

Match-Induced Dehydration and Its Association with External Load in Elite Academy Football Players

Marta Tomljanović^a, Ana Kezić^b, Daniela Čačić Kenjerić^c

^aFaculty of Kinesiology, University of Split, Croatia

^bCro Sport Talent & Health and Longevity Lab, Faculty of Kinesiology, University of Split, Croatia

^cFaculty of Food Technology, University of Osijek, Croatia

Purpose: The aim of this study was to investigate pre- to post-match changes in hydration status and examine associations between dehydration markers and GPS-derived external load variables in elite academy football players during official competition.

Methods: Thirty-eight elite male academy football players (15–19 years) participated in the study, resulting in 69 match observations collected across 10 official matches. Hydration-related variables included pre- and post-match body mass (BM), urine specific gravity (USG), handgrip strength (HS), percentage dehydration (%deh), fluid intake (W), and estimated rehydration requirements (REHA). External load was monitored using 10-Hz GPS devices and included total distance covered, relative running intensity, maximal velocity, high-intensity running distance, sprint distance, and accelerations/decelerations. Pre- to post-match differences were assessed using paired-samples t-tests, while associations between dehydration and GPS variables were analyzed using Spearman's rank correlation coefficients.

Results: Significant reductions in body mass were observed following match play ($P < 0.001$), with players losing 0.9 ± 0.5 kg on average, corresponding to a mean dehydration level of $1.2 \pm 0.7\%$. Urine specific gravity increased significantly post-match ($P = 0.001$), indicating deterioration in hydration status. Although mean dehydration remained below the commonly cited 2% threshold, 11.6% of observations exceeded this value. Fluid intake during matches (1.0 ± 0.5 L) appeared insufficient relative to estimated rehydration requirements (2.9 ± 1.1 L). A significant positive correlation was observed between %deh and total distance covered ($\rho = 0.283$, $P = 0.019$), whereas no significant associations were found for other GPS variables. Midfield players demonstrated significantly greater relative running intensity than defenders and forwards ($P < 0.001$), although no positional differences in dehydration were identified.

Conclusions: Elite academy football players demonstrated significant match-induced deterioration in hydration status during official competition. Individualized hydration monitoring and fluid replacement strategies may be important for optimizing recovery and reducing exercise-induced fluid deficits in elite youth football.

Keywords: urine specific gravity; fluid balance; body mass loss; rehydration; GPS monitoring; adolescent athletes; match demands.

Introduction

Maintaining euhydration is essential for optimal physiological function and athletic performance, particularly in intermittent high-intensity sports such as football¹⁻². Football match play is characterized by repeated accelerations, decelerations, sprinting actions, and changes of direction performed over prolonged periods, resulting in substantial metabolic heat production and sweat loss³⁻⁴. During competitive matches, players typically cover between 8 and 13 km, with a considerable proportion of energy expenditure converted into heat, thereby placing significant demands on thermoregulatory and fluid balance mechanisms⁵. Consequently, dehydration frequently occurs during football activity and may negatively influence physiological and physical performance.

Youth football players represent a particularly vulnerable population regarding hydration management due to ongoing biological maturation, altered thermoregulatory responses, and inconsistent hydration behaviors⁶⁻⁷. Previous research

has demonstrated a high prevalence of hypohydration among elite adolescent football players even before the beginning of training or competition. Phillips et al. (2014)⁶ reported that 77% of elite European youth football players presented with urine specific gravity (USG) values indicative of hypohydration prior to training sessions, while Arnaoutis et al. (2013)⁸ observed dehydration prevalence exceeding 89% in young soccer players attending a summer training camp. Furthermore, young athletes frequently fail to adequately replace sweat-induced fluid losses during exercise when drinking ad libitum, often replacing less than 50% of total fluid losses⁹⁻¹⁰.

The physiological consequences of dehydration during football activity are well documented. Reductions in body mass exceeding 2% have been associated with impairments in physical and technical performance, including repeated sprint ability, intermittent running capacity, dribbling performance, and increased perceived exertion¹¹⁻¹³. Additionally, dehydration combined with exercise-induced heat stress may further compromise cardiovascular and thermoregulatory function,

potentially affecting match performance and recovery¹⁴. Given the demanding nature of elite academy football, effective hydration strategies are therefore essential not only for maintaining performance but also for reducing physiological strain during competition.

