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EFFECTS OF HYDRATION STATUS ON AEROBIC PERFORMANCE FOR A GROUP OF MALE UNIVERSITY RUGBY PLAYERS

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ABSTRACT

Aldridge G, Baker JS, Davies B. Effects Of Hydration Status On Aerobic Performance For A Group Of Male University Rugby Players. ***JEP****online* 2005;8(5):36-42. The object of this study was to examine the effects of hydration status on exercise performance in a group of amateur athletes under conditions of hypohydration (HYPO) and euhydration (EUH) at 'neutrally stable' temperatures. Eight healthy, physically active, amateur University rugby players (age 21.0±1.4 yrs, BMI 28.3±6.1 kg/m^2) underwent two 12 hr programs of hydration (fluid abstinence and consumption at ~20 °C) in order to induce states of EUH and HYPO. The participants completed two 30 min cycle ergometer tests under each hydration state in a random order. Changes in performance were measured using heart rate (HR), rate of perceived exertion (RPE) and relative rate of oxygen uptake (VO_2). Urine osmolality values (UOsm) were also measured to quantify hydration status. UOsm values were EUH 385±184 mOsm/kg and HYPO 815±110 mOsm/kg. In the EUH condition, from rest to 30 min, HR values ranged from 78±12 to 116±12 beats/min, RPE 6±0 to 11±2 units and VO_2 5.7±2.1 to 16.8±3.4 mL/kg/min. In the HYPO condition, HR 85±9 to 124±13 beats/min, RPE 6±0 to 13±2 units and VO_2 6.2±2.8 to 20.1±3.5 ml/kg/min (mean±SD, $p \leq 0.05$). In conclusion, HR, RPE and VO_2 variables increased significantly under HYPO conditions when compared to EUH conditions at ~20°C and therefore having a detrimental effect on performance.

Key Words: Hypohydration, Euhydration, Aerobic Exercise

INTRODUCTION

It has been established that insufficient fluid intake during exercise results in increases in heart rate, core temperature and oxygen utilisation; with decreases in performance measures such as increased fatigue and inefficiency (1). It has also been observed that a less than adequate hydration status is detrimental to performance (1) and furthermore, it appears that dehydration has a greater detrimental effect on aerobic, compared to anaerobic ability. In addition to performance decrements, poor hydration has also been attributed to being the influential factor in several exercise related fatalities that include heat illness and reduced homeostatic control, due to poor thermoregulation (2). However, even with this apparent decrease in performance and adverse health effects, physically active individuals tend not to consume enough fluids during, or prior to, exercise (3). This observation has been shown to alter with age where evidence suggests that the sensation of thirst may decrease (4). Competitive team sports appear to provide insufficient breaks in play for adequate fluid ingestion. This observation becomes more relevant when exercising at higher temperatures where heat fatigue is more prominent (3).

The negative effect of poor hydration has been investigated in many exercise/sports settings using various methods for altering hydration. Changes in physiological and performance-influencing variables such as reduced motor performance, reduced muscular endurance, cardiovascular drift, reduced sweat rate, blood volume and heat dissipation in addition to heat illness have all been studied (2,5,6). The majority of cases have employed measurement protocols in conditions of increased temperature (>30 °C in some instances). Conversely, a number of studies have shown little or no negative differences in the endurance properties of poorly hydrated athletic performers (1,7). The latter studies have taken place under more 'neutral' ambient temperatures and for relatively short exercise regimes even where significantly large reductions in body mass occurred from dehydration methods (e.g. 22 °C and 5.6 % decrease in body weight (7)). The significant negative effects, therefore, that inferior hydration has on many of these variables may be attributed to the high ambient temperatures recorded when these exercise regimens were administered (1).

Methods for promoting fluid loss vary from the use of diuretics and exercise-induced fluid loss, to the more extreme methods that utilize fluid loss in saunas and combined 'exercise in the heat' induced methodologies (1,5). Amongst the existing 'hydration versus performance' literature Dengel *et al* (8) examined the effects of hydration status on the rate of perceived exertion using a combined 'exercise in the heat (38 °C)' dehydration protocol. It was postulated that hydration status had no significant effect on self-stated rate of perceived exertion (RPE) values using a sub-maximal exercise protocol at 22 °C. The purpose of this study was twofold. Firstly, to examine the relationship between aerobic performance and hydration status, under more 'neutral' ambient temperatures utilizing a more 'natural' method of fluid loss such as experienced in the cooler climates (~20 °C).

A state of poor hydration in this study is referred to as "*hypohydration*", which, as defined by Barr (1) describes fluid loss induced prior to exercise as opposed to exercise-induced "*dehydration*" which as its name suggests occurs during prolonged and/or in addition to high temperature climates. Euhydration will be used to describe those participants who are in a state of adequate hydration (2).

