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Effect of Morning v. Evening Training on Sweat Rate and Sweat Sodium of Competitive Ultimate Athletes

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Abstract Hydration is essential to any individual's well-being, especially for athletes and those who are physically active. A significant amount of water is lost through sweating, which can be detrimental to sports performance. Ultimate frisbee or Ultimate, is a high-intensity intermittent sport with significant demands on cardiovascular and muscular endurance and is often played outdoors. This study aimed to explore the effects of time-of-day specific training on the sweat rate and sweat sodium concentration of competitive ultimate athletes in a tropical setting. Data was collected from 14 competitive ultimate athletes during one morning (AM) and one evening (PM) training session during the competitive season in the hot months of April to early June. Bulb globe temperature (WBGT) recorded during AM sessions was 31.69 ± 2.7°C, air temperature (TA) of 38.45 ± 3.0°C, and relative humidity (RH) of 38.7 ± 8.3%. For PM training sessions, the WBGT was measured at 25.25 ± 1.6°C, TA at 27.89 ± 1.4°C, and RH at 74.55 ± 10%. No significant difference was seen between the average whole-body sweat rate (WBSR) of competitive ultimate players in the AM and the PM sessions. On the other hand, mean whole-body sweat sodium concentration (WBS [Na+]) was observed to be significantly different for AM and PM training sessions. This study underscored the significance of developing personalized hydration strategies that consider both environmental conditions and the specific type of exercise to be undertaken.

Keywords Frisbee Training, Environmental Conditions and Sweat, AM vs PM Training

1. Introduction

It is well known that the amount of electrolytes and water lost in sweat varies between individuals and between activities [1] and that replacing the sodium lost through sweat may improve physical performance [2]. Previous research explored the electrolyte and water losses through sweating in different sports, but there have been very limited studies on these in Ultimate frisbee (Ultimate). One existing study on hydration in Ultimate players during a match measured body mass changes through sweat rate and voluntary fluid intake [3], but did not take into account sweat rate and sweat sodium concentration. Given the high cardiovascular demands of Ultimate [4], it is relevant to look into factors related to hydration especially because exertional heat illness rates are highest for endurance-type events [5]. The sport being played outdoors also makes the players more susceptible to environmental conditions affected by the time of practice especially in tropical countries [6]. Training in the morning or evening also affects adaptations that are important when preparing for a specific game time or schedule [7].

This research addresses a gap in the literature regarding training time and its effects on hydration, sweat rate, and sweat sodium concentration. This information could be useful in optimizing hydration strategies for certain training times. In Ultimate, players' hydration status is often not monitored, which can pose a risk of dehydration and heat illness. This research could provide a better understanding of the demands of Ultimate in terms of hydration in hot and humid conditions. Additionally, it may be used as a guide to mitigating hypohydration and heat illness cases in the scheduling of Ultimate tournaments. The study hypothesizes that sweat rate and sweat sodium concentrations are affected by playing competitive Ultimate at different times of the day.

2. Materials and Methods

Twenty-seven competitive Ultimate players, including 15 male and 12 female players, volunteered to participate in this study. However, analysis of data was done only for those with completed data (14 players – 8 males and 6 females). The measurements for this cross-sectional study were done during the competitive season. The data was collected during the morning (from 8 AM to 12 NN) and evening (7:30 PM to 10 PM) for each study participant.

The training sessions began with a general warm-up (20 minutes). The drills that followed consisted of movement drills (10 minutes), drills for defensive strategies (15 minutes), and play executions (15 minutes). Game simulation play was then done for the remainder of the training session (60 minutes). The participants rated their AM training sessions to have a mean of 14.9 ± 2.1 on the Borg RPE scale (Table 3), indicating an intensity reaching "Hard" and "Very Hard". They reported it to be at 14.5 ± 1.7, indicating a similar rating during the PM training session.

Table 1. Participant demographics and pre-training hydration status (N=14)

Participants (N=14)	
Sex	F=6, M=8
Age (years) ± S.D.	22.71 ± 3.17
Body mass (kg)	62.32 ± 11.13
Height (cm)	166.85 ± 7.71
Pre-training hydration status	
AM training	
Euhydrated	50.00%
Hypohydrated	50.00%
Severely Hypohydrated	-
PM training	
Euhydrated	50.00%
Hypohydrated	42.86%
Severely Hypohydrated	7.14%

A total sample size of 9 was calculated using G*Power [8] where an effect size of 1.14 was computed for the measurement of sweat sodium [9]. The participants included were current members of the Philippine National Team, the Philippine National Team training pool, or part of a team that has consistently been participating in the highest level of tournaments. Participant demographics can be found in Table 1.

