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Research article

Preexercise urine specific gravity and fluid intake during one-hour running in a thermoneutral environment – a randomized cross-over study

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Abstract

Urine specific gravity is often used to assess hydration status. Athletes who are hypohydrated prior to exercise tend to ingest more fluid during the exercise, possibly to compensate for their pre exercise fluid deficit. The purpose of this study was to evaluate the effect of additional fluid intake on fluid balance and gastrointestinal tract comfort during 1h running in a thermoneutral environment when athletes followed their habitual fluid and dietary regimes. Sixteen men and sixteen women ingested a 6% carbohydrate-electrolyte solution immediately prior to exercise and then every 15 minutes during two runs, with a consumption rate of 2 $mL.kg^{-1}$ (LV, lower volume) or 3 $mL.kg^{-1}$ (HV, higher volume) body mass. Urine specific gravity and body mass changes were determined before and after the tests to estimate hydration status. During exercise subjects verbally responded to surveys inquiring about gastrointestinal symptoms, sensation of thirst and ratings of perceived exertion. Plasma glucose, heart rate and blood pressure were also evaluated. Men had higher preexercise urine specific gravity than women (1.025 vs. 1.016 $g{\cdot}mL^{-1}$ HV; and 1.024 vs. 1.017 $g{\cdot}mL^{-1}$ LV) and greater sweat loss (1.21 ± 0.27 L vs. 0.83 ± 0.21 L HV; and 1.18 ± 0.23 L vs. 0.77 ± 0.17 LV). Prevalence of gastrointestinal discomfort increased after 45 min. No significant differences on heart rate, rate of perceived exertion, blood pressure or glycemia was observed with the additional fluid intake. From these results it appears that additional fluid intake reduces body mass loss and thirst sensation. When compared to the men, however, preexercise euhydration was more common in women and an increased fluid intake increases the risk of body mass gain and gastrointestinal discomfort.

Key words: Hydration, urine specific gravity, exercise, gender, gastrointestinal discomfort.

Introduction

Fluid replacement during exercise has been studied extensively and the importance of carbohydrate-containing drinks, in particular, on performance and prevention of dehydration is well established (Montfort-Steiger and Williams, 2007, Ostojic and Mazic, 2002), with exogenous carbohydrate supplementation being important in maintaining plasma glucose levels during exercise and refilling emptied muscle glycogen stores (Casa et al., 2000, Sawka el al., 2007). Individuals are encouraged to consume drinks before and during exercise in order to delay depletion of glycogen stores and replace water lost in sweat, and thus delay exhaustion (Maughan and Shirreffs, 2008). Ensuring adequate hydration includes starting exercise in an euhydrated state and fluid intake should be sufficient in order to preserve body mass loss to less than 2% of the preexercise mass, although athletes should avoid gaining body mass due to fluid overload (Sawka et al., 2007).

Therefore, determining athletes' preexercise hydration status is relevant to fluid balance and urine specific gravity is a commonly-used measure that is considered practical, non-invasive and a reliable parameter (Armstrong et al., 1994, Casa et al., 2000, Sawka et al., 2007). The National Athletic Trainers' Association (NATA) recommends that athletes should begin all exercise sessions well hydrated, with a urine specific gravity at or below 1.020 $g{\cdot}mL^{-1}$ (Casa et al., 2000). It has been observed, however, that in general male athletes start exercise in a hypohydrated state (Stover et al., 2006*a*) and tend to increase the volume of fluid ingested during exercise, possibly to compensate for this fluid deficit (Maughan et al., 2005). Previous studies described no physiological benefit on fluid balance by increasing fluid intake at rates to match the fluid loss in men exercising for one (Robinson et al., 1995) or two hours (Daries et al., 2000) in moderate ambient temperature. Furthermore, these studies have reported that when subjects ingested the higher volumes of fluid offered they experienced uncomfortable abdominal fullness and severe gastrointestinal symptoms preventing some from completing their trials. Most of these studies investigated athletes who were purposely euhydrated prior to exercise, however this may not accurately reflect what happens in the field.

