Exercise fluid replacement: is thirst enough?*

Christiano Antônio Machado-Moreira, Ana Carolina Vimieiro-Gomes,
Emerson Silami-Garcia and Luiz Oswaldo Carneiro Rodrigues

ABSTRACT

The present work proposes a review about exercise fluid replacement and a discussion whether, during exercise, the fluid ingested according to thirst is sufficient to maintain hydration. Exercise sweat loss, mainly in the heat, can cause dehydration, can alter the hidroelectrolyte balance, disturb thermoregulation, presenting a health risk and/or impairing the athletic performance. It has been asserted that athletes do not drink, spontaneously, the sufficient fluid volume to prevent dehydration during the physical activity. Thus, international recommendations to fluid replacement during physical activities have been proposed. According to the American College of Sports Medicine (ACSM), about 500 mL of fluid on the two hours before the exercise must be ingested. During exercise, they propose that athletes should start fluid replacement since the beginning in regular periods and should drink enough fluid to restore all the sweating losses or ingest the maximal volume tolerated. The National Athletic Trainer's Association (NATA) proposes the following recommendations: ingestion of 500 to 600 mL of water two or three hours before exercise or other sport drink and ingestion of 200 to 300 mL 10 to 20 minutes before exercise starting. During exercise, the fluid replacement should match the sweating and urine losses and at least should maintain hydration status reaching maximal body weight losses of 2%. After the exercise, fluid replacement must restore all the fluid losses accumulated. In addition, ACSM and NATA asserted about fluid temperature and palatability, beverage carbohydrate and electrolyte additions according to exercise duration and intensity and recommended hydration schedules to provide easier access to fluid ingestion. However, other authors contest the use of hydration schedules based on predetermined fluid volumes and suggest that fluid replacement according to thirst is enough to maintain body homeostasis.

Keywords: Thirst. Hydration. Exercise.

INTRODUCTION

The fluid loss through sudoresis during exercise may lead the body to dehydration, with increase of osmolality, of plasma sodium concentration(1-2) and decrease of plasma volume. The higher the dehydration, the lower the ability of redistribution of the blood flow to the periphery; the lower the hypothalamus sensibility to sudoresis and the lower the aerobic ability for a given cardiac debt(3). The physiological adjustments derived from dehydration, the fluid intake protocols and the role of thirst are the focus of the present review.

One of the first studies concerning the alterations of the fluid balance in hot environments was conducted in 1938, which shows a concern in observing the physiological behavior of the body in activities performed in hot environment since then. Adolph and Dill(4) analyzed the fluid losses through urine and sudoresis, the fluids intake and the urine concentration (specific gravity) in exercise on the desert (hot and dry environment), finding increase in sudoresis, with consequent increase in the fluids intake, stabilization or decrease of urine excretion and increase in the urine concentration.

The physiological effects of the exercise-induced dehydration have been studied through the comparison of several physiological responses of individuals whenever they do not replace the fluid losses during an extended exercise, or partially or completely replace them. A decrease of the plasma volume is observed with the beginning of the exercise. Such reduction is influenced by the type and intensity of the exercise, as well as by the adopted posture(5). Consequently, there is a progressive reduction of the plasma volume associated with exercise which may be compensated through fluids ingestion during it(6-10). The variation in volume is lower when the fluids intake is higher(10) and may be prevented if the fluids intake index is equal to the fluids loss index.

The increases in the plasmatic osmolality and plasma sodium concentration during exercise are many times correlated with the increase in the esophagus temperature(10), due to the stimulus for the sudoresis reduction which occurs in higher dehydration indices. Such evidence suggests that an important target for the fluids intake would be preventing variations in the osmolality and in the plasma sodium concentration, as originally proposed by Dill *et al.*(11).

Some studies have shown that the sudoresis rate decreases with the increase of the dehydration indices(12). In the study by Mountain *et al.*(13), nine individuals performed exercises in hot environment in three different intensities and under three hydration levels: 0% (self-hydrated), 3% and 5% (hipohydrated). It was found that the higher the hydration percentage, the higher the sudoresis threshold; the lower the sudoresis sensibility and the lower the sweat production.

