STATE OF THE ART
REVIEWS

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Dehydration and Thermal Strain in Junior Tennis

Abstract: *Playing tennis effectively and safely in the heat can be particularly challenging in junior tennis, especially during organized tournament competition when young players have to compete in demanding environmental conditions several times on the same day. With sweat rates ranging from 0.5 L to more than 2.0 L per hour, a young player can readily incur significant total body water and sodium deficits during a very long match or when participating in multiple matches on the same day over several days in a row. On-court thermal strain can be quite high, as tournament-level tennis can elicit appreciable metabolic heat production and storage, even during doubles; this can be exacerbated by poor hydration as well as carryover effects from previous same-day competition and heat exposure. Appropriate and effective safety and performance guidelines for young tennis players training and competing in the heat should focus on readily modifiable risk factors such as hydration management and scheduling of play versus any purported inherent thermoregulatory disadvantages in this specific age group.*

Keywords: athletes; player safety; sweating; thermoregulation; youth

Regular participation in competitive junior tennis and associated training and practice is an effective way for youth to engage in physical activity that will help them to achieve and maintain beneficial gains in body composition, musculoskeletal and cardiovascular health, and overall fitness.[1] As with any youth sport, to encourage and reinforce continued participation and success, it is critical for parents, coaches, and junior tennis administrators to keep the tennis experience fun and rewarding and the injury risk minimized.[2-5] Playing tennis effectively and safely in the heat, however, can be particularly challenging, especially during organized tournament competition when young players have to compete in demanding environmental conditions several times on the same day.[6,7] Unfortunately, there are very little tennis-specific data on hydration and thermoregulatory challenges and responses in natural outdoor settings with junior players; accordingly, most hot-weather preparation, on-court, recovery, and scheduling recommendations and guidelines for effectively managing hydration, reducing thermal strain, optimizing performance, and minimizing heat illness risk on court are not sport specific and evidence based.

A number of recent studies, however, have provided significant new insight to physiological responses and tolerance of young athletes during exercise and tennis in the heat as well as some of the specific challenges facing young players

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that increase the risk for significant body water deficits, thermal strain, and performance decrements. In particular, 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 and capable of performing well in a hot environment and are at greater risk for incurring heat illness compared with adults.[8-14] However, more current research does not support this viewpoint, indicating that children (9 to 12 years old) do not have insufficient cardiovascular capacity, less effective thermoregulation, or lower exercise-heat tolerance when hydration is amply maintained.[15-18] Accordingly, appropriate and effective safety and performance guidelines for young tennis players training and competing in the heat should focus on readily modifiable risk factors such as hydration management and scheduling of play versus any purported inherent thermoregulatory disadvantages in this specific age group. The tennis-specific information presented here supporting this perspective can help parents, coaches, and tennis-governing bodies improve the health and safety of youth tennis players during training and competition in the heat, so that they continue to participate and enjoy the health-enhancing benefits of the sport.

Hydration Status and Thermal Strain

Fluid and Electrolyte Losses and Rehydration

As on-court environmental heat stress (air temperature, humidity, and solar radiation) and intensity and duration of play increase, the need for evaporative cooling and sweating increases proportionately as well. Sweating rates in excess of 1.0 L per hour have been measured with young adolescent players during tennis practice[19] and tournament competition[6] in the heat, even during doubles play. With older adolescents, sweating during play and practice can often reach 2.5 L per hour[20,21] or more with intense activity in hot and humid weather. Although sweat losses in younger tennis players during practice or competition have not been reported, one can expect that 9- to 12-year-old boys and girls, for example, would have similar on-court sweat losses during warm- to hot-weather tennis as has been reported (300 to 700 mL per hour) during nontennis exercise in the heat.[15-18,22]

