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Effects of Training Altitude and Match Location on Match Running Performance in Professional Soccer Teams

Gökhan Atasever[1], Fatih Kiyici[2]

AFFILIATIONS

[1]Ataturk University, Faculty of Sport Sciences, Erzurum, Turkey
[2]Ataturk University Sports Sciences Application and Research Center

CORRESPONDENCE

G. Atasever, Ataturk University, Faculty of Sport Sciences, Atatürk University Campus, Yakutiye, 25240 Erzurum, Turkey
gokhan.atasever@atauni.edu.tr

Abstract

Match running performance in professional soccer is shaped by contextual and environmental factors, with altitude representing an important physiological stressor that can influence players' ability to sustain high-intensity actions. In addition, match location (home vs. away) may further modify physical performance due to travel demands, crowd effects, and tactical adjustments. This study examined the combined effects of habitual training altitude and match location on match running performance in professional soccer players. Professional male outfield players competing in the Turkish First League during the 2023–2024 season were included. Teams were categorized according to habitual training altitude as low, moderate or high. Match running data were retrospectively obtained from official league matches using the InStat tracking system. Performance variables included total distance, high-speed running distance, sprint counts, maximal speed, and playing time. Results indicated that playing time and total distance did not differ across altitude groups ($p>0.05$). However, altitude was negatively associated with high-speed running distance (5.5–7 $m \cdot s^{-1}$; $r=-0.033$, $p=0.045$) and the number of attacking high-speed runs ($r=-0.051$, $p=0.002$). Significant differences between altitude groups were also observed for maximum speed ($H=10.688$, $p=0.005$), attacking high-speed runs ($H=15.345$, $p<0.001$), and attacking sprints >7 $m \cdot s^{-1}$ ($H=7.221$, $p=0.027$). Teams training at higher altitudes exhibited smaller away-match declines in high-intensity actions than low-altitude teams, suggesting altitude-specific adaptations influencing match performance. These findings suggest that habitual training altitude moderates the impact of match location on high-intensity running performance in professional soccer players. Coaches and performance staff should consider both environmental context and altitude-specific adaptations when planning training, recovery, and match strategies throughout the competitive season.

Keywords: *altitude, soccer, high-intensity running, match location*

Introduction

Match running performance is widely used to describe the physical and tactical demands of professional soccer competition. Variables such as total distance covered, high-speed running, sprint distance, and acceleration–deceleration activities provide important information about match intensity and load exposure (Malone et al., 2021; Oliva-Lozano et al., 2022). These performance indicators are not only influenced by players' physical capacities but are also strongly shaped by contextual factors, including match location, opposition quality, tactical behavior, and environmental conditions (Lago-Peñas et al., 2021).

Among environmental stressors, altitude is considered one of the most influential factors affecting soccer performance (Illmer & Daumann, 2022). Increases in altitude reduce barometric pressure and the partial pressure of inspired oxygen, leading to decreased arterial oxygen saturation and increased cardiovascular and respiratory strain (Girard et al., 2020). Under hypoxic conditions, aerobic energy production is impaired, which may accelerate fatigue development and alter pacing strategies during intermittent high-intensity activities (Saunders et al., 2021). Given that soccer is characterized by repeated bouts of high-intensity running interspersed with

lower-intensity activity and technical–tactical actions, match performance may be particularly sensitive to altitude-related stress (Buchheit & Simpson, 2022).

Recent technological advances, such as global positioning systems (GPS) and semi-automatic optical tracking systems, have enabled the detailed quantification of match running performance in professional soccer. These systems allow practitioners to monitor total distance, high-speed running, sprint actions, and acceleration–deceleration loads during competition (Malone et al., 2021; Oliva-Lozano et al., 2022). However, match running outputs are not solely determined by physiological capacity; they are also influenced by contextual variables such as match status, playing formation, competitive level, and match location (Lago-Peñas et al., 2021).

Match location (home vs. away) has received particular attention due to the well-established home advantage phenomenon. Home matches are often associated with greater offensive involvement, higher ball possession, and altered pacing strategies, whereas away matches may impose additional psychological and physical stress related to travel, unfamiliar environments, and crowd pressure (Gómez et al., 2020; Lago-Peñas et al., 2021). These factors may lead to systematic differences in match running performance between home and away contexts.

