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HYDRATION AND THERMAL STRAIN IN YOUTH SPORTS: RESPONSES AND RECOMMENDATIONS TO MINIMIZE CLINICAL RISK AND OPTIMIZE PERFORMANCE IN THE HEAT

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- Ensuring that young athletes are healthy, sufficiently fit and rested, well-hydrated, well-nourished and progressively acclimatized to the environment is critical to improving exercise-heat tolerance and minimizing the risk of exertional heat illness in youth sports.
- As the heat and/or humidity rise, outdoor athletic activities should be appropriately modified for safety and performance, in relation to the environmental conditions and individual athlete health status and fitness.
- All youth athletes should be closely monitored in the heat. Any significant deterioration in performance with notable signs of struggling and developing exertional heat illness is sufficient reason to immediately stop participation and seek appropriate medical attention.
- With sufficient preparation, appropriate modification, adjustment to the known contributing risk factors and close monitoring, exertional heat illness is usually preventable, and the vast majority of healthy children and adolescents can safely participate in outdoor sports – even when it is hot.

INTRODUCTION

The advantages of appropriate regular exercise and other physical activity are well known. For school-age youth, healthy participation in sports and other physical activities can provide important physical, physiological, psychological and social benefits, as well as establish a continuing foundation for lifelong overall health, fitness and success (FIMS/WHO, 1998; Koivusilta et al., 2012; Micheli et al., 2011). The return on regular and sufficient physical activity, and quality physical education and sports participation as a student-athlete can even extend to enhanced academic achievement (Rasberry et al., 2011; Singh et al., 2012).

Youth athletes face particular performance and safety challenges when practicing or competing in the heat. This is especially evident during "two-a-days" or organized tournament competition when young athletes have to practice or play in demanding environmental conditions more than once on the same day (Bergeron, 2009). Only recently has there been an increase in sport- and physical activity-specific published studies on hydration and thermoregulatory challenges and responses in natural outdoor settings with active youth. Accordingly, the growing (albeit slowly) evidence-informed support for current hot-weather recommendations and guidelines for effectively managing hydration, reducing thermal strain, optimizing performance and minimizing exertional heat illness risk is recognized and welcomed (Bergeron et al., 2011; Rowland, 2008).

Notably, there has been a long-standing perspective that children are less effective than adults in regulating body temperature during exercise in the heat and consequently are less tolerant to a hot environment, and thus are at greater risk for incurring exertional heat illness. More current research, however, does not support the viewpoint that amply hydrated children (9-12 yr) have insufficient cardiovascular capacity, less effective thermoregulation or lower exercise-heat tolerance (Inbar et al., 2004; Rivera-Brown et al., 2006; Rowland et al., 2007; 2008). Therefore, effective and appropriate heat safety guidelines for youth athletes training and competing in the heat should focus on the readily modifiable risk factors such as intensity and duration of activity, hydration management, frequency and duration of breaks and recovery time between sessions and contests, in relation to the on-site environmental conditions – not any purported thermoregulatory disadvantages inherent to children and adolescents. The information presented here can help all adults (parents, coaches, teachers, tournament administrators and health care providers) who work with and oversee youth athletes during sports practice and competition in the heat to keep kids safe and improve their opportunities for achieving and enjoying a healthy and optimal performance.

SWEAT LOSSES AND REHYDRATION

Adolescent athletes are readily capable of sweating in excess of 1.0 liter per hour (L/h) during practice, training and sport competition in hot conditions (Bergeron et al., 2006). Notably, sweating rates can often reach 2.5 L/h or more with older adolescents during strenuous physical activity in hot and humid weather (Bergeron, 2003). Accordingly, as environmental heat stress worsens (air temperature, humidity and/or solar radiation climbs) and intensity and duration of physical exertion are greater, the need for evaporative cooling and sweating proportionately increases and the risk for incurring a measurable body water deficit is concomitantly and proportionately amplified. Boys and girls (9-12 yr) have been shown to typically sweat 300 to 700 milliliters (mL)/h during non-sport exercise in the heat (Bergeron et al., 2009; Inbar et al., 2004; Rivera-Brown et al., 2006; Rowland et al., 2007; 2008). However, reports on sweat losses in this age group during outdoor sports practice, training or competition are limited.