In recent years, global positioning system (GPS) technology has become widely implemented in football to quantify external match load and monitor players' physical demands during training and competition. GPS-derived variables such as total distance covered, relative running intensity, high-intensity running distance, sprint distance, and accelerations/decelerations are considered important indicators of match workload and fatigue development in football players^{3,15}. In particular, high-intensity running and repeated accelerative actions have been shown to represent some of the most physiologically demanding aspects of modern football match play¹⁶⁻¹⁷. The integration of GPS monitoring into sports science practice has therefore enabled a more detailed understanding of individual match demands and player-specific physiological responses. Since greater external load is associated with increased metabolic heat production and sweat loss, GPS-derived metrics may also contribute to explaining individual variability in dehydration responses during competition. However, despite the growing body of literature investigating hydration status in football players, limited evidence currently exists regarding the interaction between match-induced dehydration and GPS-derived external load variables during official competitive match play in elite academy football players. Most previous studies have focused either on hydration responses in training environments or on isolated performance outcomes, with relatively little attention given to the simultaneous assessment of hydration markers and objective external load metrics obtained during real-match conditions. Given the high physiological demands and developmental characteristics of elite youth football players, a better understanding of the relationship between external match load and hydration responses may provide important practical implications for individualized fluid replacement strategies and recovery optimization in academy football settings.

Therefore, the aim of this study was to investigate pre- to post-match changes in hydration status in elite academy football players and to examine the association between dehydration markers and GPS-derived external load variables during competitive match play. It was hypothesized that players would demonstrate significant post-match dehydration, reflected through reductions in body mass and increased urine specific gravity values, and that greater external match load would be associated with higher levels of dehydration.

Methods

Participants

The study included male football players from the HNK Hajduk academy system competing in the 1st Croatian Football League and the Al Abtal International Cup. A total of 38 players aged between 15 and 19 years participated in the study, resulting in 69 individual match observations collected across 10 official competitive matches (five cadet and five junior matches). Goalkeepers and players who participated for less than 60 minutes were excluded from the final analysis. According to playing position, the sample consisted of defenders, midfielders, and forwards. Sociodemographic and anthropometric characteristics were recorded for all participants, including mean height (181.2 ± 8.4 cm), body mass (72.4 ± 9.2 kg), BMI (20.2 ± 2.1 kg/m²), and training experience (7.5 ± 1.5 years). All players were fully

engaged in regular training and competitive schedules consisting of five training sessions per week, one official match, and one recovery day.

Ethical approval was obtained from the appropriate institutional ethics committee prior to data collection (Class: 003-08/25-04/001, No. 2181-205-02-05-25-001). Written informed consent was obtained from all participants and their legal guardians prior to participation.

Study design

Hydration-related measurements were conducted immediately before and after each official match. Pre-match assessments included body mass (BM-pre), urine specific gravity (USG-pre), and handgrip strength measurements (HS-pre). Body mass was measured using a calibrated digital scale to the nearest 0.1 kg, while urine samples were analyzed using a handheld refractometer to assess hydration status. Players were measured barefoot and wearing minimal clothing. Handgrip strength was assessed using a dynamometer, with the highest value obtained from three maximal attempts recorded as an indicator of neuromuscular status. During matches, all players were provided with individually labelled water bottles and instructed to consume fluids exclusively from their assigned bottles to allow accurate monitoring of individual fluid intake (W). Any urine output during the match was recorded and included in subsequent fluid balance calculations. Immediately following the match, body mass (BM-post), urine specific gravity (USG-post), and handgrip strength (HS-post) assessments were repeated using identical procedures. Percentage dehydration (%deh) was calculated as: ((pre-match body mass – post-match body mass) / pre-match body mass) × 100. Rehydration requirements (REHA) were estimated according to current hydration guidelines recommending ingestion of approximately 1.5 L of fluid for each kilogram of body mass lost during exercise. Environmental conditions were relatively stable across all matches, with ambient temperatures ranging from 15 to 18°C and relative humidity ranging from 55% to 67%.

Urine specific gravity (USG) was used as a marker of hydration status and measured immediately before and after each match using a handheld refractometer. Based on current sport hydration guidelines, USG values ≤1.020 were classified as euhydrated, whereas values >1.020 indicated hypohydration¹⁸. Pre- and post-match USG values were compared to evaluate match-induced changes in hydration status.

