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Hydration Indicators: Analyzing Urine Specific Gravity, Color, and Thirst in Female Athletes Before Training

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ABSTRACT

Hydration plays a crucial role in athletic performance and overall health, yet there is a dearth of research specifically focusing on hydration status especially among female athletes in Malaysia. The primary aim of this study was to examine the pre-training hydration status and to investigate the relationship between the urine specific gravity (USG) with urine color (UC) and thirst scale (TS) in female athletes (age 21.6 ± 1.1 years). Thirty varsity athletes from various sports (n = 30, Height: 1.61 ± 6.4 m; Weight: 56.3 ± 8.5 kg) volunteered to participate in this study. Measurements of hydration biomarkers were taken prior to the training session. Urine samples were collected, and a handheld refractometer was used to assess the USG. The thirst level was measured using a 7-point TS and the UC was determined using a Urine Color Chart. The USG assessment indicates the athletes were already in dehydrated condition prior to the training session (1.028 ± 0.2). There was also a significant relationship between USG and UC ($r = 0.81$, $P \leq 0.05$) and UC and TS ($r = 0.77$, $P \leq 0.05$). In conclusion, this study underscores the importance of monitoring pre-training hydration in female athletes using practical tools applicable in sports settings. The findings strongly recommend implementing hydration strategies for female athletes to prevent dehydration and enhance athletic performance.

Keywords: dehydration, student athletes, female, urine specific gravity

INTRODUCTION

Hydration is a critical determinant of athletic performance, influencing a wide range of physiological and biochemical processes. Water constitutes over 60% of the human body and plays an essential role in maintaining both cognitive function and physical performance (Sawka et al., 2007; Brent & Nash, 2024). Despite its importance, athletes' understanding of hydration strategies remains fragmented, often resulting in inadequate fluid intake before and during physical activity (Brent & Nash, 2024). Athletes are therefore encouraged to consume sufficient fluids before, during, and after exercise to achieve euhydration. Adequate hydration helps minimise metabolic strain and supports thermoregulatory processes during exercise (Casa et al., 2000), while also reducing the risk of heat-related illnesses (Convertino et al., 1996). Maintaining optimal hydration is essential for sustaining cognitive functions such as concentration, decision-making, and reaction time, all of which are crucial for athletic performance (Jakiwa et al., 2020). Consequently, well-hydrated athletes are more likely to remain mentally alert, focused, and capable of performing at their peak during training and competition (Atan & Kassim, 2019, 2020).

Exercising in hot and humid environments presents additional challenges to athletes, particularly in tropical regions such as Malaysia (Atan et al., 2019). During exercise, metabolic heat production increases, and sweating becomes the primary mechanism for heat dissipation and body temperature regulation. However, inadequate fluid replacement may lead to dehydration, impairing both physiological function and sports performance. Even a modest body water deficit of 1–3% can negatively affect endurance capacity, muscular strength, speed, coordination, cognitive focus, and thermoregulatory efficiency (Casa et al., 2000; Kenefick, 2018).

Voluntary dehydration has increasingly been identified as a common phenomenon among athletes, with similar patterns observed across different environmental conditions (Osterberg et al., 2009; Williams & Blackwell, 2012). Evidence suggests that many athletes begin training or competition in a dehydrated state without being aware of it and often fail to replace fluids in proportion to their losses (Arnaoutis et al., 2015). Dehydration may occur unintentionally due to factors such as high exercise intensity, environmental heat stress, or limited access to fluids. In contrast, voluntary dehydration refers to the conscious restriction of fluid intake for various reasons, including behavioural or perceptual factors (da Silva et al., 2012). Accurate assessment of hydration status is therefore essential for the prevention, identification, and management of heat-related illnesses (Minton & Eberman, 2009). Various methods are available, ranging from laboratory-based measures such as urine osmolality to practical field-based approaches including body mass changes and urine colour assessment (Minton & Eberman, 2009; Meyer et al., 2012; Armstrong et al., 1998). Despite the well-established importance of hydration in athletic performance, it is often overlooked in training preparation, including among female athletes. Addressing this gap may contribute to enhanced performance, reduced injury risk, and improved overall health (Atan et al., 2022).