For 9-12 year-olds, consuming 100-250 mL (~3-8 oz.) every 20 min, and up to 1-1.5 L (~34-50 oz.)/h for adolescent boys and girls, is generally enough to sufficiently minimize sweating-induced body water deficits during sports activity in the heat, as long as pre-activity hydration status is good. However, drinking voluntarily and regularly to thirst during practice, training or competition, may not be sufficient to avert a significant post-exercise body water deficit following a long session or contest (Bergeron, 1996; 2003; 2009). The cumulative effect can be particularly evident when participating in multiple sessions on the same day over several days in a row. Resulting sizable body water deficits (often considerably greater than 2% or 3% of body mass) can have a measurable negative effect on subsequent cardiovascular and thermal strain, exercise-heat tolerance, performance and safety. Accordingly, effective practical strategies to encourage sufficient fluid intake during physical activity in the heat and optimize hydration status in recovery to the extent possible and appropriate can play an important role in maintaining performance and reducing exertional heat illness risk.

Compared to flavored or unflavored water, a carbohydrate-electrolyte drink has been shown to be more effective in encouraging voluntary fluid intake in young boys during exercise in the heat (Rivera-Brown et al., 1999, Wilk and Bar-Or, 1996). More recently, however, unflavored water was equally effective as a carbohydrate-electrolyte sports drink in maintaining body weight in physically active young girls during intermittent exercise in the heat (Wilk et al., 2007). High-level, fit junior tennis players also displayed only a small difference in *ad libitum* fluid consumption when water consumption was compared to commercial sport drink intake during intense on-court training in the heat (Bergeron et al., 2006). Because elite young athletes may be more informed and regularly encouraged to rehydrate sufficiently, a more consistent fluid intake rate and volume during training and competition, regardless of beverage flavoring and appeal, may reflect a more disciplined fluid consumption behavior characteristic of expert tennis players and other athletically experienced competitors. Likewise, non-athletically experienced children may be more influenced by the flavoring of a sports drink that would thus prompt more measurable differences in fluid intake between the different beverages.

Through the adolescent years, a young athlete's sweat rate increases with growth and maturation. Sweat electrolyte losses (particularly sodium and chloride) generally increase as well, due to a greater rate of sweating and higher sweat sodium concentration. Therefore, sweat sodium losses can be substantial, even for a young athlete who is well-acclimatized to the heat. Accordingly, optimal rehydration can be challenging and often involves more than simply ample fluid intake. With pre- or early pubescent athletes, the potential sweat-induced sodium deficit incurred during a single practice/training session or game or match is not likely to be substantial, and thus is not likely to have a significant physiological or performance impact. Accordingly, a normal diet will typically be sufficient to maintain day-to-day electrolyte balance, even if only water is consumed during athletic activity. Older adolescents, however, generally sweat considerably more and can lose from 2 to nearly 5 g of sodium/h (Bergeron, 1996; 2003). A more deliberate effort to match sodium intake during and between each session or event with individual sweat sodium losses is imperative to offset these greater electrolyte losses and to better retain and distribute the large volume of ingested water to all body fluid compartments (Mitchell et al., 2000; Sanders et al., 1999; 2001; Shirreffs and Maughan, 1998). Otherwise, insufficient sodium intake may result in incomplete rehydration and negatively affect physiological function and performance. This can also increase the risk for incurring exertional muscle cramps in a young athlete (Bergeron, 2008).

THERMAL STRAIN DURING PRACTICE AND COMPETITION

While recent research with 9-12 year-olds indicates that youth in this age range are not at any maturation-based disadvantage and consequent greater risk for incurring exertional heat illness compared to adults, youth sports training or competing in the heat can certainly challenge cardiovascular and thermoregulatory capacity and exercise-heat tolerance in this young population. Even with ample hydration, a child's metabolic heat production, heat storage and thus body core temperature will rapidly increase during vigorous physical activity in the heat. Strong and constant sun exposure can contribute further to accumulating heat storage and physiological strain. Notably, repeated complex, intermittent activity patterns with varying, frequently demanding workloads and short recovery periods that are characteristic of many competitive youth sports can greatly exacerbate thermal and cardiovascular strain, compared to continuous exercise (Mora-Rodriguez et al., 2008). This suggests and supports a potentially greater clinical risk warranting particular caution and monitoring of youth during long periods of recurring high-intensity activity in certain sports (e.g., soccer, singles tennis or football conditioning drills) in the heat.

With the stark exception of American football, there have been very few reported exertional heat stroke deaths in most youth sports – even with those held outdoors in the heat. However, the incidence of exertional heat illness among high school athletes and those treated in emergency departments reported by the Centers for Disease Control and Prevention more fully underscores the true extent of this problem that has a predominant frequency and severity with football (Centers for Disease Control and Prevention, 2010; 2011). In other sports, self-determined and self-controlled pacing to avoid dangerous levels of physiological strain, by slowing down and/or modifying the intensity of play, likely plays an integral role in minimizing thermal strain and extending the opportunity to continue training and play in a range of challenging environmental conditions (Tucker, 2009). Unfortunately, while visible indications of extensive thermal strain are routinely observed in young athletes in a variety of sports during hot-weather training and competition, the prevalence and extent of significant physiological strain and body core temperature responses that do not result in emergency department treatments are largely unknown in football and other youth sports.