METHODS

Subjects

The participant group consisted of 8 regularly active male athletes (3 forward players and 5 back players) randomly selected from the University rugby teams. Participants were fully familiarised with testing procedures, non-smokers, devoid of performance enhancing drugs, supplements or medication; of a healthy disposition and with no known history of cardiovascular, respiratory or renal

disorders. All testing procedures were approved by the University Ethical Committee. Participants, after being fully informed of all procedures, gave written consent to undertake them and were made fully aware they could terminate testing at any time.

Experimental Overview

Participants attended the laboratory on two occasions with a 7-day interval between testing. Hydration programs were assigned in a random manner by a single invigilator who had no verbal motivational input. Testing sessions took place between 10 am and 12 noon. Each hydration protocol (as shown) involved regulated intake of fluids over the 12 hr period prior to testing as previously recommended (9). Participants were requested to refrain from strenuous physical activity, caffeine and alcohol during the 24 hr period prior to testing.

The hydration protocols are presented in Table 1. Participants were asked to refrain from urination during the 30minute period prior to testing and instructed to collect urine samples upon arrival. Samples were collected in inert plastic containers, stored at room temperature and were not left longer than 15-20 minutes prior to analysis. UOsm markers for HYPO and EUH were measured and compared against ranges converted from the positional statement of the National Athletic Trainers' Association (10,11).

Table 1. Hydration Protocol.

Hydration Protocol
EUH *- Consume 'plenty' of fluids during the day before and especially in the 12 hour period prior to testing (recommended approx. 1.5-2.0 litres)*
Overnight fast *500ml fluid two hours prior to trial* *Obligatory breakfast of 2 lightly buttered slices of toast on the morning of the test* ***HYPO*** *- Overnight fast* *Obligatory breakfast of 2 lightly buttered slices of toast on the morning of the test* *Fluid = Water flavoured with squash cordial - 5ml cordial per 100ml water*

The aerobic exercise environment was implemented using a standard aerobic 30 min cycle ergometer test at a constant power output of 75 Watts (75 rev/min with 1 kg resistance). Participants were instructed to exercise with hands securely gripped on the handlebars. Seat height for each participant was standardized and all were given the same level of verbal encouragement. Heart rate (HR) (beats/min), hydration status (mOsm/kg) and rate of perceived exertion (RPE) using Borg's' 15-point scale (12) were the primary variables measured. Percentages of oxygen and carbon dioxide (%O_2 and %CO_2), along with total volume of expired gases were also measured and the rate of oxygen uptake relative to body weight (VO_2, STPD) was calculated via the Haldane transformation. These variables were used as primary indicators of performance. HR, RPE and expired gases, were recorded at rest, and at the last minute of the 10, 20 and 30 min exercise stage respectively by the same investigators. Fluid was restricted during trials until the post-testing period when participants in both hydration states were directed to drink water with an appropriate concentration of electrolytes to prevent the onset of mild hyponatremia (9). All data collection was carried out in a controlled laboratory environment at both constant temperature (22-23 °C) and pressure (770 mmHg).

Anthropometric and Physiological Measurement

Participant BM and height (without footwear) were recorded prior to trials. BM (Seca, 770 digital platform scale, Cranlea, U.K.), wearing underwear only, and height (stadiometer, Cranlea, U.K.), were recorded to within 0.1kg and 0.01m respectively. Aerobic cycling was performed on a calibrated Monark ergometer (Monark, 824E, Varberg, Sweden) and HR's were assessed using Polar Heart Rate Monitors (Polar Elecro, T31, Leisure systems Ltd., Southampton, U.K.). UOsm was measured in duplicate via freezing point depression to the nearest 1 mOsm/kg (Advanced Micro Osmometer, Model 3300, Partridge Green, West Sussex, U.K. calibrated against known standards of similar

concentration). VO2 was assessed using open circuit spirometry and Douglas bags (Harvard Apparatus, Kent, UK). Expired gas concentrations were analyzed using a Servomex Gas Analyser, series 1400 (Crowborough, E. Sussex, U.K.), calibrated with known gas concentrations both prior to and during trials. Gas volumes were recorded with a dry gas meter (Harvard Apparatus, Kent, UK).

Statistical Analyses

Following confirmation that data sets were normally distributed, differences between both experimental conditions were analysed by means of paired T-tests (Microsoft Excel 2002 data package) and $p \leq 0.05$ (i.e. 95% confidence limit) was regarded as a statistically significant. The degree of linear relationship between variables was examined using Pearson's product moment correlational analysis. All data re reported as mean±SD.

