

Influence of mild dehydration on perception of effort and execution of golf and mental concentration tests in female collegiate golfers

Whitney Elizabeth Stevenson

Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of

Master of Science
In
Human Nutrition, Foods, and Exercise

Valisa E. Hedrick, Chair
Kevin P. Davy
Jennie L. Zabinsky

Wednesday, May 9, 2018
Blacksburg, VA

Keywords: (dehydration, perception of effort, reaction time, executive cognitive function, motor function, sport performance, female collegiate golfers)

Influence of mild dehydration on perception of effort and execution of golf and mental concentration tests in female collegiate golfers

Whitney Elizabeth Stevenson

ABSTRACT

Water is arguably the most important nutrient given that even minor deficits lead to performance detriment for athletes and, in a matter of days, total absence causes fatality for all. Despite this, several reports suggest that an overwhelming amount of the athletic population competes and trains in a dehydrated state. The impact of dehydration on leisure sports, such as golf, is less certain given that fine motor skill sports have received less attention in the literature and that existing research on dehydration and golfers is largely limited to males. In this randomized, controlled, crossover pilot experiment, elite female golfers on the Virginia Tech Women's Golf Team (n=6) completed four laboratory simulated golf holes in both euhydrated and dehydrated states. Euhydration (mean urinary specific gravity [USG]=1.009; range=1.003–1.021) was attained by following the NCAA hydration guidelines, and dehydration (mean USG=1.021; range=1.018–1.026) was attained via a 12 hour overnight fast from fluids. No significant interactions of condition by time for perceived effort, 7-iron distance and accuracy, putting accuracy, reaction time, and executive cognitive function were found between euhydrated and dehydrated states. However, although not significant, euhydrated participants demonstrated improved 7-iron and putting accuracy and reported less perceived effort as compared to performance during their dehydrated state. Based on USG levels, NCAA hydration recommendations may not be adequate to induce a euhydrated state for all athletes. More research is needed with larger sample sizes to further elicit the impact of hydration status on variance in motor and cognitive function for elite golfers.

Influence of mild dehydration on perception of effort and execution of golf and mental concentration tests in female collegiate golfers

Whitney Elizabeth Stevenson

GENERAL AUDIENCE ABSTRACT

Besides oxygen, our bodies need water more than anything else to function. Water is so vital to health that its absence can cause death in just three days. Athletic populations, in particular, should aim for adequate hydration to optimize sport performance, to avoid heat illness, and to promote overall health and wellbeing. Despite this importance, few studies have investigated the impact of hydration status on athletic performance of golfers, and of these studies, none have been done with females. In this experiment, female golfers on the Virginia Tech Women's Golf Team (n=6) completed four laboratory simulated golf holes in both euhydrated and dehydrated states. Adequate hydration (euhydration) was attained by following the NCAA hydration guidelines, and dehydration was attained by restricting participants from drinking any fluid for 12 hours overnight. Performance in both adequate hydration and dehydration was measured by perceived effort, 7-iron distance and accuracy, putting accuracy, reaction time, and executive cognitive function. No significant interactions for any of the measures resulting in differences over time were found. However, although not significant, euhydrated participants demonstrated greater 7-iron and putting accuracy and reported less perceived effort as compared to performance during their dehydrated state. One participant did not reach adequate hydration by following the fluid intake guidelines during the hydration visit; therefore, NCAA hydration recommendations may not adequately hydrate all collegiate athletes. More research is needed with larger sample sizes to determine the impact of hydration status on motor and cognitive function of elite female golfers.

ACKNOWLEDGEMENTS

I would like to lovingly thank

My advisor, Dr. Hedrick, for her ineffable support and patience and for her radiant positivity daily. You are a true joy to be around and a major reason I can celebrate the success of this defense.

My committee members, Dr. Kevin Davy and Jennie Zabinsky, for their valuable assistance and time.

Michelle Rockwell, Kristen Chang, and Heather Cox for their investment in me as an aspiring dietitian.

Coach Robertson, Coach Abbott, Coach Brown, friends, and family who pushed me in endurance as a student-athlete.

My lab mates, Alexa, Emily, Anna, and Natalie, and all graduate students for their good humor and company.

Mom and Dad for teaching me, above all, how to love. No words or act of gratitude could repay you for all you have given me.

My Lord and Savior for grace abounding. *You, O Lord, are a shield about me, my glory, and the lifter of my head. – Psalm 3:3*

TABLE OF CONTENTS

Chapter 1: Review of Literature	1
Water Functions	1
Dehydration and Water Regulation	1
Dehydration in an Athletic Setting	3
Measures of Hydration.....	4
Water Intake Recommendations	6
Beverage Consumption Patterns of Athletes	8
Prevalence of Dehydration Among Athletes	8
Impact of Dehydration on Exercise Performance.....	10
Golf	14
Relevance of Dehydration in Golf	15
References.....	18
Chapter 2: Cognitive and Physical Performance of Euhydrated and Dehydrated States in Collegiate Female Golfers.....	22
Abstract.....	22
Introduction.....	24
Aims and Hypotheses	26
Methods.....	26
Measures	30
Statistics	32
Results.....	33
Discussion.....	38
Conclusion	42
References.....	43
Chapter 3: Future Directions and Conclusion	45
References.....	47
Appendices.....	48
Appendix A. Approval Letter	48
Appendix B. BEVQ-15.....	49
Appendix C. Deary-Liewald choice reaction time test screenshots	50
Appendix D. Trail Making A and B instructions and instruments	51
Appendix E. Borg Scale.....	54

Chapter 1: Review of Literature

Water Functions

Water is vital to maintain life. Besides oxygen, human bodies need water more than anything else to function, and in its absence death can occur in just three days.¹ Water functions in cell structure, transport of nutrients and waste throughout the body, and temperature and acid-base homeostasis.¹ Fluid also comes from sources outside of water like juice, milk, sports drinks, soups, fruits, and vegetables.¹ Contrary to some beliefs, coffee and tea do provide fluids, but are considered less efficient hydrators due to the diuretic effects of caffeine.²

The recommended level of adequate water intake is very general, based on retrospective data of healthy individuals.^{3,4} In 2004 the Institute of Medicine established the adequate intake for water based on the median intake of all fluids, including fluid from food, reported in the survey data.³ Suitable daily allowance for water for adults over the age of 19 is 3.7 L/day for men and 2.7 L/day for women.³ Total water intake constitutes all water in beverages and food, with approximately 80% coming from beverages and 20% coming from food.³ Therefore, the estimated fluid needs from beverages alone is slightly less at ~3 liters for men and ~2 liters for women.¹ These guidelines are very generic, and individual needs vary depending a number of demographic and environmental factors such as sex, age, physical exertion, geographic location, ambient temperature, body temperature, etc. Equations using age, caloric intake, and/or weight are used to estimate specific individual fluid needs.⁵

Dehydration and Water Regulation

The human body stores water both within cells and outside cells.⁶ Intracellular fluid (ICF) and extracellular fluid (ECF) account for all the water in the body, approximately 65% and 35% of total body water, respectively.⁶ Humans turn over 5–10% of their total body water each day,

which requires regulatory processes to maintain fluid balance and thereby sustain hydration.⁶ Water loss occurs through the kidneys by urination and through the gastrointestinal tract by defecation, in addition to water vapor evaporated on the skin by sweating and air expired through the lungs by respiration.⁵ Factors that affect these pathways and contribute to water loss include the use of dietary diuretics such as caffeine and alcohol intake, eating a high protein diet, high ambient temperature, low humidity, high altitude, presence of fever, etc.⁵ Therefore, the body can be losing large amounts of water without apparent sweating – for example, by insensible (unmeasurable) processes in the lungs – demanding fluids to be replaced accordingly.

Euhydration represents the normal daily water content of an individual.⁷ The steady-state conditions of hyperhydration and hypohydration represent positive and negative deviance from normal body water content, respectively.⁷ While dehydration and hypohydration are often used interchangeably, they have slightly different purposes.⁸ Dehydration refers to the process of fluid loss (hyperhydration to euhydration and euhydration to hypohydration). Dehydration can be used more generally, while hypohydration refers to the outcome of low body fluid and illustrates a more specific state of uncompensated fluid loss.⁸ Hypohydration is defined as >2% body weight loss.^{6,9}

Water balance is regulated in the body by renal water retention and secretion through the release of hormones such as antidiuretic hormone arginine vasopressin (AVP), angiotensin II, cortisone, aldosterone, epinephrine and norepinephrine.^{5,9} The posterior pituitary releases AVP in response to increased body temperature and decreased blood volume.⁹ Renal fluid retention is no longer sufficient to balance water in the body following large amounts of fluid loss, such as through sweating, vomiting, or diarrhea.⁹ In turn, the kidneys release renin which produces angiotensin II, eventually leading to vasoconstriction and thirst mechanisms.⁵ Ultimately, thirst

aids in the fluid intake required for restoration of blood volume. Peripheral osmoreceptors and oropharyngeal mechanisms often act as buffers and downregulate thirst well before full restoration of fluid volume.⁹ Solutes in food, such as salt, can stimulate thirst to counteract this brief, immediate response and, therefore, reduce the occurrence of involuntary dehydration following significant losses of sweat.^{1,9}

Dehydration in an Athletic Setting

Dehydration can be defined as “the loss of fluids and salts essential to maintain normal body function.”¹⁰ In general, dehydration occurs when fluid loss exceeds fluid intake; thus, water balance should be monitored and maintained throughout exercise.¹⁰ Hydration status can be categorized into euhydration between $\pm 1\%$ body weight[†]; minimal dehydration between 1% and 3% body weight loss; significant dehydration between 3% and 5% body weight loss; and serious dehydration at $>5\%$ body weight loss.⁹⁻¹¹

Water is arguably the most important nutrient for athletes.¹ Compared to essential macronutrients that provide the body with energy, water is still valued above nutrients with energetic utility.¹ The anticipated effect of dehydration on athletic performance becomes apparent after understanding this reality.¹ Generally, 1% body weight loss borders euhydration and the onset of dehydration.⁹ With a fluid loss of more than 1% body weight, exercise performance, thermoregulation, and appetite decrease.^{2,9} Additionally, thirst sets in at the 1% loss mark.¹ At 2% loss, the thirst response increases, and there is a loss of appetite, general discomfort, and an increase in heart rate.^{1,8} As the severity of dehydration progresses past 2% body weight loss, heat exhaustion (moderate severity) and heat stroke (highest severity) become a greater concern.¹ At 4% body weight loss, body temperature and respiratory rate increase,

[†] Other sources note water balance fluctuates between $\pm 0.5\%$ total body weight.²

concentration decreases, headaches, irritability, and sleepiness ensues, and athletic performance reduces severely, exhibiting a 20% – 30% loss in physical work capacity.^{2,7} Finally, at 8% loss death can occur.²

The American College of Sports Medicine (ACSM) takes the position that fluid intake during prolonged exercise should be sufficient to limit any body mass loss to less than 2%.⁸ The goal of hydration during exercise is to keep body weight loss to less than 2% in order to avoid reduced plasma volume, reduced cardiac output, impaired sweat responses, and electrolyte imbalance.^{1, 12} Losing 2-3% of body weight is very common among athletes and can occur relatively quickly during training and competition.¹

Measures of Hydration

There is no gold standard to assess hydration status at either the athletic, clinical, or population level.^{4,5,9} Plasma or serum osmolality is the most accurate indicator of hydration and measures the number of solutes, primarily sodium, chloride, bicarbonate, glucose and urea, per kilogram of water.^{9,13} An increase in plasma osmolality of 2% (~5 mmol/kg) signals the need for compensatory fluid intake secondary to dehydration.⁹ While plasma osmolality is considered the most accurate measure of hydration status, the need to draw blood limits the settings in which plasma osmolality can be used. Next in validity and reliability is urine and saliva osmolality measures.⁹ Succeeding osmolality, urine specific gravity (USG) estimates hydration status and the concentrating and diluting function of the kidneys.⁵ The expected value for specific gravity in a clinical setting falls between 1.010–1.025.⁵ The National Athletic Trainer's Association provides slightly lower reference ranges, suggesting athletes should fall on the more hydrated side.¹¹ Measures less than 1.010 imply euhydration, measures between 1.010 – 1.020 are considered minimal dehydration, measures between 1.021 – 1.030 qualify for significant

dehydration, and measures >1.030 qualify for serious dehydration.^{1,11} Even more feasible measures include percent body weight change and urine color analysis with increasing validity of measures, respectively.¹ Urine color, urine volume, and body weight are the most practical self-monitoring methods for athletes to assess their daily hydration status.¹ Urine indices, however, reflect current volume of fluid consumed and are consequently lesser indicators of overall hydration status.⁴ In addition, frequency of urination can also be used to indicate hydration status.¹ An adequately hydrated individual urinates every one to two hours; therefore, less frequent urination can flag dehydration.¹

Some argue the human mechanism of thirst is the only hydration monitor that is necessary.¹⁴ One consensus panel agreed "using the innate thirst mechanism to guide fluid consumption is a strategy that should limit drinking in excess and developing hyponatremia (low blood sodium) while providing sufficient fluid to prevent excessive dehydration."¹⁴ Thirst can be defined as a desire to drink resulting from the deficit of water.⁷ The ACSM also defines thirst as a mechanism of the body to signal it is headed towards dehydration.¹⁰ Therefore, the ACSM argues athletes should not rely on thirst as an indicator of hydration and recommends athletes drink fluid before feeling thirsty.¹⁰ Sports dietitians recommend athletes calculate their sweat rates to determine their individual fluid needs.¹ Sweat rate can be calculated by using the following formula:¹

$$\frac{[(pre\ exercise\ weight - post\ exercise\ weight)\ lb * 16\ to\ 24\ oz/lb] + fl\ oz\ consumed\ during\ exercise}{Hour\ of\ exercise}$$

Water Intake Recommendations

Scientific recommendations for upholding hydration before exercise, maintaining hydration during exercise, and promoting rehydration after exercise vary across organizations (Table 1).

