Heat and Hydration Considerations for Junior and Collegiate Tennis Players

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SUMMARY

Heat and hydration may not be the first considerations of tournament directors, coaches, and athletes, when preparing for tennis. However, health risks and performance decrements are associated with both. The demands of tennis, particularly during multi-day tournaments, predispose players to increased core body temperature and large fluid losses. This combination of factors can lead to decreased performance and exertional heat illnesses such as heat cramps, heat syncope, or heat exhaustion. By identifying individual fluid and salt needs, designing a replacement plan, and reducing core body temperature during and between matches, athletes can optimize performance while minimizing risk of heat illness.

INTRODUCTION

Tennis is not commonly included in discussions of thermoregulation, heat illness, and hydration in sports. Its exclusion may be due to the low prevalence of serious heat illness (35), when compared with sports such as football, or due to an underestimation of the length of heat exposure, which cannot be overlooked when events last more than 1 hour. The main issue is that tennis players are exposed to hot humid conditions for extended (and possibly repeated) periods while they perform at high metabolic rates (46).

Air temperatures at summer tournaments may exceed 40°C (104°F) (27,34,45), and wet bulb globe temperatures (WBGT), which take environmental humidity and the sun’s radiative force into account, may surpass the critical WBGT level of 30°C. In this scenario, both the radiant energy of the sun (which has anecdotally resulted in court-level air temperatures topping 65°C, 150°F) and the convective force of the warm air moving across the body, heat the player. In addition, the physical demands of tennis compel the athlete to contend with the heat that is produced by his/her own body. During exercise, body heat accounts for most of the energy that is released when nutrients are metabolized. Therefore, the more energy a player needs (i.e., playing intensity), the more heat will be produced. In a cool environment, convection allows this heat to be transferred from the working muscles to the blood, which relays the heat to the skin surface where evaporation and further convection cool the blood that returns to muscles (58). However, a hot environment reduces the ability of the body to dissipate heat from the blood at the skin surface (60).

Under these conditions, heat storage in the tissues surrounding the muscles can occur due to compromised thermoregulation. Heat storage and the resulting increased core body temperature (Tc) is a serious concern for player performance and safety. Education regarding the precautions that should be taken prior to, during, and after play is valuable for tournament organizers, coaches, and athletes to avoid illnesses, as well as to optimize performance.

THE PHYSICAL DEMANDS OF TENNIS

To understand the risk of heat illness to tennis players, it is important to comprehend the energy requirements (and thus the heat production) imposed by the exercise intensity. Three common methods of measuring exercise intensity are heart rate (HR), maximal oxygen consumption (VO2max), and blood lactate concentration. All these techniques have...
been measured in a number of studies (16,20,28,34,36,37,39,56). During matches, HR ranges from a low of 94 beats per minute (bpm) in doubles play to a high of 190 to 200 bpm, associated with all-out efforts during long singles rallies. Overall, mean HR values, however, lie between 140 and 160 bpm, depending on the competitiveness of the match (28).

The average VO2max values for tennis players have been measured at 55 mL·kg⁻¹·min⁻¹ for males and 45 mL·kg⁻¹·min⁻¹ for females. Metabolic heat production from muscular contraction peaks when athletes are at their VO2max, and therefore, the more important value to take into account is relative exercise intensity (i.e., percentage of VO2max). Tennis athletes typically average 46 to 56% VO2max over the course of a match (29,56,57), showing that tennis players produce great amounts of metabolic heat while competing. In comparison, relative exercise intensity was recently evaluated during a simulated American football practice and was found to average 55% of VO2max when standing time was included in the calculation (33). Although football players may not be afforded the same cooling abilities as tennis players due to their uniforms (4,33), the parallel between the great amounts of metabolic heat produced in both sports has not been overlooked (46).

Study of blood lactate accumulation provides the final verification of the high levels of exercise intensity present in tennis. As an athlete performs more anaerobic exercise of high intensity, lactate accumulates in the blood. Therefore, higher concentrations of lactate are associated with higher work intensities (57), as summarized by Fernandez et al. (28). With blood sample collections normally restricted during live matches to between-game rest periods, average lactate concentrations are low (1.8-2.8 mmol/L) (28). However, concentrations as high as 8 mmol/L have been measured in practice settings immediately after intense points (24,57).

