

Hydration in the Pediatric Athlete — How to Guide Your Patients

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Abstract

Hydration is arguably among the foremost priorities youth athletes, parents, and coaches habitually consider as vital for sports. Insufficient hydration and a resultant measurable sweat-induced body water deficit can negatively affect performance and, in some athletic scenarios, can be a danger to a young athlete's health and safety, especially during vigorous physical activity in a warm-to-hot environment. Accordingly, it is essential to be well hydrated prior to practice, training, and competition and minimize total body water deficits incurred while being mindful of the greater sweat losses and hydration needs/challenges that accompany physical growth and maturation. Informed clinicians can play a key role as trusted resources in providing the most effective guidelines and making the best overall individual recommendations regarding hydration for youth athletes.

Introduction

Physicians and other health care providers play a key role as informed and trusted resources to youth athletes and parents on a variety of challenging issues that arise from youth sports participation, especially when it comes to health and injury prevention. One of the most conspicuous and concerning issues particularly evident during the summer months is playing effectively and safely in the heat. Central to this concern, hydration is arguably among the foremost priorities youth athletes, parents, and coaches habitually consider as essential before, during, and after any hot-weather workout, be it practice, training, or competition — that is, drinking regularly to prepare for and offset often obvious extensive losses of sweat and intrinsic prompts of thirst. However, it should not be just a summertime priority. Young athletes can feel the reinforcing influence of ample hydration on athletic performance in a variety of situations and sports settings. They also may appreciate how inadequate hydration can ultimately be a contributing determinant in a loss or underachievement

during practice, training, or competition in a wide range of environmental conditions. Informed adults also recognize that appreciably insufficient hydration and a resultant measurable sweat-induced body water deficit can be a danger to a young athlete's health and safety, especially with vigorous activity in the heat. Accordingly, maintaining hydration is typically emphasized and encouraged by parents and coaches and opportunities and facilities for rehydration are characteristically provided and readily accessible at all youth sport activities and events. However, it is not always fully appreciated what adequate hydration means and how it is appropriately achieved.

The intent here is to provide an up-to-date practical general “primer” for clinical providers to better guide their pediatric patients and parents in maintaining adequate hydration during sports practice, training, and competition — in *all* environments and athletic/sport scenarios, with a particular emphasis on warm-to-hot conditions. With an appropriate understanding of the hydration demands and challenges that kids face during sports and the individual and environmental contributing factors that limit maintaining optimal hydration, providers can be more effective resources. Clinicians also can be instrumental in the community in improving heat safety and well-being for all youth involved in sports and recreational physical activities by promoting and providing education on proper hydration and other proactive health and safety measures. Effective pathways include being actively involved with schools, sports clubs, and local parks and recreation programs and by serving on local, regional, or national sport or sports medicine advisory committees.

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Essential Knowledge for the Clinician

A longstanding perspective has emphasized that children are less effective in regulating body temperature, incur greater cardiovascular and thermal strain during vigorous physical activity in the heat, and thus have lower exercise heat tolerance compared with adults. This view was initially

based on early studies showing maturational differences in body surface area-to-mass ratio, exercise economy, and cardiac output while particularly underscoring a substantially lower sweating capacity and rate in children (3,19,21,22,26,48). However, it has since been shown that children have higher levels of relative (to body mass) evaporative cooling and sweating efficiency, thus yielding lower mass-dependent heat storage (28). Accordingly, with this and other evidence dismissing any notable adult-child differences, the contemporary perspective is that adequately hydrated youth athletes are not at a distinguishing cardiovascular or thermoregulatory disadvantage compared with similarly fit, hydrated, and acclimatized adults during exercise in the heat (39).

