Original research

Incidence of pre-game dehydration in athletes competing at an international event in dry tropical conditions

James P. Finn and Robert J. Wood

Abstract **(Nutr Diet 2004;61:221–5)**

Objective: This study tested the hypothesis that the pre-game hydration status of athletes competing at an international event in dry tropical conditions may be inadequate. Differences in hydration status among athletes due to the athlete's place of origin and to activities during the previous 24 hours were also investigated, as well as the suitability of urine colour as a marker of hydration status.

Design: There were 93 male athletes tested prior to their first game, with 68 retested three to four days later. A comparison between subjects' urine specific gravity (U_{sg}) was made with urine colour (U_{col}), subjects' origin and previous 24 hours' activities as indicated in a questionnaire. No prior warning was given for either test.

Subjects: Subjects were selected on the basis of the environmental conditions they anticipated for competition and had therefore prepared for: indoor air conditioned (volleyball n = 43), outdoor (touch football n = 32) and indoor non-air conditioned (basketball n = 18).

Setting: The 2001 Arafura Games, an international event held in dry tropical conditions in Australia.

Main outcome measures: Urine specific gravity (U_{sg}); urine colour.

Statistical analyses: Differences in U_{sg} between the first and second sampling periods were compared using a Student's t-test (paired). For differences in distribution of hydration levels between sports, Fishers exact tests with Bonferroni adjusted alpha levels were used. Stepwise linear regression was used to determine the effect of athletes' variables on U_{sg}.

Results: The U_{sg} of all samples (mean ± standard deviation) was 1.020 ± 0.008, with 6% classified with serious dehydration, 50% with significant dehydration, 31% with minimal dehydration and 14% were well hydrated. There was no difference between the first and second sample ($P = 0.166$). There was a significant relationship between U_{sg} and fluid intake rating ($P = 0.015$), but no relationships between U_{sg} and other questionnaire items. There was a high correlation (r = 0.87) between U_{col} and U_{sg}, though U_{col} tended to underestimate hydration levels.

Conclusion and application: Findings are of some concern as dehydration was prevalent among athletes. Recommendations are for hydration education to specifically target those groups identified as high risk, irrespective of whether athletes had spent the previous six months in a tropical environment, and to promote U_{col} to be used by athletes for monitoring hydration status.

Key words: dehydration, urinalysis, Arafura Games, tropical environment, team sport

School of Science and Primary Industries, Charles Darwin University, and **National Heat Training and Acclimatisation Centre, Darwin**
J.P. Finn, PhD, Head of School, Centre Coordinator
Northern Territory Institute of Sport, Darwin
R.J. Wood, PhD, Senior Sport Scientist
Correspondence: J.P. Finn, School of Science and Primary Industries, Charles Darwin University, Darwin NT 0909. Email: paul.finn@cdu.edu.au

J.P. Finn and R.J. Wood jointly undertook the study design, data collection, statistical analysis and drafted the paper.

Introduction

A well regarded position on fluid replacement recommends that individuals 'drink adequate fluids during the 24-hour period before an event…to promote proper hydration before exercise or competition' (1). Athletes who begin exercise with less than normal volume of body water are likely to experience adverse effects on cardiovascular function (2), temperature regulation (3) and exercise performance (4). The effect of dehydration (reduced body fluids) is more serious when competing in a hot environment, as the dehydrated athlete is not able to cope with hyperthermia (5,6). Dehydration is likely to be exacerbated when competing in a series of events over a number of days, since athletes typically replace only 30% to 70% of sweat loss incurred during exercise (7) and weight lost during an event can still persist despite free water availability for 24 hours post-exercise (6). Subsequent games within a tournament are frequently little more than 24 hours apart. Dehydration resulting in as little as 2% decrease in body mass may affect performance (8). Dehydration has been shown to affect performance in aerobic events (9), intermittent sprints (10), team games (11,12), and to decrease time to exhaustion (13).

The Arafura Games are held in Darwin, in the tropical north of Australia, every two years. The 2001 event was held in the dry season during May, when the average outdoor maximum temperature is 32.0°C with an overnight minimum average of 22.1°C. The average 9am and 3pm relative humidity for May are 67% and 43%, respectively. The competition included 26 sports, over 20 nations and over 3000 athletes. Visiting athletes' hydration status may be compromised through the demands of travel. Many competing athletes are not acclimatised to the heat, and subsequently their hydration status may be less than optimal. Local and some visiting athletes are acclimatised to environmental conditions, although their hydration may be influenced by other factors, such as changes in diet and activity levels.

