5-2018

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Recommended Citation

Hamer, Elika, "The Effects of Mild Dehydration on Cycling Performance in the Heat" (2018). *Health, Human Performance and Recreation Undergraduate Honors Theses*. 60.
https://scholarworks.uark.edu/hhpruht/60

The Effects of Mild Dehydration on Cycling Performance in the Heat

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A thesis submitted to the Honors College at the University of Arkansas in partial fulfillment of the requirements for the degree Bachelor of Science in Kinesiology with Honors

April 18, 2018

Abstract

Introduction: Hypohydration exceeding 2% of body mass (bm), affected by heat and thirst level, leads to decreased athletic performance. Both physiological and psychological factors of dehydration have an impact on an athlete's perceived performance. However, it is unclear whether the effects of psychological, physiological, or both have a negative impact on athletic performance caused by mild hypohydration. **Purpose:** The purpose of this study was to determine if mild hypohydration affects exercise performance in trained cyclists while blinding their hydration state. **Methodology:** Eleven competitive male cyclists participated in two blinded experimental trials, hypohydrated and euhydrated states by intra-venous infusions. The experimental criterium simulation test includes cycling through 3 sets of 20-minute steady state followed by a 5km race. **Results:** During the 5km time trial, the hypohydrated trial (39.0±0.5°C) resulted in significantly higher core temperatures compared to the euhydrated trial (38.5±0.2°C; $P<0.05$). Cycling speed was significantly faster in the euhydrated vs. the hypohydrated trial (27.3±0.1 vs. 26.2±0.7 $\text{km}\cdot\text{h}^{-1}$; $P<0.05$) due to greater cycling power output (304±6 vs. 286±10 W; $P<0.05$). **Conclusion:** Overall, the study found that mild hypohydration led to impairment in exercise performance in the heat compared to euhydration, when subjects were unaware of their hydration state. These responses might have been a response of great heat strain and/or cardiovascular impairment.

Introduction

Water is a very important aspect in the human body because it approximately makes up 73% of lean body mass in young adults (McDermott, 2017). Hypohydration is one of the concerns for athletes as it is important for them to drink plenty of water to replenish the loss of fluids during exercise and to have electrolyte balance for peak performance. Hypohydration is defined as "a deficit of body water that is caused by acute or chronic dehydration" (McDermott, 2017). On the contrary, euhydration is when the body has the optimal water content (McDermott, 2017). Hypohydration exceeding 2% of body mass (bm) would decrease exercise performance and increase thermoregulatory strain (Bardis et al. 2013). This is especially seen when people are exercising in the heat due to greater sweat loss. According to other studies, they have seen that thirst is a sign of dehydration, and consequently athletes' exercise performances get impaired (Berkulo, 2015; Greenleaf, 1992). Therefore, factors surrounding hypohydration such as the heat and thirst level can affect athletic performance.

Heat stress plays a role in dehydration due to fluid loss during exercise. Dehydration during exercise has been seen to negatively affect athletic performance in athletes (Sawka et al. 2012). Many researchers emphasize that fluid replacement during exercise in the heat is important in which many recommend maintaining hydration status within 2% of baseline for performance and health (Sawka et al., 2007). Furthermore, when improving hydration status even by ad libitum consumption of water may enhance athletic performance while exercising in the heat due to replacing about two-thirds of sweat loss (Kavouras, 2011). This signifies that replacing fluids orally satisfies thirst and therefore satisfies physiological effects of hydration. Moreover, another study has shown that completely replacing lost fluids in terms of prescribing the amount an athlete drinks further improved performance compared to just ad libitum drinking if you compare the two (Bardis, 2017). In Bardis's study, cyclists performed in the heat, and by the end of the trial, the athletes had a higher core temperature and mild hypohydration that lead to thermoregulatory strain for the ad libitum drinking compared to prescribed drinking (Bardis, 2017). Mild (~1 %) to moderate (~2 %) hypohydration has been seen to reduce high-intensity cycling performance in the heat in some population (Wilk, 2014). Therefore, replacing lost fluids during exercise to maintain hydration state is very important for peak athletic performance.

