Dietary Intake Behaviors of Recreational Mountain Hikers Climbing “A” Mountain in Summer and Fall

by

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ABSTRACT

More than 200 hikers are rescued annually in the greater Phoenix area. This study examined the impact of hiking in hot (HOT), dry temperatures versus moderate (MOD) temperatures on dietary intake behaviors as well as markers of heat stress. Twelve recreational mountain hikers climbed “A” Mountain four consecutive times (4-miles) on a HOT day (WBGT=31.6 °C) and again on a MOD day (WBGT= 19.0 °C). Simulated food and fluid behavior allowed participants to bring what they normally would for a 4-mile hike and to consume both ad libitum. The following heat stress indicators (mean difference; p-value), were all significantly higher on the HOT hike compared to the MOD hike: average core temperature (0.6 °C; $p=0.002$), average rating of perceived exertion (2.6; $p=0.005$), sweat rate (0.54; $p=0.01$), and fluid consumption (753; $p<0.001$). On the HOT hike, 42% of the participants brought enough fluids to meet their individual calculated fluid needs, however less than 20% actually consumed enough to meet those needs. On the MOD hike, 56% of participants brought enough fluids to meet their needs, but only 33% actually consumed enough to meet them. Morning-after USG samples ≥1.020 indicating dehydration on an individual level showed 75% of hikers after the HOT hike and 67% after the MOD hike were unable to compensate for fluids lost during the previous day’s hike. Furthermore, participant food intake was low with only three hikers consuming food on the hot hike, an average of 33.2g of food. No food was consumed on the MOD hike. These results demonstrate that hikers did not consume enough fluids to meet their needs while hiking, especially in the heat. They also show heat stress negatively affected hiker’s physiological and performance measures. Future recommendations should address food and fluid consumption while hiking in the heat.

DEDICATION

This work is dedicated to all of my family and to Jason. They have been my biggest fans since my time at ASU began. Without their love, support, and encouragement I would not have been able to accomplish what I have today. Completing graduate school and this thesis was not a simple task, but this past year is just a blink in time compared to the path it has paved for my future success. Thank you for all that you have done, are still doing, and will do for me.

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Next, thank you to the study participants for hiking four times up and down "A" Mountain not only twice, but the first time in such undesirable temperatures. I did a practice run the weekend before and could only complete one climb, not without difficulty. It was not an easy task and your perseverance was commended and greatly appreciated. Finally, a big thank you to the additional undergraduate and graduate students that played an integral role in helping to prepare and execute this research alongside us. Without your help, data collection would have been a near impossible task.

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CHAPTER 1

INTRODUCTION

In the greater Phoenix area, more than 200 hikers are rescued each year taking a toll on hikers and rescue teams alike. Reports write that rescue trips require a team of 15-20 professionals, can last 4-5 hours of hiking with heavy gear, and may even require a helicopter evacuation, said to cost an average of $1,000 per hour (Bagni, 2018; Boehm, 2018; Parks and Recreation, 2015). The City of Phoenix has made strides to alleviate this burden on hikers and rescue crews with a campaign termed *Take a Hike. Do it Right.*, where they blatantly state not to become a statistic. Very broad information is given with little to no information regarding food and fluid intake (Parks and Recreation, 2015). Although the campaign began back in 2015 the trend of mountain rescues by the Phoenix Fire Department has still been on the rise with an already 125 rescues as of July 1st, 2018 (Trierweiler, 2018).

Research on hikers is surprisingly limited when compared with the popularity of this outdoor recreational activity. Little to no hiking studies have been conducted in hot temperatures although the effects of hot temperatures on physical activity have been more widely documented (Sawka, Wenger, Young, & Pandolf, 1993). Of the few hiking studies, there was one with data on food and fluid consumption, but that research was conducted in cooler climates (Ainslie et al., 2002). The effect of a moderate to high-intensity hike in a hot environment compared to a moderate environment on dietary intake behaviors of hikers has not been recorded. A few retrospective cross-sectional studies looked at exertional heat illnesses and hyponatremia in hikers at the Grand

Canyon, but dietary intake behavior of those hikers was unknown (Backer, Shopes, Collins, & Barkan, 1999; Noe, Choudhary, Cheng-Dobson, Wolkin, & Newman, 2013). Further research could benefit not only recreational hikers in hot, dry climates but also other individuals in that environment with the need to perform any kind of physical activity. Occupations ranging from wildland and volunteer firefighters, park rangers, mountain rescue crews, construction workers and even athletes training outdoors are affected by the heat respective to their activity. Additional research can also improve recommendations to the general public interested in hiking, benefiting the community, city officials, and rescue resources.

Purpose of Study

The purpose of this study was to examine the impact of a hot environment (95 – 100+°F) versus a moderate environment (75 – 80°F) on dietary intake behaviors (food and fluid intake) as well as the physiological effects of these hiking conditions on recreational mountain hikers in the Phoenix area. Additionally, researchers hope to be able to provide more detailed recommendations and potentially update food and fluid guidelines when hiking in Phoenix, Arizona.

Research Aims and Hypotheses

Main hypothesis. An approximate ~4-mile mountain hike in Phoenix, Arizona in a hot climate versus a moderate climate will not change the dietary intake behavior of recreational hikers during the hikes.

Secondary hypothesis. An approximate ~4-mile mountain hike in Phoenix, Arizona in hot a climate versus a moderate climate will not influence the macronutrient needs of recreational hikers during the hikes.

List of Research Aims

- Examine individual variation in fluid balance during both a hot hike and moderate temperature hike
- Evaluate differences in heat stress indicators like sweat rate and core temperature for individuals between a hot hike and a moderate temperature hike
- Compare the amounts of food and fluid brought for each hike to the demands of the respective hike
- Provide more information towards improving food and fluid guidelines for mountain hikers in a hot, dry environment

Definition of Terms

Dietary intake behavior: Personal food and fluid consumed as well as rescue water consumed

Macronutrient intake: Water/fluids, carbohydrate (CHO), protein, and fat

Hot environment/climate/temperature: 35°C – 37.8°C (95°F – 100+°F)

Moderate environment/climate/temperature: 23.8°C – 29.4°C (75°F – 85°F)

Sweat Rate: The rate at which an individual is sweating, which can be calculated for a period of activity using variables such as body weight loss, volume consumed, urine loss, and the duration of the activity. An equation is provided in Chapter 3.

Core Temperature: The intestinal temperature measured using a telemetric pill swallowed by the participants. More details are provided in Chapter 3.

Wet Bulb Globe Temperature: A measure of heat index taking into account various environmental factors such as humidity, solar radiation, and wind speed. More details are provided in Chapter 2.

Delimitations and limitations

Delimitations

- Recreational hikers
- Age 18-40
- Arizona or other hot, dry environments
- ~4-mile hike - "A" Mountain terrain varies- dirt, paved, and rocky

Limitations

- Did not control food and fluid intake or provide standardized food and fluid during the hikes in order to simulate personal hiking habits
- Heart rate and activity tracking data was not measured for two participants on the hot day
- Convenience of "A" mountain hiking location being in close proximity to the researcher's field lab

- "A" Mountain hike repeated four times (climbs) to gain the ~4-mile distance
- Mentality of expecting repeated ups and downs (climbs) possibly affected hiker motivation to continue rather than a constant climb to the peak and then a constant descent to the base

CHAPTER 2

REVIEW OF LITERATURE

Hiking, especially mountain hiking, can present a hiker with various types of terrain and levels of physical intensities. Specific types of terrain may involve trails surfaced with dirt, rock, and/or paved cement. A hike can range from only an hour long, lasting several hours, or even carry on for multiple days, which is often referred to as backpacking or trekking. Differences in intensities and terrains contribute to the unique dynamic demands of hiking as an endurance activity. In this chapter, a review of the literature for the macronutrient recommendations and factors that may affect performance while hiking in the heat are presented.

