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Pre-exercise hypohydration prevalence in soccer players: a quantitative systematic review.

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Abstract

Pre-exercise hypohydration can impair soccer performance and has been extensively studied in different soccer populations. Therefore, the aim of this systematic review was to report hypohydration prevalence, measured by blood or urine samples, in different soccer populations based on sex (males and females), performance level (professional and recreational players) and context (training sessions and games). The Pubmed, Web of Science and SPORTDiscus databases were systematically searched until November 2018. Data were pooled to compare hypohydration prevalence between the different subgroups. Following the systematic search selection process, 24 studies were included. The results indicated that overall pre-exercise hypohydration prevalence was 63.3 %, 37.4 % and 58.8 % for urine specific gravity (USG), urine osmolality (U Osm) and urine colour, respectively. Furthermore, no study implemented blood samples to examine hypohydration prevalence in soccer players. The subgroup analyses using USG data indicated that pre-exercise hypohydration prevalence was significantly higher amongst males (66.0 %; $p = 0.001$), professional soccer players (66.2 %; $p = 0.020$) and before a training session (79.6 %; $p < 0.001$). Pre-exercise hypohydration prevalence was 46.8 % among female soccer players, 55.6 % in recreational soccer players and 41,3 % before a game. The subgroup analyses using U Osm data indicated that hypohydration prevalence was significantly higher before a training session (52.6 %; $p = 0.023$). Based on these results, it can be concluded that hypohydration prevalence in soccer players is of major concern. Future research should explore how pre-exercise hydration status can be improved in a sustainable way.

Keywords: *hydration; hypohydration; soccer players; systematic review*

Introduction

Hypohydration, defined as a decrease in total body water content due to a mismatch between fluid intake and fluid floss, is known to decrease plasma volume and increase plasma osmotic pressure (1). Although the increased plasma osmotic pressure mobilizes fluid from the intracellular space into the extracellular space, this amount of fluid is not sufficient to restore plasma volume completely (1,2). As a consequence, skin blood flow and the sweating response will decrease during exercise thereby increasing body core temperature and thermoregulatory strain since the ability to transfer heat from the exercising muscles to the skin surface is impaired (1). The decreased plasma volume also results in a decreased cardiac output and increased heart rate during exercise leading to a higher physiological strain (1 - 3). In hot and humid environments, the presence of hypohydration exacerbates the thermoregulatory strain since the body's potential to dissipate heat is further diminished. This diminished potential is due to a decreased heat loss capacity and a greater dependence on sweating for evaporative cooling (3).

When hypohydrated, soccer players have significantly higher heart rates, ratings of perceived exertions, blood lactate levels and body core temperatures (4,5). Regarding soccer performance, hypohydration is reported to cause a significant decrease in aerobic performance, dribbling skills, sprint performance and cognitive skills (5 - 14). Despite a multitude of studies demonstrating the negative effects of commencing exercise in a hypohydrated state on performance and previous position statements emphasizing the importance of optimal hydration (euhydration) in order to achieve optimal sport performance and minimal thermoregulatory and physiological strain, many soccer players still start their games and training sessions in a hypohydrated state (4 - 6, 14). Several factors can contribute to causing a state of hypohydration. For instance, altitude has a diuretic effect whilst a cold environment decreases the drive for thirst and ad libidum fluid intake. Insufficient knowledge regarding understanding the risks of hypohydration as well as the importance of maintaining euhydration, due to a lack of player education, can contribute as well. Similarly, having no well-developed or individual hydration plan could contribute to being in a state of hypohydration (15).

The pre-exercise hydration status can be monitored by using urine and blood based methods such as urine specific gravity (USG), urine osmolality (U Osm), urine colour (U Col) or plasma osmolality (P Osm) (16 - 18). P Osm is reported to be the primary indicator of hydration but requires a blood sample, a high level of expertise and is the most expensive method. Hydration assessment methods based on urine samples are recognized as both reliable and practical but are under the confounding influence of diet, timing of fluid intake and the renal responses to exercise (19).

Many studies already examined and reported pre-exercise hypohydration prevalence in different soccer populations (i.e. males and female soccer players; recreational and professional soccer players) and different contexts (i.e. training session or game). Nevertheless, no clear insight exists on the overall prevalence of pre-exercise hypohydration in soccer players.

Therefore, the aims of this systematic review were (1) to separately report pre-exercise hypohydration prevalence in soccer for the different hydration assessment methods, and (2) to examine possible differences in pre-exercise hypohydration prevalence in various subgroups based on sex, performance level and context.