Moreover, heat stress can cause poor athletic performances because the blood vessels dilate and all the blood rushes to the skin and not to the muscles during exercise. The body thermo-regulate by keeping similar hydration status throughout activities, and is mainly controlled by evaporative heat loss (McDermott, 2017). When the body does not have enough fluid, sweat response will be impaired which leads to increase in core temperature and decline in exercise performance (McDermott, 2017). In a study that compared the effects of hypohydration on endurance exercise performance between temperate and cold air environments have shown that hypohydration impairs endurance exercise performance in temperate but not cold air (Cheuvront, 2005). Moreover, even a mild degree of hypohydration can negatively affect cycling performance due to greater thermal stress since it is seen that core temperature can be greater in the mild dehydrated trial versus the euhydrated trial (Bardis, 2013). The lower body temperature in the euhydrated trial is most likely due to having enough water to sustain greater sweating levels that cool the body down (Bardis, 2013). This can further emphasize that heat stress is an important factor that plays in hypohydration and exercise performance. Another study has shown that hypohydration negatively affects aerobic performance not only by core temperature but also when skin temperature (T_{sk}) is ~27°C, and even warmer skin intensifies (–1.5% for each 1°C T_{sk}) these decrements; and high core temperature (~40°C) alone does not impair aerobic performance

(Sawka, 2012). Therefore, the combination of hypohydration and the environment play a role in athletic performance.

Furthermore, thirst plays an important role in the body's homeostatic mechanism for fluid levels by acting as one of the main psychological indicators to replenish lost fluids and can influence the result of athletic performance (McKinley, 2004). Hypohydration has both physiological and psychological factors that can affect an athlete's perceived performance (Goulet, 2011). The meta-analysis by Goulet (2011) shows that time trial performance improved when subjects drank solely to attenuate thirst compared with drinking to completely replenish fluid loss or to not drinking at all (Cheung, 2015). Some of the problems with people drinking fluids are that, it alters thirst perception and does not separate the physiological and psychological factors. Many studies done in the past on hydration on exercise performance used oral fluid replacement, which does not separate the physiological fluid replacement and the psychological thirst sensation. Cheung's experiment is one of the few that blinded the subjects to their hydration status. They tested whether hydration and thirst sensation had a combined or separate effect on aerobic exercise performance (Cheung, 2015). From this, they found that neither the physiological effects from the dehydration status nor the perception of thirst, separately or combined, affected sustained poor exercise performance in the heat for a healthy and fit population (Cheung, 2015). However, this study used mouth rinsing instead of actually swallowing the fluid, which may have not completely blinded the subjects from thirst because it eliminated only the oral but not the pharyngeal reflex. Another recent blind study looked at the effect of dehydration during cycling performance in the heat using active but non-trained and non-heat acclimated males (James, 2017). Yet again the study concluded that hypohydration of about 2.5% body mass impairs athletic performance even when the subjects were blinded to their hydration state (James, 2017). In this, water was infused directly into the stomach using a gastric feeding tube to replace lost fluids on top of orally ingesting water every 10 minutes to eliminate the thirst factor (James, 2017). The subjects did not know whether they were getting ingested with additional water or not, so this was a blinded study (James, 2017). However, it is still unclear whether athletic performance is impaired due to the effects of psychological, physiological or both from mild hypohydration on specifically trained cyclists by blinding their hydration status intravenously.

Therefore, the purpose of this study was to determine if mild hypohydration affects exercise performance in trained cyclists even when they do not feel thirsty. Many studies have looked at hypohydration exceeding 2% body mass, but this study focused on the mild hypohydration of 1% to 2% body mass in a warm environment that facilitated higher sweat rate. The intravenous rehydration methods were used along with 25 ml of water to sip periodically during cycling to set up a blinded dehydrated and euhydrated state while measuring athletic performance by the power output measured in wattage and time trial times on the stationary bike. The primary objective of this study was to blind the subjects to their thirst level to observe whether hypohydration still affects athletic performance in cyclists in the heat comparing the dehydrated and euhydrated states. Our primary hypothesis was that the cyclists will have poor performance on the 5-k time trials while mildly dehydrated with or without the thirst sensation compared to the euhydrated state.