Notably, research on hydration among female athletes remains limited compared to studies focusing on male populations, despite increasing female participation in sport. Several physiological differences must be considered when examining hydration in female athletes. Hormonal fluctuations associated with the menstrual cycle can influence fluid balance, thermoregulation, and sweat responses (Holtzman & Ackerman, 2021; Olzinski et al., 2019). Variations in estrogen and progesterone levels may alter fluid retention and electrolyte regulation, thereby affecting hydration requirements across different phases of the cycle. Additionally, female athletes generally exhibit lower sweat rates and different sweat composition compared to males at a given exercise intensity, which may influence hydration strategies (Ichinose-Kuwahara et al., 2010). Previous studies have also reported a high prevalence of dehydration among female athletes prior to training and competition (Castro-Sepulveda et al., 2016; Kobayashi & Yasuda, 2022). Given these unique physiological characteristics, there is a need for more targeted investigation in this population. Therefore, the present study aims to examine the pre-training hydration status among female athletes. It is hypothesised that female athletes may already be in a dehydrated state prior to the commencement of training sessions.

Method

Participants

Thirty (n=30) female athletes competing in varsity/state level volunteered to participate in the study (Age: 21.6 ± 1.1; Height: 1.61 ± 6.4 m; Body Mass: 56.3 ± 8.5 kg). Data was collected during competitive season. Written consent form was obtained from the participant's after being thoroughly informed of the benefits and potential risks of the study. Initial screening was performed through health screening questionnaire to ensure the athletes are healthy and did not have any metabolic conditions or disease that will effect on the results of the study. This study was approved by the University Ethics Committee.

Experimental Design

The study was completed over a 3-week period which each participant must attend two sessions. The participants were clearly explained with the procedure and familiarized with the TS during the first session study along with height and body mass measurements. During the second session, the USG, UC and TS were obtained to determine their hydration status of` these female athletes prior to their regular training session. No data will be collected during menses.

Urine Specific Gravity (USG)

Upon arrival, participants were required to empty their bladders. In the privacy of a toilet, participant voided a small sample of midstream urine into a container before the training session. The investigator established the volume of the urine and recorded the specific gravity immediately using a hand-held refractometer (refer Figure 1) (Sur- Ne Atago Co. Ltd, Japan) (refer Table 1 for hydration status) [20].

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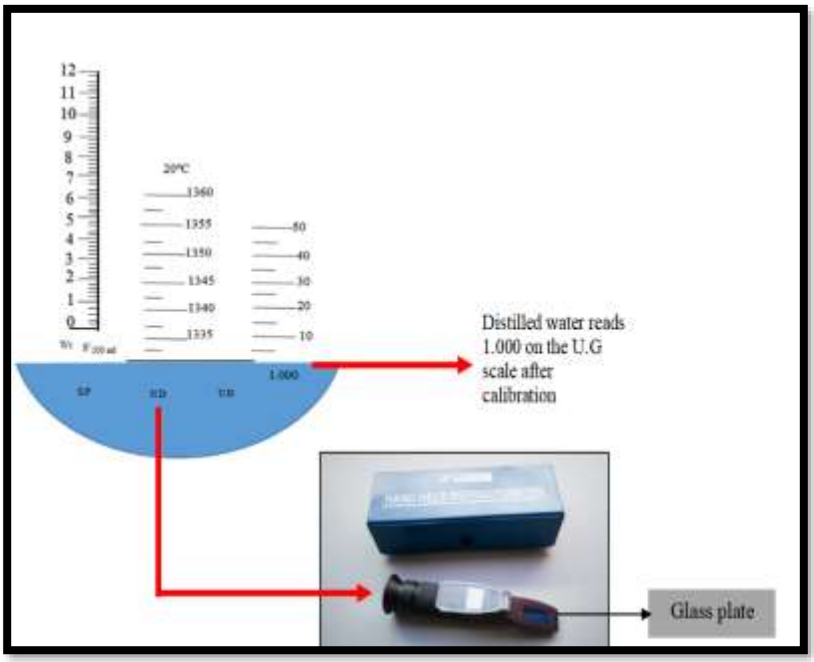
The USG procedure:

1. Ensure the refractometer provides a zero reading with deionised water. Calibrate
2. with a flathead screwdriver if necessary.
3. Use a transfer pipette to asprire ~1 mL of urine onto the measurement surface of
4. the refractometer. The lid must be closed gently otherwise urine may splatter.
5. Take the reading.
6. Clean the refractometer with tap water and disposable paper towels.

