PRE-PRINT

Body Weight Changes in Child and Adolescent Athletes during a Triathlon Competition

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ABSTRACT

We examined young athletes during a triathlon performed in a hot climate. Complete or partial data were available for 95 athletes competing in the National Triathlon Championship in Costa Rica. Mean±SD for age and body weight (BW) were 13.1±2.5y and 46.3±11.5kg, respectively. Race requirements included: 500m swimming, 15km cycling, 3.5km running for juniors (9-13y); 800m swimming, 30km cycling, 8km running for seniors (14-17y). WBGT on race day was >31˚C. BW recorded pre- and post-race was available for 92 athletes and performance data were available for 83 of these. Information regarding symptoms experienced during the race was available for 95 athletes. Change in BW (%ΔBW) was calculated and ranged from +0.6% to –2.4% for junior boys (–1.2±0.9%), +0.7% to –2.5% for junior girls (–1.3±0.9%), 0% to –2.8% for senior girls (–1.3±0.9%), and +0.6% to –4.5% for senior boys (–1.7±1.1%). Eighteen participants reported no medical symptoms. Of 77 participants who reported symptoms, 42.9% reported exhaustion/fatigue, 36.4% reported side stitch/cramp, and 23.4% reported dizziness. Participants reporting no medical symptoms achieved almost identical (P=0.99) %ΔBW as those reporting at least one symptom. %ΔBW was more negative (P=0.005) in participants who reported dizziness" (-1.9%ΔBW) compared with those who did not (-1.4%ΔBW). %ΔBW was associated with performance in junior girls (r=0.47, P=0.02) and senior boys (r=0.51, P=0.01), with a trend in junior boys (r=0.41, P=0.053) but not in senior girls (r=0.004, P=0.99). Young athletes participating in a triathlon in a hot climate can tolerate mild to moderate levels of dehydration, without detrimental effects to self-assessed health.

KEYWORDS: Heat Stress, Thermoregulation, Hydration

INTRODUCTION

Over the last decades sport participation among youth has been popular. The 2009-10 High School Athletics Participation Survey, for example, found that sports participation increased by ~95% since 1971, with a staggering 10-fold increase in female participants (THE NATIONAL FEDERATION OF STATE HIGH SCHOOL ASSOCIATIONS, 2009). In Canada, the 2008 Physical Activity Monitor found that 75% of children and youth participated in sports (Canadian Fitness & Lifestyle Research Institute, 2010), and children who participate in sport are more likely to be physically active (Canadian Fitness & Lifestyle Research Institute, 2009). Such popularity in youth sport participation requires an awareness of the factors that are associated with the health and well-being of the child athlete (Meyer *et al.*, 2007;Jeukendrup & Cronin, 2011). The need for this greater understanding is further highlighted by the unique physiological responses of the growing child, particularly in the context of thermoregulation and exercise in the heat. This issue is highly relevant for children from Latin America and other tropical countries, because these young athletes live and train in a tropical area and are exposed every day to a high level of environmental heat stress.

Based on findings from controlled laboratory studies, children exercising in the heat demonstrate a greater rise in core body temperature for a given level of dehydration (Bar-Or *et al.*, 1980), lower sweating rates (Bar-Or, 1989;Drinkwater *et al.*, 1977;Haymes *et al.*, 1975;Falk, 1998), and a different sweat electrolyte composition (Meyer & Bar-Or, 1994) when compared to adults. These growth-related characteristics have been taken as reinforcement for the need for child-specific advice for the medical practitioner charged with the care of the young athlete participating in sport competitions in hot or humid climates. To safeguard the child’s health and well-being while exercising in the heat during recreational and competitive events, fluid intake guidelines were established (American Academy of Pediatrics Committee on Sports Medicine, 1982) and then reinforced (American Academy of Pediatrics.Committee on Sports Medicine and Fitness, 2000). These recommendations focus on avoiding dehydration and are based predominantly on laboratory-based studies indicating that children do not respond to high heat stress as effectively as adults. Consequently, succeeding investigations tended to utilize experimental designs in which the child was fully hydrated at the start of an exercise session and was allowed to drink at least *ad libitum* during the session; the degree of dehydration reached in these studies seldom exceeded 1% of initial body weight (Meyer *et al.*, 1995;Rivera-Brown *et al.*, 1999;Rivera-Brown *et al.*, 2008;Wilk *et al.*, 2000;Wilk & Bar-Or, 1996;Wilk *et al.*, 2007). It remains unclear, however, to what extent these artificial conditions truly reflect the young athlete's real-life responses, when competing under hot climatic conditions.