Methods for determining hydration status include monitoring body mass changes and various blood and urine markers (14). Urinalysis is a valid and reliable method for determining moderate changes in fluid balance (15). Previous research on hydration status of athletes has involved assessing hydration status each morning, or analysing fluid losses throughout competitions. However, as recommendations about fluid intake for athletes are primarily to ensure adequate hydration levels for competition, then measurement of pre-game hydration status should be considered more critical than at the aforementioned times.

This study tested the hypothesis that the pre-game hydration status of athletes competing at an international event in dry tropical conditions may be inadequate. Additionally, the extent to which differences in hydration status among athletes may be explained by an athlete's place of origin and activities during the previous 24 hours were also investigated. Arafura Games athletes from different sports and regions were compared, and the impact of activities during the previous 24 hours was investigated. The measures were repeated to determine differences over the course of the tournament. Based on these results, recommendations are made for teams at future Arafura Games and similar tournaments held in dry tropical conditions as well as feedback to agencies involved in hydration education.

Methods

Subjects

Subjects comprised 93 male athletes (Table 1) competing at the Arafura Games in the sports of indoor volleyball (n = 43), touch football (n = 32) and basketball (n = 18). Volleyball was selected as subjects had prepared to play in an air conditioned indoor stadium (actual conditions: 24°C, 50% humidity, 19.7 WBGT), basketball players had prepared to compete indoors with no air conditioning (actual conditions: 28°C, 48% humidity, 22.8 WBGT), and touch football players prepared for outdoor games in the early evening (actual conditions: 24°C, 64% humidity, 20.9 WBGT). Although hydration status was measured before games were played, we hypothesised that whether the event was to be outdoor or indoor, with air conditioning or not, may influence an athlete's preparation. The project was approved by the human ethics committees of the Australian Institute of Sport and of the Charles Darwin University. Fifty-seven percent of subjects were visitors from non-tropical areas.

Table 1. Descriptive data for athletes who participated in the study (n = 93)

Age	*Sport*	*Self-rated previous 24 hours*					
(years)	*(n)*	*fluid intake*		*alcoholic drinks*	*caffeine cups*	*activity (training)*	
25 ± 5	Volleyball (43)	poor	(12%)	0 (57%)	0 (43%)	none	(7%)
	Touch football (32)	OK	(61%)	1 to 2 (13%)	1 (43%)	light	(30%)
	Basketball (18)	v. good	(25%)	3 to 4 (10%)	> 1 (14%)	moderate	(54%)
		excellent	(2%)	4 to 6 (10%)		heavy	(9%)
				> 6 (10%)			

Procedure

Approximately one hour prior to the scheduled game starting time athletes were approached and details of the study explained. Athletes had no prior warning of the study so they could not adjust their regular routines. No warning was given of another sample being required later in the tournament.

Athletes were required to complete an informed consent form and a short questionnaire to provide details on activities undertaken during the previous 24 hours. The questionnaire asked about time spent in the tropics (< 6 months, 6–24 months, > 2 years), self-perceived fluid intake rating (very poor, poor, OK, very good, excellent), alcohol intake (none, 1–2, 3–4, 5–6, > 6 standard drinks), volume of intake of drinks including caffeine, self-perceived activity intensity (none, light, moderate, heavy), whether they had taken any vitamin supplements and whether they had suffered any adverse effects from the heat.

A 60 ml specimen collection container was supplied to the athletes for provision of a mid-stream urine sample. The samples were immediately placed on ice and the majority of samples were analysed within one hour and all within two hours. Urine specific gravity (U_{sg}) was measured using a handheld refractometer (Atago URC-NE, Japan). The U_{sg} values were categorised into levels of hydration based on the criteria of Casa et al. (12). The four levels were well hydrated (U_{sg} < 1.010), minimal dehydration (U_{sg} 1.010–1.020), significant dehydration (U_{sg} 1.021–1.030) and serious dehydration (U_{sg} > 1.030). The urine colour (U_{col}) was also categorised using an eight-scale chart (16). The same investigator determined urine colour ratings and was blinded to U_{sg} values. Of the 93 athletes tested prior to their first game of the tournament, 68 were tested again prior to the last game to be played before the finals. The time between tests was three days for touch football and four days for volleyball and basketball.

