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Pregame Urine Specific Gravity and Fluid Intake by National Basketball Association Players During Competition

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Context: Urine specific gravity (USG) has been used to estimate hydration status in athletes on the field, with increasing levels of hypohydration indicated by higher USG measurements (eg, greater than 1.020). Whether initial hydration status based on a urine measure is related to subsequent drinking response during exercise or athletic competition is unclear.

Objective: To determine the relationship between pregame USG and the volume of fluid consumed by players in a professional basketball game.

Design: Cross-sectional study.

Setting: Basketball players were monitored during Summer League competition.

Patients or Other Participants: Players (n = 29) from 5 teams of the National Basketball Association agreed to participate.

Main Outcome Measure(s): Pregame USG was measured for each player on 2 occasions. Athletes were given ad libitum access to fluid during each game and were unaware of the purpose of the study. Volume of fluid intake was measured for each player. To assess sweat loss, athletes were weighed in shorts before and after each game.

Results: Sweat loss ranged from 1.0 to 4.6 L, with a mean sweat loss of 2.2 ± 0.8 L. Fluid intake ranged from 0.1 to 2.9 L, with a mean fluid intake of 1.0 ± 0.6 L. Pregame USG was greater than 1.020 in 52% of the urine samples collected and was not correlated with fluid volume consumed during either of the games ($r = 0.15$, $P = .48$, and $r = 0.15$, $P = .52$, respectively).

Conclusions: Approximately half of the players began the games in a hypohydrated state, as indicated by USG. Fluid intake during the game did not compensate for poor hydration status before competition. Furthermore, sweat losses in these players during games were substantial (greater than 2 L in approximately 20 minutes of playing time). Therefore, both pregame and during-game hydration strategies, such as beverage availability and player education, should be emphasized.

Key Words: hydration, dehydration, voluntary fluid intake, sweat losses, thermoregulation

Key Points

- Pregame hypohydration was noted in half of the professional basketball players studied.
- Fluid intake during games failed to compensate for pregame hypohydration.
- Sweat losses during games were substantial: more than 2 L in approximately 20 minutes of playing time.

Dehydration has been implicated in the impairment of skilled sport performance. As little as 2% dehydration impaired the skill performance (defined as number of shots made and sprint speed) of adult (17- to 28-year-old) male players during a simulated basketball game in a study by Baker et al.[1] Moreover, these players experienced progressive deterioration in performance as the level of dehydration increased to 4%. Ensuring adequate hydration includes initiating exercise in a euhydrated state and matching fluid intake to sweat rate during exercise. On the field, athletes' pregame hydration status has been assessed by measuring urine specific gravity (USG),[2–5] which has been shown to correlate with urine osmolality with reasonable reliability ($r = 0.68$, $P = .02$).[6] The National Athletic Trainers' Association recommends that athletes begin activity with a USG at or below 1.020 to ensure adequate hydration.[6]

Field research suggests that approximately 50% of individual and team-sport athletes are hypohydrated at the start of competition, with pregame USG levels greater than 1.020.[6–8] Maughan et al[9] reported that soccer players who started practice with the highest urine osmolality voluntarily drank more fluid during practice, possibly to compensate for a prepractice fluid deficit. Although higher urine osmolality was associated with a greater volume of fluid consumed, the volume was not related to better hydration during practice, as players still developed mild dehydration (1.6% of body mass) by the end of the training session.[9] It remains to be determined whether basketball players, who typically have frequent access to fluids, respond similarly.

Like soccer, basketball is a sport defined by bursts of high-intensity activity with intermittent rest periods. This type of stop-and-go action is associated with heavy sweat losses.[10] Although basketball is played indoors in a moderate climate, the intermittent, high-intensity nature of the sport coupled with the large body sizes of these athletes can lead to heavy sweat losses and dehydration.[11] However, unlike soccer, basketball provides more opportunities to drink because of closer proximity to fluids and a greater number of breaks.

The purpose of our study was to determine the relationship between pregame USG and the volume of fluid consumed by players in a professional basketball game. We hypothesized that USG would be directly correlated with volume ingested, such that basketball players would consume more fluids when their pregame USG was elevated (greater than 1.020).

METHODS

Participants

Professional basketball players (n = 29) from 5 teams of the National Basketball Association (NBA) agreed to participate. The athletes' height was 201 ± 12 cm (range, 185–226 cm) and mass was 99 ± 18 kg (range, 76–140 kg). The experimental protocol was approved by the Human Subjects Review Committee, and all volunteers gave written informed consent before participating.