Informed consent to participate was obtained before the briefing commenced. Included in the consent form was the procedure for handling and securing the data collected from the participants. The research followed procedures following the ethical standards of the Helsinki Declaration, and the University of the Philippines Manila Research Ethics Board approved the protocol (UPMREB Code 2022-0291-01).

2.1. Experimental Protocol

Briefing of participants commenced after obtaining informed consent to participate in the research. They were then given an information sheet and the Physical Activity Readiness Questionnaire (2022 PAR-Q+) to accomplish [10]. The same procedure was followed for both AM and PM training sessions. Wet Bulb Globe Temperature, air temperature, and relative humidity (Model HT30 Heat Stress WBGT meter, Nashua, NH, USA) during the observation sessions were recorded every 15 minutes throughout each training session. The duration of the training was also recorded. Blood pressure (HEM-7322 Automatic Blood Pressure Monitor, OMRON, Omron Healthcare Singapore PTE LTD.) and aural temperature (TH839S Infrared Ear Thermometer, OMRON, Omron Healthcare Singapore PTE LTD.) were recorded right before the training session started. Participants with systolic blood pressure ≥140mmHg and/or diastolic blood pressure ≥90mmHg, or aural temperature exceeding 38°C were excluded from the study [11]. Upon clearance, each participant was given a labeled screw-top container for their urine sample before their pre-training body mass was measured. Body mass was then measured (RD-901 InnerScan Dual, TANITA Corporation, Tokyo, Japan) with participants wearing minimal clothing. They were then given a bottle of water, which was pre-weighed using a kitchen weighing scale (Model KD-200 Digital Scale, TANITA Corporation, Tokyo, Japan).

Sweat patches (Tegaderm +Pad 3586, 3M) were then applied to their thigh [12-14]. The site of the sweat collection was disinfected with alcohol pads, rinsed with distilled water, and dried with sterile gauze. When the sweat patches became saturated via visual inspection or after 1 hour of moderate to intense training, whichever came first, sweat patches were removed using clean forceps and placed in a 5 ml plastic syringe. The samples were extracted into properly labeled tubes for storage. Samples that were not analyzed within 2 hours of collection were frozen to preserve them for analysis [15].

Each participant's *ad libitum* drink intake and urine output during training were also monitored [16]. During and immediately after the training, self-reported exercise intensity was measured using the Borg Rating of Perceived Exertion (RPE) 6-20 Scale. After 5-10 minutes upon the end of the training session, the participant's post-training body mass was measured and recorded.

Urine-specific gravity was measured to determine pre-training hydration status with a hand-held refractometer (Master-URC Clinical refractometer, ATAGO Co., LTD., Tokyo, Japan) in duplicates. The mean values were recorded. A USG value of <1.020 was recorded as euhydrated, >1.020 hypohydrated, and >1.030 was recorded as severe hypohydration [17].

To measure whole-body sweat loss and whole-body sweat rate, each participant's body mass was measured before and after training. This was corrected with the fluid intake and urine output during training. It was computed with the equations below [16].

$$\text{WBSL (L)} = (\text{Pre-exercise body mass (kg.)} - \text{post-exercise body mass (kg.)}) + (\text{fluid intake (L)}) - (\text{urine output (L)}); \quad (1)$$

$$\text{WBSR (L/h)} = \text{WBSL (L)}/\text{Exercise duration (h)} \quad (2)$$

To predict WBS [Na^+], the sweat [Na^+] was analyzed through ion-selective electrode technology using the Na^+ analyzer (LAQUAtwin Na-11, HORIBA Advanced Techno Co., Ltd., Kyoto, Japan) [13, 18].

The following equation was used [19]:

$$\text{Predicted WBS } [Na^+] = 0.831 \text{ thigh sweat } [Na^+] /22.98977 \text{ mg/mol} + 11.775 \quad (3)$$

2.2. Statistical Analysis

The Shapiro-Wilk Test was done to test for the normal distribution of data. Paired samples t-test was used to determine the effects of time-of-day-specific training on sweat rate and sweat sodium concentration. Statistical significance was set at $p < 0.05$. Welch's T-test was done to test for significant differences between AM and PM training conditions – WBGT, air temperature, and relative humidity. Cohen's d was used to compute the effect size ES. Participants' pre-training hydration status was assessed to be euhydrated (USG < 1.020), hypohydrated (USG = 1.020-1.030), or severely hypohydrated (USG > 1.030) (23, 34). WBS [Na^+] was classified into low (WBS [Na^+] < 60 mmol/L), moderate (WBS [Na^+] = 60-80 mmol /L), and high (WBS [Na^+] ≥ 80 mmol/L) [Na^+] [20].