External match load was monitored using 10-Hz GPS tracking devices (Catapult Sports, Melbourne, Australia), which have previously demonstrated acceptable validity and reliability for assessing movement demands in team sports¹⁵. To minimize inter-unit variability, each player wore the same GPS unit throughout all analyzed matches. The GPS analysis included total duration of activity (tot dur), total distance covered (tot dist), relative running intensity expressed as meters per minute (m/min), maximal running velocity (max vel), distance covered within different speed zones (13–19.8 km/h, 19.8–25 km/h, and >25 km/h), total high-intensity running distance (tot high int), as well as the number of accelerations (acc) and decelerations (dec) exceeding 3 m/s². Speed thresholds were based on the default Catapult classification system. GPS data were collected during all analyzed matches and subsequently used to examine associations between external match load and hydration-related variables. Data collection took place during the 2024/2025 competitive season from October to April.

Statistical analysis

All statistical analyses were performed using appropriate parametric and non-parametric procedures depending on data

distribution. Data are presented as mean \pm standard deviation (SD), together with minimum and maximum values. Normality of distribution was assessed using the Shapiro–Wilk test, in combination with visual inspection of histograms and Q–Q plots. Pre- to post-match differences in hydration and neuromuscular variables (BM, USG, and HS) were assessed using paired-samples t-tests. Effect sizes were calculated using Cohen’s d and interpreted according to standard thresholds (small = 0.2, moderate = 0.5, large = 0.8). Associations between dehydration markers (%deh and REHA) and GPS-derived external load variables were evaluated using Spearman’s rank correlation coefficients due to the non-normal distribution of several GPS variables. Correlation coefficients were interpreted as trivial (<0.1), small (0.1–0.29), moderate (0.30–0.49), large (0.50–0.69), very large (0.70–0.89), and nearly perfect (>0.90). Additionally, positional differences (defenders, midfielders, and forwards) in external load and dehydration variables were

assessed using the Kruskal–Wallis test. When significant differences were identified, post-hoc pairwise comparisons were performed using Dunn–Bonferroni correction. As several players participated in multiple matches, each match appearance was treated as an individual match observation, and findings were interpreted with consideration of the non-independence of repeated observations. Statistical significance was set at $p < 0.05$ for all analyses.

Results

Normality of data distribution was assessed using the Shapiro–Wilk test. Most hydration-related variables demonstrated normal distribution, whereas several GPS-derived variables showed deviations from normality; therefore, both parametric and non-parametric procedures were applied where appropriate.

Table 1 presents the descriptive characteristics of hydration-

Table 1. Descriptive statistics of hydration-related variables and GPS external load characteristics

	Mean \pm SD	Min	Max
BM- pre	73.1 \pm 8.6	58.4	93.0
BM- post	72.2 \pm 8.4	57.9	91.4
Δ BM	0.9 \pm 0.5	-0.4	2.3
%deh	1.24 \pm 0.69	-0.51	3.00
HS-pre	43.5 \pm 6.2	31.9	58.0
HS-post	44.3 \pm 6.0	33.6	60.5
USG- pre	1.023 \pm 0.007	1.000	1.038
USG- post	1.026 \pm 0.007	1.007	1.038
W (L)	1.0 \pm 0.5	0.3	2.5
REHA (L)	2.9 \pm 1.1	0.3	5.7
tot dur min	79.6 \pm 13.1	60.0	94.2
tot dist (m)	8442 \pm 1551	5384	12278
m/min	106.3 \pm 12.3	68.6	132.9
max vel (km/h)	28.3 \pm 2.1	24.0	33.9
13-19,8 km/h	993 \pm 359	1	1989
19,8-25 km/h	342 \pm 135	106	718
>25 km/h	77 \pm 75	0	370
tot high int (m)	419 \pm 193	106	1088
acc >3 m/s ²	19.4 \pm 8.9	6.0	39.0
dec >3 m/s ²	24.0 \pm 9.2	5.0	45.0

related variables and GPS-derived external load parameters collected during official match play. Players demonstrated a mean body mass loss of 0.9 \pm 0.5 kg during matches, corresponding to an average dehydration level of 1.2 \pm 0.7%. Although the mean percentage dehydration remained below the commonly cited 2% threshold associated with substantial performance impairment, individual values ranged up to 3.00%, indicating considerable inter-individual variability in hydration responses. No cases of severe dehydration or heat-related complications were observed during data collection.

Pre-match USG values indicated that a substantial proportion of players began competition in a state of suboptimal hydration, while post-match USG values demonstrated a further increase

following match play. Fluid intake during competition appeared insufficient relative to estimated post-match rehydration requirements. Players consumed an average of 1.0 \pm 0.5 L of fluid during matches, and estimated rehydration needs averaged 2.9 \pm 1.1 L, suggesting that players replaced only a portion of exercise-induced fluid losses during competition.