Much of the limited research to date examining thermal strain in youth sports has been conducted in tennis. Bergeron et al. (2006) examined differences in *ad libitum* fluid intake, comparing a 6% carbohydrate-electrolyte drink (CHO-E) and water, and thermal strain in highly skilled, fit junior tennis players (15.1 + 1.4 yr) during intense on-court training in a very warm environment (wet bulb globe temperature ~26.4 °C). While a number of players in this study began the monitored training sessions not well-hydrated, pre-practice urine specific gravity (indicating hydration status) was not statistically associated with body core temperature (which approached/ reached 39 °C for some players) during the 2 h practice sessions. Even well-supervised practice permits individuals to vary their own intensity and effort, without being "penalized" (affected) as severely for insufficient fluid intake. This does not, however, reinforce good hydration habits for more meaningful competitions and tournament events that might be contested in hot weather, where there is less margin of error and when a significant total body water deficit is more likely to be reflected in greater thermal strain and lower performance. However, in examining the main effect for trial (water vs. CHO-E), 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 vs. 38.20 + 0.31 °C). Although such a small difference in observed thermal strain is not likely clinically relevant or providing a noticeable performance advantage, it speaks to an apparent measurable effect of drink content (Na^+) on potentially enhancing body water distribution and thermoregulation (Mitchell et al., 2000; Sanders et al., 1999; 2001).

Bergeron et al. (2007) studied eight elite-level, early-adolescent boys (13.9 + 0.9 yr) during the first round of singles and doubles play in a national championships event in August in San Antonio, Texas, USA. Notably, pre-play hydration status (urine specific gravity) was associated with on-court thermal strain (38.7 + 0.3 °C at the end of match play), and this relationship was stronger as the matches advanced. That is, those players who began the match not well-hydrated were more likely to incur a high body core temperature as play continued. The degree of thermal strain observed in this tournament play study (exceeding 39 °C for some players) is particularly notable, as the singles matches were relatively short and contested mostly in the morning (WBGT 29.6 + 0.4 °C). This study also highlighted how even doubles play in junior tournament-level tennis can elicit considerable thermal strain in hot environmental conditions.

Appreciable levels of thermal strain have also been shown during high school preseason football practice, even when environmental conditions were not very stressful and the coaching staff took appropriate steps to minimize undue thermal strain. Specifically, there was a progressive phase-in of players wearing protective equipment and the full uniform, and only one practice session was held per day (Yeargin et al., 2010). While providing an appropriate acclimatization period at the beginning of preseason outdoor practices in the heat is critically important, especially in youth football, these cautionary steps alone are not sufficient in adequately mitigating clinical risk related to thermal strain.

Repeated–bout Effects and Scheduling Challenges

It can be a near impossible challenge for a youth athlete to maintain adequate hydration, minimize thermal strain during play and perform optimally during a hot-weather tournament when multiple games or matches are played on the same day with inappropriately short rest and recovery periods scheduled between contests (Bergeron, 2009). This is a common scenario in youth sports tournaments, especially at the state- and regional-level events where tournament administrators often do not provide for adequate rest and recovery between rounds of play. This underscores how youth sports governing bodies' guidelines for minimum rest periods between multiple matches/games scheduled on the same day are generally not sufficiently evidence-based with respect to appropriately balancing tournament administration with player well-being and performance, especially for conditions of severe heat stress.

The specific impact of previous practice/training- or competition-related physical activity and heat exposure on subsequent same-day physiological strain and performance has been only minimally examined in youth. However, field and laboratory studies on repeated-bout exercise in youth and adults clearly indicate that previous same-day strenuous physical activity and heat exposure can have a negative "carry-over" impact on physiological strain, perception of effort, and performance during the next bout of activity (Bergeron et al., 2009: Ronsen et al., 2004: Sawka et al., 1979). A greater perception of effort and, for some children, greater cardiovascular and thermal strain during a second session of identical vigorous exercise was evident in very fit youth, even with ample rehydration and body core temperature returning to baseline before starting the second exercise bout (Bergeron et al., 2009). Accordingly, there would be an expected greater effect in stressful environmental conditions, following a long intense game or match where there is appreciable incomplete rehydration and body cooling before competing again. This is not an uncommon occurrence in outdoor youth tournament events and is, at times, practically unavoidable when sweating has been extensive and between-contest time is short. This is especially true for older adolescents, who have been sweating heavily and might be facing a substantial body water and sodium deficit at the end of play.