Table 1. Hydration Recommendations for Exercise from Various Organizations

Organization	Pre-exercise	During exercise	Post-exercise
American College of Sports Medicine (ACSM)	16-20 fl oz of water or sports beverage at least 4 hours before exercise ¹⁰ 8-12 fl oz of water 10-15 minutes before exercise ¹⁰	7 – 10 fl oz of fluid every 15 minutes ¹	16 – 24 fl oz of fluid for every pound of water weight lost during exercise ¹
National Athletic Trainers' Association (NATA)	17-20 fl oz of water or a sports drink 2 to 3 hours before exercise ¹¹ 7-10 fl oz of water or a sports drink 10 to 20 minutes before exercise ¹¹	7-10 fl oz of fluid every 10 to 20 minutes during exercise ¹¹	Drink 25% to 50% more than the sweat losses 4 to 6 hours after event ¹¹ (This is equivalent to 20 to 24 fl oz per pound lost) ¹
Academy of Nutrition and Dietetics (AND)	5 to 10 mL/kg BW (~2 to 4 mL/lb) in the 2 to 4 hours before exercise to achieve pale yellow color urine while allowing for sufficient time for excess fluid to be voided ⁸	An intake of 0.4 to 0.8 L/h suits most athletes and athletic events ⁸	Drink 25% to 50% more than the sweat losses (eg, 1.25 to 1.5 L fluid for every 1 kg BW lost) ⁸ (This is equivalent to 20 to 24 oz per pound lost) ¹
The National Collegiate Athletic Association (NCAA)	Drink 16 fl oz of fluid 2-3 hours before exertion and 8 fl oz of fluid 15 minutes before exertion ¹⁵	Drink 4 fl oz of fluid every 15-20 minutes during exertion ¹⁵	After exertion drink 16-20 fl oz of fluid for every pound lost ¹⁵

Although following these recommendations can help maintain health and promote peak performance for the general population, individual fluid needs for athletes depend on a wide range of factors, including sweat rate, sport demands (e.g., intensity, duration, rest breaks), environmental factors, and acclimatization status.¹¹

Reports reveal many athletes consume less than 500 ml of fluid per hour compared to average gastric emptying rates of 1 liter per hour, or more in some cases, suggesting athletes could benefit from increasing fluid intake during exercise.¹ In some cases, athletes are limited by their maximal gastric emptying rates and are not able to consume enough fluids to achieve euhydration.¹ For example, athletes exercising in hot and humid environments at hard intensities can lose up to 2–3 liters of sweat an hour, but most can only tolerate drinking about 1 liter of fluid in an hour.¹ In this case maintaining hydration is not feasible; however, for the majority of athletes the hydration potential is attainable – it simply remains unreached by voluntary intake.¹ Other influencers on hydration needs include environment, training, and diet. Training in hot, humid environments will have a significant impact on long-duration exercise and will increase fluid consumption needs.¹ Athletes training in temperature of 80° F and low humidity can lose 3–4 pounds from fluid losses and even more at higher temperatures.⁵ Additionally, training in high altitudes, which are typically accompanied by colder, drier air and decreased air pressure, increases the breathing rate and the insensible water losses from respiration.¹ Cold temperatures and high altitudes are examples of isotonic-hypovolemia, or salt-depletion dehydration.⁹ Isotonic hypovolemia, which can also occur with diuretic use, secretory diarrhea, or vomiting, decreases the gradient in which intracellular fluid flows out of the cell, and therefore increases the percent body loss of fluid.⁹

Beverage Consumption Patterns of Athletes

A host of factors influence the amount and quality of drinking behaviors of athletes. Examples of these factors include social and cultural norms, gastrointestinal tolerance (as a result of typical practices during training), thirst stimuli, drink palatability, nutrition knowledge, and other factors.^{7,16} In addition, a number of factors outside the control of the athlete raise the question whether beverage intake can truly be ad libitum, including competition rules and format, location and availability of fluids, sport technique or speed, and gut fluid capacity.¹⁶ Despite these differences, attempts have been made to show typical beverage consumption patterns of athletes. An observational study conducted on male football and basketball players who competed for the Premier League of Bosnia-Herzegovina revealed 94 out of 100 football and basketball players reported drinking water during training with the other 6 consuming isotonic solutions or energy drinks.¹⁷ The study also revealed a majority of the athletes were not drinking the recommended amount of water prior to training or drinking enough daily to meet the adequate intake.¹⁷

Prevalence of Dehydration Among Athletes

Given that an array of organizations support the notion that athletes can adequately assess their hydration status, questions arise on why preventing dehydration is still a current obstacle for athletes.^{1,8,11} One study on the prevalence of dehydration in the National Basketball Association (NBA) reported one-half of players recorded a pre-game urine specific gravity of >1.02 (dehydration classified as a USG >1.02) and revealed drinking habits during the game did not compensate for the hypohydration.¹⁸ Similarly, in a study on football players, the average athlete only took in half as much fluid (0.84 L) as lost in sweat (1.68 L).¹⁹ Even in cool environments researchers found one-third of football players recorded a postgame urine

osmolality of >900 mOsm/kg (500–800 mOsm/kg is considered the normal reference range; greater than 900 mOsm/kg is a typical osmolality after 12-14 hours of fluid restriction).^{19,20} Moreover, in one study assessing urine specific gravity, two-thirds of college athletes from a number of different sports demonstrated levels consistent with hypohydration.²¹ Similar effects have also been observed in young age cohorts. An observational study of young soccer players in a summer training camp revealed 90% of youth began the training session hypohydrated and ad libitum water drinking did not prevent further dehydration among the players.²² One possible explanation for explaining the high prevalence is a knowledge gap in the population. Evidence suggests there is a high prevalence of dehydration and nutritional knowledge deficit at the university level.²³ A systematic review determined five out of seven studies conducted in athletic populations showed a weak positive ($r < 0.50$) correlation between nutrition knowledge and dietary intake.²⁴ Training sessions that observe dehydration among athletes, despite ad libitum water drinking, suggest the insufficiency of thirst as the sole regulator of fluid intake and the need for nutritional education among athletes. Another proposed reason why athletes exhibit a high prevalence of dehydration is that they perceive the costs of hydration as greater than the benefits, i.e., taking time out of a race or off the playing field.¹⁶

Athletes have at their disposal a toolbox of hydration measurements to determine whether their usual hydration practices are adequate.²¹ During heavy trainings, especially in hot and humid environments, athletes can weigh themselves to ensure body weight loss does not exceed 1–2%.²¹ Athletes can also monitor frequency, volume, and color of urine to assess hydration status.²¹ For endurance athletes, hyponatremia is a concern and salt losses should be taken into consideration to prevent electrolyte imbalances.¹ A recent investigation of marathon runners reported high variability in concentrations of sodium and chloride found in sweat, and

determined that one in five runners might need special sodium intake recommendations due to their high salt sweat rate, i.e., salty sweaters.²⁵ The study also found salty sweaters were not correlated with any individual characteristics, making electrolyte losses difficult to predict or estimate without measuring.²⁵ The high cost of sweat patches used in this study to determine sodium and chloride losses make this measure impractical for the majority of athletes. More practically, athletes can determine if they are a salty sweaters by working out in a black T-shirt and looking for white salt stains on the chest and under the armpits when the sweat has evaporated.²¹ In doing so, athletes can gauge how high their salt losses are and estimate sodium needs of food and drink.²¹ It is important to note, these measures are not always feasible or accurate. While these methods appear simple and practical, reports show limited use of these self-monitoring steps.¹⁷ In a study on adult and adolescent football and basketball players (average age 19.3 ± 4.58) competing at a national level, less than 44% reported habits of weighing themselves before and after training to assess water loss.¹⁷ Furthermore, less than half of the athletes reported paying attention to fluid intake 24 hours before training.¹⁷ Evidence points to the difficulty of assessing hydration status for the lay person and the need for nutritional education to change behavior patterns among athletes.

Impact of Dehydration on Exercise Performance

Physical Performance

Current literature suggests the greater the percent body weight loss the greater physiologic response and detriment to exercise performance.¹¹ Exercise refers to any and all activity generated by the force of an activated muscle; exercise is quantified by force, torque, work, power or velocity.²⁶ In addition to these measures, exercise performance can be evaluated by individual sport performance. Dehydration leads to compromised cardiovascular function by

the role of water in maintenance of blood volume.⁵ Water loss beginning at 3–5% of body weight leads to a loss of blood volume.¹ Low blood volume results in low blood available for delivery to the muscles and, therefore, low oxygen delivery to muscles.¹ Less available oxygen necessitates a heavier reliance on anaerobic respiration.¹ The more the anaerobic respiration pathway is used, the quicker lactic acid builds up causing undesired effects for the athlete, including a higher rate of perceived exertion, faster onset of fatigue, decreased ability to concentrate, and decreased training and performance overall.¹ In addition to concerns of reduced plasma volume, decreased sweat responses present threats to athletes' performance and safety by causing the body to heat up faster.¹² The rise in body temperature can contribute to a greater release of catecholamines in the body.²⁷ This leads to increased rates of glycogen breakdown in the exercising muscle, which also contributes to the faster onset of fatigue.²⁷

Performance detriments of prior dehydration have been observed on a number of occasions. In general, fluid intake is not as much of a concern for sports that last less than an hour and occur in neutral environments.¹ Studies have shown no difference in performance of cyclists in competition lasting less than 60 minutes in ambient temperature.¹ The greatest effect of fluid ingestion during exercise shown in research is found in athletes who compete in endurance exercise or in hot and humid environments.¹ A review examining dehydration in competitive sports concluded in hot environments (temperature >86°F) dehydration of 2–7% reduction in body weight consistently decreased athletic performance.²¹ The authors observed a range of magnitude in the effects from 7–60% performance reductions.²¹ In ambient temperatures, performance reductions of dehydrated athletes were only observed in endurance activities lasting longer than 90 minutes.²¹ Dehydration of 1–2% body weight did not appear to impact performance of exercise lasting less than 90 minutes.²¹ However, some evidence supports

minimal dehydration (body weight loss of 1 – 2%) can impact performance of fine-motor tasks often used in team sports.²¹ Fine-motor tasks, or skill-based tasks such as a golf swing or a three-point shot in basketball, require long term development of both motor skill and cognitive function.²⁸ One study reported reduction in soccer-specific fitness test outcomes between players with 2.4% body weight loss compared to players with 0.7% body weight loss.²¹ A study in bowlers with similar disparities showed significantly worse accuracy of bowls from the line.²¹ Additionally, fluid deficits of 1.5–2% body weight loss have shown to reduce performance in 1500 m, 5000 m, and 10,000 m track races.²¹ In sum, fluid intake plays the greatest role in long-duration activity (≥ 60 minutes) performed in hot and humid environments but could have an impact on fine-motor tasks of other activities beginning at ~2% body weight loss.¹

Cognitive Performance

Cognitive performance should be considered as important as physical performance for an athlete who fights daily for even the slightest of improvement in his or her game. Cognitive performance can be defined as the ability to use the knowledge acquired by mental processes in our brains and, therefore, depends on the essential nutrients available for brain function, including water.²⁹ Thus, hypohydration results not only in physical performance detriments but also mental performance losses.²¹ It is clear that mild dehydration impacts cognitive function and mood; however, it is unclear at what point the effects materialize.²¹ Studies measuring differing aspects of performance could see consequences set in at 1%, 5%, or 10% body weight loss.²¹ A few studies have reported loss of cognitive function and alertness in mildly dehydrated individuals (body weight loss of 1 – 2%).⁵ A nutrition review reported several studies have shown higher ratings of perceived effort for individuals in a dehydrated state than in a euhydrated state.³⁰ This effect may become exacerbated in hot, uncomfortable environments.³⁰

On the other hand, one study showed no changes in cognitive performance of recreational athletes after 50 minutes of cycling with no fluid.³¹

While many agree there are a number of reasons that contribute to impaired cognitive performance, there is still much research to be done on the roles of each factor to better understand their importance. For example, a study on soccer players concluded that the researchers were uncertain whether the impairment was attributed to water loss alone or whether negative psychological effects resulting from a greater perception of effort play a role as well.¹² Perception of effort is often measured using a Rate of Perceived Exertion (RPE) Scale or the Borg Scale to estimate how hard the individual perceives he or she is working during exercise.³² The authors of the soccer study concluded moderate dehydration was detrimental to soccer performance, yet the exact physiological cause remained unclear.¹² Some have proposed the sensation of thirst increases the athlete's perception of effort leading to a reduction in physical effort.³³ While evidence on this is equivocal, research suggests that dehydration is one of many factors in a complex regulatory system that leads to mental fatigue.³³