The findings from this research helped us better understand the effects of mild hypohydration on trained athletes. Also the results supported to identify whether hypohydration affecting exercise performance was psychological, physiological or both.

Methods

Since we were determining whether hydration affects athletic performances, it was important that we examine individuals that are competitive athletes. We recruited eleven male cyclists that are categorized as Category three or higher determined by the USA Cycling licensure system or that qualify with the VO_2 Max test in which they need to have a VO_2 peak greater than 55 ml/kg/min. The participants also needed to be free of any cardiovascular, metabolic, renal disease, and history of heat stroke (age 19-39). All subjects that participated signed an Informed Consent that has been approved by the University's Institutional Review Board.

Over the course of this study, the subjects that took part visited the lab four times in a counterbalanced, cross-over design:

1. Information visit
2. Familiarization visit
3. Hypohydrated (HYP) trial (single blinded)
4. Euhydrated (EUH) trial (single blinded)

The subjects were asked to refrain from the consumption of alcohol and over-the-counter drugs twenty-four hours prior to each visit. The subjects were required to drink additional four cups of water the night before and two cups 2-3 hours prior to arrival. As the subjects came into the information visit, they were notified of what was asked of them throughout the study. To ensure confidentiality, we coded the records of the subjects. Then, we provided an informed consent and the medical history sheet for them to sign and fill out before moving on to the measuring of other parameters. We measured the subject's body composition using Dual energy X-Ray absorptiometry (DXA), and their maximal oxygen consumption (VO_2 max) as well as heart rate (HR) during the test. The VO_2 max was measured on an electronically braked ergometer (Racermate Veletron, Seattle, WA) along with a nosepiece as the subject breathes in room air and exhale into a mouthpiece attached to a metabolic cart (Parvo Medics' TrueOne® 2400, Sandy, UT). This initial test began at 100 watts (W) and increased by 40 W every 2 minutes until exhaustion. HR was measured every 2 minutes and at the end. Subjects recorded their nude body weight with the scale provided three days prior to the two experimental trials. These tests were to ensure the guidelines are met and provide a safety factor for the subjects.

The subjects came in for the second time before we started the experimental trials to go through the entire criterium simulation test so that they were familiar with the protocol. The set up and the measures taken in this trial was the same in both experimental trials that followed except for the IV infusions. The subjects were allowed to drink as much water as they wanted during the exercise. In order to determine the amount of water that was provided in the EUH trial, we measured the sweat rate by looking at the changes in body weight. The weight measurement took into account of the water intake and urine output. Furthermore, during this visit, the subject went through measuring the oxygen consumption using nose clips and breathing through a mouthpiece.

Next step, the experimental trials were approximately seven days apart. Upon arrival at the counterbalanced experimental trials, we collected a urine sample to determine the subject's hydration level. The euhydration level was based off of the urine specific gravity < 1.020 (Kavouras, 2011). Prior to the trials, the subjects were required to consume a standardized meal for sufficient energy, and measured their nude body weight in a private bathroom. Then, the subjects entered the environmental chamber to exercise. For all trials, the environmental chamber was set to 30°C and 30% relative humidity. All subjects underwent two experimental criterium cycling performance tests. Each performance test was measured on a cycle ergometer, and they went through three sets of 20 minute steady state of 15km sessions at 50% peak power output preceded by a 5km of 3% hill climbing at race pace. The two experimental trials were equivalent except for the hydration state. For both, subjects consumed 25 ml of water every 3km to stabilize the thirst factor. In addition, in the EUH trial, they were infused with 0.9% NaCl to match the amount of sweat loss determined in the familiarization trial through an IV infusion set (Cheung, 2015). To ensure a blinded study, we connected the subjects to an IV infusion set without infusing them with anything for the HYP trial.

Experimental Measures

Core temperature was measured by a rectal thermistor (Mon-A-Therm Core, Manllinkrodt Medical, St. Louis, Missouri, USA) that was inserted in the subject 10 cm past the anal sphincter (Cheung, 2015) by the subject himself. Skin temperature was measured via the four iButtons (DS1922L, Maxim Integrated Products Ins, Sunnyvale, CA, USA), skin temperature thermocouples, which were attached to the skin at four sites (the deltoid, pectoral, thigh and lateral calf) on the right side of the body. We recorded both temperatures every 3km during the whole study. Heart rate was measured with a wireless heart rate monitor (Polar Electro, Oy, Finland) every five minutes during the trials as well (Cheung, 2015).