HIKING

Hiker rescue data. Several studies have documented the prevalence of search and rescues (SAR) for those hiking and visiting National Parks. Most are retrospective studies that acquired information from park ranger incidents and/or medical reports. A retrospective study on US National Parks between the years 2003 and 2006 found 12,337 SAR operations of which 3,912 (~32%) were day hikers (Heggie & Heggie, 2009). Malcolm and colleagues (2014b) recorded data on preventative search and rescue (PSAR) teams (additional teams with the goal of educating visitors about dangers as well as frequently patrolling trails) at the Grand Canyon National Park in 2011 and 2012; their report indicated the assistance of 750 hikers and a total of 300 SAR missions each year. They also found that hiker assist frequencies correlated with the maximum daytime temperatures, with heat related hiker assists significantly higher at or above 95°F

(Malcolm, Heinrich, & Pearce, 2014b). Several studies reviewed ten-year time frames for SAR incidents at Yosemite National Park. The first study examined data from January of 1990 to December of 1999. Within that time frame were 1,912 SAR missions with common complaints of lower extremity injuries, dehydration, hypovolemia, and hunger (Hung & Townes, 2007). A similar study examined incident report data from 2000 to 2009. This study found 1,088 backcountry medical calls with extremity pain as the main complaint for 53% of cases. Overall, over half of incidents at 54% occurred during the second half of the hiking trip. Furthermore, 78% of cases occurred between the warmer summer months from June-September, yet only 15% reported the weather on their trips as "hot" (Boore & Bock, 2013).

It is possible additional cases of injury and/or dehydration may have occurred but were not reported. Thus, the rate of heat-related illness and injury could be much higher. Malcolm and colleagues (2014a) conducted an additional study demonstrating that having PSAR teams at the Grand Canyon positively influenced search and rescues. These PSAR teams saved an annual amount of $300,000 in fiscal savings while resulting in a 42% reduction in heat-related search and rescues (Malcolm, Hannah, & Pearce, 2014a). Kortenkamp and colleagues (2017) conducted a systematic review on articles published about hiking injuries, illnesses, rescues and prevention recommendations. Approximately 560 prevention recommendations were pulled from 91 articles published between 1970 and 2015. The researchers created a Haddon matrix to categorize recommendations using a system-oriented approach for accident prevention. They determined that multiple aspects of outdoor systems and their interactions with hiker behavior/characteristics was the most effective way to approach an accident prevention program. The prevention recommendations in the systematic categories the researchers built as well as their percentages are as follows: 60% changing hiker's decisions and behaviors, 39% institutions and sociocultural practices, 8% social influences of groups and relationships, 16% equipment, 16% agent of harm, and 27% education (Kortenkamp, Moore, Sheridan, & Ahrens, 2017).

Many resources are exhausted during a hiker rescue and not only hikers are affected. Future solutions to decrease hiker rescue prevalence should focus more on educating the community about heat stress and its association with dehydration as well as providing more detailed recommendations on fluid needs so that hikers can be adequately prepared during their next adventure.

Hiker preparedness. Boore and colleagues (2013) reviewed SAR reports between 2000-2009 and further surveyed those individuals involved in incident reports between 2007 and 2009 about hiker preparedness. They concluded that roughly 13% of those surveyed felt that better gear would have prevented their incident and 14% reported being underprepared for their hike. Furthermore, 54% reported that although they were involved in a SAR incident, they were experts in their activity and 46% were considered beginners. Most respondents stated that appropriate footwear and having enough water would have prevented and/or minimized their SAR incidents (Boore et al., 2013). Additional research, a cross-sectional study surveyed 199 hikers and their preparedness in New Hampshire during the summer of 2011. It was found that only ~18% of hikers carried all ten items the researchers deemed essential and that hikers between the age of 50-59 years old were the most prepared, carrying more than seven of the essential items. These listed items were a result of an education initiative of the New Hampshire Fish and

Game and New Hampshire Outdoor Council which included: 1. Map 2. Compass 3. Extra Clothing 4. Rain Gear 5. Fire Starter 6. Light 7. Extra Food and Water 8. Knife 9. First Aid Kit 10. Whistle. The most common reason (32%) hikers gave for not being well prepared with all 10 items was because it was intended to be a "short trip". Fortunately, hiker preparedness was found to have increased with hiking experience and greater fitness levels (Mason, Suner, & Williams, 2013). Interestingly, essential item "extra food and water" was the most common item carried with the majority of hikers (88%) bringing some form of food/water. Additional details on amounts, type, and nutrient compositions were not reported.

CURRENT RECOMMENDATIONS

Hiking activity recommendations in Phoenix, Arizona. The City of Phoenix Parks and Recreation Department began the *Take a Hike. Do it Right.* campaign in 2015 to provide access to recommendations for several different categories related to hiking. A summary of the categories is showcased on an infographic posted online and at various trailheads. The purpose of these recommendations is to ensure the safety and health of all hikers, regardless of experience level. They range from advice about the weather, fitness level, hydration, and clothing. A summary of these recommendations are as follows: *Watch the Weather*: This recommendation mentions how individuals are not always aware of how detrimental the Arizona heat can actually be and suggests hiking in the mornings or when there is plenty of shade so that ambient temperatures are cooler. *Dress Appropriately*: In a short and succinct sentence the flyer recommends proper footwear, clothing, a hat, and sunscreen, but does not specify what "proper" is. *Bring Water:* This recommendation is a little more detailed than the last and it is to hydrate before your hike, take plenty of water on your hike, and after consuming half of your total water, to turn around. The practicality of this is questionable as hikers may not want to quit before completing the whole hike, and/or are just unaware of the importance of hydration. *Keep in Contact:* Simple and short, this recommendation is to carry a cellular phone, but this might not always be as practical as it sounds either because some trails might put hikers in an area without cellular service. *Team Up:* This recommendation focuses on the recommendation to not hike alone. It also says that if a hiker is hiking alone, to at least tell others when they plan to start and end as well as where they are going hiking. *Be Honest:* As more of a personal category, this recommendation urges hikers to be honest about their health. If they have conditions that might affect them during their hike and/or put them at a higher risk like asthma, heart problems, diabetes, or knee/back pain then the hiker should be cautious and not push themselves. *Don't Trailblaze:* Another simple recommendation is to stay on the trails that are designated and to not deviate from them while enjoying the scenery. Lastly, *Take Responsibility:* This sort of summarizes the previous sections and states not to be the person that was not prepared or should not have been there due to certain health reasons. It closes saying to be a responsible hiker (Parks and Recreation, 2015).

Macronutrient recommendations for activity. The human body utilizes macronutrients; carbohydrates, fats, and proteins for a mix of biological processes. Proteins are the building blocks of muscle; carbohydrates are major sources of energy, and fats are important for cell membranes, immune health, and can also be used for energy. Macronutrient intake recommendations vary based on the individual's characteristics and the characteristics of the activity performed (Thomas, Erdman, &

Burke, 2016). Here, a brief description of general recommendations for each macronutrient is provided.

Carbohydrates: Carbohydrates (CHOs) are the main source of energy, thus are a main macronutrient one needs to refuel during and after exercise or activity. Individualized recommendations for carbohydrate intake can be determined by knowing the individual's body weight and regular activities performed. The general recommendation for fueling before an exercise or activity is to consume 1-4 g/kg of CHOs between 1-4 hours before starting. For endurance activities, like hiking, the recommendation for CHOs to refuel with during activity lasting between 1-1.5 hours is 30-60 g/hr. Furthermore, recommended intakes of CHOs to refuel with during ultra-endurance activities lasting between 2.5-3 hours, is up to 90 g/hr (Thomas et al., 2016).

Protein: The period found to be most beneficial when consuming protein, is after exercise or activity. The general recommended intake post-activity, during the recovery period, is between ~20-30 g (Thomas et al., 2016).