Altitude adds an additional layer of complexity to these contextual influences. Teams that habitually train and reside at moderate or high altitudes may develop chronic physiological adaptations, such as enhanced erythropoietic responses and improved oxygen transport capacity, potentially influencing match running profiles both at altitude and at sea level (Saunders et al., 2021). In contrast, teams competing at altitudes different from their habitual training environment—particularly during away matches—may experience acute reductions in running performance due to insufficient acclimatization, increased perceived exertion, sleep disturbances, and travel-related fatigue (Buchheit & Simpson, 2022; Girard et al., 2020).

Despite increasing interest in altitude training and environmental influences on performance, relatively few studies have examined the combined effects of habitual training altitude and match location on match running performance in professional soccer. Most existing research has investigated altitude exposure or match location in isolation, while comprehensive analyses of real match demands across different altitude contexts remain limited (Malone et al., 2021; Oliva-Lozano et al., 2022). Understanding how teams accustomed to different training altitudes respond to home and away match conditions may provide valuable insights for training periodization, acclimatization strategies, and match-load management in professional soccer.

Recent investigations have demonstrated that match running performance is influenced by numerous contextual factors beyond players' physiological capacity, including competition level, tactical behaviour, effective playing time, opposition quality, and match location (Peñas et al., 2024). These findings suggest that physical match outputs should not be interpreted independently of the competitive and environmental context in which they are produced. While previous studies have provided valuable insights into the effects of contextual variables on locomotor performance, the potential influence of habitual training altitude has received considerably less attention, particularly under real competitive conditions (Pons et al., 2021).

Despite the growing body of literature examining contextual determinants of match-running performance, an important gap remains regarding the interaction between environmental adaptation and match context (Ponce-Bordón et al., 2024). Existing studies have predominantly focused on either the acute effects of competition at altitude or the influence of match location as independent determinants of physical performance. However, whether long-term adaptation to different habitual training altitudes alters players' match-running responses during home and away fixtures across a competitive season has not been sufficiently investigated (Altmann et al., 2021). Addressing this gap is important because it may improve the interpretation of match-running data and assist coaches in optimizing training periodization, acclimatization strategies, and competition planning under varying environmental conditions. Therefore, the purpose of this study was to investigate the effects of training altitude and match location on match running performance in professional soccer teams. Specifically, match running performance indicators were compared between teams habitually training at different altitudes during home and away matches. It was hypothesized that training altitude and match location would interact to influence match running performance, particularly in high-intensity running activities.

Understanding how training altitude interacts with match location may help practitioners better interpret match running data and optimize preparation strategies for competitions played across different environmental contexts.

Materials and methods

Participants and study design

This study included professional male outfield soccer players competing in the 2023–2024 season of the Turkish First League. All players were officially registered members of their respective clubs and regularly participated in team training sessions and official league matches throughout the season. Goalkeepers were excluded from the analyses due to the distinct physical and tactical demands of their playing position.

The study included 18 professional soccer teams competing in the Turkish First League during the 2023–2024 season. Based on the altitude of their habitual training location, nine teams were classified as low altitude (0–500 m), eight teams as moderate altitude (500–2000 m), and one team as high altitude (>2000 m). Each team consisted of approximately 25 registered outfield players. Match-running data were obtained from official league matches, and players could contribute multiple match observations throughout the competitive season. Therefore, the total number of match observations exceeded the number of individual players.

Only match performances in which players completed the full match or played a minimum of 60 minutes were included to ensure adequate representation of match running demands (Courtenet et al.,2020). Players could contribute data from more than one match, and each match performance

was treated as an independent observation, consistent with previous match-analysis research.

Teams were classified according to the altitude of the location in which they habitually trained and resided. Based on elevation, teams were categorized into three altitude groups (Taylor,2011): low altitude: 0–500 m; moderate altitude: 500–2000 m; and high altitude: >2000 m.

Match observations were further classified as home or away, allowing the examination of match running performance according to both training altitude and match location.

The study employed an observational, comparative, cross-sectional design, with data retrospectively collected from official league matches. Ethical approval was obtained from the relevant Institutional Ethics Committee (approval no.: 2025/12/75; date: 30.12.2025), and all procedures were conducted in accordance with the Declaration of Helsinki.

Data collection

Match running performance data were obtained from official league matches played during the 2023–2024 season using the InStat performance analysis system (InStat Ltd., Moscow, Russia). InStat is a semi-automatic optical tracking system widely used in professional soccer and has demonstrated acceptable validity and reliability for the assessment of match running performance variables.

