Voluntary fluid intake and core temperature responses in adolescent tennis players: sports beverage versus water

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ORIGINAL ARTICLE

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Objective: To examine differences in ad libitum fluid intake, comparing a 6% carbohydrate/electrolyte drink (CHO-E) and water, and associated differences in core temperature and other selected physiological and perceptual responses in adolescent athletes during tennis training in the heat.

Methods: Fourteen healthy, fit, young tennis players (nine male; five female; mean (SD) age 15.1 (1.4) years; weight 60.6 (8.3) kg; height 172.8 (8.6) cm) completed two 120 minute tennis specific training sessions on separate days (randomised, crossover design) in a warm environment (wet bulb globe temperature: CHO-E, 79.3 (2.6) ˚F; water, 79.9 (2.2) ˚F; $p>0.05$).

Results: There were no significant differences ($p>0.05$) between the trials with respect to fluid intake, urine volume, fluid retention, sweat loss, perceived exertion, thirst, or gastrointestinal discomfort. However, there was a difference ($p<0.05$) in the percentage body weight change after training (CHO-E, −0.5 (0.7)%; water, −0.9 (0.6)%). Urine specific gravity before training (CHO-E, 1.024 (0.006); water, 1.025 (0.005)) did not correlate significantly ($p>0.05$) with any of these measurements or with core body temperature. In examining the main effect for trial, the CHO-E trial showed a significantly lower ($p<0.001$) mean body temperature (irrespective of measurement time) than the water trial. However, the mean body temperature in each trial was not associated ($p>0.05$) with fluid intake, fluid retention, sweat loss, or percentage body weight change.

Conclusion: Ad libitum consumption of a CHO-E drink may be more effective than water in minimising fluid deficits and mean core temperature responses during tennis and other similar training in adolescent athletes.

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Heat stress can not only diminish performance, it can readily threaten a young athlete's health and safety.[1–5] Importantly, the effects of heat stress are not limited to the venues of competition, as many children and adolescents routinely train for many hours in such conditions. Moreover, temperature regulation, thermal and cardiovascular strain, and heat tolerance during exercise in warm to hot conditions are directly modulated by hydration status.[6–11] Thus strategies to ensure appropriate and sufficient fluid intake should be emphasised, as children and adolescents often consume much less fluid than is lost through sweating during exercise in hot conditions.[11–15] In this regard, it may be beneficial to have a sports drink (as opposed to just plain water) available during practice in the heat, to prompt greater fluid intake,[13 15 16] so that body water deficit is minimised. However, to date, there are limited data that precisely describe thermoregulatory strain, as indicated by core body temperature and as modulated by hydration status, in youth athletes during sport specific training in natural outdoor field settings and conditions when sweat losses are high.

In this study, we examined differences in fluid intake, comparing a carbohydrate/electrolyte drink (CHO-E) and water, and the associated differences between drinks in core body temperature in adolescent tennis players during intense training sessions in the heat. Hydration status before training, fluid retention, and selected perceptual responses were also examined. On the basis of previous evidence,[13 15 16] we expected a difference in ad libitum intake of CHO-E compared with water, which we hypothesised would lead to a resultant difference in on-court core body temperature. These findings provide unique insight into selected on-court physiological and perceptual responses related to fluid status and thermal strain in adolescent tennis players which will help to establish more specific and effective guidelines and strategies for enhancing the safety of players during tennis training in warm to hot conditions through improved hydration.

METHODS

Subjects

Fourteen young, healthy, fit tennis players (nine male; five female; mean (SD) age 15.1 (1.4) years; weight 60.6 (8.3) kg; height 172.8 (8.6) cm) participated in this study. All subjects were highly skilled and currently training daily at a tennis academy in central Florida (United States) and were accordingly acclimatised to the heat at the time of evaluation. To reduce potential bias, limited explanations were provided to the subjects about fluid intake behaviour (on-court or off-court) and the expected outcomes of comparing CHO-E and water. Moreover, the subjects were not given any protocol for standardising their hydration status before each test session. This permitted an assessment of typical variation in pre-exercise hydration status as it related to the outcome measures. The study was reviewed and approved by the Human Assurance Committee of the Medical College of Georgia, and all subjects (and parents) gave their voluntary, written informed consent to participate in this investigation.

