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A PILOT STUDY ON HOW DO ELITE SURFSKI PADLLERS MANAGE THEIR EFFORT AND HYDRATION PATTERN IN THE HEAT

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ABSTRACT: To investigate thermal response, hydration behaviour and performance over flatwater kayaking races in tropical conditions (36.8°C and 68 % rh). Five internationally-ranked subjects participated in the 2012 Surfski Ocean Racing World Cup in Guadeloupe to the "Ze Caribbean Race 2012" [i.e., a 35-km downwind race]. Core temperature (T°C) and heart rate (HR) were measured using portable telemetry units whereas water intake was deduced from backpacks absorption. The kayakers were asked to rate both their comfort sensation and thermal sensation on a scale before and after the race. The performance was related to an increase in T°C, high HR and low water intake (WI); and (2) high values of final T°C were related to high pre T°C and greater increases in T°C being obtained with low pre T°C and (3) WI being related to high pre T°C. The present study demonstrated that the fastest kayakers were those able to paddle at the highest intensities, increasing their T°C and drinking little water without any interference from thermal sensations. Water intake was positively related to pre-race T°C, which reinforces the importance of beginning surfski races with a low T°C. This study demonstrated that well-trained kayakers drinking ad libitum were able to anticipate their intensity/heat storage ratio to prevent heat illness and severe dehydration and maintain high performance.

KEY WORDS: hot-wet climate, long distance activity, self-hydration, ecologic conditions

INTRODUCTION

Aerobic cyclic exercise is negatively affected by a hot environment; this has been demonstrated for running [1] and cycling, although it has been shown that it depends somewhat on the type of race [2]. The heat negative effects are even more marked in a humid environment (i.e., the so-called tropical climate) because the evaporative processes are limited [3]. Such results have been demonstrated for almost every cyclic sport [3], such as swimming [4], cycling [5] and running [6].

Most of the data on the thermoregulatory response to cyclic exercise come from laboratory studies [7], and few studies have focused on real-life situations in which the wind speed during cyclic activities may facilitate evaporative cooling and establish temperature balance. For instance, although cycling in tropical conditions in the laboratory has been demonstrated to be accompanied with dramatically decreased performance [5], cycling in an international race for nine days in tropical conditions did not alter homeostasis in well-trained cyclists [8]. Moreover, studies that aim to give guidelines on sports activities or describe physiological or/and behavioural responses during exercise are done on basically-trained or well trained athletes, whereas information is needed to understand the high-level athletes responses and behaviours during competitions in the heat.

Flatwater kayaking (also called surfski paddling) has been gaining popularity throughout the world. Although it is a cyclic physical activity that is particularly challenging during long-distance events in hot conditions, very few studies have investigated this sport. Sun et al. [9] demonstrated that kayakers became dehydrated during a one-hour marathon-pace event conducted in a tropicalized laboratory, but Noakes et al. [10] conflictingly demonstrated that a four-stage, 244-km surfski marathon was associated with a low level of dehydration. Ocean Surfski competitions are variable in forms, depending on the race course. Downwind Surfski races are performed with the race course going back to the wind. Consequently, paddlers' effort is intermittent. Indeed, they have to speed-up before a wave reaches them, and thereafter, just use the wave to surf, stopping paddling and just keeping the balance of the kayak. The intermittent effort pattern, allows paddlers to be more powerfull after the ''surfing'' recovery periods. Overall, downwind surfski races are high intensity intermittent endurance efforts.

The aim of the present study was thus to investigate the hydration behaviour and thermoregulatory processes during international outdoor surfski competitions performed with internationally-ranked athletes in tropical conditions and their possible relation with performance. We hypothesized that because of the sustained intensity elicited during such competitions performed downwind and the limited space on the board for water supply, the paddlers would show an increased core temperature in relation with significant dehydration.

