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Sweat rates during international open water competitions and the importance of feedings in elite swimmers

Tasas de sudoración en competiciones internacionales de aguas abiertas y la importancia del avituallamiento en nadadores de élite

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Abstract

Open water swimming is an outdoor discipline with different environmental characteristics that affect athletes. The aim of this work was to know the sweat rate during a 5 km and 10 km OWS in elite swimmers in different water temperatures and analyze hydration before competition. A total of 45 elite swimmers (22 females and 23 males) were analyzed during an international event over 5 or 10 km in different water temperature. Sweat rate ($L \cdot h^{-1}$), percentage of weight loss and drink ingestion (L) were measured. ANOVA test indicates the significance of the difference. The results showed that warm water on 10 k sweat rate is statistically significant ($p < 0.001$) (-1.99 ± 0.34 vs -1.14 ± 0.36 vs -1.48 ± 0.49 $L \cdot h^{-1}$), and in cold water with wetsuit, weight loss ($p < 0.05$) and drink ingestion ($p < 0.001$) are significant too (-2.27 ± 0.75 %; 1.31 ± 0.63 L). The results show a higher sweat rate in warm water and weight loss with wetsuit, drink ingestion is lower in cold water. This study confirms that it is important to analyze the environmental characteristics of an open water swimming competition to plan a specific hydration protocol to get the best performance.

Keywords: elite; hydration; open water; swimming; sweat rate.

Resumen

La natación en aguas abiertas es una disciplina con condiciones ambientales variables que afectan al rendimiento. La hidratación es fundamental en el rendimiento, siendo poco estudiada en aguas abiertas. El objetivo del trabajo fue conocer cómo afectan las condiciones ambientales en la tasa de sudoración en pruebas de 5 y 10 km. La muestra se compuso de 45 nadadores de elite (22 mujeres y 23 hombres) analizados durante eventos internacionales de 5 y 10 km. Se midió la tasa de sudoración ($L \cdot h^{-1}$), porcentaje de pérdida de peso y la ingesta de líquido (L). Los resultados presentan diferencias significativas ($p < 0.001$) en agua cálida de la tasa de sudoración (-1,99 ± 0,34 $L \cdot h^{-1}$ vs -1,14 ± 0,36 vs -1,48 ± 0,49), en agua fría con neopreno en cuanto a la pérdida de peso ($p < 0.05$) (-2,27 ± 0,75 %) y la ingesta de líquido (1,31 ± 0,63 L). Los resultados del estudio muestran una tasa de sudoración mayor en aguas cálidas, el uso de neopreno aumentó el porcentaje de pérdida de peso y reduce la ingesta de líquido. Este estudio confirma la importancia de planificar una estrategia de hidratación en función de las condiciones de una prueba de aguas abiertas.

Palabras clave: elite; hidratación; natación; aguas abiertas; tasa de sudoración.

Introduction

Open water swimming (OWS) is a discipline that is continuously being developed. World aquatics introduced OWS to the World Aquatic Championships in 1991 over a 25 km distance and in Beijing in 2008 as an Olympic discipline over a 10 km distance. The last World Aquatic Championships included a multiple-event format with two individual distances of 5 km and 10 km and a relay event with four swimmers, two males and two females, completing 1500 m each. There is also a world cup and European league calendar with five events over a 10 k distance. This structure and competition format gives coaches and swimmers a reason to prepare specifically for the OWS season with open water swimming specialists.