The increase of the rectal temperature related to exercise is decreased by the fluids intake during it(6-7,9-10,12,14-15). Such increase is proportionally reduced to the fluid volume ingested and is lower when the ingestion rate is close to the sudoresis rate(10,12). There is a straight relation between the esophagus temperature increase and the dehydration index(9-10), which was also verified in some of the original field studies(4).

The fluids intake reduces the rectal temperature responses only after 60-80 min of exercise(6,9-10). None of the fluids intake effects in the rectal temperature was found in a study of shorter duration, with greater intensity(16), possibly due to the exercise duration (less than 80 min). Cheuvront and Haymes(17), in a study in which the effect of water intake according to thirst over the thermoregulatory responses during exercise at 71% of the $\dot{V}O_{2max}$ and performed under different thermal stresses (cold, moderate and hot) was evaluated, did not find differences in the internal temperature in the three situations. One may conclude that the thermoregulatory responses are possible to be compensated when there is intake according to thirst and replacement of approximately 60-70% of the sweat losses.

* Laboratório de Fisiologia do Exercício, Escola de Educação Física e Terapia Ocupacional. Universidade Federal de Minas Gerais. Belo Horizonte, MG, Brasil.

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Correspondence to: Av. Antônio Carlos, 6.627, Campus Pampulha – 31310-250 – Belo Horizonte, MG, Brasil. Telefax: (31) 3499-2325. E-mail: lor@ufmg.br

The cardiac frequency is increased[7-8,12] and the ejection volume reduced proportionally to the fluids deficit which occurs during the exercise[10]. Even a light dehydration (one percent of the body weight) may increase the cardiovascular effort, which may be seen through a disproportional increase of the heart rate during exercise, besides limiting the body ability to transfer heat from the muscles in contraction to the skin surface, where it can be dissipated to the environment. Therefore, a fluid deficit may reduce performance and increase the possibility of a thermal complication[18]. However, the cardiac debt and the ejection volume do not decrease when the fluids intake rate is sufficient to prevent dehydration.

Fluids intake keeps higher rates of blood flow in the forearm during exercise[9-10], as well as in the forearm and calf at resting position during an extended exposure to heat[19]. The blood flow reduction in the forearm is proportional to the dehydration level[10]. Therefore, fluids intake during exercise may decrease the development of hyperthermia through the maintenance of the blood flow to the skin[9].

The subjective perceived exertion is increased proportionally to the fluids deficit[10]. Even partial fluids replacement has a significant effect in the subjective perceived exertion during a high intensity exercise[16]. The main effects of the fluids restriction during extended exercises of low intensity, among them the alteration of the subjective perceived exertion, have been described.

The renal function during extended exercises is not affected by indices of dehydration lower than 4%[20-21] and increased during the recovery of individuals who retain liquid during exercise[22]. Classical studies also observed that the renal function was not influenced by dehydration indices lower than 7%. Anuria was registered in a runner who drank inadequately and lost 11% of his body weight during an ultra-marathon of 88 km[21].

Once the possible effects of dehydration (in different levels) are known, issues such as: how much, how and when to intake fluids start to arise. Regular water or hydroelectrolytic solutions? How should we evaluate the hydration status? After a period in which the recommendation of "not drinking" during exercise was predominant (until about 1970), hydration protocols which have the aim to teach individuals how to hydrate themselves in order to reach hydroelectrolytic balance appeared. At the same time, these protocols became a paradigm. These protocols determine how much and what should be ingested and how often the fluids should be replaced during exercise. Nonetheless, recently Noakes (2004)[23] presents criticism about these hydration protocols. He highlights the lack of consistent scientific data in these recommendations and is in favor of thirst as an efficient physiological mechanism in order to determine the fluids intake during exercise.

In the present review, the effects of dehydration in the body are presented, the international recommendations about hydration are described and the possibility that thirst can be a sufficient regulator in order to keep an individual hydrated during exercise is discussed. Two of the main scientific consensus on hydration in exercise (ACSM (1996) and NATA (2000)) are the grounding for these reasons. A bibliographic search by key words was used in order to select the mentioned articles (thirst, hydration/dehydration and exercise) in the main data bases of the scientific articles in the biomedical sciences field (Web of Science and Pubmed). Moreover, publishing from the Exercise Physiology Laboratory of the Physical Education School, Physical Therapy and Occupational Therapy of the UFMG were selected, which corroborate the hypothesis here discussed.