Considering these sweat rates in junior tennis, it is easy to appreciate how a young player can readily incur a significant total body water deficit during competition, especially when participating in multiple matches on the same day over several days in a row.[6,19,21,23] Even when a player drinks regularly (on each changeover) during a match, a postplay body water deficit can be significant following a long contest. This can potentially have a measurable negative effect on cardiovascular and thermal strain, performance, and heat tolerance.[8,24-28] Accordingly, effective strategies to encourage sufficient fluid intake and optimize hydration status can play an important role in maintaining performance and reducing heat illness risk. Notably, poor or casual hydration habits of young players are often highlighted by the more extensive sweat losses and repeated recovery demands of tournament play (M. F. Bergeron, unpublished observations). Therefore, to promote better hydration behavior and potentially minimize body water deficits during competition, it may be helpful for young players (and their parents and coaches) to emphasize beginning all practice sessions in a well-hydrated state and to use a similar hydration schedule in practice as during competition (ie, drinking every 10 to 15 minutes on court and deliberately rehydrating promptly after practice to recover any remaining body water deficit).

Voluntary dehydration in young boys has been more effectively attenuated during exercise in the heat in previous studies when a more preferred (compared with flavored or unflavored water) carbohydrate-electrolyte drink was available.[29,30] However, Wilk et al[31] more recently have shown that unflavored water was equally effective as a carbohydrate-electrolyte sports drink in maintaining body weight in physically active young girls (10.6 ± 0.9 years) during intermittent exercise in the heat. Such conflicting findings may be related to sex, fitness, or athletic level. With high-level, fit junior tennis players, Bergeron et al[19] also observed only a small difference in ad libitum fluid consumption of water and a commercial sports drink during intense on-court training in the heat. This may, according to these authors, reflect a predominating fluid consumption behavior characteristic of experienced competitive tennis players. That is, elite players are often encouraged to rehydrate sufficiently and may likely maintain a consistent fluid intake rate on court regardless of beverage characteristics and appeal. In contrast, with less experienced young athletes, the flavoring of a sports drink may prompt more measurable differences in fluid intake volume.

Effective rehydration, however, during and after play, often involves more than simply ample fluid intake. Through the adolescent years, a young athlete's sweat rate increases with growth and maturation. Concomitantly, sweat electrolyte losses (particularly sodium and chloride) during physical activity generally increase as well, due to a larger volume of sweat and a greater sweat sodium concentration.[32,33] Acclimatization to the heat can lower one's sweat sodium concentration[32,34-36]; however, on-court sweat sodium losses can still be substantial, even for a young tennis player who is well acclimatized to the heat.[20,21] With prepubescent tennis players, the potential sweat-induced sodium deficit incurred on court is not likely to have a significant physiological or performance impact,[37] and a normal diet will typically be sufficient to maintain daily electrolyte balance, even if only water is consumed during play. This often is not the case with older adolescents, who sweat considerably more and can lose via sweating 2000 mg to nearly 5000 mg of sodium per hour.[20,21] Therefore, to promptly offset these greater electrolyte losses and to better retain and distribute the larger volume of ingested water to all body fluid compartments,[38-41] a more deliberate effort to match fluid and sodium intake during and between each match with individual sweat losses just incurred may be necessary; otherwise,

insufficient sodium intake (even with an adequate water ingestion) will hinder complete rehydration,[42] may affect physiological function and performance,[43] and can increase the risk for incurring exertional muscle cramps that are related to extensive sweating and a measurable whole-body sodium deficit.[44] This maturation-related increase in sweat sodium losses and consequent greater challenge to maintain whole-body sodium balance is typically not recognized or appreciated by a junior tennis player until she or he encounters severe sodium deficit–related problems and is properly evaluated and advised to more deliberately replace sweat water and electrolyte losses during and after play via appropriate carbohydrate-electrolyte (sports) drink mixtures and meals/snacks with higher salt content.[20,21,44] The carbohydrate (energy) provided by a sports drink can have measurable advantages for a young player as well, especially as she or he grows and matures and as intensity and duration of play increases, environmental heat stress goes up, and energy recovery needs are greater and more difficult to meet because of increased carbohydrate use and having to play multiple times on the same day.[45-48]