The current study was undertaken to examine child and adolescent athletes during a real-life triathlon competition performed in a hot climate. We were interested in documenting changes in BW, as a means to estimate dehydration, and the prevalence of self-reported symptoms of heat illness. Given the defined association between dehydration and reduced exercise performance in the heat observed in adults (Sawka & Noakes, 2007), we also examined whether a relationship existed between change in BW and race performance in children and adolescents.

METHODS

Study design

This study was approved by the Hamilton Health Sciences/Faculty of Health Sciences Research Ethics Board at McMaster University in Hamilton, Ontario, Canada. The National Triathlon Championship in El Coco, Costa Rica, was chosen for this field study for the following reasons: a large number (more than 100) of child and adolescent participants, a typically very hot environment, and long enough race duration (>1h) to challenge body hydration and thermoregulation. The race for the youngest (junior) group (9-13 years old) involved 500 m of ocean swimming, 15 km cycling and 3.5 km running; it started at 09:00. The adolescent (senior) athletes (14-17 years old) started their race at 11:00, involving 800 m of ocean swimming, 30 km cycling and 8 km running. Study participants were recruited through an invitation letter with the study information delivered to all race participants of age 17 and under either by mail or by their coaches about one week prior the event. Ninety-nine boys and girls (89%) out of the 111 9- to 17-year-old participants registered for the race agreed to participate in this study and complete or partial data are available for 95 of these.

Experimental protocol

Study participants, their parents, coaches, and the research team met the evening prior to the race to discuss details on how the study would be conducted. By design, the athletes were asked to follow their normal competition day behaviors regarding sleeping, eating, drinking, warming up, etc, because we did not want to influence these behaviors. A strength of this study is that we did not attempt to control or standardize pre-race hydration status so that the results would truly reflect the real-life conditions for these young athletes. Participants were told that all study assessments, measurements and monitoring would be done before and after the race without interference with their preparation for the competition or throughout the race. Parents were asked to complete a brief questionnaire about the general medical history of the child, and the written consent signed by a parent/guardian and verbal assent by the child/adolescent athlete were obtained.

On race day, about 15-30 min prior to the start of the race and after warming up, study participants reported to the testing area (50 m from start/finish line), where they were marked on their arms with a non-washable color marker to be identified by the research team. They voided and their nude BW was recorded using a battery-operated portable scale: BWB-800 Separate, 200 kg capacity, ±0.1 kg accuracy (Tanita®, Arlington Heights, Illinois). To assure participants' privacy the scale was placed in a tent especially prepared for this purpose, while the remote display was positioned outside of the tent. The measurement of BW was repeated in the testing area immediately upon completion of the race with a delay no longer than 5 min. Hydration status was taken as the percent change in BW (%ΔBW) calculated as: (post-race BW – pre-race BW)/pre-race BW × 100. Prior to the post-race BW check, the participants emptied their bladder into a container that we provided. The urine specific gravity (USG) was then measured by a Fisherbrand® hydrometer (Fisher Scientific, USA) in a 50 mL glass cylinder, if a urine sample of at least 40 mL was provided.

Details regarding each participant's general medical health status were obtained from the parent questionnaire, but information about medical issues experienced during the race were collected for each child by two sources:

1. A brief post-race verbal interview ("Did you experience any pain, dizziness, fainting, exhaustion, other complaints, or need for medical attention?") was conducted while the participant was being weighed.
2. A "road patrol" report, prepared by medical doctors volunteering to patrol and to provide medical help to those who might need it on the race course.