GPS-derived external load data confirmed the high physiological demands of competitive academy football, with players covering an average total distance of 8442 \pm 1551 m and with a mean relative running intensity of 106 m/min. Considerable variability was also observed in high-intensity activities, sprint distance, and accelerative actions, reflecting the intermittent and physically demanding nature of match play.

Table 2. Pre- to post-match changes in body mass, urine specific gravity and handgrip strength; results of paired-samples t-tests and Cohen's d

	Pre	Post	Mean difference	P	Effect size
BM	73.1 ± 8.6	72.2 ± 8.4	-0.9	<0.001	-1.77
USG	1.023 ± 0.007	1.026 ± 0.007	0.003	0.001	0.40
HS	43.5 ± 6.2	44.3 ± 6.0	0.9	0.052	0.24

Significant pre- to post-match reductions in body mass were observed following competitive match play ($P < 0.001$), with players losing an average of 0.9 kg (Table 2). The magnitude of this change was associated with a large effect size (Cohen's $d = -1.77$), indicating a meaningful acute reduction in body mass during matches, most likely attributable to fluid loss through sweating.

Urine specific gravity values increased significantly from pre- to post-match measurements ($P = 0.001$), suggesting a deterioration in hydration status following match play. Although the absolute change in USG values was numerically small, hydration-related alterations in urine specific gravity are typically detected at the third decimal level, supporting the physiological significance of the observed increase. The effect size for USG changes was

small to moderate (Cohen's $d = 0.40$).

No statistically significant pre- to post-match differences were observed for handgrip strength ($P = 0.052$), although a small increase in post-match values was noted. The corresponding effect size was small (Cohen's $d = 0.24$), indicating minimal practical change in neuromuscular performance following match play.

The majority of observations demonstrated dehydration levels below 2% body mass loss, while 11.6% of observations exceeded the commonly recognized 2% threshold. Despite relatively moderate environmental conditions, several players still demonstrated dehydration levels commonly associated with impaired performance.

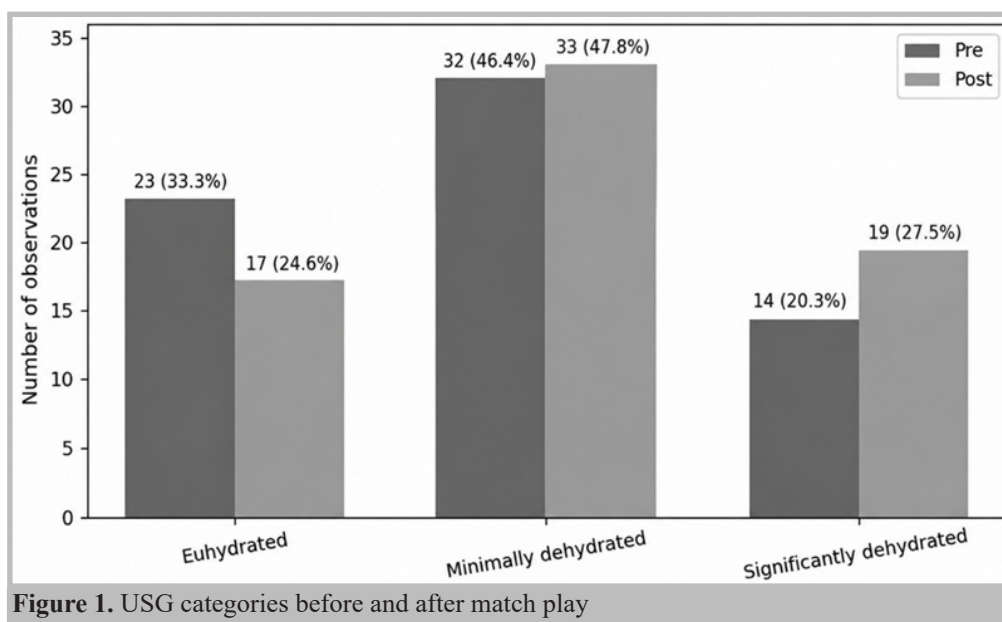


Figure 1. USG categories before and after match play

Figure 1 presents the distribution of hydration status categories based on urine specific gravity values before and after match play. A reduction in the number of euhydrated players was observed following the match, accompanied by an increase in the proportion of significantly dehydrated observations. Specifically, the number of euhydrated observations decreased from 23 pre-match to 17 post-match, while significantly

dehydrated observations increased from 14 to 19 following competition. In contrast, the proportion of mildly dehydrated players remained relatively stable between pre- and post-match measurements. These findings indicate that match play contributed to a deterioration in hydration status, with a greater number of players classified as hypohydrated after competition.