Figure 1: Handheld Refractometer Analysis



Urine Color Chart

Following the USG assessment, the hydration status was also determined by using the UC on a 1 to 8 scale. Hydrated urine color is light yellow or close to clear area and vice versa the color is dark and near to light brown (refer Figure 2). Urine samples flushed down to the toilet immediately after the analysis as well as the urine contaminated collection tray, transfer pipette and barrier glove into a biohazard bag. The hydration status then determines using the Indexes of Hydration suggested by Casa et al., [4] (Refer Table 1).

Figure 2: Urine Color Chart for Hydration Measurement

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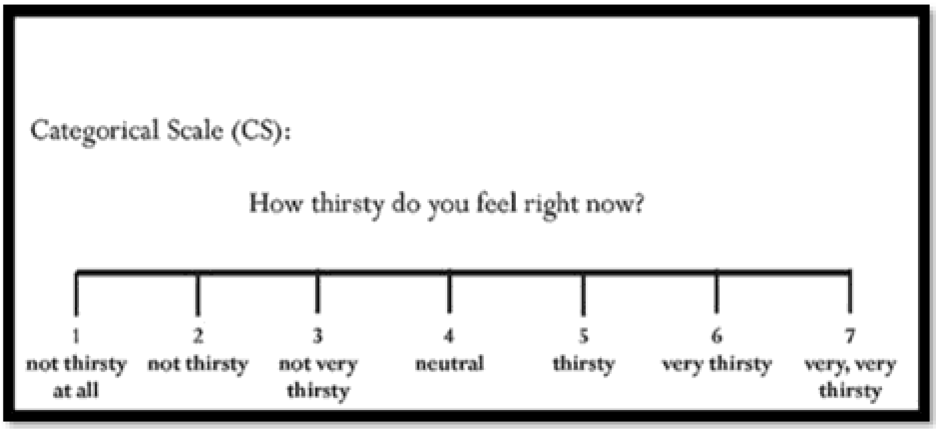
Table 1: Indexes of Hydration Status

Condition	% Body weight change	Urine Color	USG
Well hydrated	+1 to -1	1 or 2	< 1.010
Minimal hydration	-1 to -3	3 or 4	1.010 – 1.020
Significant dehydration	-3 to -5	5 or 6	1.021 – 1.030
Serious dehydration	> 5	> 6	> 1.030

Thirst Scale

After completion of urine analysis, the participants pre-training thirst were recorded by usingTS seven-point (1-7) Likert Scale (refer Figure 3). This scale provides visual analog scale to assess the thirst intensity of participants.

Figure 3: 7-point categorical Thirst Scale



Statistical Analysis

All data were tested for normality distribution and are reported as means ± standard deviations. To verify the correlation between the USG, urine color and thirst scale the Pearson Correlation (r), The correlations were distributed according to r values, which were classified as very weak (0.0 to 0.2), weak (0.2 to 0.4), moderate (0.4 to 0.7), strong (0.7 to 0.9) and very strong (0.9 to 1.0) (7). All statistical analyses were performed with SPSS software (version 19.0, SPSS Inc, Chicago, IL) with the level of significance set at P ≤ 0.0