Core Body Temperature

Even with adequate hydration, a child's metabolic heat production, heat storage, and thus core body temperature will progressively increase during long-term exercise in the heat.[12,15-17,22,29,31,49] Notably, repeated complex, intermittent exercise patterns and postural changes with varying workload and recovery periods (characteristic of competitive tennis match play) has been shown to induce greater physiological strain and yield higher heat storage and core body temperature compared with continuous exercise,[50] suggesting a particularly great clinical risk during high-intensity tournament singles tennis in extreme heat. Fortunately, to date, there have been no reported heat stroke deaths in junior tennis; however, extensive thermal strain in young players is routinely visibly observed during hot-weather events. Unfortunately, however, the prevalence and extent of significant core body temperature responses and related heat illness, as well as the consequent contributing role in performance outcome, is largely unknown in junior tennis.

In an examination of fluid intake, sweat loss, and core body temperature in highly skilled, fit junior tennis players (15.1 ± 1.4 years) during intense on-court training in a very warm environment (wet bulb globe temperature [WBGT] ~26.4°C), Bergeron et al[19] found that a carbohydrate-electrolyte drink may be more effective than water in maintaining hydration status and minimizing thermal strain. A number of players began the monitored training sessions not well hydrated, as indicated by prepractice urine-specific gravity; however, this measure, fluid intake, and percentage change in body weight were not statistically associated with core body temperature responses (which approached or reached 39°C for some players) during the 2-hour practice sessions. Notably, after every 10 minutes of on-court activity, a 3-minute break was implemented for rest, instructions/coaching, and rehydration from large prepared individual coolers containing the provided chilled beverage. Without such frequent opportunities to drink and ample beverage availability, these young players might not be so attentive to regular and sufficient fluid intake during similar practice outside of such a research study scenario and would likely incur significantly greater body water deficits than observed in this study (on average, less than 1% of initial body weight). Accordingly, thermal strain could be greater, and the relationship of 1 or more hydration measures (eg, fluid intake) would likely be more strongly associated with core body temperature. Not surprisingly, unlike tournament competition, even well-supervised practice permits individuals to vary their own intensity and effort, without being penalized per se; this can also alter the expected association between hydration status and thermal strain that typically is present when the intensity of physical activity in the heat is maintained.[26,27,51] Of course, being able to seemingly get away with poor hydration practices on training days (even in the heat) does not reinforce good hydration habits for those junior players during sanctioned hot-weather events, during which there is less margin of error and a significant total body water deficit is more likely to be reflected in greater thermal strain and lower on-court performance.[6]

To date, only 1 study has examined hydration status and core body temperature in junior tennis players during actual sanctioned tournament competition. Bergeron et al[6] studied 8 elite-level young boys (13.9 ± 0.9 years) during the first round of singles and doubles play in a national championships event during the first week in August in San Antonio, Texas. Although the singles matches were relatively short and contested mostly in the morning (WBGT 29.6°C ± 0.4°C), preplay hydration status (indicated by urine-specific gravity) was associated with on-court thermal strain, 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 core body temperature as play continued, which challenges the recent notion that hydration status does not affect thermal strain in field situations.[52-54] The measured on-court core temperature profiles for these young players (exceeding 39°C for some players) during actual national tournament-level singles and doubles (played in the afternoon on the same day) in the heat, where players will maintain a strong effort, are also in stark contrast to the proposed view that intensity of play will be reduced during competitive tennis as environmental heat stress increases, so that core body temperature is progressively minimized.[55] In fact, had the players been monitored during longer, more intense, 3-set matches played in the afternoon during later rounds of the tournament, Bergeron et al[6] speculated that on-court thermal strain would have been consistently even higher than observed during the less challenging opening matches of the first round of play because of greater heat stress, intensity and duration of play, and potential body water deficits incurred. This study also highlights how even doubles play in junior tournament-level tennis can elicit appreciable metabolic heat production and storage.