Overall protocol

The 14 subjects were tested in Bradenton, Florida, using a randomised, crossover design. Each subject participated in two test training sessions on separate days (separated by one day) during the third week of April. Each test session was conducted outdoors on hard surface tennis courts and consisted of 120 minutes of intermittent sport specific practice drills and activities (see below) that prompted extensive sweat losses. Environmental conditions (wet bulb globe temperature) were monitored continuously with a thermal environment monitor (QUESTemp°34; QUEST Technologies, Oconomowoc, Wisconsin, USA), which was set up on court (centre of training area) about two hours before the start of each training session. During the first test session, half of the group drank (ad libitum) chilled unflavoured water during the entire training session, and the other half drank an identically chilled, orange flavoured, commercially available 6% CHO-E (Na^+ concentration 21.1 mmol/l). All participants switched to the other drink for the second test session. Core body temperature was monitored during each test session, using an ingested temperature monitoring sensor that transmitted continuous readings of core body temperature (see below). On arrival at the testing area (1330–1345 hours), subjects emptied their bladders and provided urine samples. These samples were used immediately to assess pre-exercise hydration status, as indicated by urine specific gravity, using a hand held clinical refractometer (model A300CL; Spartan, Tokyo, Japan). Each subject was subsequently weighed (±50 g), using a precision scale (model UC-300; A&D Engineering, Milpitas, California, USA), while wearing a self selected dry top (girls) and a pair of shorts (specifically designated for body weight measurements). After being weighed, each subject's core body temperature was recorded and then each subject dressed for tennis. Self selected clothing typically consisted of light coloured or white shorts, a top (sport top for girls, t-shirt for boys), and sometimes a hat or visor, along with socks and tennis shoes. Each subject then picked up his/her personal pre-weighed (±0.01 g), insulated 3.8 litre beverage cooler (Igloo, Houston, Texas, USA), containing already prepared and chilled CHO-E or water, and then went to the tennis courts for the 120 minute training session (starting at 1400 hours). Once weighed, subjects were only allowed to drink from their own designated beverage cooler until after the post-session body weight measurement. No food consumption was permitted during each entire on-court training session. On completion of each training session, each subject immediately turned in his or her beverage cooler (so that it could be weighed) and refrained from consuming any further fluid until after a second body weight measurement was completed. After the post-exercise body weight measurement (in the same clothing as the pre-exercise body weight measurement), each subject emptied his/her bladder into an individual, plastic urine collection container, so that the urine volume could be determined (by weight, ±0.01 g). At pre-selected time points during each test session, core body temperature was recorded, and the subjects provided a rating of perceived thirst, gastrointestinal discomfort, and perceived exertion (see below).

Training sessions

Each of the two on-court training sessions was conducted outdoors on the same hard surface tennis courts and consisted of 120 minutes of intermittent sport specific practice drills and other activities (warm up and standard singles play). The drills and activities were conducted and controlled by one of the regular tennis academy coaches (same person for both sessions). Therefore, on each testing day, the players experienced the same workload, intensity, drill sequence, break times, and activity/rest intervals, to maintain consistency (as much as possible) in metabolic rate and load between trials. Moreover, players on the CHO-E beverage hit with those using water, to further equalise workload and metabolic rate between groups. The subjects were very familiar with all of the drills and activities, as well as the performance expectations—that is, strong effort and high intensity. Plenty of new tennis balls were available on each court, so that there would be minimal time required for retrieving tennis balls during the drills and singles play. The training sessions—that is, format and sequence of drills and other activities—were identical each day and were designed to have all players similarly, concurrently, and equally active. All drills were ''live ball''—that is, balls were hit between two players of comparable level as opposed to being fed by a coach or machine—so as to simulate actual play, with an emphasis on ground strokes (forehands and backhands), consistency, and change of direction. The volume, intensity, and types of drills and competitive singles play were typical of a pre-competition week for these young players. Each subject's designated beverage cooler was placed conveniently between courts, so that they would be readily available to the players during the regulated break times. Three-minute breaks occurred after every 10 minutes of drills for all players at the same times, during which time they could consume fluid from their respective beverage coolers ad libitum. During the breaks, the players sat or stood (by choice), while listening to the coach provide regular instructions related to the on-court training; however, there was no prompting to drink or not. For the standard singles play portion of each training session (last segment; about 30 minutes duration), subjects were permitted to consume fluid during odd-game changeovers (as in actual competition).