Cognitive performance tests used to assess a person's functional capacity for everyday tasks can be administered to athletes to measure cognitive performance in sport. A previous study on dehydration in golfers measured perceived distance to pin to appraise perceptual function, an aspect of cognitive performance.³⁴ Cognitive tests found in other exercise-related studies include but are not limited to a reaction time task, a psychomotor vigilance task, a temporal orienting task, and a duration discrimination task.³⁵ For years psychologists of many disciplines have used reaction time in particular to “[capture] the capacity of processing speed.”³⁶ Reaction time is a useful measure of sport performance because to a degree it measures cognitive performance, or processing speed, and it directly influences physical performance related to the

response to a stimuli in a sporting event. To illustrate, reaction time has been used to determine the ergogenic effect of caffeine in elite archers,³⁷ to measure performance decrements related to mental fatigue,³⁸ to indicate general fluid intelligence, to predict survival, and for a host of other outcome variables.³⁶ The Deary-Liewald choice reaction time (CRT) task is a classic mental task used to measure reaction time.³⁶ A validation study of the Deary-Liewald CRT task showed a strong positive correlation between the mean response times of the Deary-Liewald task and a validated numbers task.³⁶ Another frequently used test of cognitive function is Trail Making Test (TMT) A and B. The trail making tests measure a number of cognitive processes, including attention, visual scanning, and speed of processing, to name a few. A study on TMT B validated the task as a measure of executive cognitive function, i.e., fluid cognitive ability.³⁹ Fluid cognitive ability, or fluid intelligence, is “the ability to generate, transform, and manipulate different types of novel information in real time” and influences reasoning capabilities of an athlete during training and competition.⁴⁰ In addition, a study reported strong correlation between trail making test scores to intelligence and severity of impairment and a weak correlation to age, education, and memory functioning.⁴¹ TMT B was used to evaluate post-exercise cognitive function compared to water intake in an observational study of long distance walkers and runners.⁴²

Golf

The sport of golf is enjoyed not only by professionals, but also by recreational players – an estimated 55 million people in total.⁴³ A review study on the relationship between golf and health revealed a positive correlation between improved physical health and mental well-being and golf.⁴³ Additionally, the study suggested golf provides a potential contribution to increased life expectancy. It is suggested these benefits may be attributed to the physical and social

benefits of the exercise. Participation in golf can help individuals meet and exceed the recommended moderate to vigorous physical activity guidelines.⁴³ The average golfer achieves moderate intensity physical activity, but differences in exercise intensity and energy expenditure can vary greatly. Studying the demands of golf in terms of Metabolic Equivalent of Task (MET) reveals the intensity differences. On the low end, an individual practicing on the driving range was measured at 3 METs, light physical activity similar to walking at 2 mph.⁴³ On the high end, an individual walking and using a pull cart was measured at 5.3 METs, similar to cycling at 9 MPH.⁴³ In general, the sport of golf has low energy expenditure and is nonfatiguing.⁴⁴ Although the sport is non-contact and non-explosive demanding, 4–8 hours of prolonged walking and high cognitive demand of shot and putting execution could pose threats to homeostasis by the end of an 18 or 36 hole round.

Relevance of Dehydration in Golf

Surveys involving Professional Golf Association (PGA) Tour players revealed many reasons why dehydration commonly occurs and inhibits performance.⁴⁵ First, tour professionals admitted to being less willing to comply with hydration requirements because it increased frequency of urination.⁴⁵ Restroom facilities are often not easily accessible during competitive rounds, and players may choose to hold off on drinking to avoid pressure on pace of play from using the restroom more frequently. Second, they reported not drinking fluids because they did not feel thirsty.⁴⁵ It is important to note that stress reduces thirst, contributing to the proportional relationship between involuntary dehydration and total stress incurred by the body.^{7,45} Other reasons included an underestimation of perspiration, unpreparedness of carrying fluids, and worry of feeling uncomfortable and less athletic with lots of water in their stomachs.⁴⁵

In 2013, top-ranked professional golfer Rory McIlroy attributed his poor year of performance to mental fatigue and noted, "It's becoming more and more common that these sorts of stress-related illnesses are happening and it just shows how much of a mental toll it takes on you sometimes."⁴⁶ Hydration contributes to overall health and well-being and sport performance. It is well understood that dehydration leads to systemic and exercise-related problems. Some sport psychologists even claim dehydration can "wreck" the best of games by compromising stamina, focus, emotions, and ultimately worsening golf scores.⁴⁵ Substantial evidence to support these claims is lacking; however, some recent research has been done specifically with golfers to determine the degree to which dehydration impacts motor skill, cognitive precision, and overall performance. A recent study conducted with male elite golfers demonstrated mild dehydration (1–2% loss in body weight) lead to an 11% loss in average iron distance, near doubling of off target iron accuracy, and over a six fold increase in overestimation of distance from pin.³⁴ In addition, another study demonstrated that golfers who were dehydrated had a four stroke higher average than golfers who were euhydrated.²³

It is generally understood dehydration leads to performance detriments, yet an overwhelming amount of the athletic population competes and trains in a hypohydrated state.^{18–23} Moreover, researchers are unsure whether the detriments of low to moderate dehydration on physical performance can be attributed to water loss alone or to the self-pacing psychological effects of a greater perception of effort.^{12,33} Few studies have investigated the detriment of dehydration specifically on golfers, and more research is required to better understand the effects. Additionally, existing literature on dehydration and golfers is largely limited to male golfers. If people perish for a lack of knowledge, then dissemination of understanding is critical. Athletes need a greater awareness of the silent detriments of dehydration on their overall

performance in training and competition. Increasing the strength of evidence of the effects of mild dehydration can highlight the need for behavior change in competitive golf.

References

1. Fink HH, Mikesky AE. *Practical Applications in Sports Nutrition*. 5th ed. Burlington, AA: Jones & Bartlett Learning; 2018.
2. Gil A. Hydration and health. *Nutr Hosp*. 2015;32(2):1.
3. Institute of Medicine. *Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate: Water*. Washington: National Academies Press; 2004.
4. Popkin BM, D'Anci KE, Rosenberg IH. Water, hydration, and health. *Nutr Rev*. 2010;68(8):439-458. doi:10.1111/j.1753-4887.2010.00304.x.
5. Mahan LK, Raymond JL. *Krause's Food & the Nutrition Care Process*. 14th ed. St. Louis, Mo: Elsevier; 2017.
6. Sawka MN, Chevront SN, Kenefick RW. Hypohydration and Human Performance: Impact of Environment and Physiological Mechanisms. *Sport Med*. 2015;45:51-60. doi:10.1007/s40279-015-0395-7.
7. Greenleaf JE. Problem: thirst, drinking behavior, and involuntary dehydration. *Med Sci Sport Exerc*. 1991;24(6):645-656.
8. Thomas DT, Erdman KA, Burke LM. American College of Sports Medicine Joint Position Statement. Nutrition and Athletic Performance. *Med Sci Sports Exerc*. 2016;48(3):543-568. doi:10.1249/MSS.0000000000000852.
9. Chevront SN, Kenefick RW, Charkoudian N, Sawka MN. Physiologic basis for understanding quantitative dehydration assessment. *Am J Clin Nutr*. 2013;97(3):455-462. doi:10.3945/ajcn.112.044172.
10. ACSM. Selecting and Effectively Using Hydration for Fitness. <https://www.acsm.org/docs/brochures/selecting-and-effectively-using-hydration-for-fitness.pdf>. Accessed November 2, 2017.
11. Casa DJ, Armstrong LE, Hillman SK, et al. National Athletic Trainers' Association Position Statement: Fluid Replacement for Athletes. *Athl Train*. 2000;35(2):212-224.
12. Edwards AM, Mann ME, Marfell-Jones MJ, Rankin DM, Noakes TD, Shillington DP. Influence of moderate dehydration on soccer performance. *Br J Sports Med*. 2007;41(6):385-391. doi:10.1136/bjism.2006.033860.
13. Tuazon Sherilyn. Serum Osmolality. Medscape. <https://emedicine.medscape.com/article/2099042-overview?pa=060uRIwfqs3SEH4goGXODF6vDI%2FrbJdqy4bv205aI0GqdizqDF%2BxQQY1b8pSAjEHvdIBC0EkxUsec29D9YrbZTbyrlBJ1g%2BnBRRM20eafuU%3D#a4>. Accessed November 15, 2017.
14. Hew-Butler T, Rosner MH, Fowkes-Godek S, et al. Statement of the Third International Exercise-Associated Hyponatremia Consensus Development Conference, Carlsbad, California, 2015. *Clin J Sport Med*. 2015;25(4):303-320. doi:10.1097/JSM.0000000000000221.

15. NCAA Sport Science Institute. How to maximize performance hydration. [http://www.ncaa.org/sites/default/files/Performance Hydration Fact Sheet.pdf](http://www.ncaa.org/sites/default/files/Performance_Hydration_Fact_Sheet.pdf). Accessed August 26, 2017.
16. Garth AK, Burke LM. What Do Athletes Drink During Competitive Sporting Activities? *Sport Med*. 2013;43(7):539-564. doi:10.1007/s40279-013-0028-y.
17. Pašalić A, Jusupovic F, Rudić A, Mahmutović J, Branković S, Jaganjac A. Habits of fluid and electrolytes intake in elite athletes. *J Heal Sci*. 2015;5(1):15. doi:10.17532/jhsci.2015.238.
18. Osterberg KL, Horswill CA BL. Pregame Urine Specific Gravity and Fluid Intake by National Basketball Association Players During Competition. *J Athl Train*. 2009;44(1):53-57.
19. Maughan RJ, Watson P, Evans GH, Broad N, Shirreffs SM. Water balance and salt losses in competitive football. *Int J Sport Nutr Exerc Metab*. 2007;17(6):583-594.
20. Wilczynski C. Urine Osmolality: Reference Range. Medscape. <https://emedicine.medscape.com/article/2088250-overview>. Published 2014. Accessed October 19, 2017.
21. Maughan RJ, Shirreffs SM. Dehydration and rehydration in competitive sport. *Scand J Med Sci Sports*. 2010;20:40-47. doi:10.1111/j.1600-0838.2010.01207.x.
22. Arnaoutis G, Kavouras SA, Kotsis YP, Tsekouras YE, Makrillos M, Bardis CN. Ad Libitum Fluid Intake Does Not Prevent Dehydration in Suboptimally Hydrated Young Soccer Players during a Training Session of a Summer Camp. *Int J Sport Nutr Exerc Metab*. 2013;23(3):245-251. doi:10.1123/ijsnem.23.3.245.
23. Magee PJ, Gallagher AM, McCormack JM. High Prevalence of Dehydration and Inadequate Nutritional Knowledge Among University and Club Level Athletes. *Int J Sport Nutr Exerc Metab*. 2017;27(2):158-168. doi:10.1123/ijsnem.2016-0053.
24. Spronk I, Kullen C, Burdon C, O'connor H. Systematic Review Relationship between nutrition knowledge and dietary intake. *Br J Nutr*. 2014;(111):1713-1726. doi:10.1017/S0007114514000087.
25. Lara B, Gallo-Salazar C, Puente C, Areces F, Salinero JJ, Del Coso J. Interindividual variability in sweat electrolyte concentration in marathoners. *J Int Soc Sports Nutr*. 2016;13(1):31. doi:10.1186/s12970-016-0141-z.
26. Knuttgen HG, Kraemer WJ. Terminology and Measurement in Exercise Performance. *J Strength Cond Res*. 1987;1(1):1-10. doi:10.1519/00124278-198702000-00001.
27. Jeukendrup A, Gleeson M. Dehydration and its effects on performance. In: *Sports Nutrition: An Introduction to Energy Production and Performance*. 2nd ed. Human Kinetics; 2010. <http://www.humankinetics.com/excerpts/excerpts/dehydration-and-its-effects-on-performance>. Accessed October 20, 2017.
28. Hillyer M, Menon K, Singh R. The Effects of Dehydration on Skill-Based Performance. *Int J Sport Sci*. 2015;5(3):99-107. doi:10.5923/j.sports.20150503.02.