A heart rate monitor was strapped on the subject's chest, and a blood pressure cuff was put on the arm opposite of the catheter. An indwelling catheter was placed on the antecubital vein by an experienced technician. Blood analysis was done by taking a total of 7 blood samples measuring hematocrit, hemoglobin, and percent changes in plasma volume in this study in addition, but will be explored in another research topic.

To determine the hydration level of subjects, the subjects provided a urine sample after each trial. The urine specific gravity (USG) and the total plasma proteins (TTP) were measured via a manual refractometer (Atago SUR-NE, Tokyo, Japan). We measured the plasma and urine osmolality by freezing-point depression (Model 3250, Advanced Instruments, Norwood, MA). Moreover, EasyElectrolyte (Medica, Bedford, MA, USA) was used for an electrolyte analysis to determine the potassium, sodium, and chloride concentrations in urine.

In order to measure the differences in athletic performances between trials, the computrainer software was used to measure and record the cycling cadence, distance, power output, and watts to kg ratios during the 5km time trial sessions. Subjects did not know the performance variables during the sessions except for the distance and gearing. After every 5km during the steady state, and before and after the 5km time trial, we asked the subjects their perceived mouth dryness, thirst based off of a visual analog scale, and their stomach fullness (Rolls, 1980). The scale ranges from “not at all” to “extremely” dry. VO_2 was also measured during exercise to see the oxygen and carbon dioxide levels the body was processing.

Analysis

We calculated the descriptive data including means, standard deviations, and standard error of the means for all test variables. All data was presented in the mean ± standard deviation format. A repeated measures analysis of variance, ANOVA (trial x time), was used to determine the differences in thermoregulatory, perceptual, and cardiovascular function between the EUH and HYP trials. To follow up the ANOVA test, when having statistically significant F scores, we used the Bonferroni’s tests to see the pairwise comparisons. To see the differences in the mean values between the two trials were determined by paired t-tests. An alpha < 0.05 defined significance.

Results

Eleven male competitive cyclists concluded the study of two experimental trials, EUH and HYP states. The baseline for body mass, USG, and POsm did not differ for both trials (table 1, *P*>0.05).

Table 1. Blood, urine, and body weight parameters during criterium-like protocol for both EUH and HYP trials

	Euhydrated Trial (EUH)							Hypohydrated Trial (HYP)						
		1st bout		2nd bout		3rd bout			1st bout		2nd bout		3rd bout	
	Baseline	20 min	5 km	20 min	5 km	20 min	5 km	Baseline	20 min	5 km	20 min	5 km	20 min	5 km
BW (kg)	77.4±6.2	77.3±6.2	77.3±6.2	77.4±6.3	77.4±6.3	77.4±6.2	77.4±6.3	77.2±6.2	77.0±6.1*	76.8±6.1*	76.5±6.1*	76.3±6.1*	75.9±6.1*	75.7±6.0
ΔBW (%)	-	0.1±0.2	0.2±0.3	0.1±0.1	0.1±0.4	-0.1±0.4	-0.1±0.5	-	-0.2±0.2	-0.5±0.2*	-0.9±0.2*	-1.1±0.3*	-1.5±0.3*	-1.8±0.2*
USG	1.013±0.008							1.012±0.008						
TPP (g·L^{-1})	7.5±0.5	7.4±0.4	7.8±0.4	7.3±0.5	7.5±0.4	7.2±0.6	7.5±0.6	7.4±0.4	7.8±0.6	8.1±0.5*	7.9±0.6*	8.2±0.6*	7.9±0.6*	8.1±0.7*
POsm (mmol·kg^{-1})	292±3	295±3	302±4	296±3	304±6	296±4	304±6	291±2	294±3	301±5	296±4	301±6	295±4	302±7
P[Na^{+}] (mmol·L^{-1})	135.9±1.7	137.9±1.9	139.8±1.9	138.8±1.9	139.0±5.6	138.8±2.1	141.1±2.5	136.1±1.0	137.7±1.1	139.4±1.4	138.3±1.4	139.4±1.9	138.0±0.6	140.4±2.2
P[K^{+}] (mmol·L^{-1})	4.2±0.3	4.6±0.5	5.3±0.6	4.7±0.4	5.6±0.6	4.9±0.8	5.5±0.6	4.2±0.3	4.7±0.3	5.1±0.5	4.8±0.3	5.4±0.6	4.8±0.4	5.3±0.6
P[Cl^{-}] (mmol·L^{-1})	103.8±1.2	107.3±1.5	109.1±1.5	108.5±1.5	110.5±2.0	109.4±1.7	111.2±1.9	104.2±1.6	106.9±1.4	108.6±1.4	107.5±1.5	108.6±1.8	107.3±1.9	109.1±1.6
ΔPV (%)	-	-0.0±4.7	-6.3±3.2	2.2±5.3	0.3±6.0	7.4±5.7	2.5±5.7	-	-4.8±3.1	-8.8±4.3	-4.2±3.2*	-9.4±4.7*	-5.2±4.1*	-9.8±8.1*
Glucose (mmol·L^{-1})	6.9±1.6	6.1±1.1	6.4±1.2	5.9±0.9	5.8±1.4	5.5±0.8	5.6±1.4	6.1±1.3	5.5±1.3	6.2±0.8	5.8±0.8	5.8±0.6	5.6±1.0	5.2±1.0
Lactate (mmol·L^{-1})	-	-	7.3±3.6	-	7.1±2.7	-	6.6±2.1	-	-	6.6±2.8	-	5.7±2.7*	-	5.3±3.3*