Methods

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Review and Meta-analysis Protocols (PRISMA-P) (20). The review protocol was registered and is accessible via the PROSPERO database (CRD42016051021).

Systematic search strategy

Two researchers (BT and LC) independently searched PubMed (MEDLINE), Web of Science and SPORTDiscus (EBSCO) for published articles. Databases were searched from the dates of inception of these databases to November 2018.

Eligibility criteria

The following inclusion criteria were set: (1) the study population had to consist of soccer players and (2) the hydration status must be examined before a training session or game by means of urine (i.e. USG, U Osm and U Col) or blood (i.e. P Osm) samples. Reviews, meta-analyses and case reports were excluded. Studies that only examined first-morning urine or blood samples were not eligible (21 – 23), as well as studies where participants had an unusual nutritional status (i.e. Ramadan) (24).

Search strategy

The following search terms were combined using Boolean operators: (soccer OR football OR soccer player* OR football player*) AND (hydration OR hydration status OR hydration assessment OR hypohydration OR dehydration OR urine specific gravity OR urine osmolality OR plasma osmolality OR urine colour OR pre-exercise hydration status OR pre-training hydration assessment OR pre-training hydration status OR pre-game hydration assessment OR pre-game hydration status). Reference lists of included articles were searched by both researchers to identify potential additional articles.

Study selection and risk of bias assessment

Two researchers (LC and BT) independently searched the three databases and inserted all retrieved titles, abstracts and full texts in the Rayyan web application (https://rayyan.qcri.org) (25). Studies were independently screened for inclusion by two researchers (LC and BT) by first reviewing titles and abstract, and in a second stage reviewing the remaining full text articles. Inclusion and exclusion decisions were labelled in the Rayyan web application. In case of disagreement, a third researcher (PC) was contacted in order to reach consensus.

Risk of bias assessment was done by using the Joanna Briggs Institute (JBI) critical appraisal tool for Analytical Cross-sectional Studies (26). The JBI critical appraisal tool is used to assess the methodological quality of a study and to determine the extent to which a study addresses the possibility of bias in its design (26). Cohen's Kappa value was calculated as a measure of agreement for the screening process, data extraction and risk of bias assessment between the two researchers (27).

Data extraction and statistical analysis

Extracted data from included studies was entered into a standardised electronic reporting sheet. The variables extracted were first authors, publication year, study design, number of participants, performance level, sex, chronological age, context, hydration assessment method, hydration values (mean, standard deviation and range), pre-exercise hypohydration prevalence, temperature and humidity (Table 1). Soccer players were considered hypohydrated if USG, U Osm, P Osm or U Col was equal to or above 1.020 g/ml, 700 mOsmol/kg, 287 mOsmol/kg or colour grade three, respectively (10, 28). Corresponding authors were contacted through e-mail when any information was missing from the full text (e.g. pre-exercise hypohydration prevalence). When studies implemented an intervention design aiming to improve pre-exercise hypohydration prevalence (29, 30), only the hydration values before the intervention were extracted. One study (30) examined hydration status in sickle cell trait carriers and healthy soccer players; only the hydration outcomes of the healthy participants were extracted.

The percentage of pre-exercise hypohydrated soccer players was calculated separately for all the hydration assessment methods and was based on the baseline hydration values in the case of multiple reported measurements (i.e. hydration value of the first training session or game). Where possible, the percentage of pre-exercise hypohydrated soccer players was calculated based on sex (male versus female), performance level (recreational versus professional) and context (training session versus game). Next, Chi-square tests were performed in SPSS version 25.0 (IBM, Amonk, United States of America) to compare the hydration status between the different subgroups. A p-value smaller than 0.05 was considered statistically significant and all data are presented as mean ± standard deviation (SD).

XXX Figure 1 around here XXX

Results

Search strategy

The systematic search yielded a total of 1,361 original articles. In addition, 2 articles were identified after screening the reference lists of the included articles. After screening the title, abstract and full text, a total of 24 studies were included in this systematic review (Figure 1). A description of the 24 included articles is presented in Table 1 (29 – 52). The Cohen's kappa between the two researchers was 0.93 for the independent systematic search and 1.00 for data extraction. However, Cohen's kappa was 0.84 for the study quality assessment. For both the independent selection and data extraction process the two reviewers could always agree and involvement of a third reviewer was not necessary.