As sweat rates display wide inter-individual differences and are influenced by several factors such as sex of an athlete, physical activity patterns, and environmental conditions (Shirreffs et al., 2005), fluid demands for females may differ significantly to those for males especially when starting exercise in a hypo-hydrated state. A positive fluid balance during exercise due to an overconsumption of fluid or impaired renal water clearance might lead to cases of symptomatic exercise-associated hyponatremia (Hew-butler et al., 2008). In this context, According to the Exercise-Associated Hyponatremia Consensus Development Conference (2007) females are at higher risk of body weight gain suggestive of an absolute increase in total body water (Hew-Butler et al., 2008). However, there is little data on whether female athletes are euhydrated at the start of exercise and their subse-

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Table 1. Subject characteristics. Data are means (±SD).

	Age (years)	Weight (kg)	Height (cm)	Body fat (%)	Body surface area (m^2)	Body surface area/mass (cm^2/kg)
Men (n = 16)	23.3 (1.6)	70.1 (4.9) *	1.77 (.05) *	7.1 (3.3) *	1.86 (.04) *	266.2 (8.9) *
Women (n = 16)	21.7 (1.8)	60.1 (7.4)	1.66 (.05)	23.4 (3.8)	1.66 (.05)	276.8 (7.7)

* $p < 0.05$ significantly different from female.

quent response to an increased fluid replacement during exercise.

Therefore the purpose of this study was to compare the preexercise hydration levels between men and women following their habitual dietary and fluid regimes and the influence of different volumes of fluid ingested on fluid balance and gastrointestinal discomfort during exercise.

Methods

Participants

Thirty-two individuals (16 male and 16 female) volunteered to participate in this study; their physical characteristics are shown in Table 1. They were university athletes regularly (>3x per week) engaged in aerobic training lasting two hours. All participants were considered healthy and active as assessed by a general health questionnaire and gave their written informed consent before participating. This study was reviewed and approved by the Federal University of Viçosa's Human Ethics Committee conforming to the Code of Ethics of the World Medical Association (Declaration of Helsinki).

Preliminary measurements

At least 1 week prior to the experimental trials, the participants reported to the laboratory for a familiarization session on a motorized treadmill (EG700X, Ecafix, São Paulo, Brazil). Their body height was obtained to the nearest 0.1 cm using a stadiometer and body mass to the nearest 0.01 kg using a digital scale (model CS2000; Ohaus Corp, Pine Brook, NJ). Skinfold thickness measurements were taken at three sites, these being biceps, triceps and subscapular (males) or suprailiac (females) and were assessed in triplicate (measuring all then repeat) using skinfold callipers (Model HSK-BI; British Indicators, West Sussex, UK). Sum of skinfolds was calculated using the mean value and body fat percent was estimated as described by Jackson and Pollack (1985). A 20-min incremental submaximal running test was also performed to establish the treadmill velocity and gradient that corresponded to 75% heart rate reserve (Karvonen et al., 1957). The continuous intensity of 75% heart rate reserve assures that gastric emptying was not compromised by the exercise (Brouns, 1998). The treadmill test was started and at every 5 min continuous adjustments in the speed and gradient was applied and heart rate was controlled until a steady-state that corresponded to 75% heart rate reserve was reached. In case of this test lasting more than 20 minutes, initial treadmill velocity and gradient were adjusted and subjects performed the test again in another session. The mean treadmill velocity and gradient used was 2.4 ± 0.3 $m \cdot s^{-1}$ and 4.3 ± 0.7 % for male and 2.0 ± 0.1 $m \cdot s^{-1}$ and 3.2 ± 0.7% for females, respectively.