Sweat Fluid Losses and Rehydration

Vigorous exercise and other physical activities prompt an increase in sweating and a thermoregulatory reliance on evaporative cooling. This response is consistently exacerbated as intensity of physical activity and climatic heat stress (indoors or outdoors) increase, although sweating rates vary considerably between individuals — even in identical environmental conditions and athletic settings. Published data on sweat losses in child athletes during sports practice or competition are limited; however, sweat loss rates in 9- to 12-year-old boys and girls have been reported to be 300 to 700 mL·h⁻¹ during nonsport (laboratory) exercise in the heat (10,28,38,40,41). However, with the transition from early childhood through late adolescence, athletes, parents, and coaches need to be cognizant of and suitably accommodate the greater sweat losses and hydration needs/challenges that accompany physical growth, maturation, enhanced fitness, and a greater level of athletic and sport-specific skill. Correspondingly, most adolescent athletes are capable of sweating at rates near or well in excess of 1.0 L·h⁻¹ during sport practice and competition in the heat (7). In fact, with older adolescents (especially in boys), sweating rates can often reach 2.5 L·h⁻¹ or more with strenuous athletic/sport activity in hot and humid weather (4,5). Overall, the individual and collective effects of exercise intensity and duration, the environment (heat, humidity, solar radiation, and wind speed), and physical maturation and body size, along with other contributing heritable traits, are the determinants of sweating rate and related hydration challenges.

Considering these sweat loss rates, it is easy to appreciate how some individuals can readily incur a sizable total body water deficit during practice, training, and competition. Even when fluid is consumed voluntarily and regularly as desired to thirst, a postexercise body water deficit is often significant following prolonged and/or repeated sessions of strenuous physical activity, especially for those individuals who sweat considerably. Notably, in certain sports and other extended-duration athletic scenarios, these postexercise body water deficits can be very substantial — 2 to 4 L or more — even with ample fluid availability, opportunities to rehydrate, and regular fluid consumption throughout the activity session.

With brief to relatively short-duration athletic/sport activities or when exertion and/or participation time is minimal (especially in cool or moderate indoor or outdoor environmental conditions where total sweat loss is negligible),

youth athletes may not require much or any fluid intake *while* practicing, training, or competing, as long as they are amply hydrated and nourished at the start. Nonetheless, plenty of water should be readily available and accessible. However, when activity/play time is more extensive, 100 to 250 mL (about 3 to 8 oz) every 20 min for young adolescents and *up to* 1.0 L (about 35 oz) or a little more per hour for older adolescents are generally enough to offset sweat losses or sufficiently minimize sweating-induced body water deficits incurred during these sport activities. However, for numerous adolescent boys and girls who sweat extensively (*e.g.*, near or exceeding 2 L·h⁻¹), this rate of fluid intake is not enough to prevent a progressively increasing and ultimately sizable postexercise/play body water deficit. For these athletes and common instances, postexercise fluid intake should be 1 to 1.2 L for every kilogram (16 to 20 oz per pound) of a remaining postexercise body water deficit (10). This can be easily estimated by a pre- to postactivity change in body weight measured while wearing no or minimal dry clothing.

Any discussion on rehydration for athletes warrants specific mention of hyponatremia — a potentially deadly complication of overhydration. Hyponatremia is defined by a circulating sodium level below 135 mmol·L⁻¹, and the primary cause in sports is consumption of low- or no-sodium fluids in measurable excess of sweat, urinary, and other collective losses of body water (27). This is readily validated by a pre- to postsession gain in body weight. Early signs and symptoms typically include headache and nausea, although these and other indications are not necessarily specific to hyponatremia. More severe hyponatremia (with lower sodium levels) is generally associated with more severe neurologic signs and symptoms and clinical status, potentially resulting in obvious altered mental status, seizure, respiratory distress, coma, or even death, as a result of progressively worsening cerebral edema.