29. Kamphuis P. Cognitive performance and nutrition. *The NutriJournal*. <http://nutrijournal.danone.com/en/articles/stories/cognitive-performance-and-nutrition/>. Published 2014. Accessed November 21, 2017.
30. Maughan RJ, Watson P, Shirreffs SM. Implications of active lifestyles and environmental factors for water needs and consequences of failure to meet those needs. *Nutr Rev*. 2015;73(suppl 2):130-140. doi:10.1093/nutrit/nuv051.
31. Wittbrodt MT, Millard-Stafford M, Sherman RA, Cheatham CC. Fluid Replacement Attenuates Physiological Strain Resulting from Mild Hypohydration Without Impacting Cognitive Performance. *Int J Sport Nutr Exerc Metab*. 2015;25(5):439-447. doi:10.1123/ijsnem.2014-0173.
32. Centers for Disease Control and Prevention. Perceived Exertion (Borg Rating of Perceived Exertion Scale). <https://www.cdc.gov/physicalactivity/basics/measuring/exertion.htm>. Published 2015. Accessed November 30, 2017.
33. Edwards AM, Noakes TD. Dehydration: cause of fatigue or sign of pacing in elite soccer? *Sport Med*. 2009;39(1):1-14.
34. Smith M, Newell A, Baker M. Effect of acute mild dehydration on cognitive-motor performance in golf. *J Strength Cond Res*. 2012;26(11):3075-3080.
35. Luque-Casado A, Zabala M, Morales E, Mateo-March M, Sanabria D. Cognitive performance and heart rate variability: the influence of fitness level. *PLoS One*. 2013;8(2):e56935. doi:10.1371/journal.pone.0056935.
36. Deary IJ, Liewald D, Nissan J. A free, easy-to-use, computer-based simple and four-choice reaction time programme: The Deary-Liewald reaction time task. *Behav Res Methods*. 2011;43(1):258-268. doi:10.3758/s13428-010-0024-1.
37. Linoby A, Nias A, Husna N, Suun A. The Effects of Caffeine on Archery Performance: A Randomized, Double-Blind, Placebo-Controlled Study. In: *Proceedings of the International Conference on Science, Technology and Social Sciences (ICSTSS) 2012*. Singapore: Springer Singapore; 2014:405-413. doi:10.1007/978-981-287-077-3_47.
38. Langner R, Steinborn MB, Chatterjee A, Sturm W, Willmes K. Mental fatigue and temporal preparation in simple reaction-time performance. *Acta Psychol (Amst)*. 2010;133(1):64-72. doi:10.1016/j.actpsy.2009.10.001.
39. Arbuthnott K, Frank J. Trail Making Test, Part B as a Measure of Executive Control: Validation Using a Set-Switching Paradigm. *J Clin Exp Neuropsychol (Neuropsychology, Dev Cogn Sect A)*. 2000;22(4):518-528. doi:10.1076/1380-3395(200008)22:4;1-0;FT518.
40. Zaval L, Li Y, Johnson EJ, Weber EU. Complementary Contributions of Fluid and Crystallized Intelligence to Decision Making Across the Life Span. In: *Aging and Decision Making*. Elsevier; 2015:149-168. doi:10.1016/B978-0-12-417148-0.00008-X.
41. Corrigan JD, Hinkeldey NS. Relationships between Parts A and B of the Trail Making Test. *J Clin Psychol*. 1987;43(4):402-409. doi:10.1002/1097-4679(198707)43:4<402::AID-JCLP2270430411>3.0.CO;2-E.

42. Benefer MD, Corfe BM, Russell JM, Short R, Barker ME. Water intake and post-exercise cognitive performance: an observational study of long-distance walkers and runners. *Eur J Nutr*. 2013;52(2):617-624. doi:10.1007/s00394-012-0364-y.
43. Murray AD, Daines L, Archibald D, et al. The relationships between golf and health: a scoping review. *Br J Sport Med*. 2016:1-11. doi:10.1136/bjsports-2016-096625.
44. Stevenson EJ, Hayes PR, Allison SJ. The effect of a carbohydrate-caffeine sports drink on simulated golf performance. *Appl Physiol Nutr Metab*. 2009;34:681-688. doi:10.1139/H09-057.
45. Graham D. 8 Reasons Why Golfers are Dehydrated. Health & Wellness for Golf Performance. <https://www.golfpsych.com/golfers-dehydrated-8-reasons-why-competitive-golfers/>. Accessed November 3, 2017.
46. Macginty K. My awful year; Rory admits poor golf and mental fatigue have ruined 2013. *Belfast Telegraph*. http://go.galegroup.com.ezproxy.lib.vt.edu/ps/i.do?p=STND&u=viva_vpi&id=GALE%7CA350710497&v=2.1&it=r&sid=summon. Published November 28, 2013.
47. Janiszewski P. The Science of Starvation: How long can humans survive without food or water? <http://blogs.plos.org/obesitypanacea/2011/05/13/the-science-of-starvation-how-long-can-humans-survive-without-food-or-water/>. Published 2011. Accessed March 19, 2018.
48. The Internet Pathology Laboratory, for Medical Education. Urinalysis. The University of Utah Eccles Health Sciences Library. <https://library.med.utah.edu/WebPath/TUTORIAL/URINE/URINE.html>. Accessed May 1, 2018.

Chapter 2: Cognitive and Physical Performance of Euhydrated and Dehydrated States in Collegiate Female Golfers

Abstract

Background: Despite the observed effects and the understood importance of water as a nutrient, a number of reports suggest that an overwhelming amount of the athletic population competes and trains in a dehydrated state. A lack of agreement in the research perpetuates differing opinions when it comes to making recommendations for adequate hydration. In addition, researchers are unsure whether the detriments of dehydration on physical and cognitive performance can be attributed to water loss alone or to the self-pacing psychological effects due to a greater perception of effort. Existing literature on dehydration and golfers is largely limited to male golfers.

Purpose: The purpose of this study was to determine differences in cognitive and motor performance in elite female golfers in a euhydrated and a dehydrated state.

Methods: In this randomized, controlled, crossover experiment, female elite golfers on the Virginia Tech Women's Golf Team (n=6) completed four simulated golf holes under two conditions: a euhydrated and dehydrated state. The euhydrated state was achieved by following the NCAA hydration recommendations, and the dehydrated state was achieved via a 12 hour overnight fast from fluids. Perception of effort was measured via the Borg Scale, distance and accuracy of golf shots was assessed via a golf simulator, putting accuracy was measured by a clock-drill putting test, reaction time was measured using the Deary-Liewald choice reaction time task, and executive cognitive function was measured by the Trail Making Test B. Results from each of the tests were compared between the euhydrated and dehydrated states using repeated measures analysis of variance in SPSS version 24.

Results: Mean urinary specific gravity (USG) for the euhydrated state was 1.009 (range=1.003–1.021) and was 1.021 (range=1.018–1.026) for the dehydrated state. No significant interactions of condition by time for perceived effort, 7-iron distance and accuracy, putting accuracy, reaction time, and executive cognitive function were found between euhydrated and dehydrated states. However, although not significant, euhydrated participants demonstrated greater 7-iron and putting accuracy and reported less perceived effort as compared to performance during their dehydrated state.

Conclusion: Based on USG levels, NCAA hydration recommendations may not be adequate to induce a euhydrated state for all athletes. This pilot study should be reproduced in both males and females with a larger sample size to increase statistical power. In addition, golf performance measures are limited in a simulated setting, and real life assessment on the golf course would increase validity.

Introduction

Despite its lack of energetic yield, taste, or glamor, water is so vital to human function that it is perhaps the most important nutrient for athletes. In fact, humans can survive 30–40 days without food, but absence of water in the diet can lead to fatality in as few as 3 days.^{1,2} Moreover, human bodies are largely fluid: water contributes 55–60% of the average human's body weight and constitutes 70% of muscle tissue composition.¹ As such, the paramount role fluid consumption plays on athletic performance is apparent, yet an overwhelming amount of the athletic population competes and trains in a dehydrated state.^{3–7}

Athletes in water balance or slight positive water balance, i.e., euhydration or slight hyperhydration, should demonstrate improved performance as compared to slight negative water balance, or dehydration.¹ Euhydrated athletes have greater body fluid available to supply blood and oxygen to working muscles and to produce sweat to cool the body and prevent heat-related disorders. Some sources report water loss beginning at 1–2% of body weight leads to an increase in heart rate and a decrease in exercise performance.^{1,6,8,9} In general, dehydration of 1–2% body weight does not appear to impact exercise performance of exercise lasting less than 90 minutes; however, some evidence supports minimal dehydration can impact performance of fine-motor tasks often used in team sports.⁶ Water loss at 3–5% of body weight leads to loss of blood volume, low oxygen delivery to muscles, and faster lactic acid build up, ultimately causing higher rates of perceived exertion, faster onset of fatigue, decreased ability to concentrate, and decreased training and performance overall.¹ Severe dehydration, indicated by $\geq 4\%$ losses in body weight, can result in increased body temperatures and respiratory rate, decreased concentration, headaches, irritability, sleepiness, heat illness, and severe reductions in athletic performance and physical work capacity.^{1,10,11} The literature clearly shows that dehydration reduces skill-based performance by causing detriment to both motor skill and cognitive function,

yet research supporting a numerical threshold at which effects are displayed is equivocal.¹²

Therefore, the question remains whether decreased physical performance and cognitive performance in mildly dehydrated athletes attenuate overall sport performance.

Minimal research has examined the effects of fluid ingestion during golf as compared to its endurance counterparts, presumably due to the slow-paced, low intensity nature of the sport. Although the sport of golf reports low energy expenditure and is non-contact, non-explosive, and generally non-fatiguing, it may still pose threats to homeostasis by 4–8 hours of prolonged walking and high cognitive demand of shot and putting execution during an 18 or 36 hole round.¹³ Only two studies have examined golf performance in dehydrated athletes and only male participants were included. One study demonstrated that male elite collegiate golfers (n=15) who were significantly dehydrated (urinary specific gravity [USG] > 1.020) or ~~severely~~seriously dehydrated (USG > 1.0320) had a four stroke higher average than golfers who were euhydrated (USG < 1.010) or minimally dehydrated (USG ≤ 1.020) after a competitive 18 hole round following normal drinking habits.⁹ Another study conducted with male elite golfers (n=7) who were mildly dehydrated (change in body weight = $-1.5 \pm 0.5\%$) had an 11% loss in average iron distance, near doubling of off target iron accuracy, and over a six fold increase in overestimation of distance from pin compared to their euhydrated condition (change in body weight = $-0.3 \pm 0.6\%$).⁹ Still, more research needs to be done on cognition as a potential physiological cause of impaired performance in golf. Therefore, this study is one of the first to look at perceptions of effort in euhydrated and dehydrated states in female competitive golfers and to measure reaction time and executive cognitive function to estimate mental fatigue and reasoning capability, respectively, during golf competition and training.

Aims and Hypotheses

The purpose of this study was to examine the impact of mild dehydration on the performance and cognitive function of female elite golfers as compared to performance following standard NCAA hydration recommendations, i.e., euhydrated. Several measures were used to assess motor and cognitive function, including perception of effort, hitting distance and accuracy, putting accuracy, reaction time and fluid cognitive ability. Hitting, putting, and decision making are core elements of competitive golf. We first aimed to determine the differences in athletic performance of female golfers between a euhydrated and mildly dehydrated state by measuring ball striking distance and accuracy and putting accuracy. Second, we aimed to determine the differences in cognitive function of golfers in a euhydrated and mildly dehydrated state by measuring the rating of perceived exertion during exercise, reaction time, and fluid cognitive ability. Additionally, we aimed to identify differences over time between euhydrated and dehydrated states in motor and cognitive performance by repeated measures designed to simulate holes during a round of golf. It is hypothesized that participants in their dehydrated state will demonstrate increased perceived exertion in exercise, decreased golf performance by distance, accuracy, and number of putts made, and more impaired cognitive function as compared to their euhydrated state.

Methods

Subjects

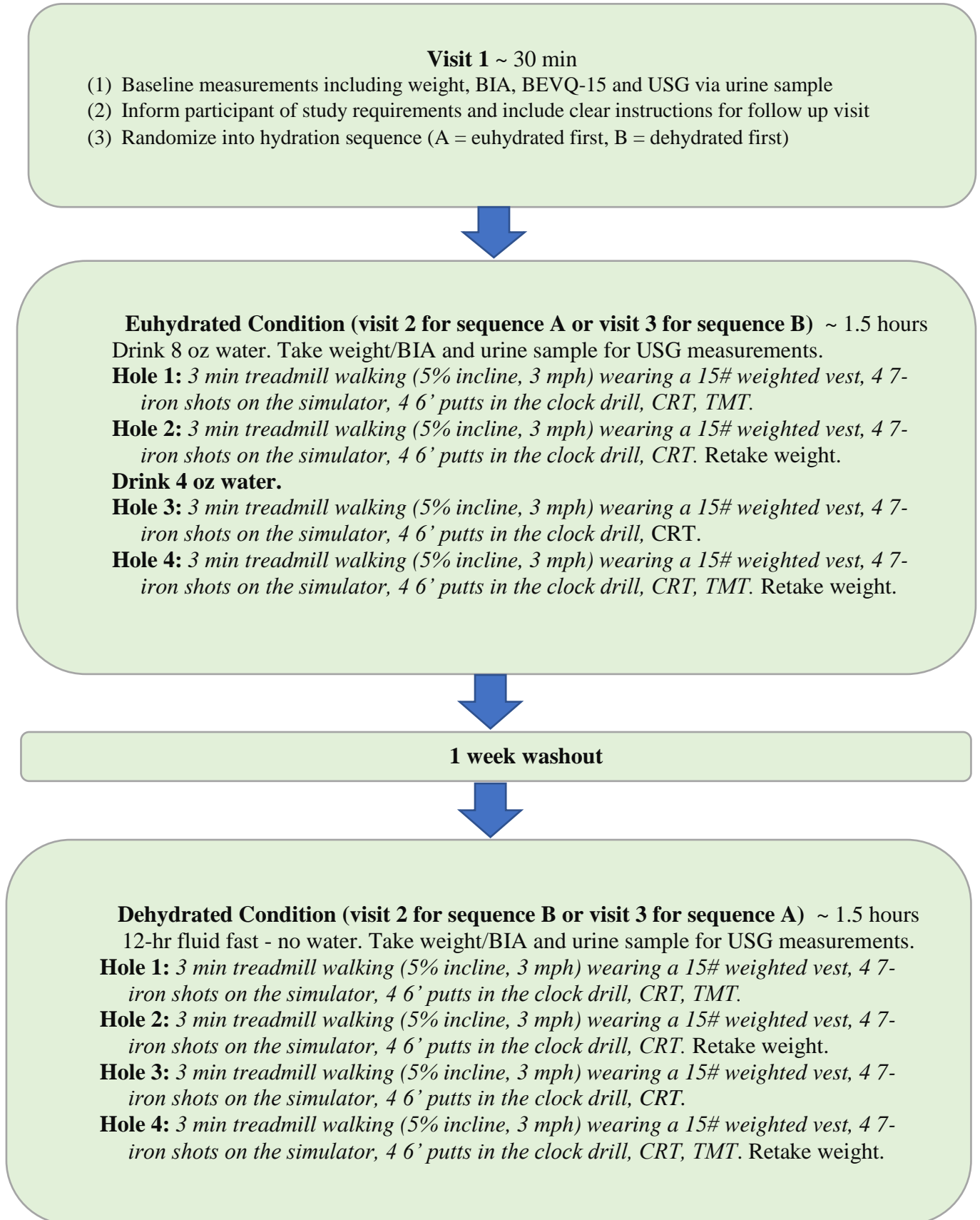
Participants included female collegiate golfers from the Virginia Tech Women's Golf Team. The sample population represented elite golfers participating in high level, regional and national competition. The study excluded any person not cleared for exercise by Virginia Tech athletic training and physician staff. Each participant signed an informed consent form signifying