Experimental Design

Over 2 years of Summer League play, we conducted a descriptive study. Athletes competed in 5 to 7 games over the course of 9 to 10 days. Measurements were taken for each player on 2 occasions, 2 to 4 days apart. No effort was made to control physical activity levels before the games; however, when the games were played in the morning, players did not participate in early morning shooting. If the game took place in the evening, players only participated in a light practice or shoot-around during the day. Approximately 1 hour before the game, participants provided a urine sample and were weighed on a digital scale (model CS2000; Ohaus Corp, Pine Brook, NJ) wearing only basketball shorts. Pregame USG was assessed within 30 minutes of collection using a clinical handheld refractometer (model A300; ATAGO Co, Tokyo, Japan). All samples were immediately discarded after this assessment.

Athletes were given ad libitum access to water and sports drink (6% carbohydrate and 18 mmol/L sodium) during the game, and the volume of fluid intake was measured. Opaque bottles were labeled with each player's number and contents of the bottle (sport drink or water). Because a staff member from each team handed the bottles to the athletes during breaks and timeouts, it was important that the bottles be labeled this way for ease of distribution. Players were instructed to drink as much or as little as they wanted but to drink only from the bottles provided to them. Efforts were made to not affect drinking behavior, though bottles were tracked throughout the game and weighed, refilled, and weighed again before being returned to the cooler. Athletes were unaware that their fluid consumption was measured and were blind to the purpose of the study. After the game, players were weighed in only basketball shorts to assess sweat loss and bottles were weighed to calculate fluid intake. If they had to relieve themselves before postgame body mass measurement, participants were asked to collect all urine. Sweat volume was calculated using the change in body mass, corrected for any urine loss and the volume of fluid consumed. All games took place in a thermoneutral environment (temperature, 20°C–22°C; relative humidity, 18%–22%).

Table. Fluid Balance Results by Game (Mean ± SD)

Game	Sweat loss, L	Fluid intake, L	Body Mass Loss, %
1	1.9 ± 0.7	1.1 ± 0.7	1.2 ± 0.5
2	2.4 ± 0.9	1.0 ± 0.5	1.6 ± 0.7
Mean	2.2 ± 0.8	1.0 ± 0.6	1.4 ± 0.6

Sweat Composition

Sweat composition was measured on a subset of players (n = 12) from 2 teams for the purpose of educating athletes and staff regarding sweat electrolyte losses. Sweat was collected via a gauze sweat patch (3M Medical Division, St Paul, MN) placed on the forearm before the game. Previous authors[12] found the forearm site to be highly correlated with whole-body sweat sodium concentration. Elastic netting held the sweat patch in place during the game. Once an adequate sample was obtained, the patch was removed when the athlete returned to the bench. The patch was placed in an airtight plastic test tube, refrigerated, and analyzed at a later time for sodium and potassium concentration via flame photometry (model IL943; Allied Instrumentation Laboratory, Lexington, MA). Total sweat sodium and potassium losses were calculated from sweat sodium and potassium concentration and volume of sweat loss.

Statistical Analysis

Bivariate correlations were calculated for USG and fluid intake (L/kg), sweat loss (L/kg), and fluid intake (L/kg) for each of the 2 games. We used paired t tests to determine differences in means. The α error level was set at .05 to establish statistical reliability. Data analyses were conducted with SPSS (version 14.0; SPSS Inc, Chicago, IL). A probability level of .05 was selected as the criterion for statistical significance. All data are presented as mean ± SD.

RESULTS

Fluid Balance

Sweat loss ranged from 1.0 to 4.6 L, with a mean loss of 2.2 ± 0.8 L. Body mass reduction throughout competition was 1.4 ± 0.6% (range, 0.5%–3.2%). Playing time was 21 ± 8 minutes out of a possible 40 minutes (length of an NBA Summer League game). A total of 52% (n = 15) of players provided pregame urine samples in which the USG was greater than 1.020. Pregame USG was moderately correlated from game 1 to game 2 (r = .61, P = .008). Pregame USG for games 1 and 2 was 1.020 ± 0.006 and 1.019 ± 0.008, respectively ($P > .05$). Fluid intake ranged from 0.1 to 2.9 L, with a mean fluid intake of 1.0 ± 0.6 L. Fluid balance values for each game are shown in the Table. Overall, players drank more sports drink than water (t_{55} = 4.135, P = .000), with mean values of 0.7 ± 0.5 L and 0.3 ± 0.4 L. This was also the case when data were analyzed separately for games 1 (P = .004) and 2 (P = .015). Pregame USG was not correlated with fluid volume consumed during either game (game 1: n = 24, r = .15, P = .48; game 2: n = 20, r = .15, P = .52; Figure). Absolute fluid intake (P = .99) and relative fluid intake (mL/kg body mass) (P = .83) were not different for