Sweat Sodium Losses

The primary electrolytes in sweat are Na⁺ (20–70 mmol·L⁻¹) and Cl⁻, with comparatively much lower levels of K⁺ (approximately 5 mmol·L⁻¹) and even less Ca²⁺ (approximately 1 mmol·L⁻¹) and Mg²⁺ (approximately 0.8 mmol·L⁻¹) (44). As with sweating rate, the sodium content of sweat is widely variable among individual children and adolescents. Moreover, as a youth athlete's rate of sweating increases during sport activity, there is an analogous increase in the individual's rate of sweat electrolyte loss (particularly sodium), owing to the resultant larger total volume of sweat and the parallel higher sweat sodium concentration that normally accompanies an increase in one's rate of sweating (13). While exercise heat acclimatization characteristically lowers sweat sodium concentration, sweat sodium losses can still be considerable, even for a youth athlete who is acclimatized to heat. With prepubescent or early pubescent athletes, a sweat-induced sodium deficit incurred during a single training/practice session or competition bout alone is not likely to be substantial enough to warrant any concern. A normal diet surrounding these bouts of activity will typically be sufficient to maintain daily electrolyte balance, even if only water is consumed during and after each practice, training session, or game/match, as the typical dietary intake of sodium for

school-aged (6 to 18 years old) children well exceeds daily recommendations (16). However, many older adolescents sweat considerably and can lose via sweating 2,000 to 5,000 mg·h⁻¹ or more of sodium. Accordingly, total body exchangeable sodium deficits can reach up to 20,000 mg or more in a single day for those teens involved in extended or multiple, same-day vigorous training/practice sessions or competition bouts in the heat (4,5).

Clinical Risks

Evaporation of sweat, assisted by additional heat exchange through radiation (from the skin to the air) and convective heat loss (from air moving across the skin), is usually enough to amply offset metabolic heat production, thus minimizing thermal strain during sport practice, training, and competition. However, when youth athletes go too hard and/or too long for the prevailing environmental conditions, the workload and consequent metabolic heat production rate during such vigorous physical activity can readily exceed the thermoregulatory capacity of sweating and other mechanisms of environmental heat exchange. Consequently, core body temperature progressively increases. If left unchecked, the degree of undue thermal strain could quickly reach and exceed a dangerous and potentially life-threatening threshold. Importantly, this scenario leading to excessive thermal strain and grave clinical risk can still occur with youth athletes who are healthy, fit, acclimatized to the heat, *and* well hydrated. The effect and resultant clinical threat to a young athlete are readily hastened and magnified when the humidity is high, as the high water content of the air acts as a barrier to sweat evaporation and thus evaporative cooling. Even though sweating freely continues, the water from the sweat glands does not evaporate as effectively and is left to collect on the skin or fall to the ground with little-to-no release of body heat to the air.

For myriad young athletes and athletic scenarios, it is impractical to avoid accumulating and sometimes measurable total body water and exchangeable sodium deficits during extended or repeated same-day bouts of practice, training, or competition (9). Core body temperature, heart rate, and overall physiological and perceptual strain are proportionally greater with incremental levels of total body water deficits (*e.g.*, 1% to 4% from a normally hydrated state), during fixed-intensity exercise (24,31,32). However, in most athletic situations, youth athletes can safely tolerate a small evolving total body water deficit (ultimately reaching 3% or less or 2% of body mass) by the end of a practice/training session or competitive event without experiencing undue thermal or cardiovascular strain and associated medical complications, as long as preactivity hydration status is good (7,8). This is especially true in activities where there is an opportunity for self-regulatory variation in workload (intensity and duration) and rest cycle frequency and duration. Nonetheless, even relatively small total body water deficits have been shown to impact athletic performance in youth athletes (18). Unfortunately, many youth sports athletes also are frequently in situations where there is strong internally or externally driven motivation to keep going or keep up (*e.g.*, in team practices with strong “encouragement” from a coach) and deliberate slowing down is seemingly not a viable option, even when the capacity to safely continue is not

evident. In these instances, in addition to the potential effect on athletic performance, an increasing body water deficit can progressively increase thermal, cardiovascular, and perceptual strain and exertional heat illness or injury risk.