It is important to note that the above values are means and represent the average value over the course of a match or practice session. Measurements may vary depending on the type of player who is controlling the match (i.e., attacking or baseline) and the court surface (i.e., grass, clay, or hardcourt). For example, average point length during a match has been observed to be as short as 3 seconds or as long as 15 seconds (36). Several past studies, as reviewed by Kovacs (36), reveal that the overall point duration averages 8.00 ± 2.58 seconds and work to rest ratios range from 1:2 to 1:5 (28). These values emphasize that, over the course of a match, a player may be in the act of playing a point for only 16 to 27% of the total match duration. However, the intensity of that active time has been shown to be high. The effect of this physiological strain spread over the course of a 2- to 3-hour match, and possibly repeated 2 to 4 times throughout the course of a day, shows great potential for heat production and heat storage.

**PERFORMANCE DECREMENTS**

The above information has revealed that tennis involves high workloads combined with exposure to hot humid environments. As Tu rises during exercise, sweat evaporation cools the skin surface. Sweating continues, whether or not the sweat evaporates (i.e., cooling the athlete), until the athlete’s Tc rises sufficiently. In this setting, becoming dehydrated becomes a serious concern for the tennis athlete. As little as a 2% drop from baseline body weight due to dehydration decreases exercise performance during endurance exercise (8,32) and tennis-specific skills (40,43). Poor prematch hydration practices and high sweat rates put tennis players at risk for becoming dehydrated, which results in a faster Tu rise and performance decrements.

Prior to match play, hydration monitored via urine-specific gravity (Uw) ranged from 1.017 to 1.025 (17,18,34), which indicated that most tennis players enter matches in a less than optimal hydration state. Typically, Uw values less than 1.015 are recommended for proper pre-exercise hydration in a warm environment (14). The normal Uw value (i.e., 1.017) (7) would not pose great risk for athletes participating in shorter events. However, prematch hydration may progressively deteriorate after multiple events within the same day or during a multi-day tournament.

Sweat rates of tennis players range from 0.5 to 2.6 L/h (12,14). In contrast, fluid ingestion during tennis has been reported from 1.0 to 1.6 L/h (12,15). Therefore, it is easy to see if a player has a high sweat rate why he or she may become dehydrated. In some instances, a player’s best efforts to rehydrate may not even be enough because fluid emptying from the stomach maximizes at the rate of approximately 1.2 L/h (22); fluid ingestion above this value may result in gastrointestinal discomfort (18).

If dehydration progresses without adequate fluid consumption, the rate of Tc rise may increase. Sawka (51), Sawka and Coyle (52), and Coyle and Montain (22) concluded that every 1% of body mass loss results in a final Tc that is 0.2 to 0.3°C higher than it would be in the same individual in a normally hydrated state. For example, during tennis match play, Tc may rise to 38.0–38.9°C (18,34,45), which may be exacerbated by increased sweat loss. Potential increased Tc rise may lead to further impairment of the cardiovascular system and earlier fatigue (21).

Contrasting views exist as to the exact mechanism(s) of dehydration-impaired performance (53); however, both views agree that exercise intensity decreases in the face of dehydration. In the case of an unchallenging drill or opponent, a decrease in performance may be acceptable to the athlete. Bergeron et al. (17) stated that certain training and competitive settings allow athletes to “get away with” a greater level of dehydration because they are not optimally challenged. However, during demanding tasks, even the smallest decrease in performance may lead to task failure.
HEAT AND HYDRATION: HEALTH CONCERNS

Secondary to decreased performance, hot environments are commonly associated with exercise-associated muscle cramps (EAMCs) or exertional heat cramps (4). The term EAMC is defined as painful spasms of the skeletal muscles following prolonged strenuous exercise (4) and are often observed in tennis players (12,35,46,55). Controversy exists as to the etiology of EAMC and exertional heat cramps (13,26,54). There appear to be 3 commonly observed predisposing factors: exercise-induced muscle fatigue (31), body water loss (14), and/or a large sweat sodium loss (4).