Coyle (2006) examined over a 7-yr period the impact of prior heat exposure incurred during same-day previous tennis play with boys during a 14's national championships annual tournament event. Adjusting for tournament seeding, Coyle found that the winner of an afternoon singles match could be reliably predicted from the amount of total heat exposure (degree minutes) acquired during the players' earlier matches on the same day. These novel findings support the rationale for longer between-contest recovery periods to minimize the potential impact from previous competition-related physical activity and heat stress. The inference should help guide same-day scheduling for all youth sports, as levels of heat and humidity increase.

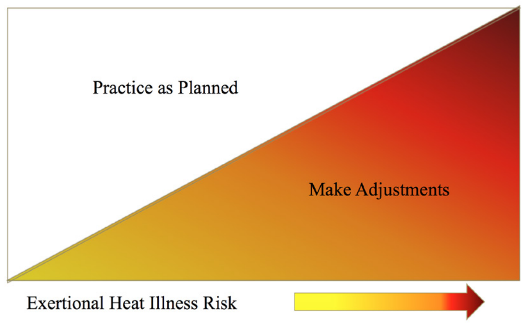
Recent Illness and Previous Bouts of Exertional Heat Illness
Current or recent illness can significantly increase physiological strain and related clinical risk during practice or competition in the heat because of the potential negative residual effects on a young athlete's hydration status and regulation of body temperature. The risk is especially significant for illnesses involving gastrointestinal distress (e.g., vomiting, diarrhea) and/or fever. A prior episode of exertional heat stroke, however, generally does not have long-term negative effects on subsequent thermoregulation, exercise-heat tolerance or exertional heat illness risk, especially for those who received prompt cooling therapy (Armstrong et al., 2007). Similarly, prior episodes of heat exhaustion or exertional muscle cramping generally do not have any long-term residual effects on a young athlete's subsequent well-being or performance during practice or play, unless the primary contributing factors (e.g., poor hydration, inadequate sodium intake or insufficient heat acclimatization) are not properly addressed and corrected (Bergeron, 2008). Notably, a history of concussion may increase the risk for exertional heat illness, secondary to autonomic nervous system dysfunction (Alosco et al., 2012).

RECOMMENDATIONS TO MINIMIZE CLINICAL RISK AND OPTIMIZE PERFORMANCE IN THE HEAT

It is easy to appreciate how youth athletes can readily incur significant total body water and exchangeable sodium deficits while participating in youth sports in the heat, especially when having to endure multiple same-day practice/training sessions, games or matches over several days or more in a row. Coaches need to appreciate this and accordingly provide frequent breaks and sufficient opportunities to rehydrate during extended practice sessions. Similarly, youth sports tournament directors should provide ample time to recover between rounds of tournament play, as environmental conditions warrant. Even when a young athlete drinks regularly during practice or play, body water and exchangeable sodium deficits following these activities can be significant. Accordingly, a deliberate effort to fully (or to the extent appropriate, given the time provided) and effectively rehydrate between practice/training sessions and contests is essential to prevent or minimize any accumulated body water and electrolyte deficits.

The other predictable challenges (besides maintaining adequate hydration) associated with practicing and competing in the heat are well-recognized by young athletes, coaches and parents. And while visible and formidable indications of thermal strain and fatigue in young athletes are routinely witnessed during hot-weather practice and competition, the full extent and prevalence of excessive body core temperature and exertional heat illness, as well as the consequent contributing role of thermal strain in performance outcome, are largely unknown in youth sports. More research is needed to better appreciate the broader scope and full extent of the physiological demands and hydration and thermal strain challenges facing youth athletes in various environments, venues, and practice and competition scenarios. This is essential before more specific and all-inclusive evidenced-based guidelines for optimally enhancing safety and performance can be established.

While recognizing the lack of sufficient sport- and age/maturation-specific data and insights to better guide parents, coaches and young athletes during and after vigorous and lengthy sports participation in the heat, certain recommendations of best practices should still be emphasized to minimize exertional heat illness risk and improve youth safety, well-being and athletic performance. Appropriate and effective safety and performance guidelines for all youth athletes training and competing in the heat should initially focus on readily modifiable risk factors such as hydration management, acclimatization and scheduling of play, with close monitoring and modifications in activity, based on the on-site environmental conditions and individualized clinical risk characteristics. With sufficient preparation, appropriate modification of and adjustment to the known contributing risk factors and close monitoring, exertional heat illness is usually preventable (Table 1).