Values are presented as mean±SD. BW, body weight; ΔBW, change in body weight; USG, urine specific gravity; TPP, total plasma protein; POsm, plasma osmolality; P[Na^{+}], plasma sodium; P[K^{+}], plasma potassium; P[Cl^{-}], plasma chloride; ΔPV, changes in plasma volume;
* denotes statistically significant difference compared to the same time point of the EUH trial (*P*<0.05)

The experimental trials included three sets of 20-minute steady state of 15km sessions at 50% peak power output preceded by a 5km of 3% hill climbing at race pace. During the second and third 5km time trial, the HYP trial (39.0±0.5°C) resulted in significantly higher core temperatures compared to the EUH trial (38.5±0.2°C; *P*<0.05; figure 3). There was a decrease in body weight for the HYP trial for the second and third 5km time trials as well (-0.9%; -1.5%; table 1). There was no difference in HR for both trials as they reached 90±4% of age-predicted max HR (figure 4). Furthermore, cycling speed (27.3±0.1 vs. 26.2±0.7 km·h^{-1}; *P*<0.05; figure 2) was significantly faster caused by greater cycling power output (304±6 vs. 286±10 W; *P*<0.05; figure 2) during the performance test in the EUH trial compared to the HYP trial. The subjects were 32 seconds and 46 seconds faster in the EUH trial than the HYP trial in the second and third 5km time trials, respectively. The 3rd bout of the 5km time trial had the biggest difference in speed between the two trials (27.25 (EUH) vs. 25.44 km·h^{-1} (HYP); *P*<0.05; figure 1). Therefore, in the EUH trial, the cyclists were able to overall perform better than in the HYP trial.