they were aware of the expectations and risks, were approved by the Virginia Tech Athletic Department for exercise, and wished to continue with participation. Compensation included a drawing for a \$25 gift card. The study was approved by the Virginia Tech Institutional Review Board (See **Appendix A**).

Study Design

The research study design is a randomized, controlled, crossover experiment (**Figure 1**). The study consists of three visits with baseline measurements taken on visit 1 and repeated measures taken on visits 2 and 3. Visits were scheduled around participants' competition to limit consequences of dehydration and around participants' menstrual cycles to avoid confounding factors on hydration status or performance. Participants were randomized into one of two groups, sequence A or sequence B, to control for potential biases in ordering of ensured euhydration or induced mild dehydration on test results. Participants in sequence A performed the tests in the euhydrated condition first, and participants in sequence B performed the tests in the dehydrated condition first. For both conditions participants were instructed to record fluid intake and to drink a minimum amount of fluid (40ml/kg of body weight) to maintain adequate water balance on the day before the visit. Euhydration on the day of the visit was expected as a result of compliance to NCAA (National Collegiate Athletic Association) hydration recommendations to drink 16 oz water 2–3 hours before exercise, 8 oz water 15 minutes before exercise, 4 ounces water every 15–20 minutes during exercise, and 16–20 ounces of fluid after exercise for every pound lost.¹⁵ Dehydration on the day of the visit was induced by a 12 hour overnight fast, which was previously used by Smith et al., and had previously demonstrated a USG ≥ 1.010 and a 1-2% body weight loss.⁹

Figure 1. Study Design



All sessions were held in the Willis and Mary Blackwood Indoor Golf Facility on site at Virginia Tech. During visit 1 researchers obtained baseline measurements including weight, body composition via bioelectrical impedance analysis (BIA), USG via urine sample and typical beverage intake via a beverage questionnaire (BEVQ-15) (**Appendix B**). Participants were given instructions to meet hydration requirements based on the sequence assigned and were provided with a fluid intake log to fill out before returning for their second visit.

Participants were asked to eat a standardized breakfast of 2 pieces of toast (with peanut butter and jelly or honey) and a banana. During visit 2 researchers measured participant weight and USG from the urine sample upon arrival. For the exercise bouts, participants first performed 3 minutes of walking on a treadmill (5% incline at 3 mph) wearing a 15 pound weighted vest to mimic competition demands of carrying a golf bag. Second, participants began the golf-specific tests in the simulator by performing a typical warm up (~5 minutes). The golfers hit 4 full shots with their 7 iron towards the simulator target. Next, the golfers performed a clock drill putting test in which 4 six-footers were set up on the putting green around the hole. Participants were instructed to putt as many balls in around the hole, and the total number of putts made were recorded. Third, participants underwent two cognitive function tests: the Deary-Liewald choice reaction time task and the Trail Making Test B. This series of tests was repeated 4 times to simulate 4 holes with the exception of Trail Making Test B, which was only performed at the beginning and the end (holes 1 and 4). At completion of the second set of tests (hole 2), weight was taken again to ensure weight loss did not exceed 5% of body weight (classification of serious dehydration) for the safety of the participants, and participants in the euhydrated condition were given 4 oz of water.¹⁶ At the end of the fourth set of tests (hole 4), weight was

retaken and recorded. To aid in proper rehydration post-test, participants were given water or Gatorade and instructed to drink 16–20 ounces of fluid for every pound lost.

A washout period of at least 7 days was implemented before participants reported back for the third and final visit to conduct the same tests in the opposite condition, i.e., those who were tested in the dehydrated condition at visit 2 were then re-tested in the euhydrated condition at visit 3 and vice versa. Similarly in visit 2, the night before visit 3 participants filled out the fluid intake log and met hydration requirements. Also, participants were asked to eat the same breakfast of 2 pieces of toast with peanut butter and jelly or honey and a banana. Participants repeated the tasks from the previous visit and all data was recorded.

Measures

Weight and Body Composition

Body weight and total body water was measured to the nearest 0.1 kg using a digital scale (model 310GS; Tanita, Tokyo, Japan).

Urinary Specific Gravity

USG estimates hydration status and the concentrating and diluting function of the kidneys.⁸ The expected value for USG in a clinical setting falls between 1.010–1.025.⁸ However, these expected values are more liberal compared to the classifications used by the National Athletic Trainers' Association (NATA). NATA considers USG values <1.010 well hydrated, 1.010–1.020 mild dehydration, 1.021–1.030 significant dehydration, and USG values >1.030 serious dehydration.¹⁷ For the purpose of this study, NATA values were used. USG was determined using a handheld refractometer (ATAGO 4410 Urinary Specific Gravity Refractometer, Bellevue, WA) at the beginning of each visit.

Heart Rate

Heart rate was measured using a Polar A300 heart rate monitor with a chest strap to estimate beats per minute at the end of each three minute weighted walking exercise test.

Perception of Effort

Perception of effort was measured using a Rate of Perceived Exertion (RPE) Scale or the Borg Scale (**Appendix C**) at the end of each three minute weighted walking exercise test. The Borg scale estimates intensity level during exercise based on how hard the individual perceives he or she is working.¹⁸ The scale numerically represents an individual's perception of intensity ranging from no exertion (score of 6) at all to maximal exertion (score of 20).¹⁸ Validation studies have shown strong correlation between perception of effort using the Borg scale and actual heart rate of the individual.¹⁸

Motor Performance

Distance (yards) and off-target accuracy (yards) were measured using the Foresight Sports golf simulation and GC2 quadrascopic launch monitor. Prior testing by the manufacturer of the GC2 monitor established a distance accuracy of 2-3 yards for 150 to 200 yard golf shots. For each simulated golf hole, participants were asked to hit 4 shots with their 7 iron towards the simulator target to the best of their ability. The simulation target was set to visually represent each golfer's typical full shot distance using a 7 iron. Putting accuracy for each round was determined by the total number of putts made out of 4 attempts in a clock-drill putting test.

Cognitive Performance

The Deary-Liewald choice reaction time task and Trail Making Test B were used to measure cognitive function in this study, **Appendices D** and **E**, respectively. The Deary-Liewald

CRT task represents mean reaction times of the participants.¹⁹ The CRT task is administered through the Deary-Liewald Reaction Time Tester program downloaded on the investigator's laptop. Procedures for this test simply require the subject to press keys on a computer in response to flashing cues on the screen as fast as they are able. The cues are flashing "X's" in four boxes that correspond to the four keys the participants rest their middle and pointer fingers on. The participants had a total of 30 cues flash each within 200 to 1500 milliseconds of each other. The program reports mean response time, the variable of interest, as well as other variables including number of correct responses. Trail Making Test B requires the participants to connect the numbers 1 to 13, but also a letter in alphabetical order following each number, i.e., 1-A-2-B, etc. by tracing with a pen. Trail Making Test B measures fluid cognitive ability.²⁰ Fluid cognitive ability, or fluid intelligence, is "the ability to generate, transform, and manipulate different types of novel information in real time" and influences reasoning capabilities of an athlete during training and competition.²¹

Statistics

Statistical analysis of the euhydrated condition versus the dehydrated condition was assessed using repeated measures ANOVA to determine differences within subject conditions over time. Two-way repeated measures ANOVA was used to determine if there was an interaction between time and hydration status on the dependent variables impacting the main effects, e.g., whether the magnitude of the effect of time on hitting accuracy depends on the condition.

Paired samples t-tests of the averages were used to interpret the main effects by comparing the means of dependent variables in euhydrated and dehydrated conditions. Variables used to assess hydration status included USG and change in body weight. The dependent

variables tested include perception of effort (RPE), heart rate (HR), 7-iron distance and off-target accuracy, successful putts, mean CRT time, and TMT-B time. Analysis of average RPE scores over time included a 2 x 2 (holes 1 and 4) repeated measures analysis of variance to determine differences between the two hydration conditions (euhydrated vs. dehydrated). Analysis of motor performance task data over time included a 2 x 2 repeated measures analysis of variance to determine differences between the two hydration conditions and the first and last time points for each of the following: average shot distance (yards), off-target accuracy (yards), and total putts made. Similarly, analysis of cognitive performance included a 2 x 2 repeated measures analysis of variance to determine differences between the 2 hydration conditions and the mean CRT times and TMT times. Significant values were assessed by the determined significance level ($p \leq 0.05$). All analyses were performed using SPSS Statistics 24.

Results

Demographic Characteristics

Seven female golfers enrolled in the study, however, only six completed all sessions. Of the six golfers, all were between the ages of 19 and 22 (**Table 1**). All of the participants were white (100%). All were golfers participating in elite level, regional and national competition (i.e., competition on the Virginia Tech Women's Golf Team). Typical total fluid intake via the BEVQ-15 ranged from 26 to 167 fl oz per day. The mean typical total water consumption was 53 fl oz per day and ranged from 22 to 120 fl oz per day.

Table 1: Participant Demographic Characteristics (n=6)

Age (years), M (SD)	20.8 (1.1)
Race/Ethnicity, n (%)	
White	6 (100%)
Height (cm), M (SD)	167.6 (6.5)
Baseline Weight (kg), M (SD)	63.8 (10.0)
Baseline BMI (kg/m ²), M (SD)	22.6 (2.0)
Baseline Total Body Water (kg), M (SD)	34.2 (3.2)
Baseline USG, M (SD)	1.017 (0.006)
Typical total fluid intake via BEVQ-15 (fl oz), M (SD)	71 (50)
Typical total calories from beverages intake via BEVQ-15 (kcal), M (SD)	126 (98)

Comparison of Body Weight between Hydration Conditions

The initial weight at the beginning of the euhydrated visit was $1.53 \pm 0.73\%$ higher as compared to baseline weights at visit 1 ($p = 0.091$), while the initial weight at the beginning of the dehydrated visit was only increased by $0.74 \pm 0.88\%$ as compared to baseline weight at visit 1 ($p = 0.439$) (**Table 2**). Furthermore, there was no significant difference in the initial euhydrated weight and initial dehydrated weight (mean difference = $0.78 \pm 0.52\%$, $p = 0.194$).

Comparison of USG between Hydration Conditions

The initial USG at the beginning of the euhydrated visit was significantly lower than the baseline USG at visit 1 (mean difference = 0.010 ± 0.007 , $p = 0.034$), and USG at the beginning of the dehydrated visit was significantly higher than the euhydrated USG (mean difference = 0.012 ± 0.004 , $p = 0.030$) (**Table 2**). There was no significant difference in baseline USG and the dehydrated visit USG. One participant was not able to give a urine sample at the beginning of the dehydrated visit; therefore, only five pairs were used for USG analysis between conditions. Of the USG values at visit one, one classified as significantly dehydrated (1.021), four classified as minimally dehydrated (1.010–1.020), and 1 classified as euhydrated (<1.010). The minimum USG from visit 1 was 1.007 and the maximum was 1.023.

Table 2: Comparison of Body Weight (kg) and Urinary Specific Gravity (USG) across Baseline and Euhydrated and Dehydrated States

Variable	Baseline Mean (SD)	Euhydrated Mean (SD)	Dehydrated Mean (SD)	p-value
Weight, kg	63.3 (9.0)	64.3 (9.8)	63.8 (9.9)	0.160
USG	1.019 (0.004) ^a	1.009 (0.007) ^{a,b}	1.021 (0.003) ^b	0.014

^aIndicates significance between groups at p=0.034

^bIndicates significance between groups at p=0.030

Comparison of Heart Rate between Hydration Conditions

Difference in heart rate was not significant between the euhydrated and dehydrated states.