The number of elite international open water swimmers is increasing due to the growth of the discipline, but not many studies have analyzed them. The first topic to be analyzed in the scientific literature was the energy requirements of an OWS event (Baldassarre et al., 2017). OWS is one of the most challenging FINA disciplines, because of the diversity of the environmental conditions (Shaw et al., 2014). This diversity creates a challenge for coaches, and for swimmers in adapting the physiology of their bodies to the conditions where they will perform. A lot of studies have analyzed the different conditions where OWS could be performed, including temperature, humidity or other variables according to the ambience (Murphy et al., 2021; M. J. Tipton et al., 2017). Extreme conditions could be unsafe for swimmers, so it is important to control the environmental issues (M. Tipton & Bradford, 2014). In extreme situations, the supplementation of fluids, electrolytes and/or carbohydrates is extremely important to maintain athletes' performance and guarantee their health during the activity (Shirreffs & Sawka, 2011). Environmental conditions create a need for feeding during competitions, so FINA includes a feeding zone during 10 km and 25 km events. The beginning of feeding zones in competitions requires an analysis of the key nutritional considerations for an OWS event (Shaw et al., 2014). Some studies have assessed the use of supplementation with carbohydrates in open water events and the physiological impacts, as well as the effects on perceptual parameters and performance (Baldassarre et al., 2022). The hydration status makes changes in the body composition of an athlete and some studies have analyzed these changes in open water swimmers (Weitkunat et al., 2012), but the event that has been analyzed is a 25 km ultra-endurance course, so it is difficult to compare the situation of the 5 km and 10 km events that are more common in the world aquatic calendar. It is important to know how an OWS event affects the hydration status of an elite open water swimmer over 10 km and 5 km distances, because it is a key aspect of athletes' performance in these events (Cox et al., 2002).

Hydration status has been analyzed in a number of different ways and sports and is commonly known as one of the key performance factors in competitive sport (Maughan & Shirreffs, 2010). One of the ways to study hydration status is through body mass changes, but it is important to have repeated measures that emphasize the athlete's psychology, and it is also important to obtain biochemical markers to be accurate (Armstrong, 2005). The most valid biochemical marker is plasma osmolarity, but it is tested in the laboratory and is invasive, so the scientific literature has started to use urine specific gravity as a new marker of hydration during a competition event (Sommerfield et al., 2016). There are some different characteristics to analyse regarding hydration in a sport, including the availability of fluids, the environmental characteristics and the intensity of the sport, with all these characteristics allowing studies to draw conclusions about the risk of hypohydration for each sport (Belval et al., 2019). It is common to see in scientific literature the use of swimming as an indoor discipline; this is normal because it is the most popular one, but open water swimming is sometimes not as widely studied as indoor swimming, and here we have an example of this. Not enough studies have analyzed the hydration status of elite swimmers in competitive distances.

Different environmental conditions will make changes in variables related to hydration status. There are some works that analyzed these changes based on different temperatures or humidity conditions. It is important to confirm that the hydration status before the competition could be determinant of the result, confirming that in cold events normal hydration could be enough but in warm events get hypohydration before the event is so important (Maughan & Shirreffs, 2010). There are studies that confirms warmer water increase sweat rate (Robinson & Somers, 1971) but there are no studies measuring this changes in competition and specially in open water swimming competition.

The aim of this work is to know the sweat rate during a 5 km and 10 km OWS in elite swimmers in different water temperatures and analyze whether the hydration strategy adopted before competition is effective for preventing dehydration.

Method

This study used a cross-sectional descriptive design. The participants were notified, and all of them voluntarily read and signed the informed consent form. The research was approved by the bioethics committee of the University of Extremadura (Ref: 3/2021) and was carried out respecting the ethical principles established in the Declaration of Helsinki.

Participants

The study population comprised a total of 45 elite swimmers, 22 females and 23 males, who compete with the national open water swimming team. The physical characteristics of the participants can be seen in Table 1. The average number of FINA points achieved based on the 1500 m personal best of the participants was 772.55 ± 39.86. Some studies have confirmed that performances in middle and long distances in a 50 m swimming pool correlated with open water swimming performances (Baldassarre et al., 2019). The competitive levels of the swimmers included 19 at tier 5 and 26 at tier 4 following the classification of athletes developed by McKay (McKay et al., 2022).

Table 1. Physical characteristics of research subjects.

	Female (n=22)	*Male (n=23)*
Age (years)	23.20 ± 3.79	25.29 ± 2.71
Body mass (Kg)	63.65 ± 2.96	70.73 ± 8.51
Percentage of body fat (%)	15.18 ± 3.25	10.54± 3.52
∑7 skinfolds (mm)	82.41 ± 20.73	52.45± 21.56

Data given as mean ± SD.