Although rare, some athletes lose 2.5 to 3.5 L of sweat per hour in hot and humid climates. Thus, the potential for a significant body water deficit exists during a 2- to 3-hour match or training session. Even with a low concentration of salt (sodium chloride, table salt: chemical formula NaCl) in the sweat, an impressive 5- to 12-g loss of salt per hour is possible, among older teens and adults (11). To put this in perspective, an average American consumes about 8 g of salt per day; 8 g is equivalent to approximately 1 tablespoon. Thus, without adequate salt in the diet, a deficit of total body sodium can develop.

With respect to preventing heat illnesses that involve dehydration and a whole body salt imbalance (i.e., heat cramps, heat exhaustion), athletes may add sodium to their diet by simply salting their meals or eating processed foods (11). A can of soup, for example, contains about 2 to 2.5 g of sodium; a serving of canned tomato juice contains about 1.5 g (3). The sodium content of some vegetables increases greatly when they are canned; for example, raw green beans contain 0.1 to 0.3 g of salt, but the same vegetable contains 0.5 g when canned. In comparison, fluid-electrolyte replacement beverages contain a small amount of salt (0.1-0.3 g NaCl) per 20 oz container. Supplemented the diet, at least 1 hour before and after competition or training, with a serving of half teaspoon (1 g) of table salt combined with 32 oz of a sport drink is an easy way to add additional fluid, carbohydrate, and salt to one’s diet. For those athletes who are especially prone to heat cramps or dehydration, sodium-containing fluids (e.g., quarter teaspoon [0.5 g] of table salt added to 32 oz of sport drink) during exercise may be instituted as part of the hydration plan. Salt tablets can be useful, as long as they are consumed with enough water. Importantly, any method for increasing salt intake should be tested prior to competition, to determine which routine is tolerated best.

It is reasonable to consider the long-term effects of adding salt to one’s diet. Presently, the U.S. government recommends that adults consume only 1.5 to 2.3 g of sodium per day (48), which is equivalent to 3.8 to 5.8 g of table salt. In view of the increasing rate of obesity and high blood pressure in Americans, this recommendation is prudent. However, this advice is not given specifically for young, lean, healthy tennis players who have normal blood pressure. Our suggestions regarding salt replacement are given to prevent heat illnesses, which challenge athletes during multi-day tennis tournaments in summer months. Due to a wide range of individual-specific salt needs and environmental stressors, it is difficult to put a numerical value on how much additional salt is too much. Thus, salt supplementation should be slowly incorporated into an athlete’s hydration plan to avoid ill effects that may be associated with oversupplementation.

An athlete may start by adding a few of the previously mentioned higher salt-containing foods to their pre- or inter-tournament diet or by adding a small amount (i.e., quarter teaspoon) of salt to their sport drink between matches. Should exertional heat cramps persist, slowly increasing salt supplementation is then advised.

Heat acclimatized highly trained athletes typically have a lower amount of salt in their sweat (0.8-1.5 g/L of sweat) (1), but occasionally a tennis player has “salty” sweat due to his/her heredity. Table 1, adapted from Bergeron 2003 (11), presents a relevant example of how salt imbalance may occur when exercise duration, sweat rate, and daily salt intake are held constant. First, it is useful to know that sweat contains a wide range of 0.8 to 4.0 g of salt (NaCl) per liter. Second, the reader should note that the critical factor in salt balance is the different sweat salt contents. Third, if the sweat rate is greater than 2 L/h, a salt imbalance will be more likely regardless of sweat salt concentration.

Past studies of illnesses within tennis matches have found muscle cramps to account for 5.7% of all medical reports (55) and the incidence of all heat-related illnesses to be about 1 per 100 athletes (35). The incidence of heat-stroke (a medical emergency) and severe heat exhaustion in tennis is relatively low. Thermoregulatory strain during tennis has been shown to be “moderate,” and Tc tends to remain within safe levels (45). For example, Bergeron et al. (15) demonstrated that collegiate athletes are able to avoid heat illness while maintaining fluid-electrolyte balance over 3 successive days of tennis play; this emphasizes that proper hydration decreases the risk of exertional heat illnesses (4).