Extensive sweating also can lead to a significant whole body exchangeable sodium deficit and contracted interstitial compartment, initially prompting subtle fasciculations, which can eventually progress to more severe and debilitating muscle spasms (6). These muscle cramps are notably different from comparatively sudden-onset exercise-associated muscle cramping that is localized (*e.g.*, affecting solely the calf or hamstring muscles), constant, asymmetric, and responsive to passive stretching and is more likely to have been prompted by muscle overload and fatigue (45). In contrast, hyperexcitable neuromuscular junctions in a contracted interstitial fluid compartment can incite widespread skeletal muscle cramping, even when there is minimal or no muscle overload and fatigue (6,20). With rehydration, plasma volume is preferentially restored (30,42,43), quickly prompting a reduced drive to drink. Moreover, an increase in renal free water clearance often results before complete restoration of the interstitial spaces. The consequent increase in urine production deceptively suggests sufficient whole-body water recovery despite the interstitial fluid compartment remaining somewhat contracted. This particularly occurs when plain water or very low-sodium fluid is consumed alone (36). Therefore, complete postexercise rehydration involves more than just ample water intake, as often extensive sweat sodium losses need to be replaced as well to achieve optimum hydration status — that is, the most advantageous distribution and retention of water to all body fluid compartments (30,43,46). Importantly, a whole body exchangeable sodium deficit usually is not detectable from measuring serum electrolytes (4,43), especially following exercise where there is a significant sweat-induced body water deficit and circulating sodium concentration is predictably normal or somewhat elevated (4,35,42). Accordingly, postexercise serum sodium concentration should not be used to indicate the presence or absence of a whole body exchangeable sodium deficit. Any determination of exchangeable sodium status should be based minimally on a suitable estimate of sweat sodium loss compared with dietary sodium intake.

Best Practices

Exertional heat illness in most cases is preventable when modifiable contributing factors are adequately and appropriately addressed for the environmental conditions and individual health/fitness status. While adequate hydration recognizably is integral to heat safety and athletic/sport performance, dehydration is not the only or even the most important contributing factor to excessive thermal strain. An excessive workload for the conditions and/or health, fitness, and heat acclimatization status can readily put a youth athlete at risk, even if s/he is well hydrated. All health care providers who act as a resource to youth athletes and their parents, as well as schools and other stakeholder organizations, should be familiar with current heat safety and hydration policy statements, guidelines, and recommendations from recognized organizations and governing bodies on training and competing in the heat (2,11,15,34). These authoritative, evidence-informed best practices place an

appropriate practical emphasis on addressing modifiable factors to meaningfully assist in keeping all youth athletes safe and performing well, particularly in hot weather. While individual hydration and heat safety challenges also must be considered and addressed, these universal measures for all children and adolescents involved in sports are a great place to start in sensibly making sports participation safe and enjoyable in all environmental conditions.

Specific to instances of challenging hydration management, as long as there is no underlying acute or chronic clinical condition that needs to be addressed to minimize risk during training and competition or is not compatible with safe sports participation, the clinician should focus on 1) determining individual hydration challenges and needs (*e.g.*, estimated sweat and electrolyte loss rate in typical athletic scenarios) and 2) making practical and appropriate recommendations to address these hydration factors that can be easily and effectively implemented. To the extent feasible, objective measures of sweat losses, body weight deficits incurred, and other indirect indicators of hydration status such as urine frequency, volume, and color can be helpful in determining the extent of the problem and the appropriate solution on an individual basis. Importantly, in most typical athletic scenarios, a small total body water deficit (from a normally hydrated state) is well tolerated and incurred levels of dehydration and electrolyte losses are usually replaced sufficiently day to day by an adequate diet and regular normal fluid intake. Accordingly, more assertive rehydration strategies (water and electrolyte intake), while being careful not to overhydrate, are primarily warranted for individuals who incur repeated extensive sweat losses (4,6,9).

What Your Youth Athlete Patients and Parents Need to Know

It is important for youth athletes and parents to appreciate that, while adequate hydration is integral to sports, it is not sufficient in ensuring heat safety or optimal performance. There are numerous other factors that play a contributing role in personal well-being and athletic achievement. It is also important for clinicians to explain how rehydration involves more than just ample water intake. Other nutrients (primarily sodium and carbohydrate) play key roles in assisting with and optimizing body water distribution and retention.