MATERIALS AND METHODS

Five internationally-ranked subjects (i.e., 2012 Surfski World ranking 1-20; age: 29.4 ± 4.1 years; weight: 82.5 ± 10.1 kg; height: 180.2 ± 6.4 cm) participated in the "Surfski Ocean Racing World Cup in Guadeloupe "Ze Caribbean Race" [i.e., a 35-km downwind race from Vieux-Bourg to Deshaies, Guadeloupe; i.e., in mean environmental conditions of 36.8 ± 2.4°C and 68 ± 3% rh, respectively). All signed informed written consent, and the protocol was approved by the ethics committee of Guadeloupe University and conducted according to the Declaration of Helsinki.

The session was performed in the early morning (starting at 8 a.m.). Core temperature ($T_{°C}$) was measured 10 minutes before and immediately after the 35 km (i.e., when the subjects passed the finish line) with a CorTemp^{TM} 2000 ambulatory remote sensing system (HQ Inc., Palmetto, FL, USA), using pills that were given at least 3 hours before the race. Heart rate (HR) was monitored continuously with a portable telemetry unit (Polar RS800SD, Polar Electro, Kempele, Finland) recording HR values every 5 seconds. Nude body mass was assessed (±0.1 kg) before and in the 15 minutes after the race (Planax Automatic, Teraillon, Chatoux, France). The change in body mass, corrected for fluid intake and urine loss, but not accounting for metabolic fuel oxidation, metabolic water gain, or respiratory water losses, was used to estimate sweat loss. As no aid stations were used in the surfski sessions, fluid intake (i.e., water at ambient temperature) during the race was estimated as the difference in backpack water weight. The kayakers were asked to rate both their comfort sensation (CS) and thermal sensation (TS) on a scale before and after the race. The scale was determined on modified four-point [from 1 (comfortable) to 4 (very uncomfortable)] and seven-point [from 1 (slightly cool) to 7 (extremely hot)] scales [11]. The outside temperature and hygrometry were monitored every 15 minutes for the duration of the race (QUESTemp° 32 Portable Monitor, QUEST Technologies, Oconomowoc, WI, USA).

The following variables were analyzed using paired t-tests: $T_{°C}$, variation in $T_{°C}$ ($\Delta T_{°C}$), water intake (WI), difference in body mass (ΔBM), total body water loss (TBWL), and HR in absolute and relative values (i.e., hr^{-1}). Pairwise correlations were used to analyze the effect of the following variables on performance: water intake and $T_{°C}$ increase (BM, ΔBM, WI, TBWL, lean body mass: LBM, and body surface/weight ratio). Stepwise multiple linear regressions determined the best predictors of performance, water intake and $T_{°C}$. Data are displayed as mean ± SD, and statistical significance was set at $p < 0.05$.

RESULTS

Performance. The performance (expressed in sec) was significantly and inversely correlated with the $\Delta T_{°C} \cdot h^{-1}$ and TS: Perf = $-6110\Delta T_{°C} \cdot h^{-1} + 12\,961$; $R^2=0.75$, $p < 0.05$ (Figure 1); and Perf = -556TS +

TABLE 1. Performance, core temperature ($T_{°C}$), change in $T_{°C}$ (delta $T_{°C}$), body mass (BM) and body mass loss (BML), water intake (WI) and total body water loss (TBWL), heart rate (HR), thermal comfort (TC) and sensation (TS) during the 35 km surfski race.

Variable	Unit	Results
Performance	s	9817 ± 582
	$m \cdot s^{-1}$	3.6 ± 0.2
T°C before	°C	37.1 ± 0.4
T°C after		38.5 ± 0.3a
ΔT°C	°C	1.4 ± 0.2
	$°C \cdot h^{-1}$	0.5 ± 0.1
Δ BM	kg	-2.1 ± 1.2
	$kg \cdot h^{-1}$	-0.7 ± 0.4
WI	L	1.7 ± 0.8
	$L \cdot h^{-1}$	0.6 ± 0.3
TBWL	L	-3.7 ± 1.7
	$L \cdot h^{-1}$	-1.4 ± 0.6
HR	bpm	160 ± 9
TC		1.2 ± 0.4
TS		3.0 ± 1.0