Fat: Fat, although often viewed negatively, provides energy especially for endurance activities. There are no general recommendations for fat intake pre, during, or post-exercise like there are for CHOs and protein. However, because fat is indeed an important aspect of a balanced diet, daily intakes should be approximately 20% of total macronutrient intake (Thomas et al., 2016).

Fluids/Water: It is most beneficial to begin activity in a euhydrated, or well hydrated state. A recommendation to achieve euhydration is to consume 5-10 mL/kg of body weight (or ~2-4 mL/lb) of fluids between 2-4 hours prior to exercise/activity. Due to varying sweat rates, it is difficult to recommend a specific amount of fluids to be consumed during exercise, but no more than 2% of an individual's body weight should be lost. It has been found that a general recommendation for athletes is to consume between 0.4-0.8 L/hr of fluids during activity (Sawka et al., 2007).

FACTORS INFLUENCING PERFORMANCE

Fitness and Energy

Fitness and energy expenditure. Simply defined, aerobic or cardiorespiratory fitness is a marker of physical condition that influences performance in activity. The level of fitness an individual possesses affects their core temperature and sweat rate. Higher aerobic fitness is associated with a lower resting core temperature and a higher sweat rate, which allows the body to cool more efficiently (Cheung & McLellan, 1998; Powers & Howley, 2015; Sawka & Montain, 2000).

The demands of hiking result in energy loss, also called energy expenditure. Energy expenditure (EE) during activity, such as recreational hiking, can be calculated using predictive equations or by wearing monitoring devices, the latter being a more practical method while being physically active. There is no gold standard for wearable devices, however a reputable one to note is the Zephyr Bioharness (Bioharness-3, Zephyr Technology, Annapolis, USA). This device combines triaxial accelerometry, heart rate (HR), and respiratory rate (RR) measured with a device inserted into a strap worn around the individual's chest. The benefit of this device is the ability to determine EE through the use of multiple sensors, allowing a more reliable EE output. It also provides an activity score (A), which can be used to calculate metabolic equivalents, (METs)

(Ainsworth, Cahalin, Buman, & Ross, 2015). Ainsworth and colleagues (1993) created the Compendium of Physical Activities to classify and identify energy costs of various physical activities (Ainsworth et al., 1993). The newest Compendium, as it has been updated a few times, lists several hiking variations and their assigned MET values which are listed as: *hiking or walking at a normal pace through fields and hillsides at 5.3 METs, hiking cross country at 6.0 METs, backpacking, hiking or organized walking with a daypack at 7.8 METs, and hiking with hunting gear at 9.5 METs* (Ainsworth et al., 1993; Ainsworth et al., 2000; Ainsworth, et al., 2011).

Substrate utilization. The energy system for muscle contraction lasting up to ten seconds is the phosphagen system utilizing adenosine triphosphate (ATP) and phosphocreatine. On the other hand, CHO derivatives glucose and muscle glycogen (the storage form of glucose) are utilized for high-intensity exercise between 10-180 seconds via the anaerobic glycolytic pathway. The energy systems needed for activity lasting longer than two minutes are aerobic pathways utilizing derivatives of both CHO and fat. This is the ideal energy pathway for endurance activities like hiking but is not used exclusively and does not always activate immediately. Each energy system begins and crosses to the next depending on the intensity, duration, type of training and frequency, as well as gender and fitness level of the individual. These derivatives (i.e., muscle and liver glycogen, lipid within the muscle, triglycerides in adipose tissue, and amino acids within the blood, liver and gut) have been found to shift usage throughout endurance exercise and/or sports (Thomas et al., 2016). Stated above, hiking is an endurance activity, but with the demands of mountain hiking and its continuously changing intensities it is likely there are those shifts in energy usage. From the start, the average hiker will begin utilizing glucose in the muscles and as the climb up begins to intensify the hiker will likely use that available glucose quickly and need to begin the shift to glycogen and lipid oxidation. As the hike continues in duration, fat oxidation is likely to be prioritized at a steady state. Ainslie's hill-walking research (2002) with long-distance hikers (8-miles) found enhanced fat oxidation as the main energy source and that the blood glucose levels of their hikers were actually maintained throughout the hike. However, they did consume lunch during the hike, which could have influenced substrate usage. It was reported that as the hikers began to ascend, both CHO and fat oxidation increased, but after ~2.5 miles CHO oxidation decreased as fat oxidation increased, remaining that way for the rest of their hike (Ainslie et al., 2002).

Acclimatization/Acclimation. Proper heat acclimatization decreases adverse effects when being physically active in hot climates. This process involves gradually adapting the body's systems to optimally perform under hot conditions therefore experiencing less strain while doing so. A few important adaptations consist of increased sweat rates allowing for more efficient cooling and thermoregulation, reduced electrolyte loss (particularly net sodium) and increased total body water allowing for better electrolyte/fluid balance, and a reduced heart rate, reduced core temperature, and the sparing of muscle glycogen (Hori, 1995; Sawka, Wenger, & Pandolf, 1996; Periard, Racinais & Sawka, 2012). The processes of both acclimatization (in a natural setting) and acclimation (in a controlled setting) are not too extensive. It has been found that adaptations begin on the very first day of exposure and up to 80% of the adaptations can occur between the fourth and the seventh day of continued heat exposure; similarly, the beneficial effects of acclimatization can also quickly decline if exposure is ceased

(Pandolf, 1998; Shapiro, Moran, & Epstien, 1998). A review by Periard and colleagues (2015) suggested a better process for acclimatizing would be in a natural outdoor setting instead of a controlled environment, such as a lab or fitness center, in order to better adapt to the conditions in which the activity is likely to occur in (Periard et al., 2015).

Environmental Factors

Heat stress. Heat stress can begin when the environmental temperature is just above 20°C (68°F) and can be exacerbated with relatively high humidity (Galloway & Maughan, 1997). As the average temperature in Phoenix, Arizona in September is 90°F and 66°F in November, heat stress is likely to affect recreational hikers at some time or another (National Weather Service). Environmental heat combined with exercise increases physiological strain (Nadel, 1977). The detrimental effects of heat stress are cumulative and are due to environmental conditions such as temperature, humidity, solar radiation, and air flow (wind) interacting with the physical work rate of the individual and their associated metabolic heat production. (Sawka et al., 1996). The wet-bulb globe temperature (WBGT) takes into account all of those environmental factors and is one of the most widely used indexes of heat stress, frequently used to monitor the safety of military personnel and athletes (Budd, 2008).

Exertional heat-related illnesses. The most well-trained and beginner hikers are susceptible to exertional heat-related illnesses. Exertional heat illnesses (EHI) include muscle cramping, heat exhaustion, heat syncope and even exertional heat stroke (EHS). These EHIs can begin to develop at body temperature above 36°C (96.8°F) (Binkley, Beckett, Casa, Kleiner, & Plummer, 2002). Common outdoor activities at risk for an EHI include hiking, rock climbing, cycling, adventure racing, and ultra-endurance road races (Pryor, Bennett, O'Connor, Young, & Asplund, 2015). Factors that make individuals more prone to these conditions includes being recently ill, dehydrated, using certain medications, and not being accustomed to outdoor activities in hot climates. Heat exhaustion is commonly seen in athletes and can be resolved by treating symptoms and replacing fluid loss (Armstrong et al., 2007b).