Euhydrated heart rate was 5 bpm higher than the dehydrated heart rate (See **Tables 3 and 4**).

Table 3. Comparison of Mean Heart Rate between Euhydrated and Dehydrated States

Variables	Euhydrated Mean (SD)	Dehydrated Mean (SD)	Difference Mean (SE)	p-value
Heart rate (bpm)	120.9 (16.9)	115.9 (14.2)	5.0 (2.0)	p = 0.057

Table 4. Comparison of Heart Rate within Groups over Time

Variables	Hole 1 Mean (SD)	Hole 4 Mean (SD)	Difference between Hole 1 and Hole 4		Condition by Time Difference F (p-value)
			Mean (SE)	p-value	
Heart rate (bpm)					
Euhydrated	120.0 (13.4)	122.5 (19.4)	2.5 (2.5)	0.366	0.019 (0.896)
Dehydrated	114.7 (13.3)	116.8 (17.1)	2.2 (2.7)	0.451	

Comparison of Motor Function between Hydration Conditions

Motor function variables of interest included average shot distance (yards), off-target accuracy (yards), and total putts made. Paired samples t-tests revealed numerical differences in data, but no statistical significance for any of the data pairs (**Table 5**). There was a significant

decrease in 7-iron hitting distance between holes 1 and 4 in the euhydrated condition (mean difference = 5.1±1.6 yards, p = 0.025) and in the dehydrated condition (mean difference = 3.5±1.4 yards, p = 0.049). However, no significant interactions of condition by time for distance or for other motor performance measures were indicated (**Table 6**).

Table 5. Comparison of Mean Motor Performance Measures between Euhydrated and Dehydrated States

Variables	Euhydrated Mean (SD)	Dehydrated Mean (SD)	Difference Mean (SE)	p-value
Distance (yards)	157.7 (8.7)	155.2 (10.9)	2.5 (1.0)	p = 0.055
Accuracy (yards)	7.9 (1.5)	7.7 (1.9)	0.2 (1.0)	p = 0.858
Putts made (out of 4)	2.9 (0.7)	2.6 (1.1)	0.3 (0.4)	p = 0.516

Table 6. Comparison of Motor Performance Measures within Groups over Time

Variables	Hole 1 Mean (SD)	Hole 4 Mean (SD)	Difference between Hole 1 and Hole 4		Condition by Time Difference F (p-value)
			Mean (SE)	p-value	
Distance (yards)	161.4 (9.3)	156.3 (7.6)	5.1 (1.6)	0.025	0.391 (0.559)
	157.5 (11.1)	154.0 (11.1)	3.5 (1.4)	0.049	
Accuracy (yards)	6.5 (3.1)	7.2 (3.2)	0.7 (1.2)	0.581	2.796 (0.155)
	7.1 (3.3)	10.4 (4.9)	3.3 (2.2)	0.200	
Putts made (out of 4)	2.7 (1.2)	3.0 (0.9)	0.3 (0.7)	0.661	0.077 (0.793)
	2.2 (1.0)	2.7 (0.8)	0.5 (0.3)	0.203	

Comparison of Cognitive Function between Hydration Conditions

Analysis of cognitive function included rate of perceived exertion (RPE), choice reaction task (CRT) time, and trail making test B (TMT-B) time. A rating of 9 on the Borg Scale (RPE) would be considered very light perceived exertion, and a rating of 11 would be considered light.

Paired samples t-tests revealed numerical differences in data between the euhydrated and dehydrated states, but no statistical significance for any of the cognitive data pairs (**Table 7**).

Both cognitive function test times were higher in the euhydrated condition, but neither differences in euhydrated and dehydrated CRT times nor TMT-B times were significant.

Similarly, there was no difference in cognitive function over time between hydration conditions nor was there an interaction between time and condition on cognitive function. (**Table 8**).

Table 7. Comparison of Mean Cognitive Performance Measures between Euhydrated and Dehydrated States

Variables	Euhydrated Mean (SD)	Dehydrated Mean (SD)	Difference Mean (SE)	p-value
RPE	10.5 (2.1)	10.9 (1.6)	0.4 (0.6)	p = 0.544
CRT time (ms)	391.4 (22.3)	377.9 (39.9)	13.5 (9.0)	p = 0.194
TMT-B time (sec)	59.4 (12.8)	58.3 (14.0)	1.1 (6.1)	p = 0.865

Table 8. Comparison of Cognitive Performance Measures within Groups over Time

Variables	Hole 1 Mean (SD)	Hole 4 Mean (SD)	Difference between Hole 1 and Hole 4		Condition by Time Difference F (p-value)
			Mean (SE)	p-value	
RPE					
Euhydrated	9.9 (1.8)	10.9 (2.2)	1.0 (0.5)	0.111	0.484 (0.518)
Dehydrated	10.6 (1.6)	11.3 (1.9)	0.8 (0.5)	0.178	
CRT time (ms)					
Euhydrated	399.8 (25.4)	386.6 (24.3)	13.2 (8.0)	0.159	1.629 (0.258)
Dehydrated	382.8 (33.7)	379.4 (45.5)	3.3 (6.1)	0.610	
TMT-B time (sec)					
Euhydrated	65.7 (20.0)	53.1 (10.7)	12.6 (7.8)	0.168	0.144 (0.720)
Dehydrated	67.6 (24.9)	49.1 (8.3)	18.5 (9.9)	0.121	

Discussion

The results of this pilot study demonstrate trends of improved golf performance and perception of effort in euhydrated athletes. Although not statistically significant, euhydrated participants' 7-iron distance was greater by 2.5 yards, putting accuracy was 7.5% higher, and weighted walking was perceived as 3.8% easier as compared to their dehydrated state. These findings suggest euhydration may improve the motor and cognitive skills of competitive golfers, consistent with results of another study that demonstrated golfers who were dehydrated had a four stroke higher scoring average than golfers who were euhydrated.³ A recent study conducted with male elite golfers (n=7) demonstrated mild dehydration (1–2% loss in body weight) lead to an 11% loss in average iron distance and near doubling of off target iron accuracy after hitting only 30 golf balls in a temperature controlled laboratory (temperature: 20.6 ± 0.3 C; humidity: $53.6 \pm 3\%$).⁹ Additionally, the study reported dehydrated golfers demonstrated over a six fold increase in overestimation of distance from the pin.⁹ The results suggest the detriments of dehydration present themselves earlier than in other sports, such as cycling. Minor improvements in distance can play a much bigger role in a round of golf than the physical inches gained. Two to three yards of extra distance can impact the confidence and the demeanor of the player. Elevated confidence can in turn improve ball striking and other areas of the game which then improves demeanor. Similarly, decreased perception of effort can enhance demeanor to improve performance. The higher putting percentage found during euhydration may secure one stroke that is the difference between first and second place.

There was a significant decrease in 7-iron hitting distance over time between holes 1 and 4 in the euhydrated condition (mean difference = 5.1 ± 1.6 yards, $p = 0.025$) and in the dehydrated condition (mean difference = 3.5 ± 1.4 yards, $p = 0.049$). More research is warranted to determine the cause of this loss in distance, e.g., fatigue, stress hormones, etc. The loss in distance in the

euhydrated state was ultimately similar to the loss in distance in the dehydrated state, because no significant interactions of condition by time for distance or for other motor performance measures were indicated.

Heart rate in the dehydrated state was lower than heart rate in the euhydrated state, trending in the opposite direction as expected as previous studies have shown a strong correlation between perception of effort using the Borg scale and actual heart rate of the individual.¹⁸ One possible explanation for the trend in heart rate is physical adaptations to training in dehydrated conditions, an area that warrants more research in golfers. Furthermore, a difference between resting heart rate and peak heart rate could have existed and would have accounted for variability in resting heart rate between hydration conditions; however, resting heart rate data was not collected. Because the trend did not reach statistical significance, future studies with larger sample sizes likely will see heart rate trend in a direction consistent with the literature.^{1,18}

Dehydration is one of many factors in a complex regulatory system that leads to mental fatigue.²² A few studies have reported higher ratings of perceived effort for individuals in a dehydrated state than in a euhydrated state and others have shown loss of cognitive function and alertness in mildly dehydrated individuals (body weight loss of 1 – 2%).^{8,23} Some have proposed the sensation of thirst increases the athlete's perception of effort leading to a reduction in physical effort, which could lead to a reduction in hitting distance for golfers.²² Previously, reaction time has been used to determine the ergogenic effect of caffeine in elite archers,²⁴ to measure performance decrements related to mental fatigue,²⁵ to indicate general fluid intelligence, to predict survival, and for a host of other outcome variables.¹⁹ The small sample size, including one participant whose USG indicated significant dehydration during the euhydration visit, may have contributed to the lack of significant differences in cognitive

function between hydration conditions. Further research should be conducted to elicit the potential impact of hydration status, as golfers who are properly hydrated may demonstrate improved reaction time, and thus have delayed mental fatigue and greater ability to sustain effort throughout prolonged competitions.²⁵

Overall, the sample population reflected current literature's estimates that a majority of athletes train and compete in a dehydrated state.³⁻⁷ Using the USG classifications for hydration ($USG < 1.010$) and dehydration ($USG \geq 1.010$), 86% of participants at baseline demonstrated dehydration. Furthermore, the average euhydrated hydration status was significantly more hydrated than baseline, and the average dehydrated hydration status was significantly different from baseline, corroborating the high prevalence of dehydration among the sample population.

Finally, the results suggest NCAA recommendations for before exercise and daily fluid needs based on weight administered by a fluid intake log may not be appropriate for all athletes.¹⁵ One participant out of six did not achieve euhydration despite reported compliance to the written guidelines on her fluid intake logs but was, in fact, significantly dehydrated ($USG = 1.021$). Participants in the euhydrated condition followed personalized hydration guidelines the day before (40 ml of fluid/kg of body weight) and standard hydration guidelines (drink 16 fl oz 2-3 hours before exercise, 8 fl oz 15 minutes before exercise, and 4 fl oz every 15 minutes of exercise) on the day of the euhydration visit.¹⁵ It is possible that a food dye, such as blackberries or beets, a drug, or the presence of hemoglobin or myoglobin could have changed the color of the urine causing a false USG measurement.²⁶ In the future, researchers should obtain another indication of hydration status, such as an accurate baseline measure of weight to measure weight change, or use a dietary recall can help eliminate false USG measurements. Blood glucose tests could also be added to measure potential confounding detriments on cognitive-motor

performance. In this study, it is not known whether the abnormally high USG was caused by inadequate fluid intake or by a tainting substance in the urine, but preliminary evidence suggests current hydration guidelines administered by a fluid intake log may not ensure euhydration of all athletes. Thus, more research should be done on effective hydration education methods and hydration planning practices.

Limitations of the study include small sample size ($n=6$) and limited generalizability from a laboratory setting to the golf course. A similarly designed study that measured differences in performance over time in male golfers who consumed a caffeinated carbohydrate beverage or a placebo beverage had a sample size of 20.¹³ Stevenson, et al. additionally repeated measures and conducted data points over 18 holes. Four hours of testing over the course of 18 simulated holes is more similar to competition conditions than 1 hour of testing over the course of 4 simulated holes. Greater statistical power as a result of more participants and prolonged exercise would have likely led to statistical significance. In addition, although the present study was designed to simulate four holes of golf via metabolically equivalent exercise, hitting, putting, and cognitive demands, true performance results should be measured on the golf course in a competitive round. The accuracy of the GC2 monitor for distance should also be considered as the difference between hydration conditions was within the reported error of the simulator. The collection of resting heart rate would have allowed for further insight into the impact of hydration status on changes in heart rate during exercise. Finally, a single weight measurement was not adequate to establish a baseline weight and USG. Smith et al. conducted three visits with weight measurements to calculate a baseline weight from used to find percent body weight loss from euhydration and dehydration conditions.⁹

Conclusion

Although no significant differences between euhydrated and dehydrated states were found, based on the trends of these results and the findings of other studies, a similarly designed study with a larger sample size might elicit results showing decline in motor or cognitive performance due to dehydration. Based on USG levels, NCAA hydration recommendations may not be adequate to induce a euhydrated state for all athletes. More research is needed with larger sample sizes to further elicit the impact of hydration status on variance in motor and cognitive function for elite golfers.