Protocol

Participants performed no exercise on the day before each test and menstrual cycle of the female participants was not recorded, aiming to investigate females in their typical pre training situation. Efforts were made to minimally alter the typical behavior of the participants, so that they maintained their habitual intake of food and drink. Diet was recorded during the 24 hours before the first trial and replicated for trial 2. Nutrition protocols were checked before each trial. Subjects reported to the laboratory after a 12-hr overnight fast but were allowed to drink water *ad libitum*. This was to ensure that they had an empty stomach and to avoid effects of different meals on rate of gastric emptying. All the subjects received the same standard preexercise meal (Table 2) to minimize differences in initial glycemic status and gastric content. The composition of the meal aimed at replicating usual practice with low fat and adequate energy to minimize gastrointestinal tract discomfort. Participants performed all of their tests at the same time of day (between 7:00 and 9:00 a.m.) and under temperate environmental conditions of 23 ± 0.2°C and 63-65% relative humidity. Each test was separated by approximately one week. On arrival, subjects remained seated for 10 min before a finger-prick blood sample was drawn using a micro lancet and analysed for plasma glucose. The subjects were asked to empty their bladder and defecate if necessary and body mass was recorded on a digital scale in underwear or dry shorts, and brassiere for females. A urine sample was collected and the preexercise urine specific gravity was assessed within 30 minutes of collection and was analysed using a clinical handheld refractometer (model A300; ATAGO Co, Tokyo, Japan) that was calibrated with distilled water prior to the beginning of each test and reviewed periodically between measuring the urine samples, with the same individual measuring all urine samples. Thereafter, the volunteers ingested the preexercise meal and remained rested for 1h. A heart rate transmitter (Polar S610, Kempele, Finland) was placed around the chest and preexercise plasma glucose, heart rate and blood pressure using a manual mercury sphygmomanometer (Wan Med, São Paulo, Brazil) were determined. Thereafter, a bolus of higher (HV) or lower (LV) volume (3 or 2 $mL \cdot kg^{-1}$ body mass, respectively) of 6% carbohydrate-electrolyte drink (Gatorade Thirst Quencher; The Gatorade Co., Chicago, IL) was ingested within 1 minute. Additional nutritional compositions are shown in Table 2.

A 5-min warm-up was completed followed by a 60-min run at a fixed predetermined speed and gradient equivalent to 75% heart hate reserve. At every 15 min during the exercise one of the body mass-adjusted volumes of carbohydrate-drink was provided and blood sampling was performed. Blood pressure was measured at

Table 2. Nutritional composition of pre-exercise meal and carbohydrate-electrolyte drink.

Nutritional analyses	Apple 100 (g)	Juice 200 (mL)	Salt Biscuit 30 (g)	Cereal Bar 25 (g)	Carbohydrate-electrolyte drink 100 (mL)
Energy Content (kcal)	60	90	140	110	25
Carbohydrates (g)	15.3	22	20	16	6
Proteins (g)	0.1	-	3.0	1.0	0
Total fat (g)	0.3	-	5.0	4.0	0
Fiber (g)	1.9	-	< 1.0	1.0	-
Sodium (mg)	-	-	180	30	45
Potassium (mg)	115	-	-	-	12
Chloride (mg)	-	-	-	-	42
Calcium (mg)	7	-	38	13	-

every 20 min while heart rate was taken every 10 min. At the end of the trial, any excess sweat was toweled and volunteers were weighed as prior to the trial. Subjects were asked to empty their bladder as fully as possible and to collect the entire volume in a container provided and the postexercise urine specific gravity and urine volume was assessed. Sweat volume was calculated using the change in body mass, corrected for any urine loss and the volume of fluid consumed. The relatively small changes in mass due to substrate oxidation and other sources of water loss (primarily evaporative loss from the lungs) were ignored as these would have been similar in both trials. The order of the experimental trials was randomized, and the study employed a counterbalanced crossover design.

Questionnaires

Every 15-min during exercise subjects were requested to verbally answer a short questionnaire, as previously described by Jeukendrup et al. (2000), containing questions regarding the presence, at that moment, of gastrointestinal problems scored on a 10-point scale (1 = not at all and 10 = very very much). Ratings of perceived exertion were obtained using a 6- to 20-point Borg scale (Borg, 1970) at every 15 min and thirst sensation was reported at the same time using a 9-point scale (Maresh et al., 2004) with verbal anchor ranging from 1 (not thirsty) to 9 (very thirsty).

Statistical analyses

The data were tested for normality of distribution and are presented as the mean ± standard deviation (SD). Variables were analysed by two-way ANOVA and the Scheffe *post hoc* test. Data analyses were conducted with SPSS (version 14.0; SPSS Inc, Chicago, IL). A probability level of 0.05 was selected as the criterion for statistical significance.