Statistical analyses

Differences between the first and second U_{sg} for the 68 athletes tested at the beginning of and then late in the tournament were compared using a Student's t-test (paired). Among these subjects, analyses of data from the questionnaire were performed on the first sample only. The extent to which U_{sg} values could be predicted from sport, time spent in the tropics, and previous 24-hour total fluid intake, alcohol consumption, caffeine consumption, and activities undertaken was investigated. Athletes who indicated that vitamin supplements had been taken in the previous 24 hours (33 samples) were excluded from the analysis of U_{col} as this can cause unusual colour changes. However, as U_{sg} depends on the total osmotic load consumed and the number of osmoles in vitamin tablets is small compared to the total osmotic load of daily food intake, vitamin ingestion does not influence U_{sg} (Armstrong, personal communication, July 2003). Due to the small sample size (n = 2) of the number of athletes that rated their fluid intake as 'excellent', these data were pooled with the 'very good' level for the analyses. The small sample (n = 2) of subjects who had spent the previous six to 12 months in the tropics were pooled with the group who had more than two years so only two categories (tropical, non-tropical) were analysed. As some sample sizes for hydration status within a sport were five or less, to test whether the distribution of hydration levels differed between sports, three Fishers exact tests were used and a Bonferroni adjusted alpha level applied. To assess the effect of sport, time spent in the tropics, and previous 24-hour total fluid intake, alcohol consumption, caffeine consumption, and activities undertaken on U_{sg} value, a SPSS statistical package was used (SPSS Inc, Chicago, SPSS for windows, version 12 2003). Data were analysed by linear regression using a forward stepwise model. A significance level of $P \leq 0.05$ was used for all analyses.

Results

Using the hydration classification of Casa et al. (12), in the current study most athletes (87%) arrived at their sporting event in some state of dehydration. The U_{sg} of all samples (mean ± standard deviation) was 1.020 ± 0.008. The U_{sg} level was not different ($P = 0.17$) for the first (1.018 ± 0.009) and second sampling periods (1.020 ± 0.008) (n = 68).

Table 2 shows the breakdown of hydration ranges for each sport. There was no difference ($P = 0.51$) in U_{sg} between those who had lived in a tropical region for greater than six months (1.019 ± 0.008, n = 40) and those who had not (1.020 ± 0.009, n = 53). There was similarly no difference ($P = 0.73$) between those in the tropical

Table 2. Sample size (%) for athletes according to the NATA Index of Hydration Status. The data is shown for all U_{sg} tests combined (n = 161) and for each sport

	overall		*volleyball*		*touch football*		*basketball*	
well hydrated	22	(14%)	5	(6%)	13	(28%)	4	(11%)
minimal dehydration	50	(31%)	30	(38%)	11	(24%)	9	(25%)
significant dehydration	80	(50%)	42	(53%)	17	(37%)	21	(58%)
serious dehydration	9	(6%)	2	(3%)	5	(11%)	2	(6%)

group who were locals (1.020 ± 0.009, n = 29) and those who had travelled to Darwin (1.021 ± 0.009, n = 11). The distribution of values into well hydrated, minimal dehydration, significant dehydration and serious dehydration ranges differed between volleyball and touch football (adjusted alpha level $P = 0.00$) such that the volleyball players were on average, less hydrated than the touch football players.

Analysis between U_{sg} and the questionnaire responses prior to the first sample indicated that fluid intake rating appeared to be the only significant factor ($P = 0.015$), though only accounting for 6.5% of the variance of U_{sg}. The athletes that rated their fluid intake as very poor or poor (n = 11) had a mean U_{sg} of 1.024 ± 0.006 (range 1.013–1.032), while those rating themselves very good or excellent (n = 25) had a mean U_{sg} of 1.017 ± 0.008 (range 1.002–1.031). The predictor variables excluded by the model were at the following significance levels: sport ($P = 0.861$), time spent in the tropics ($P = 0.871$), alcohol consumption ($P = 0.630$), caffeine consumption ($P = 0.613$), and activities undertaken ($P = 0.487$) for the previous 24 hours.

There was a high correlation (n = 128, r = 0.87, $P = 0.00$) between U_{col} and U_{sg} (Figure 1). Compared to the range of U_{sg} values, the U_{col} tended to indicate better hydration levels. A U_{col} rating of 1 or 2 is considered to be well hydrated (12). There were 20% of samples rated in this range, compared to 22% of samples rated as well hydrated based on U_{sg} values. Also, using U_{col}, 27% rated as dehydrated (colour rating ≥ 5), compared to 56% based on U_{sg} values.

Discussion

Despite public education about hydration for sporting events, there has been no official assessment of the effectiveness of such campaigns. To the best of our knowledge this is the first study to assess the hydration status of athletes at a large international sporting event in our region.

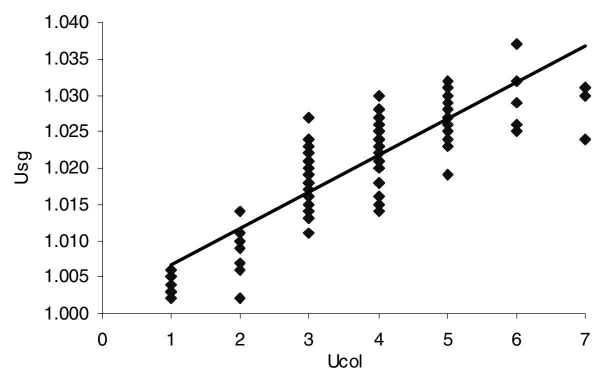

Figure 1. Relationship between urine colour (U_{col}) and urine specific gravity (U_{sg}), showing the line of best fit (n = 128, r = 0.87, $P = 0.00$)

While adequate hydration is important in a temperate climate, this is even more so in tropical regions where the risk of heat stress is significantly greater. Greater heat stress was demonstrated when physiological responses in tropical (32°C, 60% relative humidity) and temperate climates (23°C 60% relative humidity) were compared (17).