Repeated-Bout Effects and Scheduling Challenges

Perhaps the biggest challenge for a junior tennis player to maintain hydration (sufficient water and electrolyte balance and distribution to all fluid compartments), minimize on-court thermal strain, and perform optimally is during hot-weather tournament play, when multiple matches are scheduled on the same day with inappropriately short rest and recovery periods between contests. This is a common scenario in junior tournament tennis, especially at state- and regional-level events; it often prompts subsequent poor performance or withdrawal from play, when a just-completed match is particularly long and difficult. Unfortunately, tennis-governing body guidelines for minimum rest periods between multiple matches scheduled on the same day and tournament administrators do not seem to sufficiently emphasize adequate rest and recovery and player safety.[56]

The specific impact of previous competition-related physical activity and heat exposure on subsequent same-day physiological strain and performance has not been well examined in youth; however, related field and laboratory studies on repeated-bout exercise in adults strongly indicate the potential for physiological carryover effects from previous same-day strenuous physical activity having a negative impact on the next bout of activity.[57-61] This has been more recently confirmed in children in a study by Bergeron et al,[22] in which 24 healthy, young athletes (nontennis) were examined during two 80-minute intermittent exercise (treadmill and cycle ergometer) sessions in the heat (33°C), with a 1-hour rest and recovery period in a cool environment between the bouts. Even with ample hydration and core body temperature returning to baseline before starting the second bout of exercise, a 1-hour rest and cool-down period was not sufficient to avert greater perception of effort and, for some children, greater cardiovascular and thermal strain during the second session of identical exercise. Notably, such ideal conditions are not typical of a hot-weather junior tennis tournament scenario, as players cannot similarly take advantage of the entire rest, cool-down, and rehydration period, beginning as soon as the first match is complete. Accordingly, it is less likely that, when given only 1 hour between matches, a young tennis player will begin the next match fully recovered. This is especially true following a very long, intense match for a heavily sweating older adolescent, who might be facing a 5- to 6-L body water deficit at the end of play, not to mention the potential extensive sodium and carbohydrate recovery needs as well.[20,21]

From the same national tennis championships event where the Bergeron et al[6] study was conducted, Coyle[7] examined match outcome and environmental data over a 7-year period. With the effect of tournament seeding removed, Coyle found that the winner of an afternoon singles match could be effectively predicted from the degree minutes (heat exposure) acquired during the players' earlier matches on the same day, further emphasizing the potential impact of carryover effects from previous competition-related physical activity and heat stress.

Recommendations

The recommendations presented here should be considered and are appropriate for on-court practice/training sessions in the heat as well.

- Junior tennis players often begin competition measurably dehydrated, which can increase on-court cardiovascular and thermal strain. Regular fluid intake during play and a deliberate effort to fully rehydrate between on-court sessions should be a priority for all young players, especially in the heat.
- Effective rehydration involves more than simply ample water intake. Sufficient electrolytes (especially sodium) need to be consumed as well, to offset potentially extensive sweat-related electrolyte losses and to better retain and distribute the ingested water. This can be accomplished by consuming an appropriately salted sport drink and meals/snacks with high sodium content during and after play, respectively.
- Other nutrient (carbohydrate) advantages of a carbohydrate-electrolyte drink play a proportionately bigger role on court and during the recovery period between matches, as a child grows and matures, and as match duration, intensity, and heat stress increase and should be accordingly considered for use during and after play.
- Multiple competitive matches on the same day can pose a particular heat injury risk and performance challenge because of insufficient recovery time and rehydration, as well as potential carryover effects from the previous match. Tennis-governing bodies and tournament directors should provide longer rest and recovery periods between same-day matches as environmental heat stress increases, to improve player safety and performance.

Concluding Remarks

With adequate hydration, youth athletes do not seem to have less effective thermoregulatory and insufficient cardiovascular capacities compared with adults during exercise in the heat. However, junior tennis players are very capable of incurring significant body water and sodium deficits during on-court training and competition that can negatively affect performance and readily increase the risk for exertional heat illness. Competing at all in an unsafe environment can put young players at great risk, even if they are well hydrated. More research needs to be done to better appreciate the dehydration and thermal strain challenges facing junior tennis players, so that more specific evidence-based guidelines for enhancing safety and performance can be established. However, with evolving information, it is increasingly clear that the emphasis should be less on accommodating purported inherent disadvantages of young players to focusing more on readily modifiable risk factors such as scheduling of play and hydration management. AJLM

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