XXX Table 1 around here XXX

Study characteristics

The 24 included studies accounted for a total of 642 soccer players. To examine the hydration status, 17 studies used USG (29 – 35, 37 – 41, 43 – 45, 49, 50), 3 studies used U Osm (46 - 48), 2 studies used a combination of USG and U Osm (36, 51), 1 study used a combination of USG and U Col (42), and 1 study used a combination of U Osm and U Col (52). A total of 19 studies assessed male soccer players (31 – 34, 36 – 38, 40 – 42, 44 - 52) whereas 5 studies examined female soccer players (29, 30, 34, 39, 43). Professional level soccer players were analysed in 19 studies (29, 32 – 39, 41 – 43, 46 - 52) and 5 studies examined recreational players (30, 31, 40, 44, 45). Hydration status before a training session was investigated in 11 studies (30, 34, 38 – 40, 43, 46, 47, 49, 50, 52) whereas 10 studies assessed hydration status before a game (31 – 33, 36, 37, 41, 42, 44, 48, 51). Two studies examined the hydration status before a training session and a game (29, 35) whilst one study did not report the context (45).

Risk of bias assessment

The risk of bias assessment of the included studies resulted in JBI scores that ranged from 3 to 8 out of 8 (Table 2). Seventeen studies failed to clearly describe the inclusion criteria leading to a high risk of inclusion bias. Also, 14 studies failed to identify confounding factors and implement strategies to deal with these confounding factors leading to a high risk of performance bias (Figure 2).

XXX Table 2 around here XXX

XXX Figure 2 around here XXX

Subgroup analyses

Twenty-one out of the 24 included studies could be pooled and were subsequently analysed using Chi-square tests (29-32, 34-37, 39-52). After pooling the results, USG, U Osm or U Col values indicated pre-exercise hypohydration in 63.3 % (346 out of 547 players), 37.4 % (52 out of 139 players) and 58.8 % (20 out of 34 players) of the soccer players, respectively (Table 3). When using USG as an isolated hydration marker, a significant number of participants presented as hypohydrated in males (χ^2 (1, N = 547) = 10.709; *p = 0.001*), professional soccer players (χ^2 (1, N = 547) = 5.416; *p = 0.020*) and before a training session (χ^2 (1, N = 492) = 73.735; *p < 0.001*). Using U Osm, a significant higher number of participants were hypohydrated before a training session (χ^2 (1, N = 139) = 5.175; *p = 0.023*).

XXX Table 3 around here XXX

Discussion

The results of this systematic review indicated that the pre-exercise hypohydration prevalence of the included soccer players ranged from 37.4 to 63.5 % depending on the hydration assessment method. Since hypohydration is due to a discrepancy between fluid intake and fluid loss it is clear that the amount of fluid intake is not adequate to compensate for the fluid loss. Among other influencing factors, a lack of knowledge regarding the thermoregulatory and physiological consequences of hypohydration and unawareness of nutritional and fluid requirements to counter hypohydration could possibly explain this high hypohydration prevalence in soccer players (3, 15, 45).

The pre-exercise hypohydration prevalence was significantly higher amongst male soccer players (66.0 %) in comparison to female soccer players (49.4%). It is reported in the literature that males experience a higher fluid loss due to hormonal and body composition differences between both genders (53). Consequently, males should ingest a higher fluid volume compared to females to compensate for this higher fluid loss. The discrepancy in fluid intake needs between males and females could therefore be a possible explanation for the higher hypohydration prevalence in male soccer players. Nevertheless, and although the hypohydration prevalence is significantly higher amongst male soccer players, almost half of the female soccer players start a training session or game hypohydrated. Therefore, both male and female soccer players should aim to improve their pre-exercise hydration status.

Pre-exercise hypohydration prevalence was higher in professional soccer players (66.2 %) in comparison with recreational soccer players (55.6 %). One study reported that out of 156 professional soccer players 141 started a training session in a hypohydrated state (34). Similar results are reported in the studies of Philips et al., (2014) and Silva et al., (2011) since 11 out of 14 and 17 out of 20 professional soccer players respectively were hypohydrated before a training session (49, 50). These results are surprising since one would hypothesize the opposite as professional players should have more resources at their disposal, such as an individually tailored hydration plan, to counteract pre-exercise hypohydration. Nevertheless and despite the significantly lower hypohydration prevalence in recreational soccer player still more than half of them started a training session or game hypohydrated. Hence, it is important that both professional and recreational soccer players should pay more attention to achieving euhydration and aim to improve their pre-exercise hydration status.