Hydration levels can be seen in Table 2. These levels were measured separately for both distances. Hydration level is an important variable because it could affect the sweat rate if it is too low. Hydration levels were measured using urinary density (g/mL). In 5 km events, minimum dehydration values were constant throughout the day before the competition and did not show significant changes approaching the competition day. In 10 km events, the values improved. Hydration status started at minimal dehydration levels and rose to values near euhydration on the competition day. Urine density values are related to different hydration status as Casa et al. confirms: euhydration (< 1.010); minimal dehydration (1.011–1.020); significant dehydration (1.021–1.030); serious dehydration (> 1,031). (Casa et al., 2005)

Table 2. Urinary density

	5 km (n=13)	10 km (n = 32)
Hyd-48 (g/mL)	1012.85 ± 6.05	1016.36 ± 6.41
Hyd-24 (g/mL)	1016.86 ± 6.7	1016.59 ± 6.35
Hyd Comp day (g/mL)	1015.50 ± 8.44	1011.72 ± 5.73

Data given as mean ± SD. Urinary density (g/mL), 48 and 24 hours before the competition and on the day of the competition.

Variables

Body composition of subjects: Skinfolds were measured to identify subjects' characteristics by an ISAK certified researcher with a skinfold caliper (Holtain Ltd., United Kingdom), while weight was measured using a digital scale with an accuracy of 0.1kg (SECA 769, GmbH & Co. KG, Hamburg, Germany). The number of skinfolds measured by the ISAK procedure totalled seven (biceps, abdominal, supraspinal, subscapular, triceps, front thigh, medial calf) (Stewart et al., 2011) this skinfolds were collected by the same investigator certified by ISAK, and the body fat percentage was calculated using the Yuhasz equation (Yuhasz, 1977).

Hydration status: The hydration levels of the swimmers were measured 48 and 24 hours before the competition day and on the same day of the competition. The hydration levels of athletes during the competition were collected via urine specific gravity (U_{sg}) following the instructions of the scientific literature (Sommerfield et al., 2016). The U_{sg} was measured with a digital refractometer (Kern & Sohn, Ballingen, Germany) in the morning with the first urine of the day without any fluid or food ingested. Once samples had been collected, using aseptic technique, 2 ml of each sample was pipetted into the refractometer for analysis, following the manufacturer's guidelines. Normal urine density are between 1.005 g/mL and 1.030 g/mL. References associated urine density with hydration status were cited in procedure section (Casa et al., 2005).

Sweat rate and weight loss**:** The sweat rate was calculated in all the competitions following the same procedure. The athletes were weighed using a digital scale with an accuracy of 0.1 kg (SECA 769, GmbH & Co. KG, Hamburg, Germany) when they arrived at the competition zone and the researcher-controlled fluids that they ingested until they finished the event. When the event had finished, all the athletes were weighed again. The quantity of fluid ingested between measurements was delivered by the researcher and the athlete had to return the bottle to allow the researcher to confirm the amount of fluid they had ingested. In the feeding zone during the competition, athletes and coaches planned before each race the quantity of liquid they would drink, and the researcher was in the feeding zone to check that the plan was carried out. The sweat rate was calculated through the difference in weight pre and post competition without the drink ingested divided by the event time. The unit used to measure the sweat rate was litres per hour ($L \cdot h^{-1}$) (Armstrong, 2007). Weight loss was measured as a percentage (%). Drink ingested was calculated in litres (L). In the 10 km events there were feeding zones during the race, but in 5 km events there were no feeding zones, so the drink ingested was the fluid that the athletes drank between being weighed, before and after the race.

$$Sweat\ Rate\ (L \cdot h^{-1}) = \frac{(Weight_{Pre} - Weight_{Post}) - Drink\ Ingested}{Time}$$

Procedure

Samples were measured during world championships, world cups, European championships and European cups in the open water swimming season. Two distances were measured: 5 km (n = 13) and 10 km (n = 32). The water temperature was a characteristic used in classifying events, including hot water events (T > 26.5 ºC), normal water (20 ºC > T < 26.5 ºC) and cold water with a wetsuit (T < 20 ºC). This classification was based on FINA rules (Manson, 2017).

Data analysis

Data are presented as the mean ± standard deviation (SD). Standard statistical methods were used for the calculation of the mean and SDs. The Shapiro-Wilk test (n < 50) was conducted to show the distribution of the studied variables, and Levene's test was used for homogeneity of variance. One factor ANOVA with Bonferroni Post-Hoc. The differences were considered statistically significant when $p < 0.05$ [SPSS statistical package, version 29.0 was used (SPSS, Inc., Chicago, IL, USA)]. To complete this analysis, Cohen's d effect size (d) were calculated. The following values were used to interpret Cohen's d (25): very low (0–0.2), low (0.2–0.6), moderate (0.6–1.2), high (1.2–2.0), and very high (>2.0).