Table 3. Associations between dehydration (%deh) and GPS variables using Spearman's rank correlation coefficients

GPS variable	rho	P
tot dur min	0.208	0.087
tot dist (m)	0.283	0.019
m/min	-0.104	0.394
max vel (km/h)	-0.004	0.971
13-19,8 km/h	0.169	0.164
19,8-25 km/h	0.057	0.640
>25 km/h	-0.112	0.360

tot high int (m)	0.002	0.990
acc >3 m/s ²	-0.097	0.429
dec >3 m/s ²	0.113	0.357

Table 3 presents the associations between dehydration percentage (%deh) and GPS-derived external load variables. A statistically significant positive correlation was observed between %deh and total distance covered ($\rho = 0.283$, $P = 0.019$), indicating that players who covered greater distances during match play tended to experience higher levels of dehydration. Although the strength of this association was small, it suggests that greater

overall locomotor demands during match play are associated with increased dehydration responses.

No significant associations were identified between %deh and other GPS variables, including relative running intensity, maximal running velocity, high-intensity running distances, sprint distance, accelerations, or decelerations ($P > 0.05$).

Table 4. Differences in external load and dehydration according to playing position using Kruskal-Wallis test with post-hoc Dunn-Bonferroni correction

Position	n	tot dist (m)	m/min	tot high int (m)	%deh
Forwards	21	7539 ± 2007	105.8 ± 9.7 ^b	423 ± 188	1.04 ± 0.55
Defenders	28	8371 ± 1113	99.2 ± 9.8 ^a	424 ± 224	1.27 ± 0.75
Midfielders	20	8993 ± 1967	116.7 ± 10.9	407 ± 157	1.40 ± 0.73

^asignificantly different from midfielders ($P < 0.001$), ^bsignificantly different from midfielders ($P = 0.009$).

Table 4 presents positional differences in selected GPS-derived external load variables and dehydration percentage. Midfield players demonstrated the highest relative running intensity (m/min) during match play (116.7 ± 10.9 m/min), followed by forwards (105.8 ± 9.7 m/min) and defenders (99.2 ± 9.8 m/min). Kruskal-Wallis analysis revealed significant positional differences for relative running intensity ($P < 0.001$). Post-hoc Dunn-Bonferroni analysis demonstrated significantly greater m/min values in midfielders compared with both defenders ($P < 0.001$) and forwards ($P = 0.009$), whereas no significant difference was observed between defenders and forwards ($P = 0.099$). Although midfielders also demonstrated the greatest total distance covered and highest mean dehydration percentage, no statistically significant positional differences were observed for total distance covered, total high-intensity running distance, or %deh ($P > 0.05$).

Discussion

The present study investigated match-induced changes in hydration status and their association with GPS-derived external load variables in elite academy football players during official competitive matches. The main findings were that: (a) players experienced significant reductions in body mass and significant increases in urine specific gravity following match play; (b) a considerable proportion of players began competition in a hypohydrated state and hydration status further deteriorated after matches; (c) fluid intake during competition appeared insufficient relative to estimated post-match rehydration requirements; (d) dehydration percentage was positively associated with total distance covered, whereas no significant relationships were observed with other GPS-derived variables; and (e) midfield players demonstrated greater relative running intensity than defenders and forwards, although positional differences in dehydration were not observed. Collectively, these findings provide novel insight into hydration responses during official elite academy football competition while simultaneously integrating objective external load monitoring obtained through GPS technology.

The observed reduction in body mass and increase in USG following competition support the initial hypothesis and are consistent with previous literature demonstrating that football

match play commonly induces measurable fluid loss and deterioration in hydration status^{6,9,13}. Players in the present study demonstrated a mean body mass reduction of approximately 0.9 kg, corresponding to an average dehydration level of 1.2%. Although this mean value remained below the frequently cited 2% body mass loss threshold associated with substantial performance impairment^{2,11}, individual observations reached values up to 3%, indicating marked inter-individual variability in hydration responses. Importantly, despite relatively moderate environmental conditions during all matches, more than 11% of observations exceeded the 2% dehydration threshold, suggesting that meaningful fluid deficits may still occur even in temperate competitive environments.