Figure 1: Cycling Speed during 5-km time trials for EUH and HYP trials

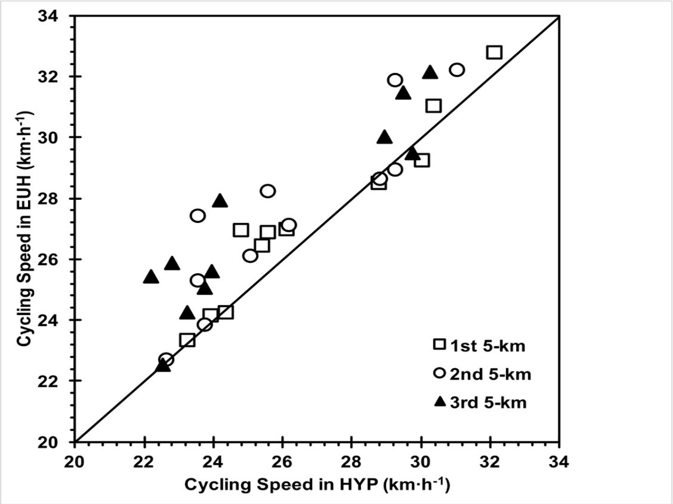
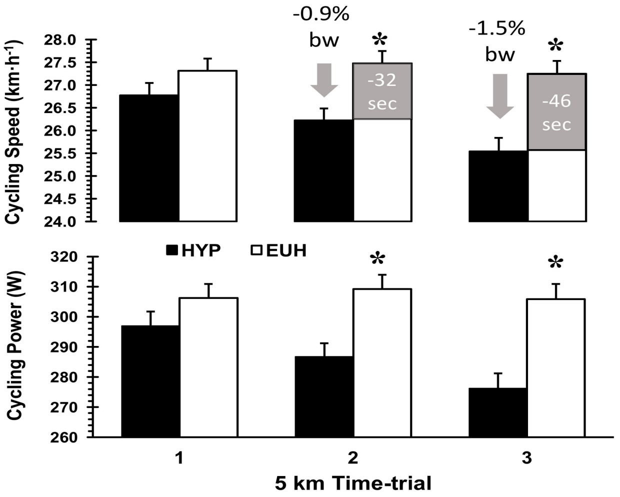


Figure 2: Cycling Speed (km×h^{-1}) and Cycling Power (W); HYP vs. EUH



* denotes the data that is statistically significant difference compared to the same time point of the EUH trial (*P*<0.05)

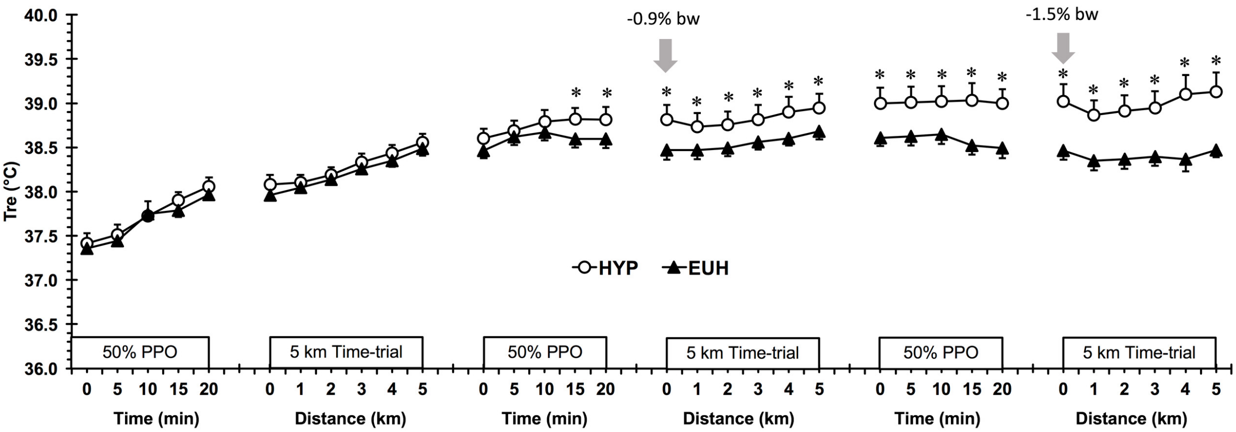
Overall, the subjects could not tell apart the two trials in terms of hydration status. Though, thirst perception had a statistical difference between the two trials, as the HYP trial for the 3rd bout, had a higher thirst perception than the EUH trial in the 3rd bout of the 5km time trial (79mm±29 vs. 60mm±32; table 2). Otherwise, as seen in table 2, generally the thirst perception, the RPE, and stomach fullness do not have statistically significant differences between the trials. These were kept constant by blinding the hydration state. During the criterium-like bouts, the subjects had significant drop in body weight throughout the HYP trial vs. the EUH trial. There was especially a change in body weight for the 5km time trial in the 3rd bout of the hypohydrated state (-1.8±0.2; table 1). The TPP levels were significantly higher in the HYP trial compared to the EUH trial as well, especially looking at the 3rd bout (8.1±0.7 vs. 7.5±0.6; table 1). POsm and the difference in concentrations for Na^+, K^+, and Cl^- were not statistically significant. Change in PV level was lower in the HYP trial (-9.8±8.1; table 1) than the EUH trial (2.5±5.7).