Results

Sweat rate and weight loss were measured in different water temperatures. The environmental characteristics affect the sweat rate, weight loss and drink ingested, which can be seen in Table 3. The sweat rate is higher in hot water (-1.99 ± 0.34) with a significant difference ($p < 0.001$) than in normal water (-1.14 ± 0.36) and in cold water with a wetsuit (-1.48 ± 0.49). The weight loss percentage is higher in cold water with a wetsuit (-2.27 ± 0.75) with a significant difference ($p < 0.05$) than in hot water (-1.65 ± 0.52) and normal water (-1.26 ± 0.71). The athletes drank less water during the cold water with a wetsuit competition (1.31 ± 0.63) with significant differences ($p < 0.001$) than in normal water temperatures (1.39 ± 0.53) and hot water temperatures (2.75 ± 0.53).

Table 3. Sweat rate, percentage of weight loss and fluid replacement in 10k open water swimmers.

	Warm water (n=6)	Cohen's D WW vs NW	Normal water (n=17)	Cohen's D NW vs CW	Cold water, wetsuit (n = 9)	Cohen's D WW vs CW
Sweat rate (L·h^{-1})	-1.99 ± 0.34***	2.39	-1.14 ± 0.36	0.83	-1.48 ± 0.49	1.16
Weight loss (%)	-1.65± 0.52	0.58	-1.26± 0.71	1.39	-2.27 ± 0.75*	0.92
Drink ingested (L)	2.75 ± 0.53	2.56	1.39 ± 0.53	0.14	1.31 ± 0.63***	2.42

Data given as mean ± SD. Significance differences shown as p < 0.05*; p < 0.001*** between different environmental characteristics. Size effect was calculated based on cohen's d, with very low (0–0.2), low (0.2–0.6), moderate (0.6–1.2), high (1.2–2.0), and very high (>2.0). WW -> Warm water; NW -> Normal water; CW -> Cold water with wetsuit

Finally, during the 5 km event there are no othern1<- water temperatures than normal water, so the variables were measured only in these conditions. It is important to note that during the 5 km event there are no feeding zones, so the drink ingested was between weight measurements, before and after the race. The sweat rate was higher than in 10 km events (-1.44 ± 0.37 vs -1.14 ± 0.36), weight loss was lower (1.18 ± 0.65 VS -1.26 ± 0.71) and the drink ingested was just 0.62 ± 0.38. These results did not show significant differences.

Table 4. Sweat rate, percentage of weight loss and fluid replacement in 5k open water swimmers

	Normal water (n=13)
Sweat rate (L·h^{-1})	-1.44 ± 0.37
Weight loss (%)	-1.18± 0.65
Drink ingested (L)	0.62 ± 0.38

Data given as mean ± SD

Discussion

The aim of this work is to know the sweat rate during a 5 km and 10 km OWS in elite swimmers in different water temperatures and analyze whether the hydration strategy adopted before competition is effective for preventing dehydration and the main conclusion it could get is that sweat rate is higher in warm water during 10km. Cold water with wetsuit in 10km events generated greater weight loss and lower drink ingestion.

The hydration status results show that the specific gravity of swimmers over 10 km and 5 km didn't affect the other variables. Hydration results show minimal dehydration but in the lowest part of the scale (Casa et al., 2005), so it could be better but have no effect on the different variables measured during the competition event. These results confirm that the hydration status will be sufficient to prevent dehydration during the competition event.

The analysis of the differences in the variables during competition in different water temperatures during 10 km OWS events was significant in terms of the sweat rate. The sweat rate in hot water temperatures is higher than in cold water with a wetsuit and in normal water. There are no studies in open water situations but there are studies in swimming pools that confirm that a higher water temperature correlates with a higher sweat rate (Maughan et al., 2009). It is commonly known that in warm condition athletes should be careful about hydration, but it is important to confirm that wearing a wetsuit increases the sweat rate and insufficient ingestion could lower performance.