Perceptual measures

Each subject provided a rating of his/her own thirst perception (how thirsty the player felt at each specified time point: before exercise; at the mid-point of the training session; immediately after the end of training, before any fluid consumption), using a numerical/category scale (1 = not thirsty at all; 9 = very, very thirsty), during the water and CHO-E trials. Each subject also provided a rating of his/her own perception of gastrointestinal discomfort (how upset the player's stomach felt at the same specific time points: before exercise; at the mid-point of the training session; immediately after the end of training, before any fluid consumption), using a numerical/category scale (1 = none; 10 = severe). In addition, each subject's own rating of perceived exertion (how hard each player felt that she/he was working at each specified time point: at the mid-point of the training session and immediately after the end of training), using the Borg category ratio scale[17] (7 = very, very light; 19 = very, very hard), was recorded during the water and CHO-E trials. Each subject indicated all perceptual ratings by pointing to a specific value on each rating scale, in such a way that other players would not hear or see a selected rating.

Core body temperature monitoring

We used an ingestible temperature sensor telemetry system (CorTemp 2000; HQ Inc, Palmetto, Florida, USA) in this study, which has been shown and noted to provide a valid and feasible measure of core temperature during rest and exercise.[18] The sensor is listed with the Food and Drug Administration for one-time use and has been safely and comfortably used in a number of other research studies conducted at the Medical College of Georgia.[16 19] For each day of testing, the temperature sensor monitor was programmed with each subject's respective sensor identifiers, so that multiple sensors could be monitored during the subsequent test session for that day. Each subject ingested (with water to assist swallowing) his/her designated sensor seven to eight hours before the beginning of the desired monitoring period (before school). This allowed enough time for it to leave the stomach and proceed far enough through the digestive tract that fluid intake just before and during testing, as well as proximity to the liver (which might have been a potential source of temperature variability), would not affect it much. Just before ingestion, the sensor was activated and confirmed to be indicating ambient temperature. After ingestion, the sensor responded immediately and appropriately to the surrounding body temperature—that is, the monitored core temperature progressively increased. During the monitoring period of each test session, core temperature was recorded in each athlete just before the start of the on-court training session (within 15 minutes) and then at regular intervals (about every 20 minutes) during and at the end (within 2 minutes after) of the training session. The sensor was normally excreted (usually within 24 hours of ingestion), as evidenced by a lack of a transmitted signal, and did not have to be retrieved. No subject indicated any discomfort or particular difficulties with the use of the temperature sensor, and no subject presented with a sensor transmission signal (indicating that the previous sensor was not yet excreted) at the time they ingested another sensor for the second test session.

Calculated measures

A change in body weight (for each on-court training session) was calculated from the difference between body weight measurements before and after exercise. Therefore percentage change in body weight was based on initial body weight measured just before each training session. The amount of sweat lost (ml) during each training session was estimated from the difference in body weight measurements before and after exercise and the difference in that player's beverage cooler weight measured before and after exercise, which indicated the subject's total fluid intake for the training session. That is, the amount of sweat lost was estimated to be equal to the combined total of a difference in body weight and fluid consumed (assuming 1 g = 1 ml). Fluid retention (not including sweat loss) was calculated as the difference between the volume of fluid consumed during training and the volume of urine collected after each training session.