Related to EHI is exertional hyperthermia, seen when the body's temperature is above 40.5°C (105°F). As heat accumulates within the body and is not released quickly, the individual is unable to cool down. Common signs and symptoms of exertional hyperthermia and these other heat illnesses include dizziness, confusion, behavior changes, coordination difficulties, and potentially collapsing. Clothing and equipment, activity intensity, environmental conditions, and acclimatization state of the individual contributes to the onset of exertional hyperthermia (Armstrong et al., 2007b). Activity heat production is 15-20 times greater than when at rest, with core temperatures rising 1.8°F every five minutes if heat dissipation is interrupted (Nadel, 1977). However, some individuals have exhibited temperatures above 40°C (104°F) and did not present symptoms, pushing their central nervous system to the onset of fatiguing, without realizing how closely they approached a life-threatening EHI (Armstrong et al., 2007b; Maron, Wagner, & Horvath, 1977). Various methods of obtaining body temperatures during and/or after activity have been used such as rectal, gastrointestinal, oral, tympanic (aural), axillary, and forehead temperatures. Rectal temperature has been deemed the gold standard method of measuring core body temperature when assessing for EHS (Casa et al., 2007; Moran & Mendal, 2002). Gastrointestinal temperature has been the only other method proven to meet the criterion for rectal temperatures, for both outdoor and indoor activity in the heat and also has the advantage to be measured continuously during the activity (Casa et al., 2007; Ganio et al., 2009; Hosokawa, Adams, Stearns, & Casa, 2016).

Fluid Balance and Hydration Status

Fluid and electrolyte balance. Fluid balance and associated water consumption is important for pre, during, and post activity because of the role water plays in cell metabolism and thermoregulation. Total body water varies throughout the day and to maintain fluid balance is to replenish fluids lost. Water can be obtained directly through food and beverage consumption as well as metabolic productions (as a byproduct of CHO, protein, and fat oxidation). Water losses can be due to sweating, losses in urine and feces, and losses through respiration. Throughout the fluid balance process, water is redistributed across different compartments in the body (Watson & Austin, 2018).

Electrolytes, vital to the body, are found in those various fluid compartments and help to maintain membrane electrochemical potentials important for the transition of fluid between the intracellular and extracellular compartments. Being in electrolyte balance is important for fluid balance as fluids move between compartments depending on their electrolyte concentrations (Sawka & Montain, 2000). When an individual becomes dehydrated and or low in sodium, the renin-angiotensin-aldosterone system (RAAS) can help to regulate fluid and electrolyte balance as well as blood pressure. In these scenarios (and others not discussed here) renin is released into circulation where it converts angiotensinogen (from the liver) into angiotensin I, then eventually into angiotensin II. Angiotensin II then leads to the secretion of aldosterone, a hormone that increases renal tubule's reabsorption of sodium along with water into the blood; therefore, increasing the amount of total body water and sodium concentrations (Fountain & Lappin, 2019). Electrolytes found in sweat are sodium, potassium, calcium, and magnesium. Sodium has the greatest amount of loss when sweating (Sawka et al., 2007). Therefore, sodium, usually in the form of sodium chloride, is one of the most important electrolytes that may need to be added to drinks for replenishment during activity, which of course can already be found in various sports drinks (Maughan, 1991). However, sodium does not need to be replaced solely with fluids. Salty foods such as trail mix are viable options and a popular choice when hiking (Backer & Shlim, 2013).

Hyponatremia and hyperhydration. A potentially fatal condition of decreased blood sodium levels below 130 mmol/L, is exercise-associated hyponatremia (EAH). A study reporting EAH in recreational hikers looked at four cases between 1990-1992. These case studies concluded EAH was due to diluted blood concentrations of sodium from sweat losses which were replaced with regular water as opposed to electrolyte fortified fluids (Backer, Shopes, & Collins, 1993). Another study compared EAH with heat exhaustion in hikers at the Grand Canyon National Park in the summer of 1993. Cases examined were from hikers requesting emergency medical services or who visited the clinic at the rim with complaints related to exercising in the heat, where average hiking temperatures ranged from 100 – 115°F. Those with confirmed hyponatremia showed serum sodium levels <130 mmol/L with symptoms ranging from headaches, dizziness, nausea and vomiting, paresthesia, as well as altered levels of consciousness. The researchers stated indirect evidence suggested these patients were hyperhydrated; replenishing with plain water instead of electrolyte fortified fluids (Backer et al.,1999). It is important to note another possible exercise-associated sodium condition, hypernatremia, where blood sodium concentrations are above 145 mmol/L. This can manifest from severe fluid restrictions and/or excess consumption of electrolytes; however, research and prevalence are not as high as hyponatremia (Hew-Butler, Smith-Hale, & Sabou, 2019).

Sweat rate. The rate at which individuals sweat during any particular activity can be calculated with several measures such as body weight, food and fluid weight, urine weight (if voided during activity), and the duration of the activity (an equation can be found in chapter 3). Higher sweat rates result in higher water and electrolyte losses. Sweat rates vary depending on the individual's metabolic requirements, duration of the activity, clothing and equipment worn, as well as weather conditions, heat acclimatization, and the training status of the individual (Sawka et al., 2007). Sweating is an important physiological response, if interrupted due to little body fluid availability and/or core temperatures rising, it will affect the body's ability for evaporative heat loss (McDermott et al., 2017). In war-time research, it was observed that some occupations in the desert elicited sweating rates between 0.3-1.2 L/hr (Adolph, 1947). Additionally, athletes that perform at high-intensities in the heat can show sweating rates between 1.0-2.5 L/hr and higher (Armstrong, Hubbard, Jones, & Daniels, 1986; Costill, 1977). Furthermore, individuals better acclimatized to their environment are able to maintain a higher sweat rate allowing for an advantage on performance (Sawka et al., 1996; Sawka & Young, 2006).

Dehydration. Dehydration or hypohydration, a body water deficit of the slightest amount, has a negative influence on an individual's health and performance. Research shows just 1% loss of body weight can start affecting cognitive functioning (Benton, Jenkins, Watkins, & Young, 2016). Aerobic exercise has also found adverse effects from dehydration directly on individuals' performance, heart rates, core body temperatures, and perceived ratings of exertion (Aldridge, Baker, Davies, & Baker, 2005; Casa, Clarkson & Roberts, 2005; Ebert et al., 2007; Hillman et al., 2011). Ainslie and colleagues (2002) researched the effects of hill-walking on the body and found similar results of dehydration and an average body mass loss of two kilograms. Body water deficits adversely affected thermoregulatory, cardiovascular, and cognitive functions of their hikers, which impaired decision-making leaving hill-walkers susceptible to fatigue and injury (Ainslie et al., 2002).

Urinary markers of hydration. Observing urine color, measuring urine osmolality, and measuring urine specific gravity have all been used to assess levels of hydration and are known as chronic measures for hydration status. On the other hand, percent body weight change is known as an acute (observed) measure of an individual's hydration status (Cheuvront, Kenefick, & Zambraski, 2015). Urine osmolality is the preferred laboratory method to assess urine hydration, examining the size of particles in urine. The larger the particles, the more concentrated the urine is (for example, due to dehydration), while smaller particles present indicate diluted, or more hydrated urine. Urine specific gravity, also performed in a laboratory setting, is a highly reliable method for assessing hydration level, which compares the concentration of the urine with that of the concentration of distilled water (Armstrong, 2007a). Measuring urine specific gravity with a refractometer pen, making this method viable for combined field and laboratory settings, has been validated with very accurate methods such as urine osmolality (Armstrong, 2007a; Chadha, Garg, & Alon, 2001). Armstrong and colleagues (1998) examined the relationships between urine osmolality, urine specific gravity, and urine color with trained individuals using dehydration, exercise, and rehydration protocols. They found that urine color changes tracked as effectively with changes seen in urine osmolality and urine specific gravity (Armstrong et al, 1998*)*.