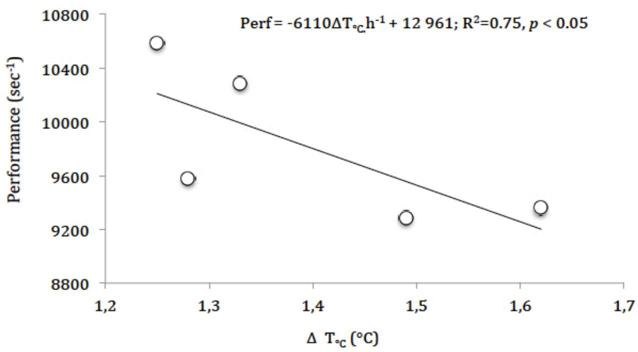

FIG. 1. RELATIONSHIP BETWEEN CHANGE IN BODY CORE TEMPERATURE (Δ T°C) AFTER VERSUS BEFORE THE RACE AND THE PERFORMANCE OBTAINED DURING THE 35 K RACE.

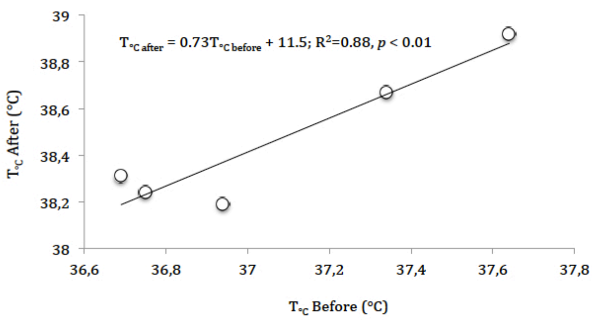

FIG. 2. RELATIONSHIP BETWEEN BODY TEMPERATURE AFTER AND BEFORE THE 35K RACE

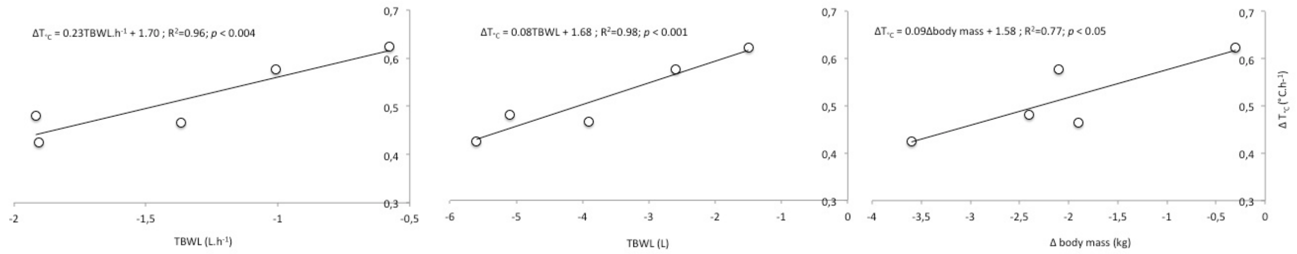

FIG. 3. RELATIONSHIP BETWEEN CHANGE IN CORE TEMPERATURE (Δ T°C) AND CHANGE IN BODY MASS (Δ BM), IN ABSOLUTE TOTAL BODY WATER LOSS (TBWL) AND CHANGE IN TOTAL BODY WATER LOSS (Δ TBWL) DURING THE 35 K RACE.