Table 2. Perceptual responses of exertion, thirst, and stomach fullness during criterium-like protocol for both EUH and HYP trials

	Euhydrated Trial (EUH)									**Hypohydrated Trial (HYP)**								
	1st bout			**2nd bout**			**3rd bout**			**1st bout**			**2nd bout**			**3rd bout**		
	Baseline	**10 min**	**20 min**	**0 min**	**10 min**	**20 min**	**0 min**	**10 min**	**20 min**	**Baseline**	**10 min**	**20 min**	**0 min**	**10 min**	**20 min**	**0 min**	**10 min**	**20 min**
RPE (6-20)	6±0	9±2	9±2	12±2	11±2	11±2	14±3	11±2	11±1	6±0	8±0	9±2	13±2	10±2	11±2	15±2	12±2	12±2
Thirst (mm)	26±24	28±12	39±24	45±25	45±26	50±26	46±26	60±32	60±32	27±20	40±19	40±20	54±30	59±26	64±26	72±29*	72±24*	79±29*
Stomach Fullness (mm)	47±35	46±31	43±26	45±32	40±29	37±19	45±32	38±29	37±22	49±32	46±31	46±28	37±25	40±23	43±27	33±24	37±23	35±19

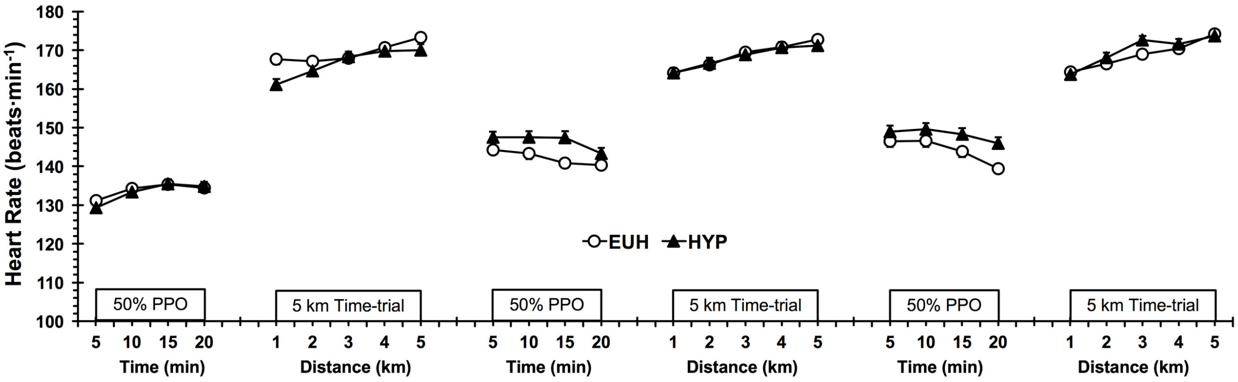
Values are presented as mean ± SD.
* denotes statistically significant difference compared to the same time point of the EUH trial (*P*<0.05)

Figure 3: Rectal Temperature for HYP and EUH (°C)



* denotes the data that is statistically significant difference compared to the same time point of the EUH trial ($P<0.05$)

Figure 4: Heart Rate (beats×min^{-1}) for HYP and EUH



Discussion

The goal of this study was to observe if exercise performance in trained cyclists was affected by mild hypohydration independent of thirst while blinded to their hydration status. The major findings were that the subjects in the EUH trial performed better than in the HYP trial due to faster time trial times and higher power output. Higher core temperatures in the HYP trial could indicate thermoregulatory strain due to heat and dehydration, which can lead to poor athletic performance.