The incidence of exertional heat illnesses at the United States Tennis Association (USTA) Boys’ Championships was summarized for 6 years between 1986-1988 and 1990-1992 by Hutchinson et al. (35). During this surveillance, 11 of 1440 athletes presented with injuries that were heat related. Of these 11, 7 athletes showed signs of early heat exhaustion and one was transported to the hospital for treatment of heat exhaustion. No cases of heatstroke were observed. This study is limited, however, because Kalama-zoo, MI (where this particular tournament is held), offers average high air temperatures of around 28°C (82°F) during July and August (44). The authors noted that all illnesses took place during 2 particular summers, which were classified as unusually hot. Despite research showing the thermoregulatory strain of tennis to be
moderate, and the observed incidence of heat-related illnesses to be low, risk still exists. To more accurately classify the thermoregulatory strain of tennis, it is important to study the strain in warmer climates that mimic unusually hot days (i.e., when risk is high). Also, the tennis literature would be improved with additional heat illness injury analysis. Within the analysis, it would be of utmost importance to make sure that fatigue, heat cramps, and heat exhaustion are further investigated to see if hydration, or a combination of the two is at fault.

Children and young adults are at particular risk of heat exhaustion during tennis training and competition in the heat (6). The cardiovascular system of maturing children is underdeveloped when compared with that of an adult as shown by Drinkwater et al. (25). Prepubertal girls exhibited an increased percentage of blood flow to the skin, a decreased venous return, and a reduced time of exercise; this occurred at the same relative exercise intensity and at the same rectal temperature as adult female subjects. Children, like adults, involuntarily dehydrate due to insufficient fluid intake during exercise in the heat (10,32,49,50). At young ages, this likely does not result in injury because children will stop exercise well before dangerous $T_c$ or dehydration occurs, possibly because organizational, peer, and competition pressures are low (6). However, as these pressures increase in later years, athletes tend to disregard their own safety and continue to exercise when they otherwise would rest. The importance of proper hydration and body temperature management cannot be emphasized too often among competitive young tennis players.

**REST PERIODS**

The previous sections have described the characteristics of tennis that directly put players at risk for heat- or hydration-related problems. The final indirect risk factor involves rest periods during a tournament or strenuous practice. Rest periods allow $T_c$ to return to the preplay level and give athletes an opportunity to rehydrate amply. However, this often is not the case during tournament play, due to the rigorous schedule of matches. Junior and collegiate tournaments typically last 3 to 4 days, and during this time, players may play up to 12 matches if they advance to the finals in both singles and doubles matches. Due to the variation of match duration (i.e., 30 minutes to over 3 hours) (15), the amount of rest a player receives on any given day also can fluctuate greatly. Thus, the USTA enforces allowable rest times between points (20 seconds), changeovers (90 seconds), and sets (120 seconds). If players split sets, a mandatory 10-minute rest is required for the boys’ and girls’ 12 to 16 year old division. The 10-minute rest period may be granted in the case of split sets in the boys’ and girls’ 18 year old division only if the referee notes that environmental stress is high prior to the start of the match. Between matches that take place on the same day, a minimum of 30 minutes is allowed before a doubles match and 60 minutes before a second singles match (30). Therefore, a player above the age of 18 years may be bound by the rules to play three 3-set matches (2 singles matches followed by a doubles match), which involve only one 60-minute and one 30-minute rest period. This difficult playing schedule, combined with poor rehydration habits, may result in an increased starting $T_c$.

### Table 1

<table>
<thead>
<tr>
<th>Athlete status</th>
<th>Highly trained, heat acclimatized</th>
<th>Highly trained but not heat acclimatized</th>
<th>Highly trained, heat acclimatized, with hereditarily high level of salt in sweat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise duration, h</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Sweat rate, L/h</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Sweat salt content, g/L†</td>
<td>1.0</td>
<td>2.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Total salt loss during exercise, g †</td>
<td>4.0</td>
<td>8.0</td>
<td>16.0</td>
</tr>
<tr>
<td>Average daily U.S. dietary salt intake, g/24 h</td>
<td>8.0</td>
<td>8.0</td>
<td>8.0</td>
</tr>
<tr>
<td>Daily salt balance, g/24 h</td>
<td>+4.0§</td>
<td>0.0</td>
<td>−8.0</td>
</tr>
</tbody>
</table>

*Information adapted from Bergeron (11).
†One teaspoon of table salt (sodium chloride, NaCl) is equivalent to about 8 g.
‡Total salt loss during exercise (grams) = exercise duration (hours) × sweat rate (liters/hour) × sweat salt content (grams/liter).
§This extra salt will be eliminated in the urine of young, lean, healthy individuals; it is not harmful if they are not obese, genetically salt sensitive, overweight, or prone to high blood pressure.
and $U_{so}$ during later matches (17). Furthermore, increased heat exposure can be a predictor of tennis match outcome (i.e., the player who has been exposed to less heat in his/her first match will more often be the winner of the second match) (23).