Statistical analysis

Descriptive statistics were calculated for all variables within each trial (water and CHO-E) and, if appropriate, at each measurement time. In addition, to examine differences in variables between trials, paired *t* tests were used when only one measurement was made per trial, and repeated measures analysis of variance was performed for each outcome when multiple measures were made for each trial. The repeated measures analysis of variance models contained fixed effect of sex, trial (water or CHO-E), and measurement time along with the two-factor interactions between trial and measurement time. Order and session effects were included as well. A Tukey multiple comparison procedure was used to examine post hoc differences. A two-factor or three-factor interaction between sex, trial, and measurement time was also examined in each model. However, none of the interactions involving sex were statistically significant and were thus removed from all models. Finally, correlations within water and CHO-E sessions between pre-exercise urine specific gravity and fluid intake, urine volume, fluid retention, percentage change in body weight, sweat loss, perceived exertion, thirst perception, gastrointestinal discomfort, and core body temperature across time were calculated. All statistical analyses were performed using SAS 8.2, and statistical significance was assessed at $\alpha = 0.05$. All results are presented as mean (SD).

RESULTS

Mean environmental conditions for both trials (water and CHO-E) were similar (wet bulb globe temperature: water trial, 79.9 (2.2) °F; CHO-E trial, 79.3 (2.6) °F; $p>0.05$), with mostly sunny skies and very little wind throughout testing. While on court, the players were completely exposed to direct sunlight throughout the training sessions (when not blocked

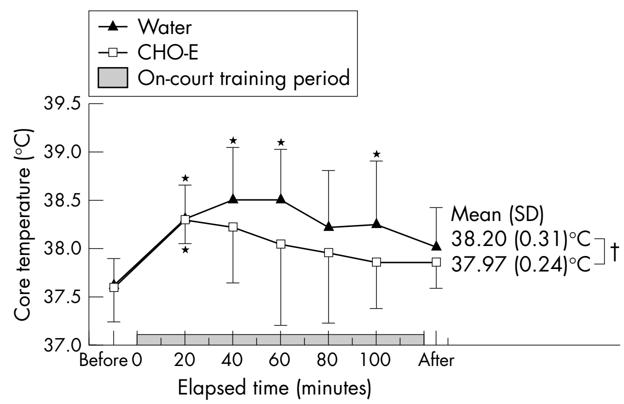

Figure 1 Core body temperature (°C) for all players recorded during specific time points before, during, and after training (about 20 minutes apart). *Significantly ($p<0.001$) higher body temperature than before exercise for the respective trial. †Significantly ($p<0.001$) lower main effect for trial—that is, mean body temperature for each trial, irrespective of measurement time. Data are presented as mean (SD). Water, Ad libitum ingestion of water; CHO-E, ad libitum ingestion of carbohydrate/electrolyte sports drink.

Table 1 Descriptive statistics by trial

Variable	Water	CHO-E	p Value
Pre-exercise urine specific gravity	1.025 (0.005)	1.024 (0.006)	0.4558
Fluid intake (ml)	1736.5 (543.3)	1896.6 (644.8)	0.0628
Urine volume (ml)	43.5 (24.4)	63.9 (49.3)	0.0515
Fluid retention (ml)	1693.0 (544.0)	1832.7 (644.5)	0.0892
Change in body weight (%)	−0.9 (0.6)	−0.5 (0.7)	0.0165
Sweat loss (ml)	2290.8 (707.8)	2171.6 (576.5)	0.1765
Rating of perceived exertion			
Mid-exercise	13.9 (3.4)	13.1 (3.3)	
Post-exercise	13.4 (2.1)	14.5 (2.8)	
Thirst perception			
Pre-exercise	2.6 (1.5)	2.7 (1.3)	
Mid-exercise	4.7 (2.0)	4.4 (1.8)	
Post-exercise	3.2 (1.8)	4.1 (1.8)	
Gastrointestinal distress			
Pre-exercise	1.2 (0.4)	1.4 (0.8)	
Mid-exercise	2.0 (1.6)	2.1 (1.7)	
Post-exercise	1.6 (0.8)	3.0 (2.3)	

Values are mean (SD). p Values are indicated when only one measurement was made per trial (paired *t* test). Water trial, Ad libitum ingestion of water; CHO-E trial, ad libitum ingestion of a carbohydrate/electrolyte sports drink.

by intermittent cloud cover)—that is, there was no shade provided by trees, buildings, or other structures.