RESULTS

Subject descriptive characteristics were: age 21±1 yrs, height 1.80±0.08 m and body mass (BM) 92.0±20.1 kg All participants (n=8) comfortably completed the 30 min cycle program. Mean UOsm values for EUH and HYPO conditions were found to be 385 ± 184 mOsm/kg and 815 ± 110 mOsm/kg respectively ($p<0.05$). Both Figure 1 and Table 2 show the observed changes in the performance related variables recorded (HR, RPE and relative VO_2) with progressive exercise under the conditions of EUH and HYPO hydration. There was an initial increase from rest to time T=5 min for HR (~30 beats/min) and RPE (~2 units). As the trial progressed, there was a gradual increase in both HR and RPE and values are greater for HYPO than for EUH. Relative VO_2 values increase from those at recorded at rest and at T≥10 min there is a virtual leveling off, with minimal increase in relative VO_2 (~15ml/kg/min). Interestingly, at T=5 min, there was no significant difference evident between the two hydration protocols for RPE ($p>0.28$) compared to a significant difference between equivalent values of HR ($p<0.05$). Table 3. Shows observed correlation coefficients (R) between HR and VO2.

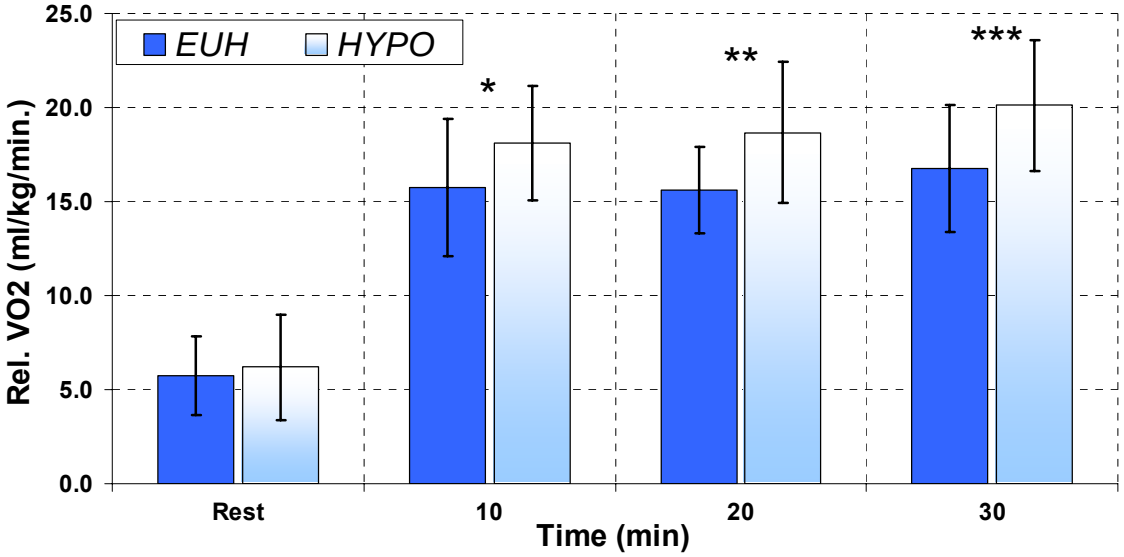

Figure 1. Changes in mean relative VO_2 with time under conditions of EUH and HYPO. Significant differences between EUH and HYPO are also shown. * Indicates significance at $p \leq 0.05$; ** Indicates significance at $p \leq 0.01$; * Indicates significance at $p \leq 0.001$**

Table 2 illustrates the progressively greater values of HR and RPE obtained for HYPO in comparison to EUH along with the progressive increase in the significant difference between protocols as the trial continued.

Table 2. HR and RPE with time under conditions of EUH and HYPO. Significant differences between protocols are also shown.

Time (min)	HR (beats/min)		RPE (units)	
	EUH	*HYPO*	*EUH*	*HYPO*
Rest	78.4 ± 12.0	84.9 ± 9.4*	6.0 ± 0.0	6.0 ± 0.0
5	107.6 ± 8.5	114.5 ± 10.4*	8.4 ± 1.8	8.9 ± 1.6
10	110.1 ± 9.3	119.4 ± 11.3*	9.1 ± 2.0	10.4 ± 1.6*
15	112.0 ± 9.2	118.5 ± 11.0*	9.5 ± 2.0	11.3 ± 2.1*
20	111.1 ± 11.7	121.5 ± 12.5*	10.1 ± 1.9	11.6 ± 2.0*
15	114.8 ± 12.7	124.3 ± 11.6**	10.6 ± 1.8	12.1 ± 2.0*
30	115.6 ± 12.4	123.8 ± 12.9**	11.0 ± 2.3	12.6 ± 2.1*

* Indicates significance at $p \leq 0.05$; ** Indicates significance at $p \leq 0.01$

Table 3. Observed correlation coefficients (R) between HR and VO_2 against RPE under both conditions of EUH and HYPO hydration status.