When considering pre-exercise hypohydration prevalence in relation to context, the chi-square analysis using USG as hydration assessment method found that hypohydration prevalence was significantly lower before a game (41.3 %) in comparison to before a training session (79.6 %). The chi-square analysis using U Osm confirmed this finding as 31.7 % of the players were hypohydrated before a game compared to 52.6 % before a training session. These results indicate that, from a nutritional perspective, soccer players spend more attention to an adequate fluid intake before a game compared to before a training session. It is also possible that soccer players are more closely monitored regarding an adequate fluid intake by the technical or medical staff before a game compared to before a training session. Even so, and since pre-exercise hypohydration can negatively impact soccer performance or impair desired training adaptations, beginning a game or training session in a hypohydrated state is undesired (4 - 15). Correspondingly, soccer players should aim to consume beverages with high sodium concentrations before exercise as electrolyte homeostasis will be easier maintained and water retention will be higher (54, 55).

Limitations

Due to the low number of studies using U Osm as a hydration status assessment tool, no further subgroup analyses based on sex and performance level could be performed. In addition, since 2 studies (out of 5) examined the hydration status using both USG and U Osm the same soccer players were included in the subgroup analyses. Also, most studies included in this systematic review examined male soccer players. As such, only 79 female soccer players (i.e. 5 studies) were included in this systematic review, in contrast to 468 male soccer players (i.e. 19 studies).

The influence of ambient temperature and humidity on hypohydration prevalence could not be examined in the context of this review due to the reported variation in the included studies. For example, in the study performed by Gordon et al. (2015) the temperature and humidity ranged from 10.2 to 34.1 °C and 25 to 94 % respectively whilst the average USG value remained 1.023 g/cm^3 (40). Nevertheless, it is reported that a hot and humid environment will aggravate the thermoregulatory strain when hypohydrated since the body's potential to dissipate heat to the environment is diminished (3).

None of the included studies used blood samples to examine the hydration status of soccer players. Despite the fact that hydration assessment techniques using blood samples are reported to be the primary indicator of hydration, they are less suited for field studies as they require a high level of expertise and are more expensive (16, 19). As a result, hydration assessment by means of urine samples are more commonly used in field studies, as they are less invasive and less time-consuming (16, 53). However, it should be noted that the use of urine samples as a valid and reliable indicator of hydration status came under scrutiny, as they do not measure intracellular or extracellular fluid directly and many variables may influence urine concentration such as diet, timing of fluid ingestion, the renal response to physical activity, ambient temperature, humidity, altitude, and timing of urine sample collection (19, 56, 57). Therefore, and although urine assessment techniques provide useful guidance regarding body fluid balance and fluid intake adequacy in the field, one should always carefully consider previous mentioned annotations before making any assumptions on the athletes' hydration status (56, 57). Interestingly, 63.3 % of the soccer players examined using USG were classified as hypohydrated whilst this percentage was only 37.4 % when U Osm was used as a hydration assessment method. This difference is surprising since the correlation between USG and U Osm is reported to be very high as USG and U Osm can be used interchangeably (16). It is possible that several confounding factors (such as for example diet and timing of fluid ingestion) influenced the results observed in this study (19, 56, 57).

Future perspectives

Due to the high pre-exercise hypohydration prevalence of soccer players (educational) interventions aiming to improve hypohydration prevalence might prove beneficial. As such, two studies reported that an educational intervention had a positive influence on pre-exercise hypohydration prevalence in female soccer players (29, 30). It should be noted however that these studies only examined short term effects and a control group was lacking. Future research should further examine whether an individual approach and educational intervention have a (long lasting) positive influence on pre-exercise hypohydration prevalence in soccer players. Furthermore, female soccer players are currently underrepresented in hydration literature as only 5 out of 24 studies examined pre-exercise hydration status in female soccer players (29, 30, 35, 39, 43). Therefore, more research should be conducted with female soccer players. Furthermore, the influence of ambient temperature and humidity on pre-exercise hypohydration prevalence in soccer players has yet to be examined. Lastly, (field) studies should examine the hydration status of soccer players with blood samples as they are reported to have a higher accuracy compared to urine samples.

Conclusion

The overall pre-exercise hypohydration prevalence amongst soccer players ranged from 37.4 to 63.5 % depending on the hydration assessment method indicating that hypohydration prevalence in soccer players is of concern. In addition, pre-exercise hypohydration prevalence was significantly higher in males, professional soccer players and before a training session compared with females, recreational soccer players and before a game respectively. Nevertheless, pre-exercise hypohydration was also considerably present among female soccer players, recreational soccer players, and before a game. This indicates that a lot of progress can still be made amongst all subgroups. Future research should further explore how pre-exercise hypohydration prevalence can be improved in a sustainable way.