References

1. Fink HH, Mikesky AE. *Practical Applications in Sports Nutrition*. 5th ed. Burlington, AA: Jones & Bartlett Learning; 2018.
2. Janiszewski P. The Science of Starvation: How long can humans survive without food or water? <http://blogs.plos.org/obesitypanacea/2011/05/13/the-science-of-starvation-how-long-can-humans-survive-without-food-or-water/>. Published 2011. Accessed March 19, 2018.
3. Magee PJ, Gallagher AM, McCormack JM. High Prevalence of Dehydration and Inadequate Nutritional Knowledge Among University and Club Level Athletes. *Int J Sport Nutr Exerc Metab*. 2017;27(2):158-168. doi:10.1123/ijsnem.2016-0053.
4. Osterberg KL, Horswill CA BL. Pregame Urine Specific Gravity and Fluid Intake by National Basketball Association Players During Competition. *J Athl Train*. 2009;44(1):53-57.
5. Maughan RJ, Watson P, Evans GH, Broad N, Shirreffs SM. Water balance and salt losses in competitive football. *Int J Sport Nutr Exerc Metab*. 2007;17(6):583-594.
6. Maughan RJ, Shirreffs SM. Dehydration and rehydration in competitive sport. *Scand J Med Sci Sports*. 2010;20:40-47. doi:10.1111/j.1600-0838.2010.01207.x.
7. Arnaoutis G, Kavouras SA, Kotsis YP, Tsekouras YE, Makrillos M, Bardis CN. Ad Libitum Fluid Intake Does Not Prevent Dehydration in Suboptimally Hydrated Young Soccer Players during a Training Session of a Summer Camp. *Int J Sport Nutr Exerc Metab*. 2013;23(3):245-251. doi:10.1123/ijsnem.23.3.245.
8. Mahan LK, Raymond JL. *Krause's Food & the Nutrition Care Process*. 14th ed. St. Louis, Mo: Elsevier; 2017.
9. Smith M, Newell A, Baker M. Effect of acute mild dehydration on cognitive-motor performance in golf. *J Strength Cond Res*. 2012;26(11):3075-3080.
10. Gil A. Hydration and health. *Nutr Hosp*. 2015;32(2):1.
11. Greenleaf JE. Problem: thirst, drinking behavior, and involuntary dehydration. *Med Sci Sport Exerc*. 1991;24(6):645-656.
12. Hillyer M, Menon K, Singh R. The Effects of Dehydration on Skill-Based Performance. *Int J Sport Sci*. 2015;5(3):99-107. doi:10.5923/j.sports.20150503.02.
13. Stevenson EJ, Hayes PR, Allison SJ. The effect of a carbohydrate-caffeine sports drink on simulated golf performance. *Appl Physiol Nutr Metab*. 2009;34:681-688. doi:10.1139/H09-057.
14. Wilczynski C. Urine Osmolality: Reference Range. Medscape. <https://emedicine.medscape.com/article/2088250-overview>. Published 2014. Accessed October 19, 2017.
15. NCAA Sport Science Institute. How to maximize performance hydration. [http://www.ncaa.org/sites/default/files/Performance Hydration Fact Sheet.pdf](http://www.ncaa.org/sites/default/files/Performance%20Hydration%20Fact%20Sheet.pdf). Accessed

August 26, 2017.

16. ACSM. Selecting and Effectively Using Hydration for Fitness. <https://www.acsm.org/docs/brochures/selecting-and-effectively-using-hydration-for-fitness.pdf>. Accessed November 2, 2017.
17. Casa DJ, Armstrong LE, Hillman SK, et al. National Athletic Trainers' Association Position Statement: Fluid Replacement for Athletes. *Athl Train*. 2000;35(2):212-224.
18. Centers for Disease Control and Prevention. Perceived Exertion (Borg Rating of Perceived Exertion Scale). <https://www.cdc.gov/physicalactivity/basics/measuring/exertion.htm>. Published 2015. Accessed November 30, 2017.
19. Deary IJ, Liewald D, Nissan J. A free, easy-to-use, computer-based simple and four-choice reaction time programme: The Deary-Liewald reaction time task. *Behav Res Methods*. 2011;43(1):258-268. doi:10.3758/s13428-010-0024-1.
20. Arbuthnott K, Frank J. Trail Making Test, Part B as a Measure of Executive Control: Validation Using a Set-Switching Paradigm. *J Clin Exp Neuropsychol (Neuropsychology, Dev Cogn Sect A)*. 2000;22(4):518-528. doi:10.1076/1380-3395(200008)22:4;1-0;FT518.
21. Zaval L, Li Y, Johnson EJ, Weber EU. Complementary Contributions of Fluid and Crystallized Intelligence to Decision Making Across the Life Span. In: *Aging and Decision Making*. Elsevier; 2015:149-168. doi:10.1016/B978-0-12-417148-0.00008-X.
22. Edwards AM, Noakes TD. Dehydration: cause of fatigue or sign of pacing in elite soccer? *Sport Med*. 2009;39(1):1-14.
23. Hew-Butler T, Rosner MH, Fowkes-Godek S, et al. Statement of the Third International Exercise-Associated Hyponatremia Consensus Development Conference, Carlsbad, California, 2015. *Clin J Sport Med*. 2015;25(4):303-320. doi:10.1097/JSM.0000000000000221.
24. Linoby A, Nias A, Husna N, Suun A. The Effects of Caffeine on Archery Performance: A Randomized, Double-Blind, Placebo-Controlled Study. In: *Proceedings of the International Conference on Science, Technology and Social Sciences (ICSTSS) 2012*. Singapore: Springer Singapore; 2014:405-413. doi:10.1007/978-981-287-077-3_47.
25. Langner R, Steinborn MB, Chatterjee A, Sturm W, Willmes K. Mental fatigue and temporal preparation in simple reaction-time performance. *Acta Psychol (Amst)*. 2010;133(1):64-72. doi:10.1016/j.actpsy.2009.10.001.
26. The Internet Pathology Laboratory, for Medical Education. Urinalysis. The University of Utah Eccles Health Sciences Library. <https://library.med.utah.edu/WebPath/TUTORIAL/URINE/URINE.html>. Accessed May 1, 2018.

Chapter 3: Future Directions and Conclusion

Athletes constantly work towards gaining a performance edge. An athlete's commitment to plan and follow through with nutrition practices can set the competitor apart in his or her field. Successful nutrition practices include intent to begin exercise well hydrated and maintain adequate hydration status throughout the activity. The sport of golf, albeit slow paced, is no exception. Hydration is key to peak motor and cognitive function in fine motor skill sports, such as golf, and essential to preventing consequences during prolonged play lasting 4–8 hours. Current literature suggests mild dehydration (1–2% loss in body weight) significantly impairs physical performance of male golfers as exhibited by 11% loss in average iron distance and near doubling of off iron target accuracy in male golfers.¹ Results from this pilot study showed that euhydrated female golfers mean 7-iron distance was 2.5 yards greater, putting accuracy was 7.5% greater, and perceived exertion during weighted walking was 3.8% easier as compared to their dehydrated state. The small sample size and the inability of the NCAA hydration recommendations to ensure euhydration may have contributed to the lack of significant differences in motor and cognitive function between hydration conditions.

Many problems have been identified with maintaining hydration among golfers, including exercise in warm environments. In order to lose 1.5% body weight, a 65 kg player only has to lose 1 kg of sweat. Over a four hour round, that is less than 250 ml (~8 fl oz) of sweat lost without replenished fluid per hour. Sweat rates of golfers playing a round in temperate conditions are estimated at 400 ml/hr.¹ Golfers in warm environments could easily lose 250 ml of sweat an hour if forgetting to drink regularly. In addition, dehydration can be voluntary among golfers. Professional golfers reported that worry of increased frequency of urination and feeling uncomfortable and less athletic prevents them from drinking lots of fluid during the round.² Other reported reasons for inadequate fluid intake include decreased sensation of thirst,

underestimation of perspiration, and unpreparedness of carrying fluids.² Additionally, general hydration guidelines may not guarantee an athlete achieves euhydration. The findings purport NCAA recommendations for before exercise and daily fluid needs based on weight administered by a fluid intake log may not be appropriate for all athletes. More research needs to be done to determine whether the current guidelines underestimate fluid requirements of some individuals or whether recording fluid intake via a log is inadequate in order to promote euhydration and its performance benefits.

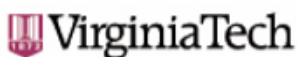
Despite the observed effects and the understood importance of water as a nutrient, a number of reports suggest that an overwhelming amount of the athletic population competes and trains in a dehydrated state, including golfers.³⁻⁷ Similarly, the findings reported 86% of participants at baseline demonstrated either minimal or serious dehydration ($USG \geq 1.010$). The high prevalence of dehydration in this sample female collegiate golfers and the potential of euhydration to improve performance highlight the need for competitive golfers to seek out professional help. Not only should athletes seek attention, but sports dietitians and sport coaches should also encourage competitive golfers to implement good hydration practices, such as weighing before and after a round to calculate sweat rates. Sports dietitians can work with athletes to overcome the obstacles to proper hydration and to reach the proposed performance benefits. Upcoming research will support the need to implement hydration plans as the impact of hydration status on variance in motor and cognitive function for elite golfers is further elicited.

References

1. Smith M, Newell A, Baker M. Effect of acute mild dehydration on cognitive-motor performance in golf. *J Strength Cond Res.* 2012;26(11):3075-3080.
2. Graham D. 8 Reasons Why Golfers are Dehydrated. Health & Wellness for Golf Performance. <https://www.golfpsych.com/golfers-dehydrated-8-reasons-why-competitive-golfers/>. Accessed November 3, 2017.
3. Magee PJ, Gallagher AM, McCormack JM. High Prevalence of Dehydration and Inadequate Nutritional Knowledge Among University and Club Level Athletes. *Int J Sport Nutr Exerc Metab.* 2017;27(2):158-168. doi:10.1123/ijsnem.2016-0053.
4. Osterberg KL, Horswill CA BL. Pregame Urine Specific Gravity and Fluid Intake by National Basketball Association Players During Competition. *J Athl Train.* 2009;44(1):53-57.
5. Maughan RJ, Watson P, Evans GH, Broad N, Shirreffs SM. Water balance and salt losses in competitive football. *Int J Sport Nutr Exerc Metab.* 2007;17(6):583-594.
6. Maughan RJ, Shirreffs SM. Dehydration and rehydration in competitive sport. *Scand J Med Sci Sports.* 2010;20:40-47. doi:10.1111/j.1600-0838.2010.01207.x.
7. Arnaoutis G, Kavouras SA, Kotsis YP, Tsekouras YE, Makrillos M, Bardis CN. Ad Libitum Fluid Intake Does Not Prevent Dehydration in Suboptimally Hydrated Young Soccer Players during a Training Session of a Summer Camp. *Int J Sport Nutr Exerc Metab.* 2013;23(3):245-251. doi:10.1123/ijsnem.23.3.245.

Appendices

Appendix A. Approval Letter



Office of Research Compliance
Institutional Review Board
North End Center, Suite 4120, Virginia Tech
300 Turner Street NW
Blacksburg, Virginia 24061
540/231-4808 Fax 540/231-0859
email irb@vt.edu
website <http://www.irb.vt.edu>

MEMORANDUM

DATE: January 8, 2018
TO: Valisa Ellen Hedrick, Whitney Elizabeth Stevenson, Kevin Davy, Jennie Zabinsky, David Lawrence Dieter
FROM: Virginia Tech Institutional Review Board (FWA00000572, expires January 29, 2021)
PROTOCOL TITLE: Validating Performance Hydration in Elite Golfers
IRB NUMBER: 17-688

Effective December 20, 2017, the Virginia Tech Institutional Review Board (IRB), at a convened meeting, approved the New Application request for the above-mentioned research protocol.

This approval provides permission to begin the human subject activities outlined in the IRB-approved protocol and supporting documents.

Plans to deviate from the approved protocol and/or supporting documents must be submitted to the IRB as an amendment request and approved by the IRB prior to the implementation of any changes, regardless of how minor, except where necessary to eliminate apparent immediate hazards to the subjects. Report within 5 business days to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.

All investigators (listed above) are required to comply with the researcher requirements outlined at: <http://www.irb.vt.edu/pages/responsibilities.htm>

(Please review responsibilities before the commencement of your research.)

PROTOCOL INFORMATION:

Approved As: **Full Review**
Protocol Approval Date: **January 4, 2018**
Protocol Expiration Date: **January 3, 2019**
Continuing Review Due Date*: **November 26, 2018**

*Date a Continuing Review application is due to the IRB office if human subject activities covered under this protocol, including data analysis, are to continue beyond the Protocol Expiration Date.

FEDERALLY FUNDED RESEARCH REQUIREMENTS:

Per federal regulations, 45 CFR 46.103(f), the IRB is required to compare all federally funded grant proposals/work statements to the IRB protocol(s) which cover the human research activities included in the proposal / work statement before funds are released. Note that this requirement does not apply to Exempt and Interim IRB protocols, or grants for which VT is not the primary awardee.

The table on the following page indicates whether grant proposals are related to this IRB protocol, and which of the listed proposals, if any, have been compared to this IRB protocol, if required.

Invent the Future

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
An equal opportunity, affirmative action institution

Appendix B. BEVQ-15

Beverage Questionnaire (BEVQ-15)

Participant ID: _____

Instructions:

Date: _____

- For the past month, please indicate your intake for each beverage type by marking an "X" in the bubble for "how often" and "how much each time".
1. Indicate how often you drank the following beverages, for example, if you drank 5 glasses of water per week, mark 4-6 times per week.
 2. Indicate the approximate amount of beverage you drank each time, for example, if you drank 1 cup of water each time, mark 1 cup under "how much each time". If applicable, indicate the specific type of beverage by marking an "X" in the bubble by the one used (i.e., type of nut milk).
 3. When trying to estimate your intake throughout the day, (i.e., water) think about the total amount you drink. For example, 3 times per day and 20 fl oz each time = 60 fl oz per day. **If you consume more 60 fl oz per day select "1 time per day" and write the TOTAL daily amount in the last column.**
 4. Do not count beverages used in cooking or other preparations, such as milk in cereal.
 5. Count milk/creamer added to tea and coffee in the tea or coffee with creamer beverage category, NOT in the milk categories; this includes non-dairy creamer. Please indicate the type of creamer (flavored, plain or sugar-free) and sweetener used by marking an "X" in the bubble by the one used, if applicable.