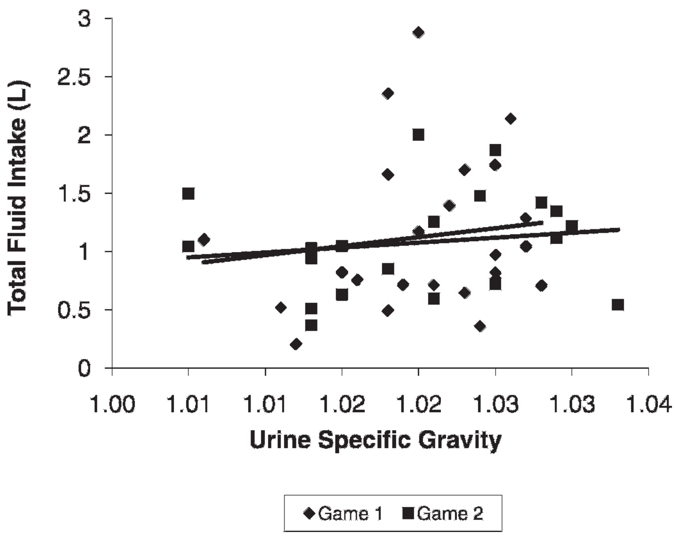

Figure. Pregame urine specific gravity versus total fluid intake. Game 1, *P* = .48; Game 2, *P* = .52.

euhydrated players (n = 22) versus those who were hypohydrated (n = 24) before each game. The correlation between fluid intake and sweat loss approached significance in game 1 (n = 29, $r = .35$, $P = .06$, with 12% of fluid intake variation due to sweat loss) and was highly significant in game 2 (n = 22, $r = .57$, $P = .006$, with 32% of fluid intake variation due to sweat loss). Heaviest sweating athletes consumed the highest volumes of fluid.

Sweat Electrolytes

Sweat sodium concentration ranged from 21.3 to 58.1 mEq/L, with a mean concentration of 41.6 ± 11.5 mEq/L. Total sodium loss (sweat sodium concentration × sweat loss) ranged from 33.2 to 161.4 mEq, with a mean loss of 82.2 ± 38.2 mEq. Extrapolating from sodium losses, salt (NaCl) loss would range from 1.9 to 9.5 g with a mean loss of 4.8 ± 2.3 g. Average sodium replacement was 16.6 ± 14.6%, ranging from 0 to 49.7%. Sweat potassium concentration ranged from 3.1 to 5.8 mEq/L, with a mean concentration of 4.9 ± 0.7 mEq/L. Total potassium loss ranged from 5.7 to 14.3 mEq, with a mean loss of 9.7 ± 2.7 mEq.

DISCUSSION

Our main finding was that voluntary fluid intake of professional basketball players during Summer League play was not correlated with pregame hydration status as assessed by USG. Such was not the case among professional soccer players studied by Maughan et al.[9] With the exception of 2 outliers, they noted a significant relationship between pretraining hydration status, as assessed by urine osmolality, and drinking response during training. The reason for the discrepancy between studies is unknown. However, given that soccer players typically have fewer intake opportunities, it is possible that those athletes who are inadequately hydrated before training become more dehydrated and have a greater perception of thirst by the time they have an opportunity to drink. Although environmental conditions were very cool (temperature = 5°C, relative humidity = 81%), sweat rates were comparable with rates in warmer environments, but players ingested less fluid than typically consumed in warmer conditions. It would be interesting to know if the association between USG and drinking is present in warmer conditions among football players. Maresh et al[13] also found that perception of thirst and drinking response were greater in individuals who were hypohydrated by 3.8 ± 0.2% compared with the euhydrated condition before exercise in the heat. According to Casa et al,[6] a USG between 1.021 and 1.030 corresponds with a level of dehydration of 3% to 5% of body mass. The basketball players' frequent access to fluids may allow sufficient opportunity to minimize further dehydration and attenuate thirst. The same may be said for tennis players, who also have ample opportunity to drink. Bergeron et al[7] noted that USG before training did not correlate with fluid intake during tennis practice. Although Bergeron et al[7] and Maughan et al[9] made no attempt to control pretraining hydration status or fluid intake, training time and intensity remained uniform for all players to standardize conditions for participating athletes. Because of the nature of Summer League play, we were unable to control exercise time or intensity in the current study. However, we believe our data reflect the habits and behavior of these athletes under similar circumstances.