Declaration of interest statement

The authors declare there is no conflict of interest.

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Table captions:
Table 1. description of the included studies (n = 24).

Table 2. Overview of the results from the risk of bias assessment using the Johanna Briggs Institute critical appraisal tool for Analytical Cross-sectional Studies.

Table 3. Pooled data of the included studies (n = 21).

Figure captions:

Figure 1. flow chart of the screening process.

Figure 2. Risk of bias of the included analytical cross-sectional studies.

Table 1. Description of the included studies (n = 24).

First author, year	Study design	n	Level	Sex	Age (years)	G / TS	Method	Mean hydration value	Range	N hypo	T (°C)	H (%)
Al-Jaser, 2006	Cross-sectional	9	Elite	Male	24 ± 4.7	G	USG	1.019 ± 0.005	1.010 – 1.025	NR	45.4 ± 2	23.6 ± 4.2
Aragon-Vargas, 2009	Cross-sectional	T1: 8 T2: 9	Elite	Male	NR	G	USG	T1: 1.022 T2: 1.014	1.003 – 1.036	5 2	34.9 ± 1.2	35.4 ± 4.2
Castro-Sepùlveda, 2015	Cross-sectional	156	Elite	Male	25.4 ± 5.2	TS	USG	1.026 ± 0.005	1.006 – 1.042	141	17 – 23	NR
Castro-Sepùlveda, 2016	Cohort	17	Elite	Female	21.5 ± 3.0	TS	USG	1.029 ± 0.009	1.014 – 1.044	14	28	56
						G (F)		1.023 ± 0.010	1.007 – 1.038		30	52
						G (O)		1.030 ± 0.006	1.020 – 1.042		29	54
Chapelle, 2017	Cohort	18	Elite	Female	17.6 ± 0.4	TS (1)	USG	1.013 ± 0.008	1.002 – 1.026	4	17.8 ± 1.1	77.1 ± 8.1
						G (1)		1.013 ± 0.004	1.007 – 1.022	1	19.3 ± 1.4	83.1 ± 9.2
						TS (2)		1.016 ± 0.007	1.003 – 1.026	7	18.6 ± 1.0	85.6 ± 0.8
						G (2)		1.009 ± 0.006	1.002 – 1.024	2	19.5 ± 0.9	80.6 ± 7.9
Coelho, 2012	Cross-sectional	U15: 36	Elite	Male	14.2 ± 0.8	G	USG	1.021 ± 0.001	1.008 – 1.030	U15: 18 U17: 7	23.2 ± 1.3	86.1 ± 3.1
		U17: 14			16.2 ± 1.2		U Osm	827.9 ± 118.8	378 - 1117	14	23.1 ± 0.2	89.2 ± 2.1
Da Silva, 2012	Cross-sectional	15	Elite	Male	17.0 ± 0.6	G	USG	1.021 ± 0.004	1.010 – 1.025	10	31.0 ± 2.0	48.0 ± 5.0
Diaw, 2012	Cohort	11	Recreational	Male	26.0 ± 1.3	G (1) G (2)	USG	1.021 ± 0.009 1.026 ± 0.012	1.005 – 1.050	5 6	24.5 – 25	65 – 68
Duffield, 2012	Cohort	13	Elite	Male	22.0 ± 4.0	TS (1)	USG	1.021 ± 0.004	NR	NR	26.9 ±	65 ± 7