Table 1 includes the descriptive statistics for the continuous variables by trial (water and CHO-E) and the paired *t* test results. Only one significant difference was detected in the paired *t* tests. Percentage change in body weight was greater ($p<0.05$) for the water trial than for the CHO-E trial.

Figure 1 presents the core body temperatures (°C) recorded at specific time points (about 20 minutes apart) during each trial. For the CHO-E trial, body temperature was significantly higher ($p<0.001$) only at 20 minutes after the start of exercise compared with the measurement before exercise. In the water trial, body temperature was significantly ($p<0.001$) higher 20, 40, 60, and 100 minutes after the start of exercise than before. However, there were no significant differences ($p>0.05$) between the water and CHO-E trial within each measurement time. Notably, in examining the main effect for trial—that is, obtaining an average body temperature irrespective of measurement time—a significantly ($p<0.001$) lower mean body temperature was observed during the CHO-E trial than during the water trial (37.97 (0.24)°C *v* 38.20 (0.31)°C respectively). Urine specific gravity measured before training (water trial, 1.025 (0.005); CHO-E trial, 1.024 (0.006)) did not correlate significantly ($p>0.05$) with any of the other measurements in table 1 or with core body temperature. NB in table 1 and fig 1, the mean (unadjusted) values are shown. However, a more rigorous repeated measures analysis was performed for each outcome variable (when multiple measures were made for each trial), taking into account the subject and adjusting for sex, day, and order. The adjusted means were used to determine statistical differences between trials (water and CHO-E) and repeated measures.

DISCUSSION

This study provides a novel insight into the hydration status, thermal strain, and associated perceptual responses in acclimatised adolescents during sport specific training in a natural outdoor setting in the heat. To date, very few such profiles have been described, especially with young athletes. Moreover, these findings provide a further valuable perspective on certain potential differences related to fluid balance and thermal strain when comparing ad libitum intake of a CHO-E beverage and water. Although the environmental conditions in this study were not extreme, the mean heat stress (wet bulb globe temperature of nearly 80°F) during each trial was within the range recognised by governing bodies as presenting a high risk,[20] and thus it is recommended that activities be restricted for children and adolescents under such conditions.[1] Therefore the ambient environment during each test session still introduced a thermal challenge to these players, even though they were accustomed to the on-court conditions.

One prominent finding that is consistent with observed typical behaviours in tennis players[21 22] was how seemingly dehydrated the players were coming into training, before any exercise related sweat losses were incurred during the on-court sessions. Urine specific gravity was fairly high before training (and virtually identical) on both days, suggesting the same level of significant dehydration right before both training sessions.[23] Clearly, these athletes need to drink more throughout the day, especially when training in these (or worse) conditions. Insufficient hydration status before training or competition is often the case with athletes in other sports as well,[24 25] even though they are often provided with guidelines and regular reminders about hydration from coaches and other sources. In addition, most of these players did not match sweat losses with an equivalent fluid intake volume during the training sessions, as evidenced by the percentage change in body weight. The total sweat loss for the group for the entire two hour training session was only just over 2 litres during each trial. Thus most, if not all, of the players probably could have more closely and comfortably offset sweat losses with a near equal amount of concomitant fluid intake. Given the number of regular breaks, the players certainly had sufficient opportunity to ingest more fluid than we observed. A loss of just less than 1.0% of initial body weight would probably not have a measurable negative effect on performance, except when taking into account that the players began each session with an apparent significant fluid deficit. Notably, the minimal percentage change in body weight shown here underscores the importance of regular breaks to consume fluid during training, if coaches and athletes want to minimise fluid deficits incurred during activity.