**RECOMMENDATIONS**

The above facts emphasize the importance of both temperature and hydration management, to optimize performance and reduce the risk of exertional heat illness among junior and collegiate tennis players. To establish proper fluid replacement habits, an athlete should verify how much he/she needs to drink, determine when to drink, and establish what to drink.

Determining the volume of fluid to drink begins with determination of sweat rate. This process is simple (Table 2), requires little time, and involves no special equipment (19). After determining the sweat rate, an in match hydration plan should be developed to replace at least 80% of fluid loss per hour. As stated earlier, this may be difficult due to high sweat rates (0.5-4 L/h) and relatively low (approximately 1.2 L/h) maximal gastric emptying rates. For example, a player with a sweat rate of 2.5 L/h may only be able to comfortably replace about 50% (1.2 L/h) without experiencing gastrointestinal distress. Consequently, the goal of replacing at least 80% of fluid while in match may not be feasible.

This fact highlights the importance of monitoring pre-, during-, between-, and post-match hydration practices. The most convenient method to determine when to drink involves a combination of body weight measurements and urine color (7). Although there is some dispute as to the validity of urine color as a marker of hydration during rehydration (9,38), it is a useful field-expedient technique. Athletes should consume enough fluid to maintain urine at a “pale yellow” or “straw” color (6). The additional body weight measurements can be accomplished by traveling with a simple bathroom scale. The accuracy of the scale is not as important as using the same scale for successive measurements. This practice will enable an estimation of how much body weight was lost. Body weight measurement allows athletes to identify mild to severe dehydration and plan fluid replenishment accordingly. A large drop in body weight combined with a darker urine color should be counteracted with increased fluid replacement.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Self-testing program for optimal hydration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Make sure you are well hydrated before the workout—your urine should be pale yellow in color.</td>
</tr>
<tr>
<td>2</td>
<td>Do a warm-up run or light drills until you begin to sweat and then stop. Urinate if necessary.</td>
</tr>
<tr>
<td>3</td>
<td>Towel yourself dry and weigh yourself on a floor scale (accurate to 0.1 kg).</td>
</tr>
<tr>
<td>4</td>
<td>Play/drill for 1 hour at your anticipated match intensity.</td>
</tr>
<tr>
<td>5</td>
<td>Drink a measured amount of fluid during your play/drill, if you are thirsty. It is important that you know exactly how much fluid you consume during your hour of exercise.</td>
</tr>
<tr>
<td>6</td>
<td>Do not urinate until post–body weight is recorded.</td>
</tr>
<tr>
<td>7</td>
<td>Towel yourself dry and weigh yourself again on the same scale used in step 3.</td>
</tr>
<tr>
<td>8</td>
<td>You may now urinate and drink fluids as needed. Calculate your fluid need using the following formula:</td>
</tr>
<tr>
<td>A</td>
<td>Enter your bodyweight from step 3 in kilograms (to convert from pounds to kilograms, divide pounds by 2.2)</td>
</tr>
<tr>
<td>B</td>
<td>Enter your bodyweight from step 7 in kilograms (to convert from pounds to kilograms, divide pounds by 2.2)</td>
</tr>
<tr>
<td>C</td>
<td>Subtract B from A $&quot;A&quot; - &quot;B&quot; =$</td>
</tr>
<tr>
<td>D</td>
<td>Convert your total in C to millimeters by multiplying by 1000 $&quot;C&quot; \times 1000 =$</td>
</tr>
<tr>
<td>E</td>
<td>Enter the amount of fluid consumed during the play/drill in milliliters (to convert from ounces to milliliters, multiply ounces by 30)</td>
</tr>
<tr>
<td>F</td>
<td>Add E to D $F =$</td>
</tr>
<tr>
<td></td>
<td>The final figure is the number of milliliters (ml) that you need to consume per hour in order to remain well hydrated. If you want to convert milliliters to ounces, divide by 30</td>
</tr>
</tbody>
</table>