A final questionnaire was completed by all the study participants to provide information about their racing experience and fluid intake on that particular day. They had free access to water and sports drinks provided by the race organizers, as well as their own supplies. For the purpose of this study, "sports drink" was defined as a beverage containing carbohydrates and electrolytes, but without caffeine or other similar ingredients. By design, we did not interfere or try to monitor fluid intake during the race because we did not want to influence the fluid intake behavior of the participants.

Environmental conditions (air temperature, humidity, and radiation) were continuously monitored throughout the race using a WibGet® heat stress monitor (Coll, Mississauga, Ontario), positioned on a tripod, one meter above ground level on the side of the road used for the cycling and running course. The environmental conditions (air temperature above 34˚C, humidity ~50%, and radiation more than 45˚C) were very challenging from the beginning (09:00 in the morning) of the competition. WBGT throughout the day was 30.3˚C (08:40 in the morning), 31.3˚C (09:45), 31.8˚C (10:20), 32.2˚C (12:05), and 32.4˚C (13:00). Although we did not measure water temperature on race day, surface water temperature around El Coco Beach is typically between 26 and 28°C according to the Ocean Research Center at the University of Costa Rica (http://www.cimar.ucr.ac.cr/en/tides-waves-tropical-pacific-ocean-temperatures.php, recovered on October 7, 2011).

Data analyses

To examine child and adolescent athletes during a real-life triathlon competition performed in a hot climate, descriptive statistics were performed on all pertinent variables, including %ΔBW. Post-race information regarding medical problems were grouped by category and tabulated; independent-sample, two-tailed t-tests were used to compare %ΔBW between participants reporting "nothing" to those reporting at least one symptom, as well as to compare those reporting each of the most common symptoms to those reporting the absence of that specific symptom. To determine whether a relationship existed between %ΔBW and race performance in children and adolescents, individual race time was plotted against %ΔBW during the race. Linear regression models were performed separately for each gender and age category.

RESULTS

%ΔBW

Of the 95 participants, complete data on %ΔBW were available for 92 participants. For general characteristics of these participants, see Table 1. %ΔBW values ranged from +0.6% to –2.4% for the boys and from +0.7% to –2.5% for the girls in the junior group, where a positive number indicates a gain in BW and a negative number reflects a loss in total BW. For the senior group, the %ΔBW ranged from 0% to –2.8% for the girls, with greater variability for the boys (from +0.6% to –4.5%). Figure 1 summarizes the proportion of junior and senior participants achieving varying values of %ΔBW. Fifteen percent of boys and 12% of girls in the junior group, and 14.3% of boys and 7.7% of girls in the senior group had %ΔBW values greater than or equal to 0, although this was never greater than 1% of initial BW; 50% of boys and 48.1% of girls in the junior group, and 10.7% of boys and 38.5% of girls in the senior group lost up to 1% of initial BW; 53.8% of boys and 48% of girls in the junior group, and 32.1% of boys and 30.8% of girls in the senior group lost between 1 and 1.9% of initial BW; 15.4% boys and 20% girls in the junior group, and 65.7% boys and 23% girls in the senior group lost between 2 and 2.9% BW; 7.1% of the senior boys lost at least 3% of BW.

Table 1. General characteristics of participants with complete body weight change data.

	Junior Girls	Junior Boys	Senior Girls	Senior Boys
n	25	26	13	28
Age, yr	11.4 ± 1.5	11.0 ± 1.6	15.2 ± 1.2	15.5 ± 1.2
Pre-race body mass, kg	40.4 ± 8.2	37.9 ± 8.7	49.3 ± 6.3	58.1 ± 7.1
Post-race body mass, kg	39.8 ± 8.0	37.5 ± 8.5	48.6 ± 6.2	57.2 ± 7.0