The present findings further demonstrated that a substantial proportion of players began matches in a hypohydrated state, with hydration status worsening following competition according to USG classification criteria. These results align with previous investigations reporting high rates of pre-exercise hypohydration in elite youth football populations^{6,8}. Phillips et al. (2014), for example, observed that approximately 77% of elite European youth soccer players presented with USG values indicative of hypohydration before training sessions, while Suppiah et al. (2021)¹⁹ reported hypohydration prevalence ranging between 20% and 44% among adolescent athletes. The persistence of suboptimal hydration before competition may reflect inadequate habitual fluid intake, poor hydration awareness, or insufficient implementation of individualized hydration strategies in academy environments. Furthermore, adolescent athletes may possess reduced sensitivity to thirst and limited ability to recognize early physiological signs of dehydration, which may further compromise voluntary drinking behaviors during exercise²⁰.

An additional practically relevant finding of the present study was the discrepancy between fluid intake during competition and estimated post-match rehydration requirements. Players consumed approximately 1.0 L of fluid during matches, whereas estimated rehydration needs approached 3.0 L on average. These findings suggest that players replaced only a portion of exercise-induced fluid losses during competition, supporting previous observations that adolescent football players frequently fail to adequately compensate for sweat losses when drinking ad libitum⁹⁻¹⁰. This phenomenon of voluntary dehydration has been

consistently described in youth athletes and may be influenced by match interruptions, limited drinking opportunities, behavioral habits, competitive stress, or underestimation of fluid requirements^{21,22}. From a practical perspective, these findings reinforce the importance of structured and individualized hydration education programs within elite academy settings, particularly considering the developmental and thermoregulatory characteristics of adolescent athletes.

A novel aspect of the present study was the simultaneous assessment of hydration markers and GPS-derived external load variables during official competitive match play. A statistically significant, although relatively small, positive association was observed between dehydration percentage and total distance covered, indicating that players exposed to greater overall locomotor demands tended to demonstrate larger fluid losses. This finding is physiologically plausible given that greater running volume increases metabolic heat production and sweat responses, thereby elevating fluid requirements during prolonged intermittent exercise^{5,14}. Interestingly, no significant relationships were identified between dehydration and high-intensity running variables, sprint distance, accelerations, or decelerations. This may suggest that cumulative overall workload, rather than isolated high-intensity actions, represents a more important determinant of match-related fluid loss in elite youth football players. Alternatively, substantial inter-individual variability in sweat rate, pacing strategies, fitness level, and drinking behavior may partially explain the relatively weak associations observed between dehydration and specific GPS-derived metrics.

The positional analysis revealed significantly greater relative running intensity in midfield players compared with defenders and forwards, which is consistent with the established physiological demands of the midfield role in football^{3,4}. Midfielders typically perform larger volumes of continuous locomotor activity and transitional movement during competition, which likely explains the higher m/min values observed in the present study. However, despite these increased running demands, no significant positional differences were identified for dehydration percentage. This finding may indicate that hydration responses during competition are influenced by multiple interacting factors beyond external load alone, including individual sweat characteristics, pacing strategies, body composition, fluid intake behaviors, and tactical match involvement. Similar observations have previously been reported by Diaz (2014)²³, who demonstrated positional differences in movement demands but less consistent differences in hydration responses among youth football players.

Interestingly, no significant changes in handgrip strength were observed following match play. Although dehydration has previously been associated with impaired neuromuscular and physical performance under more severe fluid deficit conditions¹²⁻¹³, the relatively moderate dehydration levels observed in the present study may not have been sufficient to induce measurable reductions in maximal isometric handgrip performance. Furthermore, handgrip strength may represent a relatively insensitive marker of football-specific neuromuscular fatigue when compared with lower-limb performance assessments commonly used in football monitoring systems. Nevertheless, the absence of significant changes may also suggest that players were able to maintain general neuromuscular function despite the physiological demands of competition and mild-to-moderate dehydration levels.

Several practical implications emerge from the present findings. First, hydration status monitoring should be implemented routinely in elite academy football settings, particularly

before competition, given the high prevalence of pre-match hypohydration observed in the present and previous studies. Second, individualized hydration strategies based on body mass changes, sweat responses, and match demands may be more effective than generalized ad libitum drinking recommendations. Third, coaches and sports science practitioners should recognize that meaningful dehydration may occur even under relatively moderate environmental conditions and in players who do not subjectively report excessive thirst or fatigue. Finally, the integration of GPS-derived external load monitoring with hydration assessment may provide a useful applied framework for identifying players at greater risk of exercise-induced fluid deficits during competition.