Drink ingested during OWS event showed a significant difference between cold water with a wetsuit and normal water and hot water, with less water being consumed in that order. Swimming below 20 ºC gives the competition a cold ambience where sensitivity to thirst is lower (Armstrong, 2021). During OWS competitions with a wetsuit, athletes lost more mass than in the other events. This indicates a relation between the sweat rate and the drink they ingested, as they ingested less drink than they needed. The wetsuit is a special clothing item that does not allow the swimmer to thermoregulate and the sensitivity to thirst is lower in cold water, so this characteristic makes cold water with a wetsuit the event with the highest body mass percentage lost in OWS (Belval et al., 2019). To prevent dehydration, it is recommended that swimmers should start drinking between 5 and 7 $mL \cdot kg^{-1}$ per body weight 4 hours before the competition, and if they do not produce urine or the urine is dark, they should ingest 3 to 5 $mL \cdot kg^{-1}$ per body weight during the 2 hours before the competition (Sawka et al., 2007).

There are no significant differences in 5 km events, but the results show a higher sweat rate than in 10 km events and less weight loss and drink ingested. The intensity over 5 km is higher than over 10 km (Baldassarre et al., 2017). Higher intensity in sport causes a higher sweat rate (Buono et al., 2010). Sweat rate is a time-dependent variable and 5 km races are shorter than 10 km ones, so the results show less weight loss in 5 km events because these events are shorter. All the OWS races analyzed in this study were governed by FINA. FINA does not allow feeding opportunities during 5 km races (Shaw et al., 2014), which is why swimmers ingested less drink over 5 km than 10 km; however, with the previous hydration in preparing for the race, it is enough, as the results show. An elite swimmer with euhydration before the 5 km competition will not have any hydration problems during the race without a feeding zone.

Some studies show that a 2% or more body mass change could affect an athlete's performance during endurance sports (Murray, 2007; Sawka et al., 2007), so the results confirm that some swimmers participating in these studies could be affected by dehydration during wetsuit events; however, in cold environment there are some studies that confirm that more than 2% are not affected in terms of performance (Galloway & Maughan, 1998). In conclusion, it is important to start a competition with a good hydration status and ingest fluid during the race, especially with hot water and with a wetsuit.

It is important to note that future studies should analyse core temperatures during OWS events to provide more information on thermoregulation and the approach in the scientific literature toward practical and accurate application. Sweat rate is related to thermoregulation. Future studies on core temperatures could provide more information about the temperature that an elite swimmer could tolerate depending on the hydration status.

One limitation of this study is using the analysis of some performance variables to predict how hydration status and sweat rates affect the performance athletes. More studies should analyse internal loads during an OWS event, and variables such as heart rate, blood glucose and core temperature could be interesting for the topic.

Conclusions

The results of this study enable some important conclusions to be drawn with a view to improving the hydration strategies in OWS events. The first important point is the need to guarantee euhydration before a competition ($U_{sg} < 1010$) to ensure that the sweat rate and weight loss do not affect the performance of the swimmer.

During a 10 km event in hot water conditions, it is important to ingest fluid to guarantee that the sweat rate does not affect performance too much. Before the competition, the hydration strategy should be clear and accurate.

During OWS events with a wetsuit, the weight loss is too much and will affect performance, so athletes, led by their coaches, must focus on drinking fluids during the competition, as the cold atmosphere will affect their sensitivity, so it is important to stay focused on the plan and keep to it.

OWS 5 km events have a special characteristic compared to 10 km ones in that a feeding zone is not allowed, so it is important to guarantee that the hydration status before the competition is as good as possible. Guaranteeing euhydration (U_{sg} < 1010 g/mL) and staying hydrated just before the start of the race are two important aspects if performance is not to be reduced in the race. The intensity of a 5 km race affects the sweat rate by increasing it.

Practical applications

The results of this works offer valuable information for coaches working with elite open water swimmers. Hydration status and a hydration protocol should be planned in an open water swimming event. Water temperature and distance are the key factors in the plan. Warm water will increase the sweat rate so athletes should increase the drink ingestion. Cold water with wetsuit will decrease the thirst sensitivity of the swimmer but sweat rate still high, so it is important to focus on drink all the fluid planned during the competition. Days before the competition athletes should stay hydrated and guarantee at least 1010 g/mL of urine gravity.

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