It is important to note that urine samples can vary depending on when they are collected. Common urine samples in research can be taken as spot-urine samples (collected on the spot spontaneously/randomly), 24-hour urine samples (gathering all urine voided in a 24-hour period), and first-morning urine samples (collected as the first urine void in the morning after resting). Although, because of the variability, not all urine samples hold the same value when being used to assess hydration status. There is some disagreement in the literature on the validity of spot-urine samples to accurately reflect general hydration status of an individual as it has been acknowledged that hydration status does vary throughout the day and there are many confounding variables that may affect a random sample such as drinking fluids and sweating (Maughan & Shirreffs, 2008; Armstrong et al., 2010; Cheuvront Kenefick, & Zambraski, 2015). Cheuvront and colleagues (2015) wrote a review concluding that spot-urine samples were not fit for assessing true hydration status of an individual even though they often are used for that purpose in sport science. On a larger scale, spot urine samples tend to report both false positives and false negatives when classifying dehydration (Cheuvront et al., 2015; Oppliger et al., 2005). On the other hand, first-morning urine samples are considered to be more accurate when assessing hydration status and are also used for setting comparison standards (Armstrong et al., 1998; Cheuvront, Ely, Kenefick, & Sawka., 2010; Cheuvront et al., 2015).

Classifications of general hydration levels for urine color, urine osmolality, urine specific gravity, and percent body weight change are found below (Table 1) and are based on the classifications of several combined articles (Armstrong et al., 2010; Armstrong et al., 2012; Casa et al., 2000; Oppliger, Magnes, Popowski, & Gisolfi, 2005; Sawka et al., 2007).

Table 1. *Hydration Status Classifications*

Hydration Categories	**Urine Color Chart (number) [chronic]**	**Urine Osmolality (mOsm/kg) [chronic]**	**Urine Specific Gravity (USG) [chronic]**	**Body Weight Change (%) [acute]**
Euhydrated	1 – 4	≤ 700	< 1.020	+1 % – -1%
Dehydrated	4 – 6	701 – 1,100	1.020 – 1.030	-1 % – -5 %
Extremely Dehydrated	7 – 8	> 1,100	> 1.031	> -5 %

Prescribed drinking, ad libitum, and drinking to thirst. Prescribed, programmed, or planned drinking is a method where an individual is prescribed to drink certain amounts of fluids in or at a certain amount of time. This method has yielded positive results on hydration and performance when compared to ad libitum drinking (Bardis et al., 2017). The Latin phrase, ad libitum (drinking), means to drink what is wanted when it is wanted, as in not being controlled in what can or cannot be consumed. Another method, drinking to thirst, is the method typically used in daily life. However, drinking to thirst may not be adequate for endurance exercise, especially in hot conditions as it has been hypothesized that being thirsty is already a symptom of being dehydrated (Backer et al., 1993; Cheuvront & Sawka, 2005; Kenefick, 2018).

Types of fluid. Common fluids and products consumed during and after activity with the intent to rehydrate include water, sports drinks (such as popular brands Gatorade/Powerade, fortified with electrolytes) and additional electrolyte fortified beverages and/or supplements. It is said that the average American diet includes ~150 mEq of sodium while an average sweat sodium concentration is ~35 mEq/L (Institute of Medicine, 2005; Costill, 1977). Therefore, an individual's general food consumption and regular tap or bottled mineral water is likely to replenish electrolytes lost in sweat. However, that regular (plain) water may not be able to adequately replace sodium if sweat sodium losses are particularly high and/or water intake is in excess, especially with longer duration activities in hot weather (Kenefick & Cheuvront, 2012). This could lead to hyponatremia as discussed in the section above. Furthermore, an additional benefit of sports beverages like Gatorade and Powerade are that they usually not only contain and replenish fluids and electrolytes, but also contain and replenish CHOs needed to continue activity, positively influencing both fluid balance and performance. Additionally, other electrolyte products found in concentrated forms like powders, tablets, and gels should then be paired with water to sufficiently rehydrate and replenish overall fluids also (Burke, Jeukendrup, Jones, & Mooses, 2019).

Macronutrient Application for Hiking in the Heat

The following table contains guidelines and recommendations synthesized from the above research as well as common hiking websites that a recreational hiker might review for information.

Table 2. *Macronutrient Recommendations for Hiking*

Recommendations	**CHO and/or Food**		**Fluids and/or Water**		**Electrolytes**
	Before	During	Before	During	
General (based on research presented above)	1-4 hours: 1-4 g/kg body weight of CHOs	If duration is 1+ hours: 30-60 g/hr	2-4 hours: 5-10 mL/kg of body weight (or ~2-4 mL/lb)	0.4-0.8 L/hr of fluids during activity	consuming salty snacks or sports drinks with electrolytes
American Hiking Society (AmericanHiking.org)	N/A		Consciously drink slowly over several hours	~1 L/hr	If hot and sweating profusely, water is not enough. Also eat trail mix (salty snacks), sports drinks, or add a pinch of salt and sugar to water.
Arizona (VisitArizona.com)	Eat more than normal and eat before becoming hungry.		Drink more than normal and drink before becoming thirsty.		Salty snacks or sports drinks should be consumed at every hike.
The National Park Service - Grand Canyon National Park (nps.gov)	Essential: Eat salty foods and eat twice as normal		Essential: Water- plan something with electrolytes. Don't force fluids- drink when thirsty.		See comments about food and fluids
Optimal for Mountain Hiking in the Heat (synthesized from details above)	A balanced meal 1-2 hours before providing 1-4 g/kg body weight of CHOs	Small, nutrient dense and salty snacks. Example: granola bars or trail mix that can be eaten while hiking & See *Fluids (during)*	At least 2 hours leading up to hike, consume 5-10 mL/kg body weight in fluids	1-2 L/hr fluids Tip: take periodic drinks to ensure consumption, for example every 15-20 minutes Note: Drink CHO + Electrolyte beverages for combined consumption of CHO, fluid and electrolytes. For more electrolytes see *Food (during)*	

CONCLUSION

Recreational hiking is a popular activity with a dynamic set of demands; however, this activity has proved over and over again to be potentially dangerous. Rescuing hikers is not a new issue nor is it isolated to a single area of the United States with many incident reports ranging from New Hampshire to California. Although efforts were taken in Phoenix, Arizona with the *Take a Hike. Do it Right.* campaign a few years ago, it does not appear that hiker rescue incidents have decreased much. *Bring Water* (hydration) and *Watch the Weather* (heat stress) may be the two most important guidelines that may benefit hikers if updated with more detailed recommendations, along with the addition of a food/energy category. There are many interconnected factors such as heat stress, acclimatization status, fitness level, hydration status, and substrate utilization that can affect the way a hiker performs in such extreme conditions. This study, which intends to gather information on hiker food and fluid behaviors as well as the physiological effects of hiking in a hot and moderate climate, can use the data gathered to potentially provide more detailed recommendations for an updated hiker safety campaign.

CHAPTER 3

METHODS

Participants

Potential participants were originally screened through a screening questionnaire online. Recruitment occurred throughout August and September of 2018 with the use of digital and physical flyers around Arizona State University's Downtown Phoenix and Tempe campus' as well as in the College of Health Solutions student newsletters via email. Additionally, information was sent to all club sports at Arizona State University.

Inclusion criteria. Any gender, race, ethnicity, and age between 18 and 40 were eligible to participate. Potential candidates were those who have been living in a hot, dry desert area for at least six months in the last twelve-month period, specifically Arizona (Phoenix area, Tucson, Yuma), but also Nevada (Las Vegas) and California (Palm Springs, Imperial County, East Riverside County and South-East San Bernardino County).

Exclusion criteria. The following exclusion criteria were in place for this study:

- Potential participants that are pregnant
- Potential participants using tobacco or taking medications that influence hydration status
- Potential participants consuming over 21 standard servings of alcoholic beverages per week
- Potential participants with a body weight less than 80 lbs.