Ideally, the preferred emphases for every youth athlete are to be well-hydrated before practice, training, or play and to drink regularly during these activities to sufficiently offset the ongoing sweat loss. Along with appropriate fluid intake with meals, this combined effort is often sufficient in maintaining optimal hydration from day to day. However, for those adolescent boys and girls who sweat extensively, it is impractical to avoid accumulating and sometimes measurable total body water and exchangeable sodium deficits. Rehydration must often be appropriately more deliberate, beyond relying solely on drinking to thirst, while being careful to not overdrink. Body weight differences (pre- to postexercise, prior to food and additional fluid intake) can help estimate sweat rate, body water deficits incurred, and fluid intake needs as well as assess overall hydration management. Notably, there can be a particular challenge in minimizing total body water deficits with same-day repeated bouts of physical activity — such as with tournaments and

multiple same-day practice or training sessions — when sweat losses are extensive and between-bout recovery time is minimal. In tournament scenarios with multiple same-day rounds of competition, rehydration is often modulated by how much time is available before the start of the next game or match. That is, there may be only enough time between bouts to safely and comfortably rehydrate partially, so as not to rapidly overconsume fluid, as this can lead to gastric discomfort or much worse. At the end of each day's competition, any remaining body water or electrolyte deficits should be replenished evenly through the rest of the day and the next morning before play resumes.

Parents and youth should be specifically educated about the dangers of drinking too much in a short period — that is, more than the body can handle. It should be emphasized that drinking too much too quickly can result in an excess of water in the blood (a condition called *hyponatremia* that is indicated by a markedly low blood sodium level), and this can lead to significant clinical problems including brain swelling, followed by seizure, coma, and even death (27). It is important for the clinician to clarify that early symptoms of hyponatremia typically include headache and nausea, although a youth athlete could be feeling this way for other reasons. While it is somewhat variable depending on body size, rehydration rates should generally not extensively exceed an individual's same appropriate and comfortable fluid consumption limits as during activity. Children and adolescents also should be educated on how and be encouraged to check their urine before practice, training, and competition — it should be light or straw colored. Urinating clear, frequently, and excessively is an indication of likely overconsumption of fluid — especially no- or low-sodium beverages. Providing a urine color chart for use at home should be considered (33).

The question “water or sports drinks?” underscores a highly prevalent concern for many parents. First, in contrast to earlier findings (37,49), unflavored water has been more recently shown to be equally effective as a carbohydrate-electrolyte sports drink in encouraging voluntary fluid intake in physically active young girls during intermittent exercise in the heat (50), adolescent boys during basketball (14), and notably with high-level, fit junior tennis players during intense on-court training in outdoor very warm conditions (7). So, for most kids in most athletic scenarios, when they have the opportunity to eat regular meals before and after activity (practice, training, or competition), water is appropriate and sufficient. Accordingly, in these (which should be most) circumstances, the recommendation should be to have free, regular, and ready access to water. However, the older a youth athlete gets, the longer and harder s/he goes on the field or court, in the pool, etc., the hotter it is (an increase in thermal strain prompts greater reliance on carbohydrate for energy at a faster rate) (23,25), the more s/he sweats, the sooner s/he has to practice/compete again on the same day (*e.g.*, as in tournaments), and the fewer opportunities or less time there is to eat regular meals or snacks, then sports drinks can play a proportionately greater and more effective role in providing the needed carbohydrate and electrolytes (1,17,29). All of these are contributing factors that solely or collectively increase the potential advantage of sports drinks over water alone.