						TS (2) TS (3)		1.022 ± 0.008 1.017 ±0.008			0.1	
Gibson, 2012	Cross-sectional	34	Elite	Female	15.7 ± 0.7	TS (1) TS (2)	USG	1.014 ± 0.005 1.011 ± 0.005	1.003 – 1.034	16	9.8 ± 3.3	63 ± 12
Gordon, 2015	Cohort	79	Recreational	Male	15.9 ± 0.8	TS (1) TS (2)	USG	1.023 ± 0.005 1.023 ± 0.006	1.006 – 1.033 1.007 – 1.036	60 56	10.2 – 34.1	25 – 94
Guttieres, 2011	Cross-sectional	20	Elite	Male	17.9 ± 1.3	G	USG	1.023 ± 0.006	1.012 – 1.036	10	29.0 ± 1.1	64.0 ± 4.2
Harvey, 2007	Cohort	13	Elite	Male	22.6 ± 4.9	G (1) G (2) G (1) G (2)	USG U Col	1.013 ± 0.006 1.012 ± 0.006 3.1 ± 1.5 2.6 ± 1.4	1.005 – 1.025 1.005 – 1.020 1 - 5 1 – 5	1 0 4 3	21	77
Kilding, 2009	Cohort	13	Elite	Female	23 ± 5	TS (1) TS (2)	USG	1.014 ± 0.005 1.011 ± 0.005	1.004 – 1.022 1.004 – 1.021	NR	14.4 ± 0.7 6.2 ± 1.3	64.0 ± 2.0
Kurdak, 2010	Cohort	T1: 11 T2: 11	Recreational	Male	20 ± 2	G (1) G (2) G (1) G (2)	USG	1.012 ± 0.006 1.012 ± 0.008 1.010 ± 0.006 1.006 ± 0.003	1.004 – 1.025 1.003 – 1.030 1.003 – 1.022 1.003 – 1.014	2 2 1 0	34.3 ± 0.6	64 ± 2
Magee, 2016	Cross-sectional	20	Recreational	Male	NR	NR	USG	1.016	1.003 – 1.025	6	NR	NR
Mattausch, 2017	Cohort	10	Recreational	Female	20.4	TS (1) TS (2)	USG	1.022 ± 0.007 1.024 ± 0.009	1.009 – 1.038 1.010 – 1.034	5 7	31	89
Maughan, 2004	Cross-sectional	21	Elite	Male	27 ± 4	TS	U Osm	666 ± 311	103 - 1254	NR	26.6 ± 2.3	54.8 ± 6.5
Maughan, 2005	Cross-sectional	17	Elite	Male	24 ± 4	TS	U Osm	872 ± 177	481 - 1228	6	5.1 ± 0.7	81 ± 6
Maughan, 2007	Cross-sectional	31	Elite	Male	19.6 ± 2.2	G	U Osm	678 ± 344	89 - 1116	11	6 - 8	50 – 60
Philips, 2014	Cohort	14	Elite	Male	16.9 ± 0.8	TS (1)	USG	1.024 ± 0.05	1.016 –	11	12.9 ±	50.3 ±

									1.030		0.7	2.3
						TS (2)		1.023 ± 0.006	1.013 – 1.037	11	8.9 ± 0.3	76.8 ± 1.3
						TS (3)		1.021 ± 0.004	1.014 – 1.029	10	17.2 ± 0.1	50.5 ± 0.5
Silva, 2011	Cohort	20	Elite	Male	17.2 ± 0.5	TS (1)	USG	1.024 ± 0.006	1.012 – 1.038	17	33.1 ± 2.4	43.3 ± 3.2
						TS (2)		1.023 ± 0.006	1.011 – 1.035	15	29.7 ± 2.2	60.3 ± 5.6
						TS (3)		1.021 ± 0.005	1.010 – 1.036	9	27.6 ± 0.9	75 ± 10
Van Biervliet, 2014	Cross-sectional	20	Elite	Male	14.4 – 15.8	G	USG	1.006	1.003 – 1.033	7	6 – 17	80 – 85
							U Osm	266	110 - 1233	7		
Williams, 2012	Cross-sectional	21	Elite	Male	17.1 ± 0.7	TS	U Osm	1319 ± 525	667 - 2249	14	11 ± 1.2	50 ± 3.3
							U Col	4 ± 1	NR	16		

n = number of participants; G = game; G (F) = friendly game; G (O) = official game; TS = training session; Hypo = hypohydrated; T° = temperature; H = humidity; NR = not reported; T = team; U15 = under 15; U17 = under 17; USG = urine specific gravity; U Osm = urine osmolality; U Col = urine colour.

Table 2. Overview of the results from the quality assessment using the Johanna Briggs Institute critical appraisal tool for Analytical Cross-sectional Studies.