- Potential participants with any known or suspected obstructive disease of the gastrointestinal tract, including but not limited to diverticulitis and inflammatory bowel disease, or hypo motility disorders of the gastrointestinal tract
- Potential participants exhibiting or having a history of disorders or impairment of the gag reflex
- Potential participants with previous gastrointestinal surgery
- Potential participants having felinization of the esophagus
- Potential participants that need to undergo Nuclear Magnetic Resonance (NMR) or MRI scanning during the period that the CorTemp® Disposable Temperature Sensor is within the body

Sample size. The sample size was determined with a calculation for a priori sample size and a dropout rate of 20%. The calculated effect size was based off of a large study that investigated the effect exercise has on sweat rate, which reported sweat loss per hour for not only children n=134, but also adults n= 327 (Baker, Barnes, Anderson, Passe, & Stofan, 2016).The effect size, based off of an hourly sweat loss of 1.37 ± 0.71 and 0.82 ± 0.39 L/hr for both groups, was 0.89. Based on that effect size of 0.89, an error of probability of 0.05, and a power of 0.80, the resulted sample size was 12. However, taking into account a 20% drop out rate, a total goal of 14 participants was set. Before the initial hike, 13 participants had confirmed participation and had signed informed consent forms. However, on the hot hike day one participant did not show. Therefore, on the hot hike, a total of 12 participants (7 male, 5 female) hiked. In the washout period between the hot hike and the moderate hike two participants dropped out due to unavailability and an additional one participant did not show, leaving nine participants hiking on the moderate day. Complete data for both hiking conditions are available for only 9 participants.

Study Design

This quasi-experimental and observational study was conducted at the Athl*eat* Field Lab facilities at the Arizona State University Tempe Campus and on the adjacent "A" Mountain hiking trail. This study was approved by the IRB (Appendix B) and written consent was obtained from all participants. For the purpose of the study, the participants were to hike the trail on "A" Mountain four consecutive times to cover a distance of 4.48 miles. Participants were asked to hike on two different occasions, a hot climate (95 – 100+°F) hike in the middle of September (21st & 22nd) and a moderate climate (75°F – 80°F) hike in the middle of November (16th & 17th), both on the same trail. Each hike was estimated to take no more than four hours to complete. A total of four study days were completed, two back-to-back hot hikes and two back-to-back moderate hikes, so that there were no more than seven participants hiking at once. This ensured the research team was not underpowered and were able to collect all measurements accurately. Participants were scheduled on their respective hiking days in September and November, on a Friday or Saturday, depending upon their availability. Participants visited the lab up to four times. The first time was for an informed consent meeting and to fill out a contraindications form for the core temperature-sensing capsule. The second visit was for the hot hike and a potential third visit was the day after to drop off their morning-after urine sample. The fourth visit was for the moderate hike and a potential fifth visit was to drop off that morning-after sample as well. Some participants were not able to drop off their sample the morning after so pickups were arranged with the research team and therefore participants did not need to visit the lab on more than four occasions.

Participants received an instruction list (Appendix A) at the original informed consent meeting if they consented to participate and were emailed another copy before the moderate hike because of the two-month washout period between the two hikes. Main instructions consisted to consume the core temperature pill between twelve and four hours before the hikes, to fast after 9:00 p.m. the night prior to each hike, to refrain from caffeine the morning of the hike, and to consume their standardized meal two hours before the indicated hike start time (12:00 PM ± 1:00). Additionally, the participants were informed that they were allowed to consume an additional breakfast meal in the morning before their standardized study meal if they felt hungry before the assigned meal time. However, they were provided with five generic breakfast options to choose from, which had macronutrient compositions averaging ~300 kcal, 45g carbohydrates, 10g protein, and 10g fat (*Figure 1*). They were also instructed to take photos of what they ate before the study meal and if they did not finish the whole study meal, and to share those photos with the research staff upon arriving.

Option 1	**Option 2**	**Option 3**	**Option 4**	**Option 5**
1 Plain Bagel + 1 oz Cream Cheese	4 oz Greek Yogurt + ½ cup Granola	1 Slice of Toast + 1 TBSP Peanut Butter + 1 Banana	1 Granola Bar ~200 calories (NOT protein bar) + 1 cup of 2% Milk or Soy Milk	1 Fried Egg *(w/ 1 tsp cooking oil)* + 2 Slices of Toast + 1 TBSP Jam

Figure 1. Additional Suggested Breakfast Options

Standardized meal. The standardized meal consisted of two small single serving cereal boxes and one single serve milk carton, either low fat, almond, or soy milk. The average 27g cereal boxes were mixed options from Kellogg's Cereal "Fun Pak Variety" Packages. The low-fat milk option was an 8-ounce Horizon organic milk carton, the almond milk option was an 8-ounce Silk carton, and the soy milk option was an 8-ounce Silk vanilla soy milk carton. One participant followed a gluten-free diet and so consumed her own cereal at home at one recommended serving size. The standardized study meals had an average macronutrient composition as follows: ~330 kcal, ~65g carbohydrate, ~8g protein, and ~4g fat.

Measurements and Procedures

Once participants arrived in the lab, they were given name tags with their "CAM" (Climbing "A" Mountain) number indicating their participant ID number. They were then instructed to set down any personal food and fluid that they brought on a table next to their designated CAM number. They then sat in a designated cubby to await check-in measurements, which included recording food/fluid details (characteristics and weight), collecting urine samples, and measuring dry body weight. These are described below in the following subsections.

After completing all initial, pre-hike, in-lab measurements participants and the research team departed to the base-station they set up outside around the base of the mountain were measurements and data were logged throughout the hike, including time, core temperature, field body weight, food/fluid availability, and rate of perceived exertion (RPE) scores. There was also a midway station and a peak station set up where most of the same measurements and data were also logged. These outdoor measurements are also described below. See *figure* 2 for the hiking route and research station locations.

Figure 2. "A" Mountain Hiking Route and Research Stations

Fluid Balance Measurements

Dietary intake behaviors. All of the personal food and fluid that each hiker brought was recorded with their respective characteristics of type of food, brand, and weight in grams of each product. These items were weighed on a small, calibrated scale (Sartorius ENTRIS 623-IS) then labeled with a number for logging purposes. Participants were instructed to keep all waste such as food wrappers, inedible fruit pieces, and bottles in order to be weighed again after the hike to determine consumption amounts. Macronutrient composition (calories, carbohydrates, protein & fat) of food products was determined at a later date using the popular MyFitnessPal Calorie Counter & Diet

Tracker phone application to search product types and brands recorded (MyFitnessPal, Apple iPhone Application, v 19.3.6). The researchers felt this was an appropriate method in order to simulate what the general public, including recreational hikers, might do to track their food and/or macronutrients. When searching and recording for data analysis, if a specific brand was not available in the app, an average of three similar food products was determined. Food and fluid intake, or dietary intake behavior of participants was determined by calculating the amount they consumed by subtracting pre-product weights with post-product weights, respectively for each food and fluid item.

Additionally, each time a participant arrived at the base station they were asked if they still had food/fluid available, which was recorded on a data log, in order to track roughly when they ran out of their own supplies during the hike. Upon completion of the hike days, the amounts of fluid and the amounts of food consumed by each participant on each day was then added up to a sum of the total amount of food and fluid consumed to represent each of their dietary intake behaviors. Personal fluids were originally weighed in grams (g), but then converted to milliliters (mL) with a simple 1:1 g → mL conversion as all fluids brought were water. Individual and group averages for the amount of fluid consumed and brought (mL), the amount of food consumed and brought (g), and the kilocalorie and CHO (g) composition of the foods will be reported.

Estimated CHO utilization. Participant's estimated CHO utilization was calculated based on their exercise intensity, or % heart rate max, and cross checked with a table from O'Neill and Skelton which contains exercise intensities and estimated corresponding ratios of CHO and fat oxidation (O'Neill & Skelton, n.d) The participant's calculated energy expenditure (described below) was multiplied by the corresponding percent CHO oxidized from O'Neill's table, which provided an estimate of the number of calories burned from CHO oxidation. This amount was then divided by 4 kcal/g providing an estimated amount of CHO (g) the participant used (needed for the activity), which can be compared to the amount of CHO (g) consumed pre-hike and during the hike. Group averages for the estimated amount of CHO (g) needed and the estimated CHO (g) consumed pre-hike will be reported as well as group averages for percent CHO oxidized.