Results

Urine specific gravity and fluid balance

Table 3 summarizes the results for urine specific gravity. A total of 14 male subjects (87.5%) provided pretest urine samples in which the urine specific gravity was greater than 1.020 $g \cdot mL^{-1}$ in HV and 12 male subjects (75%) in LV. The number of females with a pretest urine specific gravity higher than 1.020 $g \cdot mL^{-1}$ was 4 (25%) and 7 (43.7%) in HV and LV respectively. After exercise, however, the number of volunteers that showed a urine specific gravity higher than 1.020 $g \cdot mL^{-1}$ decreased to 6 (37.5%) in both trials for males and to 2 (12.5%) in HV and to 6 (37.5%) in LV in females.

Mean values for fluid balance are shown in Table 4. Body mass changes from pre-exercise values in HV ranged from 0.3% to -1.5% for males and from 0.8% to -0.7% for females. In LV, changes in body mass ranged from -0.15% to -1.5% for males and from 0.17% to -1.0% for females. Fluid intake in men ranged from 0.87 to 1.25 L in HV and from 0.58 to 0.87 L in LV, with respective values of 0.77 to 1.18 L and 0.51 to 0.77 L in HV and LV for women. After correction for the amount of fluid ingested, the estimated male sweat loss during the 60-min exercise in HV ranged from 0.79 to 1.83 L and in LV ranged from 0.76 to 1.67 L. Corresponding values for females ranged from 0.39 to 1.20 L and from 0.48 to 1.18 L in HV and LV, respectively.

Self-reported symptoms

The most frequent gastrointestinal complaint reported was "urge to urinate" (Table 5). Two female subjects were not able to complete one of their trials. They stopped at ~50 min during the run and expressed a maximum score in "urge to urinate" and feeling other gastrointestinal symptoms, one of them in the high-volume and one in the low-volume trial. The most frequent gastrointestinal complaints occurred between 45 and 60 min. Ratings of perceived exertion were higher ($p < 0.001$) at 60 min than at 15 min and at 45 min than at 30 min, however neither sex nor trial influenced perceived exertion. There was a significant difference ($p = 0.02$) for thirst sensation only at 60-min during LV when males presented a higher sensation (score 4) than females (score 2).

Table 3. Pre and post urine specific gravity. Data are means (±SD).

		Urine specific gravity ($g \cdot mL^{-1}$)			
		Pre test	Range	Post test	Range
Men	HV	1.025 (.004) †	1.020 – 1.034	1.015 (.008) *†	1.004 – 1.028
	LV	1.024 (.005)	1.016 – 1.034	1.016 (.008) *	1.006 – 1.032
Women	HV	1.016 (.009)	1.004 – 1.034	1.009 (.006) *	1.003 – 1.024
	LV	1.017 (.010)	1.004 – 1.034	1.015 (.009) *	1.004 – 1.030

* $p < 0.001$ Significantly different from pre test, † $p < 0.001$ Significantly different from female value for HV treatment.

Table 4. Values of fluid intake, estimated sweat loss, changes in body mass (BM) and urine output for volunteers who completed the tests. Men (n=16) Women (n = 14). Data are means (±SD).

		Sweat Loss (L)	Fluid Intake, (L)	BM change, (kg)	BM change, (%)	Urine Volume, (L)
Men	HV	1.21 (.27)	1.04 (.09) *	-.17 (.31) *	-.26 (.48) *	.19 (.21)
	LV	1.18 (.23) †	.70 (.07) †	-.48 (.22) †	-.69 (.34) †	.13 (.1 0)
Women	HV	.83 (.21) †	.89 (.11) *†	.06 (.21)*†	.09 (.36) *†	.20 (.15) *
	LV	.77 (.17)	.59 (.07)	-.17 (.16)	-.29 (.29)	.11 (.10)

* $p < 0.001$ significantly different to LV within sex. † $p < 0.001$ significantly different to opposite sex within treatment.