Study	Item								Total score
	1	2	3	4	5	6	7	8	
Al-Jaser 2006	N	Y	Y	Y	Y	Y	Y	Y	**7**
Aragon-Vargas 2009	N	Y	Y	Y	Y	Y	Y	Y	**7**
Castro-Sepùlveda 2015	N	N	N	Y	N	N	Y	Y	**3**
Castro-Sepùlveda 2016	Y	Y	Y	Y	N	N	Y	Y	**6**
Chapelle 2017	Y	Y	Y	Y	N	N	Y	Y	**6**
Coelho 2012	Y	Y	Y	Y	Y	Y	Y	Y	**8**
Da Silva 2012	N	N	N	Y	Y	Y	Y	Y	**5**
Diaw 2012	U	Y	Y	Y	N	N	Y	Y	**5**
Duffield 2012	N	Y	Y	Y	N	N	Y	Y	**5**
Gibson 2012	N	Y	Y	Y	Y	N	Y	Y	**6**
Gordon 2015	Y	Y	Y	Y	Y	Y	Y	Y	**8**
Guttieres 2011	N	Y	Y	Y	N	N	Y	Y	**5**
Harvey 2008	N	Y	Y	Y	N	N	Y	Y	**5**
Kilding 2009	N	Y	Y	Y	N	N	Y	Y	**5**
Kurdak 2010	N	Y	Y	Y	N	N	Y	Y	**5**
Magee 2016	N	N	N	Y	N	N	Y	Y	**3**
Mattausch 2017	Y	Y	Y	Y	N	N	Y	Y	**6**
Maughan 2004	N	Y	Y	Y	N	N	Y	Y	**5**
Maughan 2005	N	Y	Y	Y	Y	Y	Y	Y	**7**
Maughan 2007	Y	Y	Y	Y	Y	Y	Y	Y	**8**
Philips 2014	N	Y	Y	Y	N	N	Y	Y	**5**

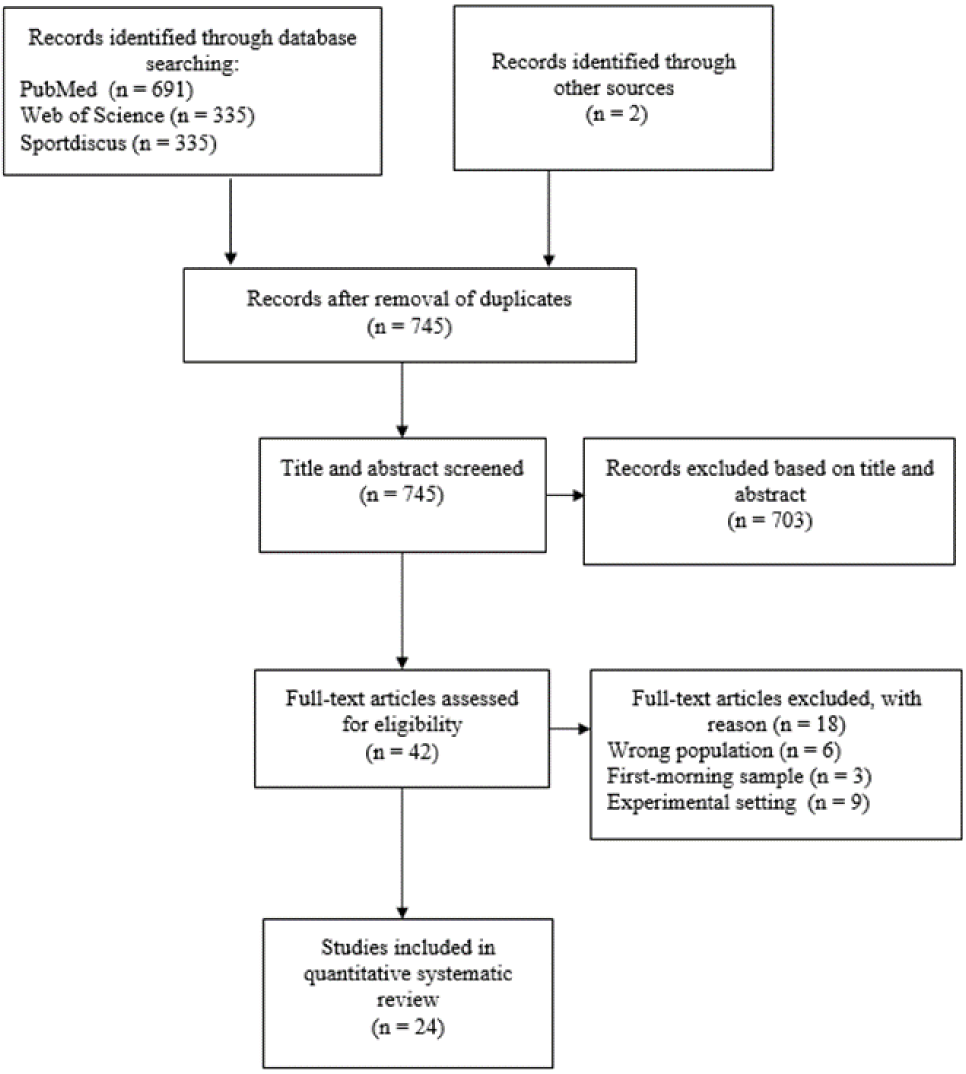
Silva 2011	N	Y	Y	Y	N	N	Y	Y	**5**
Van Biervliet 2014	N	Y	Y	Y	Y	Y	Y	Y	**7**
Williams 2012	N	Y	Y	Y	Y	Y	Y	Y	**7**