Practice as Planned or Make Adjustments?
All young athletes have the responsibility to come to practice healthy, sufficiently fit and rested, well-hydrated, and well-nourished. Coaches should also emphasize and implement progressive acclimatization – the opportunity for youth athletes to slowly and safely "get used to" (adapt) to the environment, intensity and duration of practice, and the uniform and protective equipment. This is critical to improving exercise-heat tolerance and minimizing the risk of exertional heat illness in youth sports. As the external factors (e.g., weather) or those circumstances specific to individual athletes that contribute to greater exertional heat illness risk are increasingly present, adjustments (offsetting measures) to reduce risk for all or some athletes become more urgent.

Exertional Heat Illness Risk Factors
- High heat and/or humidity
- Very little or no breeze
- Very little or no cloud cover
- Second session of the day
- Athletes who are not fully or sufficiently acclimatized to:
  - Exercising in the current environment
  - The intensity, duration and uniform/protective equipment
- Athletes who are overweight and/or unfit
- Athletes who were recently ill, especially if it involved fever, vomiting and/or diarrhea

Adjustments: Offsetting Measures
- Decrease duration and/or intensity of practice
- Provide more frequent opportunities for consumption of readily accessible fluids
- Increase the frequency & duration of breaks, and preferably these should be in the shade
- Avoid or limit participation if a child or adolescent is currently or has been recently ill
- Ensure readily available personnel/facilities for effectively treating exertional heat illness are on site
- Closely monitor all participating athletes for signs & symptoms of developing heat illness*
- Cancel or reschedule practice to cooler time

*In response to an affected (moderate or severe heat illness) child or adolescent, promptly activate Emergency Medical Services and rapidly cool the victim.

Table 1. Exertional Heat Illness Risk Factors and Adjustments-Offsetting Measures to Minimize the Risk of Exertional Heat Illness in Youth in Sports.

Accordingly, most healthy children and adolescents can safely participate in outdoor sports – even when it is hot (Bergeron, 2013; Bergeron et al., 2011; Casa et al., 2009; National Federation of State High School Associations Sports Medicine Advisory Committee, 2012). The following are key recommendations to achieve this:

- Education and clear guidelines should be regularly provided and emphasized to assist youth athletes, coaches and parents in preparing for and safely managing participation in outdoor sports in the heat.
- Graduated exposure to a hot and/or humid environment, the uniform and protective equipment, and the intensity and duration of practice/training and competition, so that young athletes can safely acclimatize to the conditions, is essential to minimize exertional heat illness risk in the preseason or when traveling to a more stressful (greater heat and/or humidity) environment.
- Prior to participating in any outdoor athletic activity in the heat, youth athletes should be well-hydrated, well-nourished, and sufficiently fit and rested. Parents and coaches should not allow participation (or should significantly limit practice, training and competition) in the heat for youth athletes who are currently ill or are recovering from illness, especially those illnesses involving gastrointestinal distress (e.g., vomiting, diarrhea) and/or fever.
- Water and other appropriate fluids should be readily accessible and youth athletes should be given regular opportunities and encouraged to consume these fluids throughout athletic activities to properly offset sweat losses and maintain adequate hydration status.
- Tolerance to physical activity decreases and exertional heat illness risk increases, as the heat and/or humidity rise. Accordingly, outdoor athletic activities should be appropriately modified for safety and performance, in relation to the environmental conditions and individual athlete health status and fitness. Effective accommodations to increasing heat stress include lowering intensity and/or duration of activities, increasing frequency and duration of breaks to rehydrate and cool down, minimizing uniform and protective gear or rescheduling to a cooler time of day – or canceling an activity altogether!
- A written emergency action plan with effective protocols for treating all forms of exertional heat illness and managing other medical emergencies during youth athletic activities in the heat should be in place and practiced, and required equipment and trained personnel should be readily available on-site.
- All youth athletes should be closely monitored in the heat. Any significant deterioration in performance with notable signs of struggling and developing exertional heat illness should be sufficient reason to immediately stop participation and promptly seek appropriate medical attention for those affected youth athletes. Moreover, all young athletes have the responsibility and should be encouraged to be honest about promptly reporting any symptoms or signs of developing exertional heat illness for themselves or their teammates.
- Any young athlete experiencing exertional heat illness should not return to practice or competition for the remainder of the current practice/training session, game or match.
- Coaches and tournament/event administrators should provide sufficient rest and recovery time between multiple same-day training sessions and contests, especially in the heat.

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