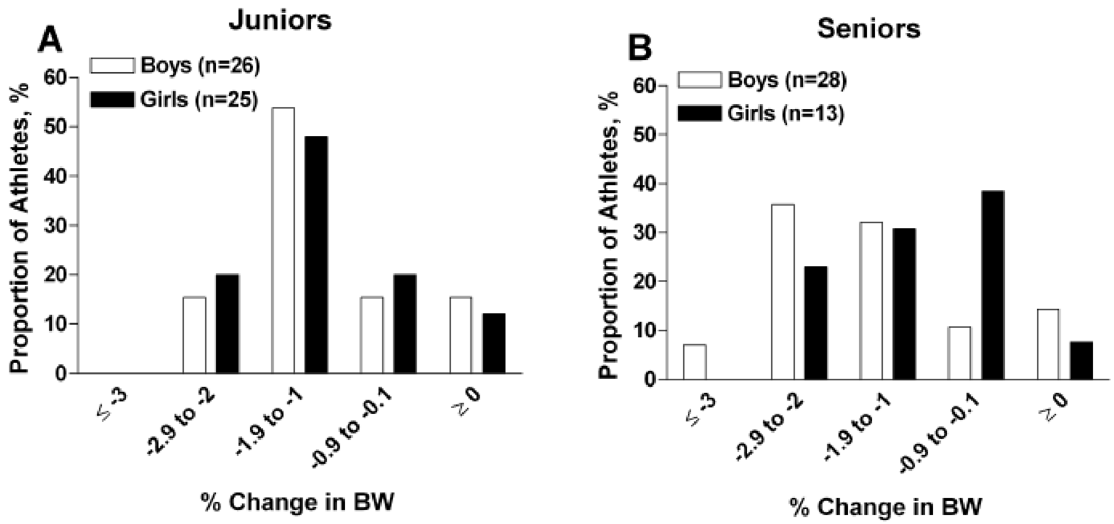

Figure 1. Values for %ΔBW in junior (**A**) and senior (**B**) triathletes (n=92).

Following the race, only 27% of participants could produce a sufficient volume of urine (≥ 40 mL) for the USG measurement (mean = 1.014; range 1.000 to 1.030 kg/L).

Self-reported Symptoms

Of the 95 participants, post-race questionnaires were available for all of them. No competitor required medical intervention during or after the race and none of the participants reported health-related problems serious enough to force them to quit the race, as reflected by the medical road patrol report. Eighteen participants (18.9%) reported absolutely no medical problems or symptoms during the race. Symptoms and complaints of the remaining 77 participants are presented in Table 2. The most frequently reported symptoms were exhaustion/fatigue by 33 participants (42.9%) and side stitch/cramp by 28 participants (36.4%). Dizziness was reported by 18 participants (23.4%). One girl who complained of chest pain and difficulty breathing at the end of the race was examined and monitored by a medical doctor, with full recovery.

Table 2. Symptoms and complaints reported by 77 participants during the post-race medical interview (participants could report more than one symptom).

Symptom	Number of answers	Percentage
Exhaustion/fatigue	33	42.9%
Side stitch	28	36.4%
Dizziness	18	23.4%
Nausea	11	14.3%
Stomach ache	6	7.8%
Cramping	4	5.2%
Leg pain	3	3.9%
Vomiting	2	2.6%
Difficulty breathing	2	2.6%
Bloating	1	1.3%
Chest pain	1	1.3%

The participants who reported no medical symptoms (“nothing”) in the post-race questionnaire and those who reported at least one symptom achieved almost identical levels of %ΔBW (-1.4±0.9% ΔBW, P = 0.99). %ΔBW was similar in the participants who reported “exhaustion/fatigue” compared with those who did not (P = 0.35); the same was true for “stitch” (P = 0.62). In contrast, the level of %ΔBW was significantly (P = 0.034) more negative in the participants who reported “dizziness” (-1.9% ΔBW, range -2.7 to -1.0% ΔBW) than in those who did not report it (-1.4% ΔBW, range -4.5 to 0.7% ΔBW). All participants except one reported fluid intake during their race. For most of them (68.5%), the beverage of preference was a combination of water and sports drink; 23.6% reported to drink water only, 6.8% sports drink only, and one participant (1.1%) reported “other” as the beverage of preference.