The most notable outcome difference between the CHO-E and water trials was the overall lower core body temperature when players were drinking the CHO-E beverage. This contrast may have been influenced by the subtle mean differences we saw in fluid intake (mean intake was slightly greater with CHO-E, but the difference was not significant) and fluid retention (again, on average, slightly greater with CHO-E) that resulted in the measured significant difference in percentage change in body weight, and thus mean body temperature.[11] That is, during the CHO-E trial, the collective effect of these and other contributory factors related to hydration status may have been sufficient to significantly modulate overall thermal strain, even though each of the associated variables was not shown to be significantly different between trials. Interestingly, the mean body temperature in each trial was not significantly associated with fluid intake, fluid retention, sweat loss, or percentage change in body weight. This was somewhat surprising, although it might simply suggest that athletes may, at times, be able to "get away with" poorer hydration habits during practice, without a fluid deficit necessarily translating into a significant increase in body temperature or risk of heat related complications. This may not be the case during actual competition, when young athletes will often maintain a strong effort, despite not feeling 100% or even having the capacity to safely continue. However, previous studies[13 15 26 27] indicate that beverage composition does not affect body temperature, with only mild levels of hypohydration, as were incurred in this study. In addition, pre-training hydration status (as indicated by urine specific gravity) did not have the expected measurable effect on selected outcome variables—that is, fluid consumption and core body temperature, as well as perceptions of thirst and exertion.

Other studies have shown more notable differences in fluid consumption, when comparing sports drinks and water, with children exercising in the heat.[13 15] The less prominent difference in fluid intake between CHO-E and water observed here may be related to differences in age or activity or an over-riding ingrained behaviour characteristic of experienced competitive players—that is, these players are encouraged to drink and are comfortable with consuming a certain amount of fluid regardless of beverage characteristics and appeal. With such subjects, a greater number of players may be needed to detect significant differences in fluid intake and retention. Lastly, the fact that some players indicated a greater perception of gastrointestinal discomfort after training during the CHO-E trial underscores the potential for individual variability in drink specific fluid intake tolerance.

These findings point to the fact that there may be measurable differences related to hydration status and thermal strain when a CHO-E beverage is compared with water during similar outdoor training sessions. However, the training protocol and environmental stress in this study did

What is already known on this topic

- Fluid intake and hydration status directly modulate thermal strain during exercise in the heat, although very few such data are available from youth sports
- Sports drinks have been shown to enhance fluid intake during exercise in the heat in children and adolescents, but most of these data are from laboratory settings

What this study adds

- This study provides a novel profile of hydration status, fluid intake, sweat loss, and core temperature responses in youth athletes during sport specific training in a natural outdoor field setting in the heat
- The findings indicate that a carbohydrate/electrolyte sports beverage may be more effective than water in minimising fluid deficits and thermal strain during tennis training in the heat in highly skilled, acclimatised adolescent tennis players

not prompt the expected relations between hydration status, body temperature, and other measures. Overall, the results of this study provide unique insight into selected physiological and perceptual responses related to fluid balance and thermal strain in adolescent tennis players during on-court training in the heat. Such insight will help to establish more specific and effective guidelines and strategies for improving the safety of players during tennis training in warm to hot conditions through improved hydration. Moreover, these findings form an important basis for continued research aimed at examining the physiological challenges and responses in adolescents during tennis and other sport participation and training in the heat. Importantly, such research should include more stressful environments and repeated same-day bouts of training and competition, as well as opportunities to more comprehensively examine potential sex and maturation related differences. Other sports should also be examined. Perhaps, most importantly, an examination of these fluid balance, perceptual, and physiological measures during actual competition may be more indicative of beverage related differences and thus should be considered (despite the inherent challenges and confounding factors associated with such research).

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