The hypothesis that pre-game hydration status of athletes competing at an international event in dry tropical conditions may be inadequate was supported. When hydration status was expected to be optimal (prior to the first event), in conditions where hydration is particularly important (in tropical conditions) most athletes (56%) had significant or serious dehydration. This is of some concern to those organising such sporting events and those involved in hydration education for sports participants.

The U_{sg} of 1.020 ± 0.008 in this study indicates better mean value for hydration levels than in a previous report (18). However, the report cited a pre-exercise U_{sg} of 1.023 ± 0.006, and no players presented with a U_{sg} below 1.012, compared to 20% of players in the current study. Differences in hydration levels between sports in the present study may have been a result of the sports being played under different environmental conditions, in which the emphasis and preparation of the players differed. Touch football had the greater percentage of well hydrated athletes but also the highest percentage of seriously dehydrated players (see Table 2). Anecdotally, the emphasis on good hydration by the 28% of touch football players who were well hydrated, their coaches and trainers was possibly a result of a recent incident of heat stress in a player during a tournament event, and the game being played outdoors. However, the fact they still had the highest percentage (11%) of seriously dehydrated players indicated the potential for the recurrence of a similar incident. An outdoor venue may have influenced some players' preparation, as touch football (outdoor) and volleyball (indoor air conditioned) differed in the distribution of players' hydration levels.

The finding of no differences in U_{sg} between the first and second sampling periods agrees with a previous report of no changes in pre-exercise U_{sg} over three consecutive days of a tennis tournament (18). The observation suggests that testing alone is unlikely to influence a player's hydration patterns. At the very least, athletes tested for the second time in both these studies, were unlikely to have communicated this information to athletes not yet tested a second time.

The purpose of this study was also to investigate the suitability of urine colour as a marker of hydration status. The need for such investigation became apparent when despite the rating of fluid intake being well associated with hydration levels, there were several athletes whose perception of their fluid intake did not correspond to their U_{sg} level. Without further education, and use of other measures such as U_{col}, these are the athletes at a high risk of the adverse effects of hypohydration. High (r = 0.80) to moderate (r = 0.68) correlations of urine U_{col} and U_{sg} have been shown previously (18,19). U_{col} tended to underestimate hydration levels in the current study. However, these results still support U_{col} as a simple, inexpensive and immediate self-measurement tool to monitor hydration status by athletes. It is very important for athletes, coaches, sport scientists and dietitians to know the hydration status of athletes in warm conditions just prior to competition. At such a time, U_{sg} or other similar laboratory measures may not always be available or practical. U_{col} was shown to be a valid and easily determined alternative, as long as athletes are aware that certain foods (20), medications (21), vitamin supplements, illnesses (22) and exercise may all influence urine colour.

It is recommended for athletes to be well hydrated prior to their event. However, good hydration practices may not provide a performance advantage over minimal dehydration (23). Increased body water reserves are likely to improve temperature regulation without causing any performance decrement (24) and therefore are in the best interests of the athlete's health. Pre-game body water reserves may become a critical factor to health and physical performance when conditions become warmer because fluid ingestion during exercise is unlikely to keep pace with high rates of fluid loss from sweating (11). While minimal dehydration may not be a concern in a temperate climate, coaches and athletes should consider the well hydrated classification as the standard for more severe environmental conditions, particularly given the fact athletes typically replace only 30% to 70% of sweat loss incurred during exercise (7). Even athletes with minimal pre-game dehydration may be targeted for education about hydration, if they are to compete in conditions of potentially high thermal stress. A likely barrier to maintaining hydration status in this population is that frequent ingestion of significant amounts of water is simply not part of the culture. Mild exercisers in temperate regions of the US were able to maintain fluid balance (25) but athletes in the present study were generally unable to counteract the large fluid losses incurred with vigorous exercise in a tropical environment.

Our recommendation for future sporting events held in a tropical environment is to increase education of the athletes about the importance of good hydration, both for local and visiting athletes, irrespective of prior experience of exercising in tropical environments. The effectiveness of the education campaign should be subsequently ascertained by assessing the hydration status of a cross-section of athletes. We also recommend that sports administrators give consideration to providing urine colour charts in the information package for self-assessment by athletes competing in a tropical environment.

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