3. Results

The data of a total of 14 participants, 8 males and 6 females were analyzed. Out of 14 participants, 7 (50%) were hypohydrated before their morning training session while the 7 (50%) other participants were euhydrated. For the evening training session, there was 1 (7.1%) severely hypohydrated individual, 6 (42.86%) were hypohydrated, and the rest of the 7 (50%) participants were euhydrated. Only 50% of the participants (7 out of 14) were euhydrated before participating in the AM and PM training sessions. Significant differences were found for the AM and PM training sessions for wet bulb globe temperature (WBGT), air temperature (TA) and relative humidity (RH%) (Table 2).

Table 2. Training conditions for AM and PM (*significance level *p<0.05*)

	AM	PM	*p*
Wet bulb globe temp. WBGT (°C)	31.69 ± 2.7	*25.25 ± 1.6*	*< 0.001**
Air temp. TA (°C)	38.45 ± 3.0	27.89 ± 1.4	*< 0.001**
Relative Humidity RH%	38.7 ± 8.3	74.55 ± 10	*<0.001**

WBGT and TA were higher during the AM session while RH% was higher during the PM training sessions. Upon analysis through a paired samples t-test, there was no significant difference between participants' sweat rates for the AM and PM while whole-body sweat sodium was found to be significantly different (Table 3).

Table 3. Whole-body sweat rate WBSR and Whole-body sweat sodium WBS [Na+] and perceived exertion of participants (Borg RPE) (*significance level *p<0.05*)

	AM	PM	*p*	*ES*
Whole-body sweat rate (L/hr)	1.07 ± 0.408	0.906 ± 0.303	*0.169*	0.39
Whole-body sweat sodium (mmol/L)	44.9 ± 9.28	31.9 ± 6.40	*<0.001**	1.81
WBS [Na^+] classification	low	low	-	-
Borg RPE	14.9 ± 2.1	14.5 ± 1.7	*>0.05*	

4. Discussion

The results on pre-training hydration status gave insights into the lack of proper hydration education and hydration strategies for the athletes. Most athletes are aware of general hydration practices, however many are not up to date on the appropriate use of sports drinks [21]. It has been found that prescribing individualized hydration protocols resulted in an improvement in hydration status in the youth [22]. Since, likely, the participants of this study were not following any hydration protocol, and the need for education on proper hydration is warranted.

Out of those who were recorded to have a hypohydrated status, 5 (35.71%) athletes were hypohydrated before both their AM and PM training sessions. One athlete was severely hypohydrated before the PM training session and might have been dehydrated because of their water intake, activities, and possibly the weather conditions throughout the day before they arrived at the training venue [23].

Similar to previous studies, 50% of the players were hypohydrated before both the AM and PM sessions [24-27]. Hypohydration can be caused by several reasons, mainly the lack of fluid intake and fluid loss through sweat. Being hypohydrated can negatively affect aerobic performance, especially with increasing heat stress values [28]. They also found that rehydration should be done regardless of higher sweat rates or a negative fluid balance. Being in a hypohydrated state before training may increase the risk of heat illness when long periods of high-intensity exercise are done in hot conditions [29]. The current research also found no significant difference in the players' self-reported perceived exertion between AM and PM trainings, although AM rating was higher than PM. Significant differences found in the WBGT heat stress index [30] may explain greater perceived exertion in the AM session. WBGT and TA were both higher in the AM session (by 26% and 38% respectively), while RH was 48% higher in the PM session. Since WBGT has been found to significantly affect skin temperature [31], then perceived exertion could have been affected by this. High skin temperature, due to heat stress conditions, should also be considered when finding solutions to alleviate the negative effects of hypohydration on performance [28].

In this study, whole-body sweat rates (WBSR) of 1.07 ± 0.408 L/h for AM training sessions and 0.906 ± 0.303 L/h of PM training sessions (Figure 1) were found to be similar to previously reported WBSR of athletes, which was observed to be at 1.13 ± 0.58 L/h [32].