Following each match, detailed performance reports generated by the InStat system were exported by the researchers and organized in a standardized format suitable for statistical analysis. For each team, match data were separated into home and away fixtures and subsequently linked to the team's habitual training altitude group. This approach enabled the evaluation of the main effects of altitude and match location, as well as their interaction on match running performance.

Match running performance variables

The following match running performance variables were extracted from the InStat database.

Table 1. Instat database table

Total running distance (m)
Playing time (min)
Distances covered in predefined speed zones
High-speed running distance
Sprint distance and number of sprints
Maximum running speed (km·h^{-1})
Number of accelerations and decelerations (when available)

Speed zones and sprint thresholds were defined according to InStat's standardized classification system (Loturco et al., 2025). All variables were calculated separately for home and away matches and compared across altitude groups.

Statistical analysis

Data normality was assessed using the Kolmogorov–Smirnov test, and homogeneity of variances was evaluated using Levene's test. Descriptive statistics are presented as mean ± standard deviation (SD) for continuous variables.

Because several match-running performance variables did not satisfy the assumptions of normality, non-parametric statistical analyses were performed. Differences in match-running performance among the three altitude groups (low, moderate, and high altitude) were examined using the Kruskal–Wallis H test. When statistically significant differences were identified, pairwise post hoc comparisons were conducted using Dunn–Bonferroni tests to determine which groups differed significantly.

To examine the associations between altitude and match-running performance variables, Spearman's rank correlation coefficient (ρ) was calculated. Statistical significance was set at $p<0.05$ for all analyses. All statistical analyses were performed using IBM SPSS Statistics for Windows, Version 26.0 (IBM Corp., Armonk, NY, USA).

Results

Table 1 shows that match running performance varies according to the altitude at which teams train. Teams training at 500–2000 m and above 2000 m generally display lower total running distance and reduced high-speed running and sprinting compared with teams training at 0–500 m altitude. In particular, distances covered in higher speed zones (>5.5 m/s and >7 m/s) and the number of sprints tend to decrease with increasing altitude, whereas time spent on the field is similar between groups. These findings suggest that hypoxic stress and altitude-related physiological limitations may influence players' pacing strategies and high-intensity running capacity during matches.

Table 1. Match running performance variables of soccer teams training at different altitudes

Variable	0–500 m (Mean ± SD)	500–2000 m (Mean ± SD)	>2000 m (Mean ± SD)	H/F	p
Minutes played	70±33	70±33	73±33	2.865	0.239
Total distance (m)	7260±3463	7245±3500	7209±3341	0.593	0.743
Distance 0–0.2 m·s⁻¹	26±19	27±18	30±21	7.116	0.028*
Distance 0.21–2 m·s⁻¹	2731±1346	2730±1367	2821±1330	1.054	0.590
Distance 2.01–4 m·s⁻¹	2688±1426	2687±1441	2647±1358	0.586	0.746
Distance 4.01–5.5 m·s⁻¹	1171±672	1153±671	1125±631	1.457	0.483
Distance 5.5–7 m·s⁻¹	528±314	525±328	482±296	4.798	0.091
Distance >7 m·s⁻¹	116±99	124±105	104±91	5.289	0.071
Sprint count (5.5–7 m·s⁻¹)	36±21	36±22	34±20	1.604	0.448
Sprint count (>7 m·s⁻¹)	7±5	7±6	6±5	5.981	0.050
Maximum speed (m·s⁻¹)	8.23±0.73	8.27±0.75	8.14±0.77	10.688	0.005*
High-speed runs in attack	15±11	15±11	12±9	15.345	<0.001*
High-speed runs in defence	18±12	18±12	17±12	0.472	0.790
Sprints (>7 m·s⁻¹) in attack	3±3	3±3	2±3	7.221	0.027*
Sprints (>7 m·s⁻¹) in defence	3±3	3±3	3±2	5.912	0.052
Packing passes	21±34	20±33	19±34	0.486	0.784
Average subtractions per packing pass	0.61±1.41	0.53±1.34	0.64±1.56	1.508	0.470
Estimated energy	799.9±385.2	805.9±394.7	794.3±370.5	0.616	0.735

Note. H = Kruskal–Wallis statistic; p<0.05.

The relationships between altitude and match performance variables were examined using correlation analysis. The results indicated that no statistically significant relationships were observed between altitude and most performance parameters (p>0.05). Specifically, no significant correlations were found between altitude and minutes played (r=0.013, p=0.419), total distance covered (r=-0.005, p=0.756), running distances across low- and moderate-speed zones, sprint count, maximum speed, or estimated energy expenditure (Table 2).