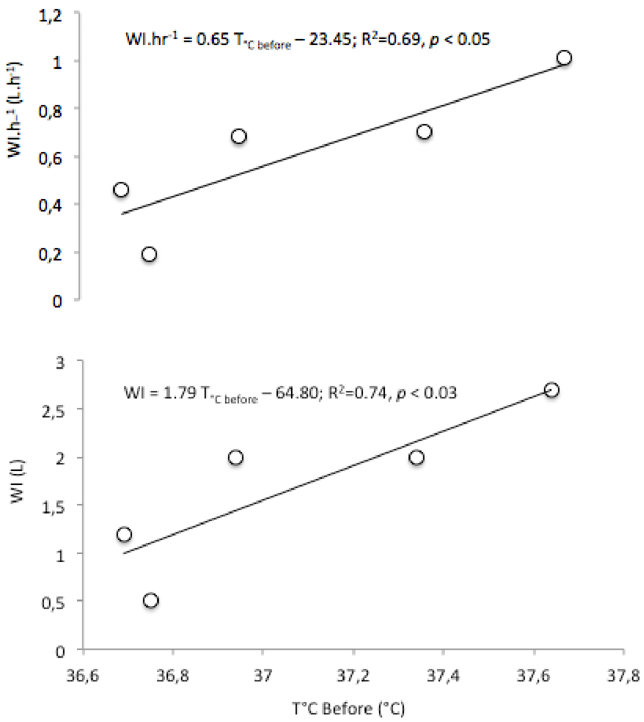

FIG. 4. RELATIONSHIP BETWEEN BODY TEMPERATURE NOTED BEFORE THE 35 K RACE AND RELATIVE WATER INTAKE $(WI \cdot H^{-1})$ AND ABSOLUTE WATER INTAKE (WI)

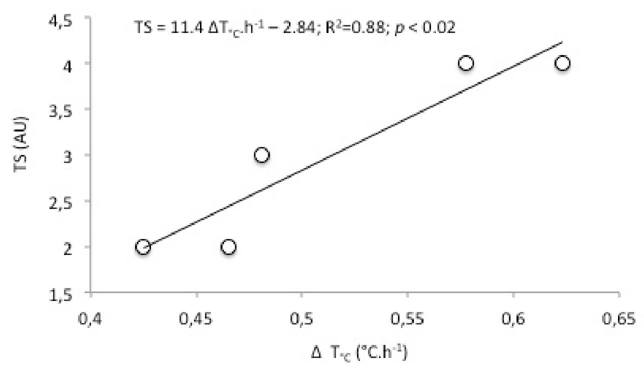

FIG. 4. RELATIONSHIP BETWEEN THE CHANGE IN CORE TEMPERATURE (Δ T°C) AND THE THERMAL SENSATION (TS) NOTED AT THE END OF THE 35 K RACE.

11485; R^2 =0.91, $p < 0.02$), indicating that the greater the performance was and the greater the $T_{°C}$ increase was and the fastest they went the more they felt hot.

Core temperature

The $T_{°C}$ measured after the race was significantly and positively correlated with the $T_{°C}$ measured before the race ($T_{°C\ after} = 0.73T_{°C\ before} + 11.5$; R^2=0.88, $p < 0.01$; figure 2). The change in $T_{°C}$ was significantly and positively correlated with change in body mass ($\Delta T_{°C} = 0.09\Delta$body mass + 1.58 ; R^2=0.77; $p < 0.05$), the TBWL ($\Delta T_{°C}$ = 0.08TBWL + 1.68 ; R^2=0.98; $p < 0.001$), and the $TBWL \cdot h^{-1}$ ($\Delta T_{°C} = 0.23TBWL \cdot h^{-1} + 1.70$; R^2=0.96; $p < 0.004$), showing lower $T_{°C}$ increase with higher body mass decrease, higher TBWL and $TBWL \cdot h^{-1}$, Figure 3.

Stepwise multiple regression analysis demonstrated strong correlations between $\Delta T_{°C}$, TBWL, and HR: $\Delta T_{°C}$ = 0.08TBWL - 0.002HR + 2.1; R^2=0.99, $p < 0.001$, indicating that the higher the HR and the lower the TBWL, the greater the $\Delta T_{°C}$ was.

Hydration

Both WI and $WI \cdot hr^{-1}$ were significantly and positively correlated with $T_{°C\ before}$ (WI = 1.79 $T_{°C\ before}$ – 64.80; R^2=0.74, $p < 0.03$; $WI \cdot hr^{-1}$ = 0.65 $T_{°C\ before}$ – 23.45; R^2=0.69, $p < 0.05$; Figure 4), indicating that the highest the $T_{°C\ before}$ the more the kayakers drank.