Significant sweat-prompted sodium deficits can occur after one long session/match/game or may evolve more incrementally over time after several successive days of training/practice or competition. In these scenarios, it is often necessary to appreciably increase daily dietary sodium intake to more closely match total sweat sodium loss. This will enhance daily sodium balance and aid in retention and distribution of ingested fluid. In many cases, it may be sufficient to simply make certain dietary choices (*e.g.*, canned soup, tomato juice and sauce, cheese, salted pretzels and peanut butter, pizza, etc.) throughout the day. This may be naturally reinforced by an increase in sodium palatability (appetite) that is typically coincident with a sodium deficit (12,47). However, for those athletes who sweat extensively, it may be essential to rehydrate with a low-sodium — 80 mg or less per 0.23 L (8 oz) serving — commercial sport drink with added salt (*e.g.*, 1.5 to 3.0 g of salt to 1 L) or a commercial rehydration beverage with inherently higher levels of sodium (up to 800 mg per serving) during and after vigorous practices, training sessions, and competition bouts. It also may be appropriate and particularly beneficial to the youth athlete for health care providers to assist a parent in working with other professionals (*e.g.*, applied physiologists and sport dietitians) at a university or comprehensive sport research/training center to identify individual sweat loss challenges and suitable rehydration strategies if clinical signs and symptoms (*e.g.*, muscle cramping, premature fatigue, or heat exhaustion) persist (4,6,17).

If a child or adolescent is currently or recently ill, especially for illnesses involving gastrointestinal distress (*e.g.*, vomiting, diarrhea) and/or fever, caution should be taken before considering participating in sports — competition or practice, especially in the heat. Because of the potential negative residual effects on a youth athlete's hydration status and regulation of body temperature, sports participation with or soon after such illnesses can readily increase physiological strain and clinical risk and, accordingly, should be limited or avoided altogether.

Youth Athletes' and Parents' Additional Roles and Responsibilities

Parents, of course, have a more influential role and responsibility in providing the right guidance and opportunity for and oversight in ensuring their child athlete is well rested, nourished (additional sodium if needed), and hydrated prior to practice and competition. This influence and responsibility progressively and appropriately lessen with a child's entry into and through the teen years, where the adolescent athlete should be primarily in charge of ensuring his or her own proper preparation and recovery. Ready access to water and sports drinks (as needed) during practice, training, and competition is always recommended for all youth athletes. Moreover, these good hydration habits should be verbally (and by example) reinforced consistently — not just for important hot weather games/matches and tournament events.

The optimal scenario is open and encouraged tripartite communication among the athlete/parent(s), coach, and health care provider. Parents should encourage and *listen* to honest self-reporting from their children on how they feel and promptly update the coach when a youth athlete's health

status changes. When there is repeated history of hydration-related problems (including muscle cramping, premature fatigue, signs of heat exhaustion, etc.) during sports practice, training, and/or competition, parents should discuss with their youth athlete's health care provider about getting these hydration challenges evaluated and a dietary hydration plan recommendation from an experienced professional.

Summary and Key Points

- All youth athletes have the responsibility to be well hydrated (normal body weight and light-colored urine) and well nourished prior to practice, training, and competition. Ample water should be readily available, and accessible and regular fluid intake should be a priority during sports and related athletic activities, especially in the heat. Weighing oneself before and after these activities with minimal clothing provides a good indication of how well hydration was managed. The primary goal is to sufficiently offset sweat losses with regular fluid intake, so as to minimize activity-related total body water deficits. If a youth athlete begins well hydrated (as indicated by normal body weight, light-colored urine, etc.), a small pre- to postsession weight loss is okay, whereas a weight gain shows that too much fluid was consumed.
- For those selected and notably fewer athletes who sweat excessively, measurable total body water and exchangeable sodium deficits are often inevitable during vigorous practice, training, and competition. These athletes, who often have history of muscle cramping, may have to add some salt to their diets and sports drinks, especially when training and competing in the heat. This helps the body hold onto water and reduces the risk of muscle cramping caused by insufficiently offset large sweat sodium losses. Importantly, knowing one's personal estimated rates of body water and electrolyte (sodium) losses from sweating is a key step in minimizing these often significant deficits and sufficiently recovering before the next bout.
- Overall, clinicians should emphasize the importance of ensuring a well-hydrated, sodium-balanced, and otherwise well-nourished state prior to practice, training, and play and that this begins with adequate daily recovery of water and electrolyte deficits incurred from the previous activity session(s). Managing these nutrient losses more optimally day-to-day and same-day session-to-session can reduce the risk of undue thermal strain and exertional heat illness as well as contribute to achieving and maintaining more optimal athletic and sport performance.

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