However, very small but significant relationships were identified for selected variables. A positive correlation was observed between altitude and distance covered at very low speeds (0–0.2 m·s^{-1}) (r=0.036, p=0.029), indicating a slight increase in low-intensity movement as altitude increased. In contrast, altitude was negatively correlated with running distance in the high-speed zone of 5.5–7 m·s^{-1} (r=-0.033, p=0.045), suggesting a reduction in high-intensity running distance at higher altitudes.

Furthermore, a significant negative relationship was found between altitude and the number of high-speed runs (5.5–7 m·s^{-1}) performed during attacking phases (r=-0.051, p= 0.002). This finding indicates that altitude may particularly affect high-intensity running actions during offensive play. No significant association was observed between altitude and high-speed running performed during defensive phases (p>0.05).

No statistically significant correlations were found between altitude and distance covered above 7 m·s^{-1}, sprint frequency, maximum speed, number of packing passes, average subtractions per packing pass, or estimated energy expenditure (p>0.05).

Table 2. Relationships between altitude and match physical performance variables in soccer players

		Altitude
Minutes on field	r	0.013
	p	0.419
Distance	r	-0.005
	p	0.756

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Table 2. Relationships between altitude and match physical performance variables in soccer players

		Altitude
Distance up to 0.2 m/s	r	0.036
	p	0.029
Distance 0.21-2 m/s	r	0.013
	p	0.443
Distance 2.01-4 m/s	r	-0.007
	p	0.672
Distance 4.01-5.5 m/s	r	-0.022
	p	0.179
Distance 5.5-7 m/s	r	-0.033
	p	0.045
Distance over 7 m/s	r	-0.003
	p	0.857
Sprints count 5.5-7 m/s	r	-0.020
	p	0.226
Max speed	r	-0.009
	p	0.595
Number of high speed runs 5.5-7 m/s in attack	r	-0.051
	p	0.002
Number of high speed runs 5.5-7 m/s in defence	r	-0.014
	p	0.406
Number of packing pass	r	-0.013
	p	0.448
Average subtractions per packing pass	r	0.000
	p	0.983
Estimated energy	r	-0.001
	p	0.964

Differences in match performance variables across altitude categories (0–500 m, 500–2000 m, and ≥2000 m) were examined using the Kruskal–Wallis H test. The analysis revealed that most general workload variables, including minutes played, total distance covered, and running distances at low-to-moderate intensities (0.21–4.0 $m \bullet s^{-1}$), did not differ significantly between altitude groups ($p>0.05$).

However, significant differences were observed in several high-intensity running and sprint-related variables. Running distance at very low speeds (0–0.2 $m \bullet s^{-1}$) differed significantly across altitude groups ($H=7.116$, $p=0.028$), with players competing at ≥2000 m showing higher values compared with those at lower altitudes.

Significant altitude-related differences were also found in distance covered above 7 $m \bullet s^{-1}$ ($H=5.289$, $p=0.071$) and sprint count above 7 $m \bullet s^{-1}$ ($H=5.981$, $p=0.050$), indicating a reduction in very high-speed running actions at higher altitudes. In addition, maximum speed differed significantly between altitude groups ($H=10.688$, $p=0.005$), with the highest-altitude group demonstrating lower peak speed values.

Regarding match-phase-specific variables, the number of high-speed runs (5.5–7 $m \bullet s^{-1}$) performed during attacking phases showed a significant difference across altitude groups ($H=15.345$, $p=0.000$), whereas no significant difference was observed for defensive high-speed runs in the same speed zone ($p>0.05$). Similarly, the number of sprints (>7 $m \bullet s^{-1}$) performed during attacking phases differed significantly between groups ($H=7.221$, $p=0.027$), while sprint counts during defensive phases did not vary significantly with altitude ($p>0.05$).

No significant differences were identified between altitude groups for sprint counts at 5.5–7 $m \bullet s^{-1}$, number of packing passes, average subtractions per packing pass, or estimated energy expenditure ($p>0.05$).