Thermal sensation and comfort

The TS was significantly and positively correlated with $\Delta T_{°C} \cdot h^{-1}$ (TS = 11.4 $\Delta T_{°C} \cdot h^{-1}$ – 2.84; R^2=0.88; $p < 0.02$, figure 5) indicating that the higher the rate of $T_{°C}$ increase, the more subjects felt hot. None of the parameters measured was correlated with TC.

DISCUSSION

The most important findings of the present study were that (1) performance was directly correlated to an increase in core temperature and high stress sensation, indirectly correlated to high HR and low TBWL; and (2) high values of final $T_{°C}$ were related to high pre-race $T_{°C}$ and a greater delta$T_{°C}$ resulted from low pre $T_{°C}$ and (3) WI being correlated to high pre $T_{°C}$.

Performance and core temperature

Some individuals demonstrated high maximal $T_{°C}$ at the end of race (i.e., 38.9°C), and the average maximal gastrointestinal temperature (i.e., a mean 38.5°C) was higher than the tympanic temperature noted during a one-hour laboratory kayak event [9] and the rectal temperature noted by Noakes et al. [10] at the end of a 4-day surf-ski marathon,. Nevertheless, these are lower than those noted by both Lee et al. [12] (39.8°C) and Byrne et al. [13] (39.9°C) during 21-km road runs in tropical environment using ingestible telemetry sensors, and far from the rectal temperatures (40.0-42.0°C) reported for heatstroke [14]. It was also lower than the critical internal temperature (assumed to be 39.7°C [15] during laboratory experiments [16] and higher during competitive situations) [17] and lower than the core temperature usually described as being the critical temperature during self-paced exercise [16]. The relatively average core temperature of the subjects could be due to the intermittent nature of the effort and to the sea-wind that probably contributed to dampen the temperature increase.

The fact the performance was directly linked to the increase in core temperature and thermal sensation; the faster kayakers increasing the more their $T_{°C}$ and having the worse thermal sensation; indicates that both changes in $T_{°C}$ and thermal sensation do not induce decrease in race performance, at least in internationally-ranked kayakers. These results reinforce the fact that internationally-ranked athletes seem to be less concerned by the anticipatory process that consist to regulate their workload accordingly to minimize heat storage [18]. Some studies demonstrated that aerobically fit individuals attained significantly greater end-point temperatures than less-aerobically fit ones [19]. The fact that highly fit runners sustain high core temperatures throughout prolonged competitions [20, 21] is in accordance with the present results showing that high performance is related to high core temperature. In this context, it has also been demonstrated that the increase in core temperature is unlikely to be a primary signal to start the anticipatory process [22]. We could also argue that the thermal sensation (TS), more than a signal is a consequence of kayaking faster, indeed, the TS was noted before and after the race, the greater TS at the arrival being observed in the fastest kayakers exercising at the higher HR and then at higher intensity.

The mean increase in $T_{°C}$ was only $0.45°C \cdot hr^{-1}$ which is very relatively low regarding the environmental conditions and the athletes' stature. Indeed, although these results agree with those noted for similar time spent running in tropical climate [21], it has been demonstrated that bigger athletes increased more their core temperature that smaller ones [23] and the present kayakers were definitively bigger (i.e., a mean of 84.5 kg) than the runners described in the study of Baillot et al. [21]. We thus would have expected higher heat production and consecutive heat accumulation in relation to exercising in hot and humid environment. However, the relation between weight and heat accumulation has been demonstrated in running, not in kayaking for which some parameters can be taken into account: 1) the lack of weight effect (bearing-effect) on the energy cost of kayaking and 2) the lack of obstacles on the ocean surface that enable the kayakers to be somewhat more convected by the wind/air than runners and 3) the fact that kayakers are constantly splashed by the ocean water, partly decreasing the core temperature.