Performance

Of the 92 participants with complete body weight data, performance data were available for 83 of them. Race results (time and ranking) were obtained from the organizers after the competition.

Racing time in the junior group ranged from 59 to 103 min for girls (75.2 ± 10.8 min) and 56 to 102 min for boys (73.7 ± 15.3 min); in the senior group the range was 112 to 150 min for girls (119.9 ± 26.3 min) and 94 to 145 min for boys (118.0 ± 12.5 min). Of these 83 participants, there was a significant positive association (Figure 2) between racing time and degree of %ΔBW in the junior girls (r=0.47, P=0.02) and senior boys (r=0.51, P=0.008), and tended to be correlated in the junior boys (r=0.41, P=0.053) but not in senior girls (r = 0.004, P = 0.99).

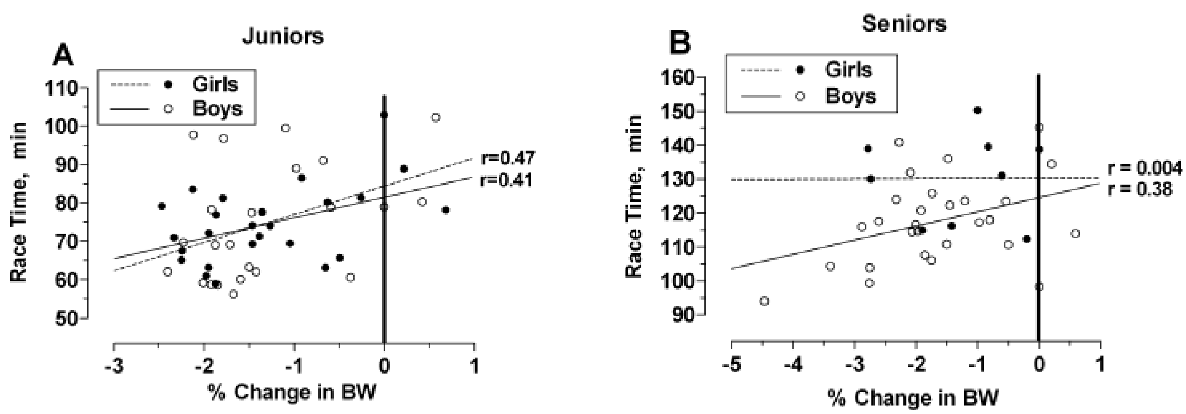

Figure 2. Relationship between race time and %ΔBW in junior (**A**) and senior (**B**) triathletes (n=83). Solid vertical line represents euhydration.

DISCUSSION

There is a general trend towards increased sport participation among children and youth, and many of these sporting events occur in hot climates. Several characteristics are believed to place children at increased risk for heat-related illness during exercise. Compared to adults, children have a higher metabolic rate per kilogram BW (Astrand, 1952), lower sweating rate (Bar-Or *et al.*, 1980;Bar-Or, 1989;Drinkwater *et al.*, 1977;Haymes *et al.*, 1975) and greater rise in core body temperature for a given level of dehydration (Bar-Or *et al.*, 1980). For these reasons, child-specific fluid intake guidelines were developed with the intent to safeguard the young athlete (American Academy of Pediatrics Committee on Sports Medicine, 1982). However, these recommendations are based primarily on laboratory-based studies and it is unknown to what extent these artificial conditions truly reflect the young athlete's real-life experiences, in terms of body fluid balance. By documenting the degree of %ΔBW achieved by child and adolescent athletes participating in a triathlon, we have added to the needed literature describing real-life experiences of young athletes. We found that none of the young athletes requested medical help or intervention either during or after the race despite levels of dehydration reaching more than 4% of BW – a level of body fluid deficit that, traditionally, would have been considered unethical for laboratory-based research in children.