Type of Beverage	HOW OFTEN (MARK ONE)							HOW MUCH EACH TIME (MARK ONE)						
	Never or less than 1 time per week (go to next beverage)	1 time per week	2-3 times per week	4-6 times per week	1 time per day	2 times per day	3+ times per day	Less than 6 fl oz (¾ cup)	8 fl oz (1 cup)	12 fl oz (1½ cups)	16 fl oz (2 cups)	20 fl oz (2½ cups)	> 20 fl oz (specify TOTAL daily amount)	
Water or unsweetened sparkling water	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
100% Fruit Juice	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Sweetened Juice Beverage/Drink (fruit punch, juice cocktail, Sunny Delight, Capri Sun)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Whole Milk: red cap, Reduced Fat Milk 2%: purple cap, or Chocolate Milk	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Low Fat 1%: green cap, Fat Free/Skim Milk: light blue cap, Buttermilk or Soy Milk	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Nut Milk (almond, cashew, coconut) <input type="radio"/> Flavored, Original, or Plain <input type="radio"/> Unsweetened	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Soft Drinks, Regular	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Energy & Sports Drinks, Regular (Red Bull, Gatorade, Powerade)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Diet or Artificially Sweetened Soft Drinks, Energy & Sports Drinks (Diet Coke, Crystal Light, artificially sweetened sparkling water, Sugar-Free or Total Zero Red Bull, Powerade Zero)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Sweet Tea (with sugar)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Tea or Coffee, black (no creamer or milk) <input type="radio"/> Sugar, <input type="radio"/> Artificial Sweetener, <input type="radio"/> N/A	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Tea or Coffee (w/ milk &/or creamer) <input type="radio"/> Sugar <input type="radio"/> Artificial Sweetener <input type="radio"/> N/A <u>Milk &/or Creamer:</u> <input type="radio"/> Milk <input type="radio"/> Half & Half or Cream <input type="radio"/> N/A Creamer: <input type="radio"/> Flav. <input type="radio"/> Plain <input type="radio"/> Sugar-Free	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Wine (red or white)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Hard Liquor (vodka, rum, tequila, etc.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Beer, Ales, Wine Coolers, Non-alcoholic or Light Beer	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
Other (list): _____	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	

Virginia Tech, 2016.

Appendix C. Deary-Liewald choice reaction time test screenshots

Deary-Liewald Reaction Time Tester

Active Dataset C:\Users\VT_SA\Documents\Graduate Research\CRT - Valisa\Euhydrate

Subject ID:

Simple Reaction Time

Number of Practice Trials: Number of Experiment Trials:

Response Range (ms) From To

Inter Stimulus Interval (ms) From To

Choice Reaction Time

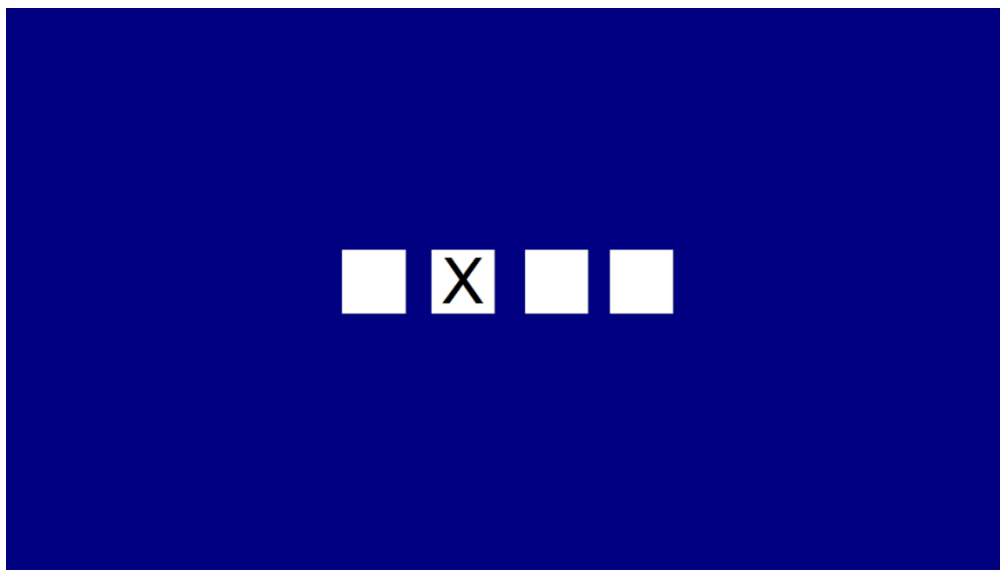
Number of Practice Trials: Number of Experiment Trials:

Response Range (ms) From To

Inter Stimulus Interval (ms) From To

CRT Key Box 1 CRT Key Box 2 CRT Key Box 3 CRT Key Box 4

System Settings



Appendix D. Trail Making A and B instructions and instruments

Trail Making Instructions

Follow these instructions exactly as the time includes the time for the instructor to correct errors made by the subject.

Equipment: Trail Making forms, pen or pencil, stopwatch

1. Using the Trail Making Part A SAMPLE, demonstrate the test to the subject. "On this page are numbers. Begin at number 1 and draw a line to 2, then to 3, then to 4 and so on until you reach End. without lifting your pencil from the paper. You should draw the lines as fast as you can. Like this." (demonstrate on the Sample)
2. Give subject pen or pencil and Trail Making Part A. "Now it is your turn. Do you have any questions? Ready. Begin."
3. Time the subject. Stop the subject if an error is made and return subject to last correct circle. The clock keeps running during corrections, but the subject should not be penalized if the examiner takes too long to explain the error. If the subject misses a circle, remind subject to touch all circles, but do not stop the subject. Stop the clock when End is reached.
4. Write time in seconds on the form and. Write subject number and date on the form
5. Using the Trail Making Part B SAMPLE, demonstrate the test to the subject. "This time the page has both letters and numbers. Begin at number 1 and draw a line to the letter A, then to the number 2, then to the letter B and so on until you reach End. without lifting your pencil from the paper. You should draw the lines as fast as you can. Like this." (demonstrate on the Sample)
6. Give subject pen or pencil and Trail Making Part B. "Now it is your turn. Do you have any questions? Ready. Begin."
7. Time the subject, correcting errors along the way. Stop the clock when End is reached. Write time in seconds on the form. Write subject number and date on the form.
8. Enter Trail Making times on the Clinical Evaluation Data Collection Form

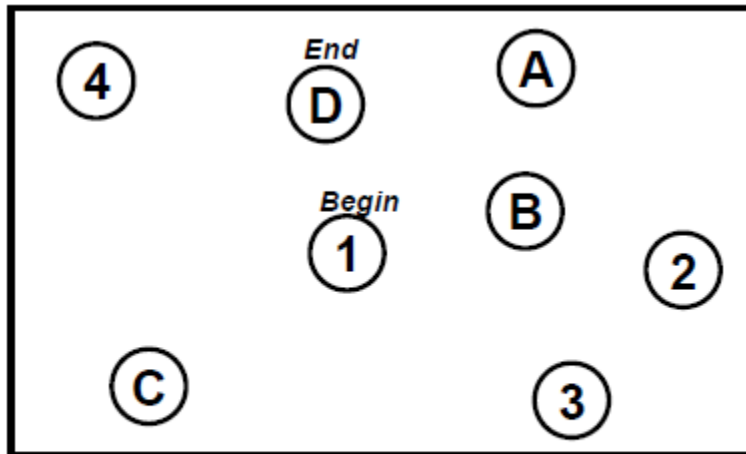
Scoring

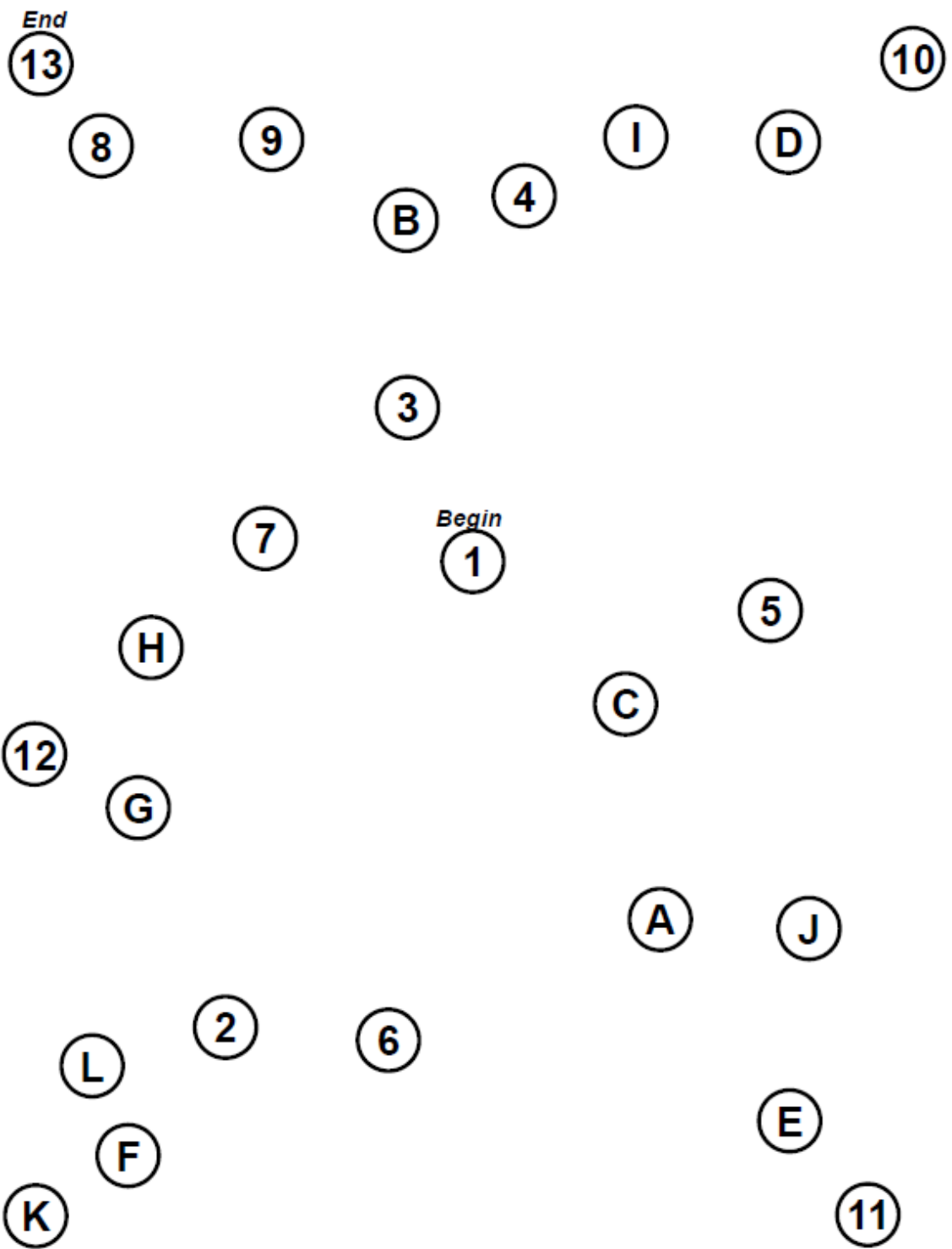
	Average	Deficient	Rule of Thumb
Trail A	29 seconds	> 78 seconds	Most in 90 seconds
Trail B	75 seconds	> 273 seconds	Most in 180 seconds

TRAIL MAKING

Part B

SAMPLE





Appendix E. Borg Scale

Instructions for Borg Rating of Perceived Exertion (RPE) Scale

While doing physical activity, we want you to rate your perception of exertion. This feeling should reflect how heavy and strenuous the exercise feels to you, combining all sensations and feelings of physical stress, effort, and fatigue. Do not concern yourself with any one factor such as leg pain or shortness of breath, but try to focus on your total feeling of exertion.

Look at the rating scale below while you are engaging in an activity; it ranges from 6 to 20, where 6 means "no exertion at all" and 20 means "maximal exertion." Choose the number from below that best describes your level of exertion. This will give you a good idea of the intensity level of your activity, and you can use this information to speed up or slow down your movements to reach your desired range.

Try to appraise your feeling of exertion as honestly as possible, without thinking about what the actual physical load is. Your own feeling of effort and exertion is important, not how it compares to other people's. Look at the scales and the expressions and then give a number.

#	Level of Exertion
6	No exertion at all
7	
7.5	Extremely light (7.5)
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

9 corresponds to "very light" exercise. For a healthy person, it is like walking slowly at his or her own pace for some minutes

13 on the scale is "somewhat hard" exercise, but it still feels OK to continue.

17 "very hard" is very strenuous. A healthy person can still go on, but he or she really has to push him- or herself. It feels very heavy, and the person is very tired.

19 on the scale is an extremely strenuous exercise level. For most people this is the most strenuous exercise they have ever experienced.

Borg RPE scale

© Gunnar Borg, 1970, 1985, 1994, 1998