The correlations between change in $T_{°C}$ and body mass loss (TBWL and $TBWL \cdot h^{-1}$) agree with theses explanations. Indeed, when running in tropical climate, because high humidity do not permit evapotranspiration, greater TBWL and $T_{°C}$ increases are usually observed in better runners [21]. In the present study, the opposite was observed with the better kayakers being effectively those with the greater $T_{°C}$ increase but the lowest $T_{°C}$ increase being correlated with higher body mass loss and TBWL; we could therefore make the hypothezis that the loss in body water was concomitant with an efficient evapotranspiration related to air convection [24] and/or ocean water cooling.

The fact that changes in $T_{°C}$ was also strongly correlated with high HR and low TBWL could lead to suppose that faster kayakers were acclimated to living and training in a hot/dry or tropical climate (i.e., Australia and South-Africa) and had made the appropriate adaptations, one of which being a greater core threshold at which the sudation process begins, higher partial pressure on the skin thus lower core temperature during exercise [25].

The $T_{°C}$ noted at the end of the races was significantly correlated with the $T_{°C}$ noted before the race, demonstrating that the lower $T_{°C}$ was at the beginning of the event, the lower it also was at the end. More importantly, however, low pre- $T_{°C}$ also allowed for greater delta $T_{°C}$ which has been demonstrated to be correlated with performance in the present study. We therefore hypothesize that the kayakers with low $T_{°C}$ at the beginning of the races were able to paddle at higher intensity, increasing their $T_{°C}$ but performing as well. This result is also consistent with those noted by Lee et al. [12] and Noakes et al. [20] for road running and Parise and Hoffman [26] for long trail running.

Fluid intake and losses

The water intake during the race was low (i.e., around $0.6\ L \cdot hr^{-1}$), especially considering the tropical climate and the sweat loss rate (i.e., a mean $1.2\ L \cdot hr^{-1}$). However, this intake is in-line with the American College of Sports Medicine [27] recommendations for running (as far as we know, there are no recommendations for flatwater kayakers) to drink 0.4 to $0.8\ L \cdot hr^{-1}$, depending on the runner's anthropometry and the intensity and distance of the event. This is also similar to the data of Noakes et al. [10] (0.4 to $0.55\ L \cdot hr^{-1}$) during a surfski marathon and those of Sun et al. [9] noted at the laboratory (i.e., 0.5-0.6 $L \cdot hr^{-1}$), but greater than the intakes noted during mass-participation road races in similar environments: Byrne et al. [13] noted a mean $0.37\ L \cdot hr^{-1}$ during a 21-km road race performed in 26.5°C WBGT, and Lee et al. [12] noted a mean $0.25\ L \cdot hr^{-1}$ during the same race four years later in the same town and similar conditions of 26.4°C and 81% rh.

Water intakes, expressed in both absolute and relative ways (WI and WI · h^{-1}) were significantly correlated with pre-race $T_{°C}$, the kayakers with the lowest pre-race $T_{°C}$ drinking the less. When considered with the results concerning both the performance and the HR, one can infer from these finding that the kayakers having the highest intensities were able to turn in the best performances without a lot of hydration. Similar results have been noted during running and long-duration exercises, with the fastest finishers in endurance events often being the most dehydrated [21], confirming the observed fact that elite endurance athletes do not drink very much during exercise [28]. The most likely explanation is that the best kayakers, being the most trained, were able to paddle at higher intensities while drinking less water and supporting higher $T_{°C}$ increases. For instance, and anecdotically, Noakes et al. [10] reported that the winner of the four-day surfski marathon lost his bottle at the beginning of a 50-km race and finished ahead with a high degree of dehydration (i.e., 4.1% of body mass loss). In the present study, our subject drank similar amount of water than elite marathon runners (i.e., a mean 0.42 · hr^{-1} extrapolated by Beis et al. [29] for the 2008 Beijing Olympic marathon).

