, and total running distance recorded over a six-match period in elite male youth soccer players.

positions now exhibit very similar running demands in match play, reflecting how modern tactical fluidity may has blurred traditional role-specific distinctions.[41,42]

The correlation magnitudes were consistent with those observed in previous research in professional soccer,[24] thereby reinforcing the relevance of linear sprint tests for the assessment of maximal sprinting capability. Peak speeds in both training and matches exhibited strong correlations with linear sprint test variables, particularly over 30 m, thereby reinforcing their relevance as indicators of sprinting ability in match situations.[33] As anticipated, the 5-m sprint performance exhibited weaker correlations with peak speeds presumably attributable to the elevated variability in initial acceleration performance (e.g., due to individual technical differences) and marginally diminished reliability. These findings are consistent with extant literature suggesting that shorter sprint distances primarily assess acceleration ability, while longer distances provide a more accurate measure of an athlete's maximal sprint capacity.[24] A number of additional in-match metrics demonstrated non-significant to only moderate correlations with sprint-test performance. These include sprint count, acceleration and deceleration count, as well as sprint and total distance. These findings imply that maximal sprint capacity does not directly translate into sprint behavior during competitive play (i.e., sprint frequency and distance). The absence of a meaningful conceptual relationship renders these relationships likely to be insignificant. This finding suggests that sprint frequency and volume are modulated by factors other than physiological transfer. Specifically, it indicates that tactical role, situational opportunity, and positional mandate play a more significant role in regulating sprinting performance than an athlete's maximal sprint speed. From a constraint-led perspective, sprint execution is shaped by task constraints (e.g., coach-prescribed tactical instructions) and environmental constraints (e.g., opposition formation) which dictate the spatiotemporal opportunities for sprint execution, effectively decoupling the occurrence of the sprint from peak speed capacity. In a similar manner, tactical periodization models posit that physical outputs are embedded within broader strategic frameworks. This means that an individual's "permission" to sprint is governed by contextual match demands rather than by isolated physical potential. Unfortunately, tactical variables were not captured in the present study, which renders this interpretation necessarily speculative. Nonetheless, incorporating measures of tactical context as potential moderators should be a priority for future research.

As with any study, this investigation is not without limitations; however, understanding these is crucial for properly contextualizing the data. First, the sample was selected in an ad-hoc manner; however, three different clubs were analyzed, making this approach more heterogeneous than previous studies, which often focus on a single academy.[38] Second, the use of GNSS technology introduces inherent inaccuracies.[29–32,38,43–45] To minimize these effects, players used the same device throughout, sensors were activated early for stable connections, and units were mounted at a standardized location.[29] Despite these limitations, the study provides valuable insights into sprint and in-match performance characteristics of national-level youth soccer players, informing both training prescription and monitoring strategies.

Conclusion

The present study confirms that linear sprint performance, particularly longer distances (e.g., over 30 m), is strongly associated with peak sprinting speeds achieved during competition. The findings of this study lend further support to the continued utilisation of linear sprint testing as a valid and practical method for assessing maximal sprint capacity in elite youth soccer. Whilst prior research has documented positional disparities in sprint demands, our findings imply that such variations may be diminishing, likely attributable to the evolving tactical and physical demands of contemporary soccer. This finding serves to emphasise the universal significance of sprinting ability across all playing positions. It is recommended that practitioners implement regular sprint testing over a distance of 30 m, incorporating split times at 5, 10, and potentially 20 m, in order to monitor both acceleration and the development of maximum speed. These assessments can inform personalised training interventions designed to enhance sprint performance in competitive settings. In view of the limited and inconsistent correlations between sprint test performance and other in-match metrics (e.g., acceleration count, total distance), future research should integrate contextual variables (e.g., tactical formations, team strategies, game phase, field zones, or ball possession) to better understand the conditions under which physical capacities translate into match actions. Furthermore, the extension of test batteries to encompass strength, jump, and non-linear sprint assessments may facilitate the attainment of a more comprehensive profile of soccer-specific physical performance.

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Author contributions

Conceptualization: M.K. and B.K.; methodology: M.K. and B.K.; analysis: M.K. and C.W.; investigation, B.K., R.K. J.S. and B.J.; writing (original draft preparation): M.K., writing (review and editing): B.K., C.W., K.W. and A.Z.; visualization: M.K. All authors have read and agreed to the submitted version of the manuscript.

Compliance with Ethical standards

The study was performed with human participants in accordance with the Helsinki Declaration and approved by the institutional review board at the German University of Health and Sport (DHGS-EK-2024-009)

Data availability statement

The data underlying this study can be obtained from the corresponding author upon reasonable request, provided there is a valid justification.

Declaration of conflicting interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Institutional review board statement

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Informed consent statement

All participants and, for those under the age of 18, also their parents, were informed of the experimental risks associated with the research and provided written informed consent to participate in the present study.

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