Plasma glucose, HR and blood pressure

There was no significant difference ($p = 0.34$) in preexercise glycemia (1 h after the preexercise meal) between the subjects. Concentrations of glucose were reduced at 15 min for males (5.19 ± 0.57 mmol·L^{-1}; 5.16 ± 0.72 mmol·L^{-1}) and females (5.06 ± 0.61 mmol·L^{-1}; 4.83 ± 0.46 mmol·L^{-1}) during HV and in LV, respectively, compared to pretest values (Men: 5.44 ± 0.6 mmol·L^{-1} HV and 5.39 ± 0.6 mmol·L^{-1} LV; Female: 5.25 ± 0.5 mmol·L^{-1} and 5.16 ± 0.4 mmol·L^{-1}). Concentrations of plasma glucose at 60 minutes were higher ($p = 0.009$) in HV (5.89 ± 0.26 mmol·L^{-1}) than in LV (5.57 ± 0.35 mmol·L^{-1}) for females. HR and blood pressure increased significantly ($p < 0.05$) from the start of the exercise and remained elevated without change during all the trials, with no differences in HR or blood pressure between the treatments or sexes.

Discussion

The present study aimed to investigate males and females hydrating using different fluid volumes during treadmill exercise under standard ambient conditions, when preexercise habitual dietary and hydration regimes were maintained. The current study adds important data to the literature where limited information is available on values for preexercise urine specific gravity of females.

Urine specific gravity

In the present study we classified as dehydrated the individuals with urine specific gravity > 1.020 g·mL^{-1}, as suggested by the NATA for trained athletes (Casa et al., 2000). We observed a wide variability in urine specific gravity values. Analyses of individual data showed that both males and females started their trials in a dehydrated state with a urine specific gravity > 1.020 g·mL^{-1} and men presented with higher values of urine specific gravity than women, but when the data are viewed as means, the female group presented minimally dehydrated with urine specific gravity between 1.010 g·mL^{-1} and 1.020 g·mL^{-1}. Studies that have evaluated subjects in a free-living situation prior to exercise have found that male athletes often started the exercise inadequately hydrated (Godek et al., 2005; Osterberg et al., 2009; Stover et al., 2006b). In addition, our findings are consistent with observations from others where males were more dehydrated than females prior to exercise (Stover et al., 2006b). Poule and Volpe (2001) measured urine specific gravity in 138 male and 125 female collegiate athletes before their practice sessions and found that only 17% of the athletes were well hydrated and that more males were dehydrated than females. Higham et al. (2009) observed consistent fluid deficits prior to activity that was independent of sex and a large degree of individual variation in habitual hydration

Table 5. Mean scores of gastrointestinal and related complaints during 60 minutes of exercise.

Treatment	3 mL.kg^{-1} (HV)								2 mL.kg^{-1} (LV)							
	Men (n = 16)				Women (n = 14)				Men (n = 16)				Women (n = 14)			
Minutes	15	30	45	60	15	30	45	60	15	30	45	60	15	30	45	60
Complaint																
Stomach problems	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1
Nausea	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Dizziness	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1
Headache	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Flatulence	1	1	2	2	1	1	1	1	1	1	1	1	2	1	1	1
Urge to urinate	1*	2*	3	4	1*‡	2*	3	5	1*	2	3	3	1	2	2†	2†
Urge to defecate	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1
Urge to vomit	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Belching	2	2	2	2	2	1	2	2	1	2	2	2	2	2	2	2
Stomach burn	1	1	2	2	1	1	1	1	1	1	1	2	1	1	1	1
Bloated feeling	1	1	2	2	1	1	1	1	1	2	2	2	1	1	1	1
Stomach cramps	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Intestinal cramps	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1
Side aches left	2	2	2	2	1	1	1	1	1	2	2	2	1	1	1	1
Side aches right	1	1	1	1	1	1	1	1	2	1	2	2	1	1	1	1
Reflux	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

* $p < 0.05$ significantly different to 60 min within sex and treatment, † significantly different to HV value within sex, ‡ Significantly different to 45 min within sex and treatment

practices in adolescent swimmers. In some sports, however, athletes often start exercise dehydrated after prolonged daily exercise sessions in warm weather or when the interval between the sessions is not sufficient to replace fluid lost (Stover et al., 2006a). The participants in the present study, however, performed no exercise the day before the tests and were not engaged in multiple practice sessions in a single day. However, females typically exercise at lower velocities, have smaller body size and lower metabolic rates that may contribute to lower sweating rates compared to males (Sawka et al., 1983), which make it plausible that it is easier for them to replace the fluid lost during previous exercise.