The estimated sweat loss rate of 1.4 L · hr^{-1}, which was greater than that reported by Noakes et al. [10], was in the range of previous reports from kayaking and running studies performed in a tropical environment (i.e., 1.22 L · hr^{-1} for Sun et al. [9]; 1.47 L · hr^{-1} for Byrne et al. [13], and 1.45 L · hr^{-1} for Lee et al. [12]) and, added to the relatively low water intake, induced a total body water loss of 4.5%. This is considered to be beyond the normal TBWL fluctuation and has been demonstrated to negatively affect endurance performance [30], even though as pointed out by Noakes et al. [10], winners of endurance events in hot environments can achieve quite high dehydration rates. However, a decrease in performance due to dehydration has been shown in subjects already dehydrated before the exercise. In the present study, we did not collect urine or blood samples before the race and thus we could not determine whether some of the subjects were dehydrated. As the better kayakers were those drinking the least, we nevertheless hypothesize that performance was not altered by pre-race dehydration or that the kayakers who drank the less, did so, because they started the race with already good hydration status.

Drinking behaviour

One of the aims of this study was to investigate the effect of a long-distance surfski paddle race in tropical climate on the hydration status of high-level-self-hydrating kayakers. As noted for running by Lee et al. [12], a limited number of studies have accurately assessed fluid balance during mass-participation endurance races and fewer have studies high-level athletes. The subjects of the present study were free to drink as much water as they wanted, with the only limit being the maximum 4 L carried in their backpacks. The mean volume of 0.6 L · hr^{-1} ingested for a sweat loss of 1.4 L · hr^{-1} clearly pointed to clear dehydration, as is usually observed in the best runners [31]. It thus seems clear that these subjects, despite great TBW loss (i.e., a mean 3.7 L) associated with a mean 0.8-1.7 L of WI inducing a 2.1 kg loss (a mean 2.5 % of body mass loss), did not present severe dehydration or heat illness while drinking ad libitum. Similar results have been described in the literature in both high-level marathoners [24] and standard runners [12], and altogether these findings reinforce the idea that ad libitum hydration is enough for endurance exercise in a hot environment [12,28], eventhough it seems that water ingestion due to ''thirst signals'' is shifted with respect to body hydration status actual changes [32].

These results indicate that the subjects of the present study were able to perform long-duration surfski paddling in a tropical climate without presenting any signs or symptoms of heatstroke, perhaps because most of them were acclimated to hot/dry or tropical climate [3] and also because, as often proclaimed by Noakes et al. [20], humans, and especially well-trained athletes are adapted to perform in a hot environment and are able to reach high exercising intensities without entering the ''risky'' heat-stroke zones.

Thermal sensation and comfort

The thermal sensation was significantly correlated with $\Delta T_{°C}$ indicating that the more the $T_{°C}$ increase the hotter the kayakers felt. As noted above, the change and $T_{°C}$ and the amplitude of this increase do not seem to represent a signal that is strong enough to slow the boat speed and exercise intensity (HR) of international kayakers. In the present study, the fastest kayakers were those with the greatest $\Delta T_{°C}$, the highest HR and the lowest WI.. Thus it is clear that they were not reluctant to work hard for achieving hight performance even though this lead them to enter in highly uncomfortable zones.

The drawback of the present study seems the low number of subjects. Nevertheless, as shown by the present study results, this did not impede from obtaining interesting results. It is obvious that further studies on higher populations and non-professional surfski paddlers will allow draw stronger conclusions about this new sport.

CONCLUSIONS

To sum up, the present study demonstrated that the fastest internationally-ranked kayakers were those able to paddle at the highest intensities, increasing their $T_{°C}$ and drinking little water without any negative interference from thermal sensations. Water intake was positively correlated to pre-race $T_{°C}$, which reinforces the importance of beginning surfski races with a low $T_{°C}$ and raises the question of pre-cooling strategies for athletes, especially those with low convection body surface. Moreover, this study demonstrated that well-trained kayakers who drank ad libitum were able to anticipate their intensity/heat storage ratio, and drank relatively low amounts of water, but enough to prevent heat illness and severe dehydration and maintain high performance.

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