EVALUATION OF THE HYDRATION STATUS

The hydration status is a crucial issue for the practice of physical activities. Therefore, the knowledge of the pre, during and post exercise hydration status of the individual becomes important for constant exercise practice. Moreover, it is essential to evaluate the hydration status in order to avoid health problems derived from dehydration.

The plasma osmolality is the main evaluation method of the hydration status in laboratory situations, where higher measurement accuracy is required[24].

The urine specific gravity has been considered a good non-invasive method for evaluation of the hydration status of the individuals[25].

The body weight variation can also be used in order to evaluate the hydration status. It is possible to evaluate the weight loss percentage from the difference of the body weight prior and post exercise to classify the hydration status (table 1).

Another practical method for body hydration estimation is the analysis of the urine color, making use of the scale proposed by Armstrong *et al.*[26]. The scale presents a good correlation with the urinary density and osmolality and with the plasma osmolality[25].

TABLE 1
Indices of hydration status

Hydration status	%Δ body weight	Urine color	Urine specific gravity
Self-hydration	+1 to –1	1 or 2	< 1.010
Minimum dehydration	–1 to –3	3 or 4	1.010-1.020
Significant dehydration	–3 to –5	5 or 6	1.021-1.030
Severe dehydration	> –5	> 6	> 1.030

Source: NATA[27]

RECOMMENDATIONS ABOUT FLUIDS REPLACEMENT

As described before, dehydration may compromise performance during exercise and increase the risks associated with exertion and heat. Moreover, according to the National Athletic Trainer's Association[27], the individuals do not voluntarily intake sufficient water to prevent dehydration during a physical activity. Conversely, fluids intake excess should be avoided, once it can also compromise the individual's performance and health. Recommendations about hydration have been proposed in international consensus with the purpose to minimize the negative effects of the fluids losses over the physiological responses to exercise.

Some of the recommendations of the American College of Sport Medicine[18] about the quantity and composition of the fluids that should be ingested prior, during and post exercise are reproduced as follows:

1. It is recommended that individuals ingest around 500 mL of fluids in the two hours that precede an exercise, in order to promote a suitable hydration and be sufficient time for the excessive ingested water excretion.
2. During exercise, the athletes should start drinking soon and at regular intervals, with the aim to ingest fluids in a rate sufficient to replace all the water lost through sweating, or ingest the highest amount tolerated.
3. It is recommended that fluids are ingested in a temperature lower than the room's (between 15 and 22^{o}C) and with attractive taste.
4. It is recommended the addition of suitable quantities of carbohydrates and electrolytes for events with duration longer than an hour, once it does not harm the water distribution through the body and improves performance. During exercises with duration shorter than an hour, there is little evidence that physiological differences occur concerning performance in case fluids with carbohydrates and electrolytes or regular water are ingested.
5. It is recommended the addition of sodium (0,5 to 0,7 g.L^{-1} of water) in the re-hydration solution in case the exercise lasts more than an hour. Such suggestion can improve taste, promoting fluids

retention and possibly reverting hyponatremia in some individuals who have ingested excessive quantities of fluids.

The National Athletic Trainer's Association[27] also recommends about the fluids replacement for athletes, which are similar to the ones of the ACSM[18], especially concerning the volume to be ingested. According to NATA[27], to guarantee the hydration status, the athletes should ingest approximately 500 to 600 mL of water or other sports drink 2 to 3 hours prior to exercise and 200 to 300 mL 10 to 20 minutes prior to exercise. The fluids replacement should be close to the losses by sweating and by urine.

DISCUSSION: IS THIRST SUFFICIENT?

It has been verified that, after several years of recommendation to athletes and physical activities practitioners to ingest set quantities or the most of fluids (regular water and sports drinks) every 15 to 20 minutes of exercise in order to avoid dehydration, such rehydration strategy may be excessive or even harmful to health.