In the present study, despite pretest hypohydration in men, the constant fluid replacement of both volumes was effective in maintaining the mean value of post-exercise urine specific gravity to less than 1.020 $g \cdot mL^{-1}$ both in men and in women. However, no difference was observed when comparing post urine specific gravity and the two volumes; except for women that had a lower value of post urine specific gravity than men in HV, probably because men already presented with a higher pretest urine specific gravity. It is also important to note that as the subjects consumed a bolus of fluid immediately prior to exercise, a possibility exists that this could have altered their hydration status upon commencement of exercise.

Fluid balance

Daries et al. (2000) studied men who were euhydrated prior to exercise, with three different volumes (0.76, 0.78 and 1.83 $L \cdot h^{-1}$) of a carbohydrate-electrolyte drink during 90-min of fixed workload running in a thermoneutral environment and observed no effect upon sweat rate or urine production, but a reduced loss in body mass. Both volumes in the present study were sufficient to limit a mean body mass loss smaller than 1% of the preexercise mass. A significant difference in body mass change was observed between treatments and the sexes with women gaining 0.06 ± 0.21 kg of body mass and showing higher urinary output in HV. The additional fluid intake, however, produced no significant differences in sweat loss but men had greater sweat losses than women in all the trials (Table 4). Higher sweat rates in males across most activities (Burke and Hawley, 1997; Chorley et al., 2007) and body mass gain in women has been observed in recent studies (Soo and Naughton, 2007; Twerenbold et al., 2003). Furthermore, in the present study females had a larger body surface area/mass ratio (277 cm^2/kg) than males (266 cm^2/kg), which may have contributed to the lower sweat loss; therefore, females may thermoregulate more efficiently (>dry heat loss) than males during exercise in thermoneutral environments. We suspect that the lower sweat rate associated with the greater fluid ingestion in HV contributed to the positive fluid balance in our female subjects. Moreover, it has been suggested that female athletes are more prone to develop syndrome of inappropriate release of antidiuretic hormone (SIADH) (Hew-Butler et al., 2008). It is unlikely that body mass gain in our female group was caused by SIADH due to the increased urine output in HV and the relatively short exercise duration. Although the body mass gain in the present study was not substantial it is important to consider that the longer the exercise duration the greater the cumulative effects of slight mismatches between fluid needs and replacement, perhaps increasing the risk of hyponatremia and gastrointestinal distress in women for activities longer than that of the present study.

Self-reported symptoms

Prevalence of gastrointestinal disturbances became greater after 45 min, when four aliquots of the carbohydrate-drink had already been ingested. Although the volumes consumed were well-tolerated, we observed a higher prevalence of gastrointestinal symptoms in HV, but there were no significant differences in gastrointestinal discomfort between the volumes ingested or sexes. Some argue that, in general, running induces more gastrointestinal complaints than other low-impact sports such as cycling or swimming. Lambert et al. (2008) however, showed that trained runners were able to comfortably tolerate constant ingestion of a carbohydrate-electrolyte solution at a rate approximately equal to their sweat rate during 90min of running at 65% VO_{2max} in 25°C and 30% RH environment. The item “urge to urinate” was the gastrointestinal disturbance most frequently indicated (Table 5). Others have also observed an intense urinary flux in subjects constantly replacing fluid lost during exercise (Amorim et al., 2001, Sanders et al., 2001). In a study by Jentjens et al. (2004) urge to urinate was the most frequent symptom when trained cyclists ingested a 600-mL initial bolus followed by 150 mL of an isoenergetic fructose plus glucose drink each 15 min during 120-min cycling at 65% $VO_{2max.}$