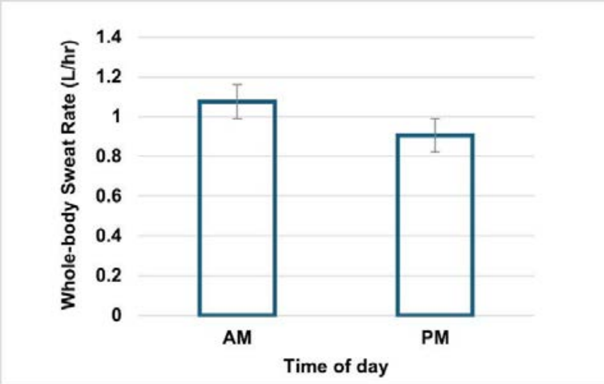

Figure 1. Whole-body sweat rate measurements (L/hr) and time of day (AM or PM)

Results also revealed that there was no significant difference in sweat rates between hot and cool training conditions, even taking into account the exercise intensity [9]. The reason for this similarity in WBSR, despite significant differences in environmental conditions, may be due to measures the athletes take to keep themselves warm during cool training conditions. Added extra layers of clothing combined with reduced fluid intake are factors mentioned in literature [17]. Similar sweat loss between players who were trained in cool conditions and those who were trained in warm conditions were found, and the fluid intake was reduced during training in cool conditions as well [33]. Similar AM and PM WBSR values also support findings that environmental conditions (WBGT, TA, and RH%) do not dictate the sweat rate of an individual and are likely affected by factors including fluid intake, exercise intensity, level of physical fitness, acclimatization to heat, inter-individual variability, and the clothing worn during exercise [33].

Even with the similarities found in WBSR values, there were negative body mass changes observed for all participants following their training session. This implies that they were not able to replace their fluid loss through sweat despite being provided with water and being instructed to drink *ad libitum*. Establishing a rehydration protocol is warranted for this group. The negative effects of hypohydration during training may be mitigated by monitoring body mass changes and by having scheduled water breaks [22].

This study found a significant difference between the AM and PM WBS [Na^+] values (Figure 2).

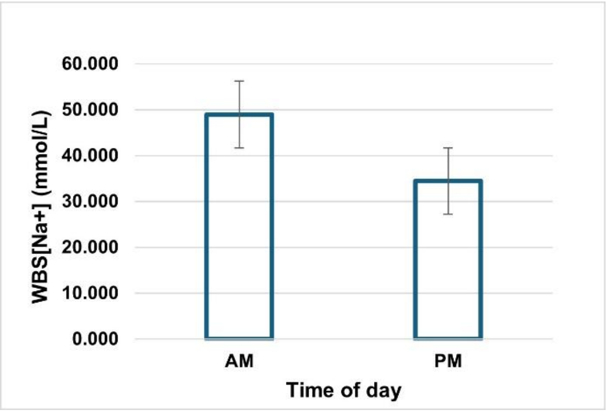

Figure 2. Whole-body sweat sodium (mmol/L) and time of day (AM or PM)

This significant difference was also seen in the value of the effect size of 1.81, which indicates that the actual and expected average differences differ by a large magnitude. This result may be attributed to the significant difference in training conditions, seen in the WBGT, TA, RH%, and RPE measurements between AM and PM training sessions. This outcome implies that training time is a relevant factor to consider regarding hydration in tropical countries. It also suggests that it is important to replenish the sodium lost through sweat during exercise, especially during AM training.

Exercising at high intensities in the heat significantly increases WBS [Na^+] [9], and this was related to the significant difference in sweat rates. In the current study, the increase in sweat rate was not seen. This may be attributed to the difference in environmental conditions wherein the research was done. Relative humidity may also contribute to the lower WBS [Na^+] in the PM training due to the water content in the air that prevents sweat from evaporating quickly, thereby lowering the [Na^+].

The WBS [Na^+] for the AM training session was seen to be higher compared to the normative data [28], which was 36.1± 10.9 mmol/L ([35.62, 54.18] mmol/L > [25.2, 47] mmol/L). WBS [Na^+] during PM training however was observed to be within the range of the normative data in previous research (25.2mmol/L < [25.5, 38.3] mmol/L < 47 mmol/L). Results of other research, where WBS [Na^+] was higher in the training condition in the heat were recorded as well [9].

This information may help competitive ultimate athletes who are constantly subjected to these extreme temperatures replenish the sodium lost during training. Sodium intake is important in promoting better water retention which greatly keeps heat illnesses from setting in [2, 5, 6, 34]. Adding small amounts of sodium chloride to the rehydration drink has been found to reduce urine output, resulting in better hydration compared to a sodium-free drink [35].

Most of the 14 participants were classified as having low WBS [Na^+], except for two participants who had moderate WBS [Na^+] during their AM training session. Literature suggests that WBS [Na^+] varies greatly between individuals [35, 36]. Following this, there must be individualized hydration strategies established appropriate to factors, such as environmental conditions and exercise intensity [36, 37].

5. Conclusions

The pronounced variation in sweat sodium concentration found between morning and evening training sessions underscores the need for individualized hydration strategies. Recognizing and addressing individualized sodium losses is pivotal for optimizing performance and well-being in athletes.

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