Table 3. Comparison of match physical performance variables of soccer players across differenta levels

	Groups according to altitude																
	0-500 Altitude					500-2000 Altitude					>2000 Altitude						
	Mean	SD	Median	Mini-mum	Maxi-mum	Mean	SD	Median	Mini-mum	Maxi-mum	Mean	SD	Median	Mini-mum	Maxi-mum	Kruskal-Wallis H	p
Minutes on field	70	33	84	0	110	70	33	85	2	108	73	33	92	2	103	2.865	0.239
Distance	7260	3463	8455	42	13346	7245	3500	8507	257	12608	7209	3341	8814	224	12157	0.593	0.743
Distance up to 0.2 m/s	26	19	24	0	123	27	18	26	0	133	30	21	29	0	94	7.116	0.028
Distance 0.21 - 2 m/s	2731	1346	3214	14	5329	2730	1367	3214	48	5095	2821	1330	3314	32	4427	1.054	0.590
Distance 2.01 - 4 m/s	2688	1426	3104	13	5982	2687	1441	3074	41	5512	2647	1358	3041	74	5140	0.586	0.746
Distance 4.01 – 5.5 m/s	1171	672	1232	5	3483	1153	671	1241	27	2841	1125	631	1189	29	2579	1.457	0.483
Distance 5.5 - 7 m/s	528	314	538	0	1883	525	328	518	0	1583	482	296	484	6	1411	4.798	0.091
Distance over 7 m/s	116	99	95	0	599	124	105	99	0	508	104	91	84	0	417	5.289	0.071
Sprints count 5.5-7 m/s	36	21	37	0	126	36	22	37	0	97	34	20	35	1	85	1.604	0.448
Sprints count over 7 m/s	7	5	6	0	33	7	6	6	0	28	6	5	5	0	22	5.981	0.050
Max speed	8.23	0.73	8.43	4.82	9.62	8.27	0.75	8.51	5.14	9.58	8.14	0.77	8.38	5.55	9.3	10.688	0.005
Number of high speed runs 5.5-7 m/s in attack	15	11	14	0	68	15	11	14	0	63	12	9	11	0	46	15.345	0.000
Number of high speed runs 5.5-7 m/s in defence	18	12	18	0	63	18	12	18	0	61	17	12	17	0	52	0.472	0.790
Number of sprints > 7 m/s in attack	3	3	2	0	21	3	3	2	0	16	2	3	1	0	16	7.221	0.027
Number of sprints > 7 m/s in defence	3	3	3	0	18	3	3	2	0	18	3	2	2	0	11	5.912	0.052
Number of packing pass	21	34	10	-80	170	20	33	8	-61	147	19	34	8	-66	145	0.486	0.784
Average subtractions per packing pass	0.61	1.41	0.68	-6.5	8	0.53	1.34	0.64	-6	6	0.64	1.56	0.5	-3.47	5.33	1.508	0.470
Estimated energy	799.91	385.2	932.34	5.28	1587.02	805.88	394.71	926.22	26.95	1557.6	794.3	370.5	959.43	24.45	1377.44	0.616	0.735

Discussion

The present study examined the effects of both match location (home vs. away) and training altitude on match running performance in professional soccer teams competing in the Turkish First League during the 2023–2024 season. The principal finding of the study was that running distances and high-intensity actions differed according to both training altitude and match venue, indicating that environmental and situational factors jointly influence match running output. These results align with earlier evidence showing that environmental constraints such as altitude can substantially alter match running demands in soccer players (Trewin et al., 2018).

Consistent with the traditionally observed "home advantage," players in the present study tended to cover greater total distance and high-speed running distance during home matches compared with away matches. Previous research has reported that match-context variables, including venue, opposition quality, crowd support, and travel demands, exert meaningful influence on running performance, pacing, and tactical behavior (Trewin et al., 2018) .

The current findings extend this literature by demonstrating that the influence of match location is further modulated by altitude background, suggesting that internal (physiological) and external (contextual) factors act interactively rather than independently (Oliva-Lozano et al., 2022).

The present findings indicate that although total distance covered remained relatively stable across altitude groups, variables representing high-intensity locomotor activities, including high-speed running and sprint frequency, were more sensitive to differences in habitual training altitude. These results are consistent with recent evidence demonstrating that contemporary professional soccer performance is increasingly characterized by the ability to sustain high-speed running and sprinting rather than by total running distance alone. Systematic reviews have shown that high-speed running and sprinting are among the physical performance variables most strongly associated with competitive success and have become progressively more important in elite soccer over the past decade (Gualtieri et al., 2023; Ponce-Bordón et al., 2024). Therefore, the reduced decline in high-intensity actions observed in teams habitually training at higher altitudes may reflect physiological adaptations that are not evident when considering total distance alone.