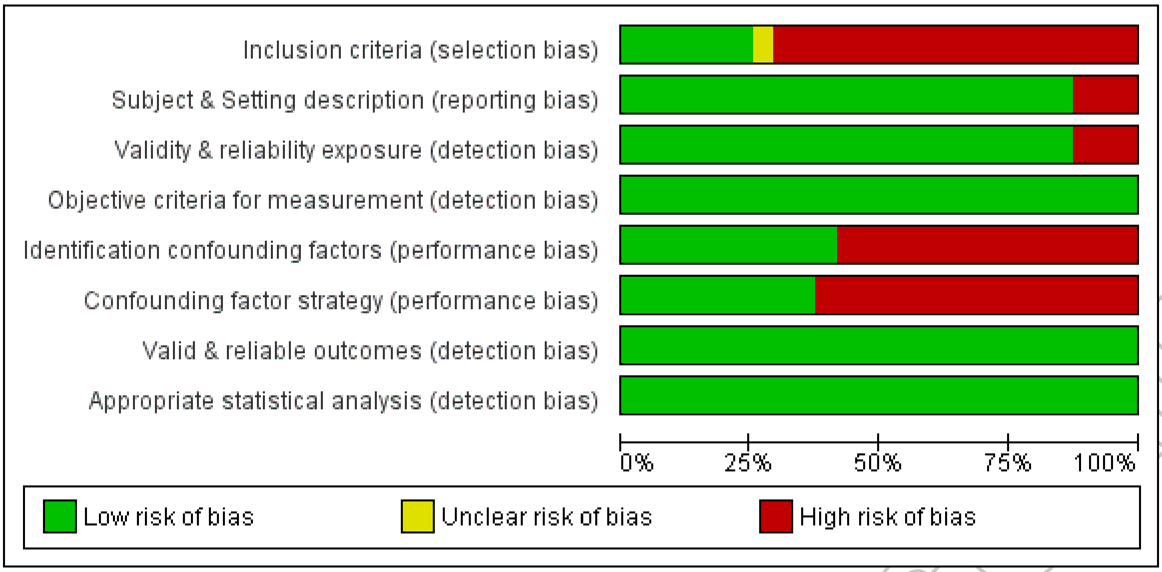
Note: Y = Yes; N = No; U = Unclear.

Table 3. Pooled data of the included studies (n = 21).

	Total n	**n euhydrated**	**n hypohydrated**	**% hypohydrated**
USG				
Total	547	201	346	63.3
Male	468	159	309	66.0
Female*	79	40	39	49.4
Elite	394	133	261	66.2
Recreational*	153	68	85	55.6
Game*	179	105	74	41.3
Training session	313	64	249	79.6
U osm				
Total	139	87	52	37.4
Game*	101	69	32	31.7
Training session	38	18	20	52.6
U col				
Total	34	14	20	58.8

n = number of participants; USG = urine specific gravity; U osm = urine osmolality; U col = urine colour. * significant lower hypohydration prevalence ($p < 0.05$)


Records identified through database searching:
PubMed (n = 691)
Web of Science (n = 335)
Sportdiscus (n = 335)
Records identified through other sources (n = 2)
Records after removal of duplicates (n = 745)
Title and abstract screened (n = 745)
Records excluded based on title and abstract (n = 703)
Full-text articles assessed for eligibility (n = 42)
Full-text articles excluded, with reason (n = 18)
Wrong population (n = 6)
First-morning sample (n = 3)
Experimental setting (n = 9)
Studies included in quantitative systematic review (n = 24)


Inclusion criteria (selection bias)
Subject & Setting description (reporting bias)
Validity & reliability exposure (detection bias)
Objective criteria for measurement (detection bias)
Identification confounding factors (performance bias)
Confounding factor strategy (performance bias)
Valid & reliable outcomes (detection bias)
Appropriate statistical analysis (detection bias)
0%
25%
50%
75%
100%
Low risk of bias
Unclear risk of bias
High risk of bias