Similarly, the hypothesis and research findings of James (2017) and Cheung (2015) have shown to agree that the hydration state of an athlete affects his or her athletic performance. James (2017) was another blinded study that utilized infusion of water with a gastric feeding tube to replace fluid loss, and found that “hypohydration equivalent to about 2.4% body mass decreased endurance performance by about 8% compared to the euhydrated trial.” Dehydration impairs athletic performance through physiological and perceptual factors, and therefore in these studies, they singled out the physiological factor by blinding the perceptual factor (James, 2017). In James’ study, they utilized 0.2 ml·kg body mass^{-1} of water ingesting orally every 10 minutes and infusing water directly into the stomach for the euhydrated trial (James, 2017). The subjects had to orally insert a gastric feeding tube to mask the subjects’ hydration status, which is different from this study that used IV infusions instead (James, 2017). IV infusions were easier to administer due to avoiding the gag-reflex of inserting the gastric tube. The subjects also performed better in the EUH trial compared to HYP trial as the subjects performed 8.1±6.4% greater amount of work (James, 2017). In another study, they had the subjects use an IV infusion as well, but they had the euhydrated-not thirsty and dehydrated-not thirsty groups to have ad libitum oral rinse of water (Cheung, 2015). In this study, the small volume of water given to the subjects were likely more effective in removing the thirst factor completely by having them swallow the liquid. Cheung’s study only eliminated the oral but not the pharyngeal reflex when mouth rinsing (Cheung, 2015). Therefore, this study administered the IV infusions and then had both trials have 25ml of water consumed during cycling. All the studies above have shown that athletes in the EUH trials performed better.

Moreover, heat stress had an effect on the athletic performance indicated by the high core temperatures associated with the HYP trial. The results could be a response of great heat strain and/or cardiovascular impairment, which was a stress placed on an athlete's body. In another study that looked at dehydration and cycling performance, the subjects' core temperatures were greater during the dehydrated trial versus the euhydrated trial, which indicated a greater thermal load (Bardis, 2013). The RPE was also higher during the dehydrated trial than the euhydrated trial (Bardis, 2013). The athletes may have had a lower core temperature in the euhydrated trial due to better sweating response. This indicates thermoregulatory efficiency in athletes that are well hydrated. Even -1% dehydration can induce lower sweat sensitivity (Bardis, 2013). Another study by Bardis (2017) that examined ad libitum drinking by cyclists, and showed that core temperature was greater in the hypohydrated trial indicating that greater thermoregulatory strain was induced (Bardis, 2017). Moreover, the sweat sensitivity was reduced in the hypohydrated trial due to changes in plasma osmolality (Bardis, 2017). Due to all the similar findings that backup the results received from this study, it can be concluded that higher core temperatures associated with hypohydration is due to poor thermoregulation, and that heat places a major stress on the athlete's body. If the body is not well hydrated, the eccrine sweating mechanism cannot function properly due to lack of body fluid to cool the body down during aerobic exercise (McDermott, 2017). Keeping the base hydration status steady helps the body to have optimal thermoregulation and maintain cardiovascular function (McDermott, 2017). Evaporative heat loss due to sweating is the most effective method to cool the body in a warm environment (McDermott, 2017).

This study additionally specified to examining the mild hypohydration as opposed to other studies that have looked at moderate hypohydration. Moderate hypohydration is when dehydration is exceeding 2% of body mass (bm) as mild is when dehydration is ~1% body mass (Bardis et al. 2013). Other studies such as James (2017) and Sawka (2012), have shown that dehydration of 2% of body mass affects aerobic performance. This study specifically looked at mild hypohydration of 1% body mass. Furthermore, Bardis' study can add onto the findings of this research as they looked at mild dehydration as well, and found that even as small as -1% can have a detrimental effect on athletic performance (Bardis, 2013).

Although the design of the study was to be a counterbalanced cross-over format, it was difficult to do so with an off number of subjects. Also, some of the cyclists may have not recorded the RPE accurately. The study was based off of the motivation of the subject, so it can vary between individuals. Some of the cyclists may have been acclimatized to warm environment due to training in a warm place, so that could have an effect on the results. By explaining the RPE scale thoroughly to the subjects as well as having an even number, and increase the number of participants could yield a more accurate result. Moreover, it would be interesting to study hydration levels regarding a cool environment with still blinding the hydration level and looking at how dehydration can affect performance. Further research could be done to examine the factors that influence these observations.

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