RESULTS

Figure 4: USG Analysis

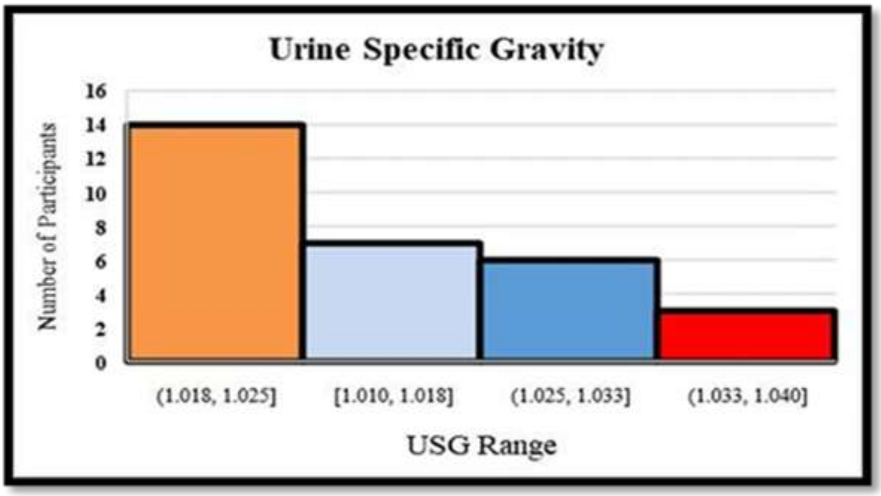


Figure 4 demonstrates the spread and concentration of USG values, with the majority falling into the dehydrated range. The figure showed almost 76.6 % (23 of the participants) were already in a dehydrated status prior to the training session. Only 23.4% (7 participants) were within the euhydrated (well-hydrated) range, indicating proper fluid balance before training. The finding highlight the concern for athletes as pre-training hydration is important for performance, safety, and recovery.

Table 2 represented mean ± standard deviation on the hydration status investigation in female athletes. The results showed that the mean USG level was 1.028 ± 0.2 which considered as significantly dehydrated. A similar trend was observed in the UC which is in the cutof between fair and dehydrated, and the TS indicates that the participants were also in the border line between thirsty and neutral.

Table 2: Mean ± Standard Deviation for Hydration Analysis

Participants	**USG**	**Urine Color**	**Thirst Scale**
N= 30	1.028 ± 0.2	4.5 ±1.5	4.5 ± 0.6

Correlation between Urine Specific Gravity and Urine color

Pearson correlation analysis showed a significant positive relationship between USG and UC ($r = 0.81$, $P < 0.05$). Referring to Figure 2, when the urine is more concentrated (higher USG), it often appears darker in color due to the increased concentration of waste products and solutes. The UC is an inexpensive and simple indicator of hydration status. Normal UC is considered as light yellow whereas severe dehydration is associated with darker color of urine. However, it is important to note that UC may underestimate the level of hydration. It is recommended to assess UC for self-assessment of hydration level when precision is not required.

Correlation between Urine Color and Thirst Scale

There was also a significant relationship between UC and TS ($r = 0.77$, $P \leq 0.05$). The UC and TS are both indicators of hydration status. Thirst is the body's way of signaling a need for hydration. When the body senses dehydration, it triggers the thirst response to encourage fluid intake. A strong and significant correlation in this present study ($r = 0.77$) shows that when athletes reported feeling more thirsty, their urine was also darker indicating dehydration. This supports the idea that thirst sensation and UC are both effective tools for monitoring hydration, especially in field settings where laboratory equipment may not be available.

DISCUSSION

This study primarily aimed to assess the pre-training hydration status of female athletes and explore the relationship between USG, UC and TS. The main finding showed that 76.6% of the athletes were already in a hypohydrated state before the regular training session. This suggests that the majority of the athletes were not adequately hydrated prior to exercise, which could negatively impact their physical performance, cognitive function, and thermoregulation during training. Proper hydration is essential for optimal athletic performance, particularly for female athletes, who may have unique physiological and hormonal responses to exercise (Holtzman & Ackerman, 2021). Monitoring hydration status before training can help prevent dehydration-related performance decline and health risks. There are several common methods to measure hydration status, ranging from laboratory settings to simple field tests. USG is widely recognized as a reliable indicator, with values typically ranging from 1.004 to 1.029 indicating well-hydrated individuals (Armstrong et al., 1998; Atan et al., 2022). In contrast, UC (refer Figure 2) is an option for assessing hydration status when no other methods are available (Armstrong et al., 1998; Kobayashi & Yasuda, 2022). Despite its limitations, UC remains a practical hydration indicator. UC assessment is the simplest, quickest, and non-invasive, making it accessible in various training settings. This allows for efficient monitoring of hydration status without the need for complex equipment or procedures (Armstrong et al., 1998; Kobayashi & Yasuda, 2022). Furthermore, combining TS with other measures such as UC may serve as a useful indicator of hydration status and provide a clearer overall picture.