The present study should also be interpreted in light of several limitations. First, although the study included a relatively large number of match observations collected during official elite competition, repeated observations from the same players may have reduced complete statistical independence between measurements. Second, hydration assessment was limited to body mass changes and urine specific gravity, while additional physiological markers such as sweat sodium concentration, plasma osmolality, core temperature, or direct sweat rate measurements were not available. Third, environmental conditions during the analyzed matches were relatively moderate, which may limit the generalizability of the findings to hotter competitive environments associated with greater thermal strain. Finally, the observational nature of the study precludes conclusions regarding causal relationships between external load and dehydration responses.

Conclusions

In conclusion, elite academy football players demonstrated significant match-induced deterioration in hydration status during official competitive match play, characterized by reductions in body mass and increases in urine specific gravity. A substantial proportion of players began matches in a hypohydrated state, while fluid intake during competition appeared insufficient relative to estimated rehydration requirements. Greater total locomotor workload was associated with increased dehydration responses, although no positional differences in dehydration were identified despite higher relative running intensity in midfield players. These findings highlight the importance of individualized hydration monitoring and fluid replacement strategies within elite youth football environments.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Ethical Committee approval

The study was approved by the Ethics Committee of the Faculty of Kinesiology University of Split (Class: 003-08/25-04/001, No. 2181-205-02-05-25-001).

Topic

Sport Science

Conflicts of interest

The authors have no conflicts of interest to declare.

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Author-s contribution

Conceptualization, Marta Tomljanović, Ana Kezić; methodology, Marta Tomljanović, Ana Kezić, Daniela Čačić Kenjerić; software, Ana Kezić; validation, Ana Kezić, Daniela Čačić Kenjerić; formal analysis, Marta Tomljanović; data curation, Ana Kezić, Daniela Čačić Kenjerić, writing—original draft preparation, Marta Tomljanović; writing—review and editing, Ana Kezić, Daniela Čačić Kenjerić; visualization Marta Tomljanović.