Individual tolerance or familiarization with fluid replacement could explain the cessation of exercise by two women at 45 and 50-min exercise in LV and HV respectively, when a maximum score of “urge to urinate” was indicated. Based on the results of stomach comfort in a study of Lambert et al. (2008) the fluid tolerance could be improved with repeated sessions of drinking while running. However, further studies are warranted to determine if tolerance to higher ingestion rates are possible with training. Besides, it is likely that a very small female subject might respond differently than a very large male subject when receiving the preexercise meal. The gastric emptying of the preexercise meal might therefore be considerably different between subjects, which might impact on gastric tolerance (Silva et al., 2009). It might be interesting in future studies to include a trial in which subjects consumed only the meal and no drink during exercise or alternatively just perform the exercise after an overnight fast, so that the individual effects of the meal could be elucidated.

Men were thirstier than women at the end of the exercise after LV. It is possible that those participants who are inadequately hydrated before testing become more dehydrated and have a greater perception of thirst when they ingest less fluid. Maresh et al. (2004) also found that perception of thirst was greater in individuals who were hypohydrated compared with euhydrated before exercise in the heat.

Considerations and limitations

Several methods have been used to measure hydration status during periods of acute fluid loss. Determination of plasma osmolality, however, appears to be the gold standard to assess hydration status (Casa et al., 2005), but it requires invasive procedures that are not practical when used by athletes and coaches in field settings. Simple biomarkers, however, such as urine osmolality as well as urine specific gravity and body weight analysed in the present study are practical measurements with reasonable accuracy and reliability to predict hydration status with athletes (Armstrong et al., 1994; Casa et al., 2000, Oppliger et al., 2005; Sawka et al., 2007). The validity of urine specific gravity measures is questionable following acute changes in body mass, as would occur following exercise-induced sweat loss (Oppliger et al., 2005). However, Armstrong et al. (1994) argue that in some situations, urine indices might be more sensitive to small changes in hydration status than are blood-derived indices and might offer a more accurate representation of chronic hydration states. The lag between exercise-induced dehydration and the point of urine collection needs further investigation.

Plasma volume in women is highly influenced by estrogen and progesterone, and there is still limited research on the effects of the chronic perturbations of menstrual cycle hormones on water handling (Sims et al., 2007). Although we did not control for menstrual cycle, it cannot be excluded that cyclical neuroendocrine variations during the menstrual cycle may have influenced the excretion of fluid in our female subjects. Controlling for menstrual cycle phase would be important to minimize the increased effects of the arginine-vasopressin levels on body water and body weight during the luteal phase (Sawka et al., 2007). There are other studies, however, that also have not reported (Soo and Naughton, 2007) or failed to record (Hew, 2005; Twerenbold et al., 2003; White et al., 1998) in which phase of the menstrual cycle their female subjects were. White et al. (1998) also argue that, direct scientific support is lacking about the hormonal fluctuation and total body water response in women, although comprehensive research defends the validity of these effects. Nevertheless, to minimize the lack of the current study in accurately estimating the menstrual cycle influence on body water, future studies investigating female athletes following their habitual dietary and hydration regimes, might apply more body weight measurements during the daily activities to establish a baseline value and verify variations during the subsequent study.

Conclusion

To summarize, men have greater sweat losses than women during exercise but additional fluid intake (HV) during 1-h running in a thermoneutral environment reduces body mass loss and thirst sensation. In women, LV fluid replacement maintains euhydration, but an increased fluid intake (HV) raises the risk of body mass gain and gastrointestinal discomfort. Preexercise urine specific gravity were higher in males compared to females, however, future investigations might explore the possible effect of cumulative training session in preexercise urine specific gravity and other ambient conditions associated with incomplete restoration of fluid balance as well as whether additional fluid intake improves performance at different levels of preexercise hydration.

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Key points

- There seems to be a wide variability in pre-exercise hydration status between male and female and efforts aimed at educating athletes about the importance of pregame hydration must be emphasized.
- The fluid ingestion during running exercise in a moderate environment reduces body mass loss and thirst sensation, but an increased fluid intake at rates to match the fluid loss might raise the risk of body mass gain in women during prolonged activities.
- Individual gastric tolerance and familiarization with fluid replacement should be taken into account when providing athletes with strategies for hydration during exercise.

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