Despite the availability of such methods, research consistently indicates that many female athletes begin training or competition in a suboptimal hydration state. Numerous previous studies have reported similar findings on the pre-training and competition hydration status of female athletes. Castro-Sepulveda et al. (2016) revealed that 47% of elite female soccer players were severely dehydrated before matches, with an average USG of 1.027, indicating significant dehydration levels. In combat sports, 89% of female athletes were found to be hypohydrated on competition day, with serious hypohydration affecting over 50% of those who weighed in on the morning of the competition (Pettersson & Berg, **2014**). Dehydration, even as little as 2% of body weight loss, can negatively impact endurance, strength, and cognitive functions **(**Atan et al., 2019; Atan & Kassim, 2019**).**

Female athletes are not exempt from these effects, and due to their potentially lower total body water, the effects may become evident faster. Dehydration can impair concentration, reduce aerobic capacity, and increase the risk of heat-related illnesses **(**Atan et al., 2022**).** Nevertheless, caution is warranted when comparing these findings across studies, as differences in sport type, environmental conditions, assessment tools, and participant characteristics may limit direct comparability. These contextual variations must be considered to avoid overgeneralization of the results.

Given the findings of this study, it is recommended that comprehensive hydration strategies be introduced and emphasized by coaches and sports practitioners to help mitigate the negative effects of dehydration in female athletes. Effective strategies include pre-, during-, and post-exercise hydration. It is recommended that athletes consume 500–600 ml of water or electrolyte-rich fluids 2 to 3 hours before exercise, followed by 200–300 ml approximately 10 to 20 minutes before activity (Machado-Moreira et al., 2006**).**

During prolonged exercise sessions (exceeding 60 minutes), beverages containing both electrolytes and carbohydrates are highly recommended. Research has shown that consuming carbohydrate-electrolyte sports drinks before and during exercise significantly enhances performance and recovery compared to consuming only water or electrolyte solutions (Orrù et al., 2018**).** Maintaining hydration during exercise is crucial for replacing fluids lost through sweat and sustaining peak performance levels. For activities lasting longer than 60 minutes, the use of carbohydrate-electrolyte fluids is especially beneficial. Monitoring sweat loss by weighing athletes before and after exercise is an effective way to personalize post-exercise hydration strategies. For every kilogram of body mass lost, approximately 1.5 liters of fluid should be consumed to achieve full rehydration and support optimal recovery **(**Horswill, 1998**).** By implementing these strategies and promoting awareness of hydration practices, female athletes can enhance their physical performance, reduce the risk of heat-related illnesses and injuries, and support more efficient recovery processes.

Practical Implications

The present findings provide clear applied value for coaches, athletes, and sports practitioners by highlighting simple, non-invasive methods for monitoring hydration status in female athletes prior to training. The use of USG, urine color, and subjective thirst offers a practical and time-efficient approach that can be easily implemented in daily training environments without the need for sophisticated laboratory equipment.

Research contribution

For coaches, these findings support the integration of routine hydration screening into pre-training protocols. Monitoring USG and urine color charts can help identify athletes who begin training in a hypohydrated state, allowing for immediate corrective strategies such as individualized fluid intake recommendations. This is particularly important in hot and humid environments, where fluid loss is accelerated and may compromise performance and safety.

For athletes, increased awareness of their own hydration status through simple indicators such as urine color and thirst perception empowers self-regulation. Athletes can be educated to recognize early signs of dehydration and adjust their fluid intake accordingly, promoting better training readiness and consistency in performance. This is especially relevant for female athletes, who may face additional physiological considerations such as hormonal fluctuations that can influence hydration status.

LIMITATIONS

Several limitations should be acknowledged when interpreting the findings of this study. First, the sample size was relatively small and limited to female athletes from a specific context, which may restrict the generalizability of the results to broader athletic populations, including male athletes or those from different competitive levels and sports. Second, hydration status was assessed at a single time point prior to training, which does not account for fluctuations in hydration throughout the day or across multiple training sessions. This limits the ability to establish causal relationships or to understand longitudinal hydration patterns among athletes. Lastly, the external factors such as environmental temperature, humidity, prior fluid intake were not fully controlled, all of which could influence hydration markers and potentially confound the results.

CONCLUSION

This study highlights a significant concern regarding the pre-training hydration status of female athletes. The findings affirm that monitoring hydration through practical tools such as USG or UC and TS can offer valuable, accessible insights into athletes' hydration levels. Furthermore, coaches and sports practitioners are urged to integrate hydration protocols before, during, and after exercise, including personalized fluid intake based on sweat loss and activity duration. By adopting evidence-based hydration practices, female athletes can optimize their performance.

Authors' Contribution

NIFF, MSZ, HKK and SAA was responsible for the design and conceptualization of the research and the drafting of the manuscript

Conflict of Interest

Authors declare that there are no conflicts of interest associated with this study.

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