References

1. Belval LN, Hosokawa Y, Casa DJ, Adams WM, Armstrong LE, Baker LB, Burke L, Cheuvront S, Chiampas G, González-Alonso J, Huggins RA, Kavouras SA, Lee EC, McDermott BP, Miller K, Schlader Z, Sims S, Stearns RL, Troyanos C, Wingo J. Practical hydration solutions for sports. *Nutrients*. 2019;11(7):1550. doi:10.3390/nu11071550
2. Sawka MN, Burke LM, Eichner ER, Maughan RJ, Montain SJ, Stachenfeld NS. Exercise and fluid replacement. *Med Sci Sports Exerc*. 2007;39(2):377-390. doi:10.1249/mss.0b013e31802ca597
3. Bangsbo J, Iai FM, Krstrup P. Metabolic response and fatigue in soccer. *Int J Sports Physiol Perform*. 2007;2(2):111-127. doi:10.1123/ijsp.2.2.111
4. Mohr M, Krstrup P, Bangsbo J. Fatigue in soccer: a brief review. *J Sports Sci*. 2005;23(6):593-599. doi:10.1080/02640410400021286
5. Laitano O, Runco JL, Baker LB. Hydration science and strategies in football. *Sports Sci Exchange*. 2014;27(128):1-7.
6. Phillips SM, Sykes D, Gibson N. Hydration status and fluid balance of elite European youth soccer players during consecutive training sessions. *J Sports Sci Med*. 2014;13(4):817-822.
7. North M, Kelly AL, Ranchordas MK, Cole M. Nutritional considerations in high performance youth soccer: a systematic review. *J Sci Sport Exerc*. 2022;4(3):195-212. doi: 10.1007/s42978-022-00171-3
8. Arnaoutis G, Kavouras SA, Kotsis YP, Tsekouras YE, Makrillos M, Bardis CN. Ad libitum fluid intake does not prevent dehydration in suboptimally hydrated young soccer players during a training session of a summer camp. *Int J Sport Nutr Exerc Metab*. 2013;23(3):245-251. doi:10.1123/ijsnem.23.3.245
9. Da Silva RP, Mündel T, Natali AJ, Bara Filho MG, Alfenas RC, Lima JR, Belfort FG, Lopes PR, Marins JC. Pre-game hydration status, sweat loss, and fluid intake in elite Brazilian young male soccer players during competition. *J Sports Sci*. 2012;30(1):37-42. doi: 10.1080/02640414.2011.623711
10. Fernández-Álvarez M, Cachero-Rodríguez J, Leirós-Díaz C, Carrasco-Santos S, Martín-Payo R. Evaluation of water intake in Spanish adolescent soccer players during a competition. *J Hum Kinet*. 2022;83:59-68. doi: 10.2478/hukin-2022-0051
11. McGregor SJ, Nicholas CW, Lakomy HKA, Williams C. The influence of intermittent high-intensity shuttle running and fluid ingestion on the performance of a soccer skill. *J Sports Sci*. 1999;17(11):895-903. doi:10.1080/026404199365452
12. Edwards AM, Mann ME, Marfell-Jones MJ, Rankin DM, Noakes TD, Shillington DP. Influence of moderate dehydration on soccer performance: physiological responses to 45 min of outdoor match-play and the immediate subsequent performance of sport-specific and mental concentration tests. *Br J Sports Med*. 2007;41(6):385-391. doi: 10.1136/bjism.2006.033860
13. Nuccio RP, Barnes KA, Carter JM, Baker LB. Fluid balance in team sport athletes and the effect of hypohydration on cognitive, technical, and physical performance. *Sports Med*. 2017;47(10):1951-1982. doi: 10.1007/s40279-017-0738-7
14. Périard JD, Eijssvogels TMH, Daanen HAM. Exercise under heat stress: thermoregulation, hydration, performance implications, and mitigation strategies. *Physiol Rev*. 2021;101(4):1873-1979. doi:10.1152/physrev.00038.2020
15. Cummins C, Orr R, O'Connor H, West C. Global positioning systems (GPS) and microtechnology sensors in team sports: a systematic review. *Sports Med*. 2013;43(10):1025-1042. doi:10.1007/s40279-013-0069-2
16. Akenhead R, Hayes PR, Thompson KG, French D. Diminutions of acceleration and deceleration output during professional football match play. *J Sci Med Sport*. 2013;16(6):556-561. doi:10.1016/j.jsams.2012.12.005
17. Varley MC, Aughey RJ. Acceleration profiles in elite Australian soccer. *Int J Sports Med*. 2013;34(1):34-39. doi: 10.1055/s-0032-1316315
18. Casa DJ, Armstrong LE, Hillman SK, Montain SJ, Reiff RV, Rich BS, Roberts WO, Stone JA. National Athletic Trainers' Association position statement: fluid replacement for athletes. *J Athl Train*. 2000;35(2):212-224.
19. Suppiah HT, Ng EL, Wee J, Taim BC, Huynh M, Gastin PB, Chia M, Low CY, Lee JKW. Hydration status and fluid replacement strategies of high-performance adolescent athletes: an application of machine learning to distinguish hydration characteristics. *Nutrients*. 2021;13(11):4073. doi:10.3390/nu13114073
20. Desbrow B. Youth athlete development and nutrition. *Sports Med*. 2021;51(suppl 1):3-12. doi: 10.1007/s40279-021-01534-6
21. Bergeron MF, Waller JL, Marinik EL. Voluntary fluid intake and core temperature responses in adolescent tennis players: sports beverage versus water. *Br J Sports Med*. 2006;40(5):406-410. doi: 10.1136/bjism.2005.023333
22. Silva RP, Mündel T, Natali AJ, Bara Filho MG, Lima JR, Alfenas RC, Lopes PR, Belfort FG, Marins JC. Fluid balance of elite Brazilian youth soccer players during consecutive days of training. *J Sports Sci*. 2011;29(7):725-732. doi: 10.1080/02640414.2011.552189
23. Díaz AC. Peso perdido y líquido ingerido y perdido en jugadores de fútbol de categoría infantil, cadete y juvenil en función de la posición ocupada en competición. PhD thesis. Universidad de Murcia; 2014. Accessed May 19, 2026. <https://digitum.um.es/entities/publication/8b181918-dbb3-44c3-a0bd-1996f16640f9>

Corresponding information:

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Correspondence to: Marta Tomljanović

University: Kineziološki fakultet Sveučilište u
Splitu; Nikole Tesle 6, Split 21000, Croatia

E-mail: tomljanovicmarta7@gmail.com