Body weight and urine samples. For the dry body weight measurements in the lab, participants were asked to change into light, dry clothing that they were not intending to hike in. The participants then delivered a pre-hike urine sample and were weighed in grams on the same small, calibrated scale (Sartorius ENTRIS 623-IS). These urine sample measurements were completed after all food/fluid were weighed. After voiding their bladders, a pre-hike body weight was recorded in kilograms (kg) on a larger, calibrated scale (SECA M891 gmbh & co, Hamburg, Germany). After the hike, they were asked to change back into their light, dry clothing, deliver a post-hike urine sample and had their body weight measured again, all following the same standard operating procedures. Field body weight measurements were taken from participants at the base-station before departing on the hike and each time they returned at the base station (SECA M891 gmbh & co, Hamburg, Germany). This was in order to monitor if they were losing up to 2% of their body weight for safety protocols, especially during the hot hike. Participants removed any backpacks and did not hold anything at the time of this measurement. Group averages for body weight loss (kg) as well as individual values for percent body weight loss (%) will be reported. An additional predicted percent body weight loss (%) without the inclusion of rescue water (described below in safety protocol) will be provided as a group average and was calculated by adding the amount of rescue water consumed to original weight loss amount.

Urine analysis. After the pre-hike, post-hike, and morning-after urine samples were gathered and weighed, the samples were separated into various smaller samples. A 30 mL urine sample was used to determine the urine specific gravity (USG) at a standard temperature of 20°C with a refractometer pen (PEN-refractometer, ATAGO, Tokyo, Japan). USG values < 1.020 were classified as euhydrated and values ≥ 1.020 were classified as dehydrated. Individual and group averages for pre-hike and morning-after USG values will be reported.

Sweat rate. Sweat rates were calculated after the completion of the hikes with the following formula. All respective measurements should be input as liters (L) and/or kilograms (kg) and were converted accordingly (Olzinski et al., 2019). Sweat lost (mL), or fluid needs during the hike, was calculated by dividing the sweat rate by the total hiking time and will be reported as a group average. Individual and group averages for sweat rate (L/hr) will be reported. Additionally, a predicted sweat rate without the inclusion of rescue water (described below in safety protocol) was calculated by subtracting the amount of rescue water from the volume consumed portion of the sweat rate equation.

Body weight loss = (body weight before) – (body weight after)

Volume consumed= (fluid/bottle weight before (+ food weight before)) – (fluid/bottle weight after + (food weight after)

Sweat rate (L/hr) = (((body weight loss + volume consumed) – (urine loss)) / (duration of exercise in hours))

Performance and Activity Measurements

Heart rate and energy expenditure. In the pre-hike check in process, Zephyr activity trackers (Bioharness-3, Zephyr Technology, Annapolis, USA) were fitted around the hiker's abdomen, just under the rib cage with the device on the left side, making contact with their skin. This device measured heart rate (HR), respiratory rate (RR), and activity (A) starting at least 15 minutes prior to the hike and throughout the duration of their hikes. These variables can be used to calculate a MET value of their activity during the hike with the following equation: **MET=** -1.1644 + (0.02947*HR) + (5.8985*A) + (0.03583*RR) (Rosenberger, Haskell, Albinali, & Intille, 2011). Then, MET-h, or energy expenditure (EE) was able to be calculated with the following equation: **EE (kcal) =** METs + body weight (kg) + activity duration (hours) (Olzinski et al., 2019). The relative intensity of the hike for each participant was also calculated using HR data and the following predictive equation using age: **%HRmax=** HR / (208 - (0.7 x age) (Riebe et al., 2018). Group averages for average intensity (%HRmax), METs, and EE (kcal) will be reported and individual values will also be reported for EE (kcal).

Intestinal core temperature. Participants ingested a core temperature tracking capsule prior to each hike (CorTemp™ system, HQ Inc., Florida, USA). An associated reading device was used to read core temperature results in Celsius before starting the hike for a baseline measurement and each time participants reached the base and peak stations. These observed station values were recorded on data logs as part of safety protocol and complete hike duration data was electronically recorded in 10-second intervals within the devices for later data extraction and analysis. Group averages for average core temperature (°C) and average maximum core temperature (°C) will be reported.

Time tracking. Time logs were recorded each time a participant arrived at and departed the base and peak stations as well as their starting and finishing times. A large digital clock was set up at the base station and all research assistants synched their wrist watches according to the main base station clock. Time was recorded in hours: minutes: seconds. Total hiking time (hr) will be reported for each individual as well as the group's average.

Rate of perceived exertion. Participants were asked to score their rate of perceived exertion (RPE) each time they reached the base station and the peak station. These values were recorded on data logs. A visual Borg RPE scale was used, and participants were briefed on how to properly score the scale prior to the hike, by pointing instead of only stating the number out loud. The scale starts at a 6 indicating "no exertion at all" and ends at a 20 indicating "maximal exertion" (Williams, 2017). Group average RPE scores and peak (top of mountain) average scores will be reported.

Environmental Measurements and Safety

Ambient conditions. During each hike, the dry-bulb temperature, wet-bulb temperature, globe temperature, humidity, and wind speed were measured in five-minute intervals with a portable Kestrel device (Kestrel 5400 Heat Stress Tracker, Nielsen-Kellerman, Boothwyn, USA). This device was placed on a tripod at the base station. The wet-bulb globe temperature (WBGT) index was then calculated with the following formula: **WBGT=** 0.1 (temperature dry bulb) + 0.7 (temperature wet bulb) + 0.2

(temperature black globe) (Armstrong et al., 2007b). Average WBGT (°C) will be reported for both hikes, as well as relative humidity (%) and ambient dry-bulb temperatures (°C).

Safety protocol. Through the various logging procedures on the hike days several safety protocols were put in place. All researchers and assistants were briefed on this protocol and if working with a data log, relayed any observed signs to lead researchers as necessary. The only clear cut off was a core temperature reading of 39.5°C, in which the hiker was to discontinue their hike. Additional warning signs to be taken into consideration if observed included a loss of > 2% of their field body weight, an RPE score of 17, and running out of personal fluid available. Furthermore, extra bottles of water were prepared for the hikes and labelled as "rescue water", which were given to hikers upon request.

Statistical Analyses

Statistical analysis was completed using SPSS Version 25 for Macintosh. The results are given as mean ± standard deviation (M ± SD). The data were checked for normal distribution and then checked for differences with dependent t-tests and nonparametric version, Wilcoxon signed rank test. A few variables were found not to be normal. However, those values that were reported and that were found to be significant for both parametric and nonparametric tests are reported as M ± SD for consistency in reporting. Significance for all tests was set at $p \leq 0.05$. All other results will be presented qualitatively and with percentages.

CHAPTER 4

RESULTS

Subject Demographics and Environmental Data

A total of twelve participants (7 male, 5 female) with a mean age of 21.6 ± 2.47 years and a mean BMI of 23 ± 3 kg/m^2 were included in the study. Only two participants were above a normal BMI categorization, being overweight and obese while 83% were categorized with a normal BMI of 18.5-24.9 kg/m^2. Previous hiking frequency and reported exercise hours per week were gathered in the original screening questionnaire. Two participants (17%) did not specify their previous hiking frequency, while two participants (17%) indicated they hiked once or more per week. Three participants (25%) indicated they hiked once or more a month (up to 3 times a month) and five participants (42%) indicated they hiked several times a year (between 2-10 times a year). One participant (8%) reported exercising 0-2 hours/week, three participants (25%) reported exercising between 3-5 hours/week, five participants (42%) reported exercising between 6-10 hours/week, and three participants (25%) reported exercising 11+ hours/week.