	RPE	
	EUH	*HYPO*
HR	0.93	0.94
VO_2	0.96	0.98

DISCUSSION

The object of this study was to compare the effect that poor hydration status has on exercise performance via the examination of various physiological parameters in healthy University rugby players of moderately athletic fitness. The majority of studies have taken place at relatively high temperatures (>30°C (6,13)) and the exacerbated negative effect that hypohydration has on athletic performance at higher temperatures has been outlined previously (1). This study therefore implemented a more 'neutral' temperature. A secondary element of the study was to investigate the use of a more 'natural' method of fluid loss, which may be representative of conditions experienced by amateur athletes in a variety of different sports. The performance related variables HR, RPE and relative VO_2, each illustrated a significant increase ($p<0.05$) under conditions of hypohydration compared to euhydrated conditions. This indicates that the physiological systems such as the cardiovascular, musculo-skeletal and homeostatic temperature regulation systems, work at greater intensities in order to sustain exercise at a given work load (75 Watts). As shown both in Figure 1 and Table 2, conditions of hypohydration produced a more negative effect on performance as exercise duration increased. This increase agrees with the findings of previous studies (1,5).

The present study also identifies the significant effect of hypohydration even at reduced exercise durations (30 min) and at 'neutral' temperatures (~20°C). With regards to relative VO_2, the study reiterates the knowledge that an individual in a state of hypohydration significantly increases their rate of oxygen consumption for a given work rate ($p<0.01$), thus increasing the likelihood of premature muscle fatigue and respiratory exhaustion. The effects of varying hydration status on values of perceived exertion reported in this study were not in agreement with those presented by others (8). The present study found that poor hydration has a negative effect on perceived exertion (i.e. an increase self stated RPE units). The perception of exertion however, could be related to the method used to induce hypohydration. This study employed abstinence from fluid ingestion to induce hypohydration where as other studies used exercise induced dehydration at 38°C (8). Prior hydration has a greater effect in reducing plasma volume than exercise-induced dehydration (1). The resulting and compensatory physiological changes such as: constriction of peripheral blood vessels to maintain blood pressure, decreased cardiac output, increased HR and decreased stroke volume may elicit a negative effect on RPE. The decreased plasma volume changes observed may lead to a greater perception of exertion. Interestingly, with a significant increase in HR between hydration protocols at T=5 min, RPE values were not significantly different between conditions. For several minutes following the commencement of the exercise task, athletes may not be aware that they are in a state of hypohydration. This may be a contributory factor to why athletes tend not to consume adequate

fluid amounts prior to performance as previously identified (3). All the participants in this study were requested to refrain from strenuous physical activity prior to testing therefore it is unlikely that muscular fatigue influenced the results. Also, the effects that diurnal/circadian variation may have on physiology and/or performance (14) were minimized as each testing session was carried out at the same time of day. Participants were also instructed to exercise with hands securely gripped on the handlebars as previous studies have shown that participant hand grip can influence the production of blood borne metabolites during ergometer testing which could possibly have affected performance (15).

There is currently no recognized 'gold standard' technique for the measurement of hydration status. However, urine osmolality values recorded in this study, are a more sensitive means of indicating changes in hydration status for more moderate levels of dehydration than measures of hematocrit and serum osmolality (16). They are also recognized as being relatively un-intrusive when compared to the invasive techniques involved in blood analysis (2). For this study, UOsm was utilized as a valid measure of hydration status in preference to urine specific gravity, as the latter, can be adversely influenced by urea, glucose and protein concentrations (16).

Individuals of an excessive competitive disposition are said to exhibit a "type A behavioral pattern" (TABP) (17). The TABP and its effect on RPE has been examined with contrasting results. Studies vary from a significantly decreased RPE value with TABP (18) to no significant differences (19). There was therefore, a need to validate RPE for use in this study under both EUH and HYPO conditions and correlation coefficients (R) between both HR and VO2 against RPE were used as a means of validation (20). Table 2 shows the correlations between hydration protocols and these variables; and with values of $R \geq 0.93$ for each, RPE values were recognized as both a valid and accurate measure of exertion throughout this study. For future studies involving individuals exhibiting TABP on self-stated exertion values, validation procedures should be explored when applying RPE values as measures of physical exertion.

CONCLUSIONS

The findings from this study are in agreement with previous investigators who have reported that poor hydration has a significantly negative effect on performance. It provides additional information concerning performance variations under more 'neutral' temperatures (~20 °C) and identifies an important consideration that relates to the method of dehydration used and the subsequent effects on the physiological responses to exercise. The study highlights a possible "stumbling block" in the use of self-state methods of perceived exertion with regards to the type-A behavioural pattern (TABP). The study also endorses the importance of adequate hydration for even the most recreational of physically active individuals. Due to the small sample size, these results should not be extrapolated to the wider recreational rugby community.

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