Recent data have shown evidence about the growing number of individuals who suffer hyponatremia (low plasma sodium concentration: indices below 135 mEq) during extended physical exercises, mainly due to hyperhydration[28]. Almond *et al.*[29] observed that during the Boston's marathon of 2002, 13% of the athletes presented hyponatremia and three athletes had concentrations of plasma sodium so low that would have the risk of dying. Besides that, it was observed in that study that several athletes drank quantities of fluids so excessive that they increased their body weight at the end of the marathon's distance.

It is known that during exercise the renal function may alter. Some studies have reported decrease of 20 to 60% in the renal function, with consequent increase in the urine concentration, in competitive exercise and laboratory situations[30]. In that matter, one of the possible explanations would be that an excessive ingestion of fluids, added to the altered renal function during exercise, could cause hemodilution and displacement of the water excess to the intracellular space, which may be lethal.

In a study conducted in our laboratory, it was verified that during intense and extended exercise (2 h), with water intake according to the ACSM[18], in temperate and hot environment the individuals presented increased urinary flow (especially in the temperate environment) and urine dilution in both thermal environments, suggesting that an excessive fluids intake may have occurred[31]. Some studies have suggested that in human beings during exercise – especially in stressing thermal environments – the thirst mechanism would not be sufficient to replace the fluids losses by sudoresis, leading to involuntary dehydration[32-33]. This dehydration would be triggered by a complex physiological mechanism that involves behavioral factors (personal habit of hydrating), gastric ability of fluids absorption, besides hormonal and central nervous system stimuli[33-34]. Thus, dehydration was considered the main factor that would affect the thermoregulation and the individual's ability to perform physical exercise in hot environment.

The need for maximum replacement the fluids losses from the observations that thirst would not be efficient in humans and that dehydration would be the main risk for the physical activities' participants in the heat became established and spread in the international consensus. Therefore, the rule would be: the more fluids ingestion (water and sports drinks) are closer to sudoresis, the lower the effects of dehydration about the physiological functions about the sports performance will be[18,32].

Conversely, considering the current discussions about the possible risks concerning hydration excess during exercise, some authors have claimed that fluids intake according to thirst is effective, that is, voluntary fluids intake as a safe strategy for fluids replacement.

Some studies, especially from the year 2000, have highlighted that the fluids replacement guided by thirst may be sufficient for the thermoregulatory responses maintenance and the ability to perform exercise, even with the small involuntary dehydration that frequently occurs in this situation[35]. Daries *et al.*[36] observed that no difference in runners's performance when they hydrated following the recommendations by the ACSM[18] and when the ingestion occurred according to thirst. Cheuvront and Haymes[17] demonstrated that the body heat was kept during exercises performed by female runners who ingested water according to thirst (what replaced 60 to 70% of the fluids losses by sudoresis, approximately 2% of dehydration percentage) in environmental conditions able to be compensated.

Some studies performed in our laboratory also corroborate the hypothesis that thirst is efficient for the fluids replacement during exercise. Carmo *et al.*[37] verified that water intake *ad libitum* was sufficient to keep the self-hydrated status of individuals that exercised for 1 hour in hot and dry environment, while if they ingested the volume recommended by the ACSM[18], they would have ingested more water than necessary. In a field study (during volleyball training sessions)[38], it was observed that the water intake *ad libitum* replaced approximately 60% of the fluids losses, which represented less than 1% of the body weight variation. Such fact shows that the players completed the training sessions self-hydrated.

The discussions about the fluid volume to be ingested during exercise in order to maintain a suitable hydration status still continue. Besides the quantity, the drink composition is also an issue for further discussion. It is important to highlight that the recommendations were designed from studies with young, healthy individuals and many times well-conditioned, which can hamper its application more widely.

It seems coherent that the intake according to thirst is sufficient and more suitable, once we believe that the central nervous system is able to correctly point the fluid volume to be ingested from information integrated by it about all the body's demands. Moreover, it is important to consider the development of the thirst mechanism as part of the evolution process of the human being, which developed along the time differentiated and perfectly integrated mechanisms in order to regulate the volume and the plasma osmolality as well as its body temperature.

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