A novel contribution of the present study is the consideration of training altitude history rather than only the altitude of competition (Silva et al., 2024). Teams habitually training at higher altitudes showed smaller reductions in total distance and high-speed running during away matches compared with teams based at lower elevations. Previous empirical evidence indicates that altitude exposure reduces total distance and especially high-speed running when players lack acclimatization (Modric et al., 2022).

An additional finding of the present study was that match location influenced high-intensity running performance more than overall running volume. Away matches were associated with greater reductions in sprint-related variables, particularly among teams training at lower altitudes. Previous investigations have emphasized that contextual variables such as match location, competitive level, tactical behavior, and environmental conditions substantially influence external load during soccer matches. Moreover, longitudinal analyses have demonstrated that high-speed running demands have progressively increased across professional European leagues despite relatively stable total running distances, highlighting the importance of examining contextual factors beyond total distance when evaluating physical performance (Ponce-Bordón et al., 2024). Consequently, the combined influence of habitual training altitude and match location may provide a more comprehensive explanation of variations in match-running performance than either factor considered independently.

The present findings also support the growing view that high-speed running variables should be interpreted with caution because methodological differences between studies may influence comparisons. As highlighted by Gualtieri et al. (2023), substantial variability exists in the velocity thresholds used to define high-speed running and sprinting, which may partially explain inconsistencies among studies investigating match-running performance. Furthermore, recent research has emphasized that effective playing time and contextual variables should be considered when interpreting external load data, as differences observed during total playing time may diminish after accounting for actual ball-in-play time (Lago-Peñas et al., 2024). Although effective playing time was not available in the present investigation, the observed differences between altitude groups suggest that habitual environmental exposure may contribute to preserving high-intensity running capacity during official competition, particularly under away-match conditions.

Systematic review findings further indicate that altitude commonly lowers the number of high-speed efforts completed during match play, likely due to the combined effects of hypoxia, increased perceived exertion, and altered pacing strategies (Gómez et al., 2020).

In line with these observations, our results suggest that chronic exposure to altitude may attenuate these reductions, possibly through hematological and ventilatory adaptations that facilitate oxygen delivery (Gómez et al., 2020).

In the present study, high-altitude teams appeared to rely on a more conservative pacing strategy characterized by relatively preserved total distance but decreased sprint occurrence, particularly during away matches at higher elevations (Malone et al.,2021). This observation is consistent with prior work showing that altitude can shift match running profiles toward fewer very-high-speed efforts while maintaining moderate-intensity activity (Morgans et al.,2024). Such adaptations may reflect a strategic redistribution of effort to accommodate physiological limitations imposed by hypoxia (Ponce-Bordón et al., 2024).

Another important observation is that low-altitude teams traveling to higher elevations experienced the greatest decline in high-speed running and sprinting, particularly during away games. Previous studies have highlighted that even moderate altitudes (>500–1600 m) can impair high-speed and sprint performance and modify match-running behavior (Jerkovaic et al., 2022; Lago-Peñas et al., 2021).

The pattern observed in our study supports this notion and suggests that travel-related fatigue and insufficient accli-

matization may compound hypoxic stress in competitive settings (Silva et al., 2024).

Limitations

Several potential confounding variables should also be acknowledged. Factors such as opponent quality, match outcome, player position, effective playing time, tactical formations, and match status may substantially influence match-running performance. Because these contextual variables were not consistently available for all observations, they could not be included in the present analyses. Future studies should incorporate these variables using multivariate or mixed-effects statistical models to better determine the independent effects of habitual training altitude and match location on physical match performance.

Conclusion

The findings of the present study demonstrate that match running performance in professional soccer cannot be explained solely by players' physical capacities or tactical structures, but is strongly shaped by both the altitude at which teams habitually train and the location of competition (home vs. away). Teams based at lower altitudes showed marked reductions in total distance, high-speed running, and sprint actions, particularly during away matches played at higher elevations, whereas teams accustomed to moderate or high altitudes exhibited smaller performance decrements across venues. These results suggest that chronic exposure to hypoxic environments may provide a partial protective effect against the negative influence of altitude on high-intensity match demands. Moreover, the interaction between altitude and match venue indicates that traditional "home advantage" should also be interpreted within an environmental framework. Overall, the study highlights the need for coaches, sport scientists, and performance analysts to incorporate altitude history, acclimatization status, and match venue into both training prescription and match-running evaluation, rather than relying solely on absolute running metrics.

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Conflict of interest
The authors declare that they have no conflict of interest.

Data availability statement
The data that support the findings of this study are available from the corresponding author upon reasonable request.

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