This triathlon was conducted in very hot conditions (WBGT >31˚C). Despite such extreme climatic conditions, none of the children and adolescents completing the race reported symptoms severe enough to require medical assistance. This was true even for those athletes who dehydrated the most. Only those reporting dizziness presented with slightly more negative %ΔBW than those who reported no symptoms. This general lack of significant medical or health effects of competition in the young athlete is consistent with the lack of documented cases of heat-related illness or injuries in children and adolescents exercising in the heat (Rowland, 2008). While the participants involved in the current study were indigenous to a warm climate, we have no reason to believe that the results would not be applicable to children in other parts of the world who are exposed to hot weather. In North America, for example, it would not be uncommon for children to compete in very hot conditions and to train year round. Repeated training itself would induce a significant amount of heat acclimation. However, it would also be important to repeat the current study in different regions of the world.

Laboratory-based studies are fairly clear in demonstrating that levels of dehydration greater than 2% BW in adults (Cheuvront *et al.*, 2003;Cheuvront *et al.*, 2005;Walsh *et al.*, 1994) and 1%

BW in children (Wilk *et al.*, 2002) can reduce exercise performance in the heat. Recommendations for fluid intake therefore encourage drinking to stay close to euhydration during prolonged exercise (American Academy of Pediatrics.Committee on Sports Medicine and Fitness, 2000) or to prevent excessive dehydration (>2% ΔBW) (Sawka & Noakes, 2007). Our questionnaire revealed that all of the participants but one reported fluid intake during the race. Indeed, 15.4% percent of boys and 12% of girls in the junior group, and 14.3% of boys and 7.7% of girls in the senior group remained completely euhydrated or had slightly positive %ΔBW values, indicating they actually gained weight during the race. In contrast, 15.4% of the Junior boys, 20% of the Junior girls, 35.7% of the Senior boys and 23% of the Senior girls lost 2-3% BW, while 7.7% of the Senior boys lost more than 3% BW. In light of these various drinking behaviors, an interesting finding in this study was that faster race times were achieved by participants experiencing the greatest degree of voluntary dehydration. A similar finding has been reported before in adults (Sharwood *et al.*, 2004). It may be that performance during competition in the heat is better for child and adolescent athletes who have a high tolerance for dehydration, indicated by negative values for %ΔBW, although our study did not address this question specifically. Alternatively, it is possible that faster competitors have higher sweat rates, resulting in similar total sweat losses in spite of faster race times (Barr & Costill, 1989), while having less time available for rehydration; their higher voluntary dehydration may be the result, not the cause, of faster racing. In light of laboratory-based studies demonstrating an inverse relationship between dehydration and exercise performance, it is also possible that the winners could have been even faster had they not become dehydrated (Below *et al.*, 1995;Fritzsche *et al.*, 2000;Wilk *et al.*, 2002). However, the children who maintained their body weight in the current study (i.e., avoided dehydration) did not have the best performance times. Clearly, more work is needed to understand the relationship between %ΔBW and performance in young athletes.

Because we did not control fluid intake in the participants, the interpretation of the USG results should be made with caution. USG measurements are best made under stable renal conditions, as fluid ingestion close to the time of measurement could create erroneous results (Oppliger *et al.*, 2005;Popowski *et al.*, 2001). This is a limitation in this study that we acknowledge. However, the fact that most of the participants (73%) could produce little (<40mL) or no urine following their race is a reasonable indicator of generalized dehydration.

In summary, we found that a proportion of heat-acclimatized children and adolescents participating in a triathlon competition in high climatic conditions voluntarily dehydrate to moderate levels, without apparent detrimental effects to their subjective assessment of health. A smaller proportion of children and adolescents avoided dehydration. We also found that faster performance times were associated with greater dehydration. Our findings raise interesting questions about the appropriateness of using laboratory-based studies to develop guidelines for active youth exercising in the heat. The current study provides justification to further investigate the impact of real-life levels of body fluid balance on exercise tolerance, physiological function, and health of active youth.

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