This table may be used to calculate the amount of fluid needed during a tennis match to remain hydrated. (Adapted from Casa D. Proper hydration for distance running-identifying individual fluid needs. Track Coach 167: 21–28, 2004. With permission.)
Finally, we consider what the athlete should drink. Some players experience additional gastrointestinal distress due to sport drink consumption, linked to the presence of fructose in many sport drinks (47). The question of “sport drinks versus water” is complicated and has been debated for decades. Sport drinks offer 3 previously described nutritional benefits to tennis players: salts, carbohydrates, and water. Also, the palatability of sport drinks may increase fluid intake during tennis play (18). These points highlight the importance of an individual hydration plan that identifies how much (based on sweat rate), when (based on playing schedule and current hydration status), and what (based on preference and exertional heat cramp history) to drink. Also, adequate electrolyte, energy, and water replacement can be accomplished in most cases during meals that are consumed between matches (59); for example, ample amounts of salt in the diet makes consumption of sport drinks unnecessary for sodium chloride replacement (41). However, a match that lasts 3 hours or more may necessitate a sport drink (14). Based on these facts, consumption of sport drinks should be emphasized before, during, and after matches when multiple matches with short rest periods limit the amount of full meals that a person can ingest. Salt should be added to the sport drink, based on the previously mentioned guidelines, in the case of an athlete who commonly suffers from exertional heat cramps. Sport drinks should also be used to encourage fluid consumption in warm environments by persons who realize that they are more apt to drink on changeovers based on the palatability of a certain sport drink.

After a hydration plan has been established, it is important for the athlete to take other measures before, during, and between matches to maintain a safe $T_c$. The most important action an athlete can take is to become heat acclimatized prior to the beginning of a tournament. This is of particular concern to athletes who travel from a cooler climate to a tournament located in a hot climate. Full heat acclimatization is accomplished by exercising in a warm environment (i.e., similar to where the tournament will take place), while gradually increasing exercise intensity and exercise duration over the course of 10 to 14 days. The benefits of doing so include decreased HR, $T_c$, perceived effort, and sweat sodium concentration, as well as increased exercise endurance time, sweat rate, and plasma volume, all of which are beneficial to performance in the heat (2,5). Artificial heat acclimation in cool climates can be accomplished by either practicing indoors in a warm environment or increasing the amount of clothing worn during exercise (2). It is very important that the athlete should not combine these 2 methods (i.e., increasing heat stress severely) and remain alert for symptoms of exertional heat illnesses (4,12,32).

During matches, the athletes also can attenuate $T_c$ rise behaviorally by altering their clothing choice. Clothing that is lightweight and porous should be chosen, to maximize the cooling benefits of sweat evaporation from the skin (42). Protection of the head and neck, by wearing a hat, also is advisable during prolonged solar exposure (42). Between matches, an athlete may have as little as 30 minutes to recover before the next match. Therefore, it is wise for an athlete to reduce $T_c$ after completion of the first match. This includes moving from direct sun exposure into a cool environment and minimizing activity. In especially warm or hot environments, athletes should avoid staying outside during rest periods, to watch other matches or exercising to “stay loose” because this will serve to increase $T_c$ (42). Also, maintaining proper hydration helps sustain a slightly lower $T_c$ (51).

SUMMARY
The heat and hydration issues that affect a tennis player are difficult to generalize due to the variability of the environment, playing conditions, food and fluid intake, clothing, and personal characteristics. It is clear, however, that tennis players are subject to high exercise intensities in warm environments and thus will incur an appreciable gain in $T_c$, which stimulates large sweat losses. Tournament officials should take these challenges into account when designing tournament locations, match times, and allocated rest periods. An athlete/coach pair who has properly prepared for play in the heat, by determining how much, when, and what to drink and by minimizing other practices that may contribute to dehydration and raise $T_c$, will be ultimately equipped to counteract both the negative performance and health risks of becoming dehydrated and high body temperature.

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