The lack of correlation between USG and fluid intake may be due in part to the sensitivity of the thirst mechanism. As dehydration occurs, the sensation of thirst typically lags behind the fluid deficit, and dehydration may reach 2% to 3% of body mass before an increase in plasma osmolality stimulates the thirst mechanism.[14,15] A noninvasive proxy for plasma osmolality, USG lags behind changes in plasma osmolality and, therefore, is not the most sensitive indicator of acute hydration status. Popowski et al[16] studied the relationship between plasma osmolality and USG during exercise-induced dehydration followed by rehydration. During dehydration, plasma osmolality increased with each percentage point of body mass lost, but USG did not change from baseline until body mass loss reached 3%. We did not collect fluid intake records or measure plasma osmolality before the game, nor did we measure USG after the game. Thus, the possibility exists that a player may have consumed adequate fluid before the game but that it was not reflected in the pregame USG. However, USG readings were moderately correlated from game 1 to game 2 ($r = 0.61$, $P = .008$). In fact, 16 of the 18 players who provided urine samples before each game had consistent USG readings (ie, if the USG was above 1.020 before game 1, it was also above 1.020 before game 2). Additionally, the late day-game times would presumably give the athletes adequate time to hydrate before the game. Therefore, we believe that pregame USG indicated the player's chronic rather than acute hydration state.

The average percentage change in body mass after the game was modest at 1.4%, which is a level of dehydration commonly found in other team-sport athletes.[9,17] Dehydration indicated by a change in body mass of 2% or more impairs performance in skill sports such as or similar to basketball.[1,18,19] Of the 29 players, 5 incurred a body mass loss of at least 2% during the game. It is also possible that a mild fluid deficit sustained during the game, coupled with hypohydration before the game, may produce a significant level of dehydration in additional players. According to the National Athletic Trainers' Association,[6] a USG between 1.021 and 1.030 may reflect 3% to 5% dehydration. In our study, approximately 50% of pregame urine samples had a USG in or above this range, and nearly all players added to this level of dehydration. Consequently, although the fluid deficit averaged only 1.4% of pregame body mass, the level of dehydration at the end of the game may have been 4% to 7% of euhydrated body mass. Efforts aimed at educating players about the importance of pregame hydration may help to offset some of the deleterious effects of dehydration on basketball performance.[1,19]

The average amount of fluid consumed during the basketball game (1.0 L) was less than half of the volume required to match sweat losses. This result is comparable with what others have found in team-sport athletes.[9,17,21,22] Broad et al[22] studied basketball, netball, and soccer teams and concluded that several factors influence fluid replacement, including provision of individual bottles, proximity to bottles, duration and number of opportunities to drink, and awareness of personal sweating rates. Given these factors, a distinct possibility exists that players in our study drank more during the game than they would have under normal circumstances. Nevertheless, the mean fluid intake was less than half of the mean sweat loss, indicating that even under the best of conditions, fluid replacement remains a challenge for certain athletes. Somewhat surprising was the volume of sweat lost (more than 2 L) with an average playing time of only about 21 minutes. This is not to say that all sweat losses occurred only during game time, as players were certainly sweating during periods when the clock was not running (eg, timeouts, free throws). However, it is worth noting that a regulation NBA game is 48 minutes in length, and very large sweat losses may be incurred by halftime of a regular-season NBA game.

Sweat electrolyte concentrations and total losses in our study were similar to the findings of others.[17,21] Heavy sweat losses coupled with high sweat sodium concentrations result in large salt losses. The current recommendation of the American Heart Association[23] is to limit sodium intake to 2300 mg per day. The recommendation, although based on sound evidence for the well-established effect of sodium on blood pressure in sodium-sensitive individuals, is not applicable to most young athletes. Yet normotensive professional basketball players may mimic the practice of relatives who have been told by a physician to restrict sodium intake due to high blood pressure. In the face of high sodium losses, restricted dietary sodium may promote an acute sodium imbalance that contributes to muscle cramping.[24] Therefore, we collected sweat samples for the purposes of educating the athletes and their athletic trainers regarding the amount of sodium lost in sweat and providing appropriate strategies for replacement.

Players drank more sport drink than water. Similarly, others[20,25–28] have noted that when given a choice, people will drink more of a flavored beverage than water. Minehan et al[29] found that male and female basketball players consumed more of a 6.8% carbohydrate sport drink with electrolytes or a flavored placebo than water alone. In its position stand, the American College of Sports Medicine[30] recognized that increasing the palatability of a beverage by adding flavoring or sodium or storing fluids at a temperature between 15°C and 21°C promotes voluntary fluid consumption, although relatively few field studies of athletes exist to confirm these benefits.

CONCLUSIONS

Our findings indicate that sweat loss in NBA players can be substantial (>2 L in approximately 20 minutes of playing time). Because fluid intake during the game did not compensate for poor pregame hydration status (as indicated by a pregame USG greater than 1.020), these data suggest that both pregame and during-game hydration strategies, such as beverage availability, awareness of sweating rate, and player education, should be emphasized.

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