The hot (HOT) hike day in September had a reported WBGT = 31.6 °C and the moderate (MOD) hike day in November had a reported WBGT= 19.0 °C. On the HOT day, four participants did not complete the entire hike. Two of the participants only completed one climb, one participant only completed three climbs, and another completed three and a half climbs. Three of those non-finishing hikers dropped out of the study between the HOT and MOD hiking days. All returners to the MOD hike, seven male and two females, completed the entire hike (4 climbs). Participant and environmental information are shown in Table 3. Differences in HOT hike times and MOD hike times were found to be statistically significant (p=0.013) with average hiking time for HOT: 1.76 ± 0.36 hr and for MOD: 1.56 ± 0.22 hr (Table 4).

Table 3. *Participant and Environmental Characteristics for HOT and MOD Hikes*

	HOT	MOD
Subjects (M/F)	7 / 5	7 / 2
Finishers (Total Hikers)	8 (12)	9 (9)
WBGT (°C)	31.6 ± 2.10	19.0 ± 0.74
Ambient- Dry Bulb Temperature (°C)	40.4 ± 2.50	22.9 ± 1.60
Relative Humidity (%)	21.4 ± 2.92	18.2 ±1.38

Values are expressed as means ± standard deviations.
WBGT: Wet Bulb Globe Temperature

Energy and Performance

Estimated EE group averages were 727 ± 302 kilocalories (kcal) for the HOT day and 684 ± 223 kcal for the MOD day and were not found to be significantly different (p=0.409). Calculated METs were also not found to be significantly different between the two days (p=0.695). However, the average core (intestinal) temperature (°C) for the group was found to be statistically significant (p=0.002) with group averages of 38.4 ± 0.4 °C on the HOT day and 37.7 ± 0.3 °C on the MOD day. The average maximum core (intestinal) temperature was also found to be statistically significant (p=0.001) with averages on the HOT day of 38.5 ± 0.36 °C and on the MOD day of 38.0 ± 0.30 °C. Furthermore, the increased heat strain observed on the HOT day may explain the statistically significant difference seen in their group average for average Rating of Perceived Exertion (RPE) scores of 13 ± 2 on the HOT hike day and 10 ± 1 on the MOD hike day (p=0.009) and average Peak RPE (top of climb/mountain) scores of 14 ± 2 on the HOT hike day and 12 ± 2 on the MOD hike day (p=0.005). On the other hand, participant's calculated average intensity was not found to be statistically significant (p=0.114). Group averages on the HOT and MOD day were 75 ± 12% and 58 ± 10%, respectively (Table 4).

Table 4. Mean ± SD for Performance and Physiological Data for HOT and MOD Hikes

	HOT	MOD	N	*p*
Total Time Hiking (hr)	1.76 ± 0.36	1.56 ± 0.22	8	**0.013***
Sweat Rate (L/hr)	1.38 ± 0.53	0.84 ± 0.27	9	**0.010***
Sweat Amt Lost (mL)	2260 ± 910	1280 ± 390	9	**0.006***
Body Weight Loss (kg)	0.80 ± 0.74	0.73 ± 0.64	9	0.844
% Body Weight Loss	1.1 ± 1.0	1.0 ± 0.8	9	0.852
Rescue Water Used (mL)	391 ± 479	56.8 ± 170	9	**0.023***
Core Temperature Average (°C)	38.4 ± 0.39	37.7 ± 0.26	8	**0.002***
Max Core Temperature Average (°C)	38.5 ± 0.36	38.0 ± 0.30	8	**0.001***
RPE Average	12.9 ± 2.02	10.3 ± 1.37	8	**0.005***
RPE Peak Average	14.2 ± 2.4	11.9 ± 2.0	8	**0.009***
METs	5.99 ± 0.48	5.92 ± 0.59	6	0.695
EE (kcal)	727 ± 302	684 ± 223	6	0.910
Intensity Average (%HRmax)	75 ± 12	58 ± 10	6	0.114

Bolded* values indicate a statistically significant difference at p<0.05. EE: Energy Expenditure was not normally distributed on the HOT day, but the results were not found to be statistically significant with either parametric or nonparametric tests so were reported with M ± SD like the other variables for consistency in reporting. RPE: Rating of Perceived Exertion. Rescue Water: Water provided to participants from researchers upon request, for safety measures.

Food and Fluid Behavior

Overall dietary intake behavior was higher on the HOT hike day compared to the MOD hike day (Table 5). There was a statistically significant difference (p<0.001) in the amount of fluid consumed on the HOT and MOD hiking days with a mean difference of 753 ± 369 mL (HOT: 1541 ± 485 mL; MOD: 787 ± 565 mL). Three hikers did consume food on the HOT hike day and zero hikers consumed food on the MOD hike day (HOT: 33.2 ± 79.7 g; MOD: 0.0 ± 0.0 g) however, comparing total food consumed there was not a statistically significant difference (p=0.248) between HOT and MOD hike days, likely due to the overall low intake.

Table 5. Mean ± SD for Food and Fluid Consumption During HOT and MOD Hikes

	Hot	Mod	N	Mean Difference	*p*
Food Consumed (g)	33.2 ± 79.9	0 ± 0	9	33.2 ± 79.9	0.248
Fluid Consumed (mL)	1541 ± 485	787 ± 566	9	753 ± 396	**< 0.001***

Bolded* values indicate a statistically significant difference at $p<0.05$.

For the HOT hike, seven of twelve participants (~58%) brought food while only three participants (25%) consumed food during the hike. On the MOD hike, only two of nine participants (~22%) brought food, but neither of them consumed any food during the hike. Foods brought by participants were categorized into four categories: Crackers, Fruit, Granola Bars, and Trail Mix. Three participants brought granola bars, three participants brought fruit, two participants brought trail mix, and only one participant brought crackers. Only two participants brought foods from two different categories, one participant brought fruit and granola bars, and the other brought fruit and trail mix. However, on the HOT hike only foods in the categories fruit and granola bars were consumed. Additionally, Table 6 contains the individual amounts of food and fluid consumed, food kcal and CHO composition, and the amount of personal fluids brought for both the HOT and MOD days

Table 6. *Individual Finishing Hiker's Energy, Food and Fluid Data for Both Hikes*

						Consumed					Brought			
Hiker	Hike Day	Hiking Time (hr)	% Body Weight Loss	Sweat Rate (L/hr)	EE (Kcal)	Fluid [c] (mL)	Rescue Water (mL)	Food (g)	Calories (Kcal)	CHO (g)	Fluid (mL)	Food (g)	Calories (Kcal)	CHO (g)
M ± SD[a]	Hot	1.76 ± 0.36	1.1 ± 1.0	1.4 ± 0.5	727 ± 302	1541 ± 485	391 ± 479	33.2± 79.9	117 ± 32	23.5± 14.3	1515± 834	106 ± 133	630 ± 498	79.7± 67.8
	Mod	1.56 ± 0.22	1.0 ± 0.8	0.8 ± 0.3	684 ± 223	787 ± 565	56.8± 170	0 ± 0	0	0	1571 ± 1090	20.8± 43.3	467 ± 125	42.0± 17.0
3	Hot*	1.13	0.0	1.3	505	1641	248	0	0	0	1642	74.9	219	27
	Mod	1.52	0.0	0.3	677	761	0	0	0	0	1717	120	555	54
5	Hot	1.53	1.3	1.8	587	1950	0	0	0	0	2724	0	0	0
	Mod	1.48	0.7	1.0	590	1052	0	0	0	0	2874	0	0	0
6	Hot	1.68	1.8	1.6	701	1410	1410	17.3[d]	92[d]	6[d]	0	240	1281	80
	Mod	1.48	1.4	1.0	667	511	511	0	0	0	0	0	0	0
7	Hot	1.33	1.7	2.2	756	1631	0	0	0	0	2124	0	0	0
	Mod	1.41	1.1	1.1	714	994	0	0	0	0	1027	66.7	378	30
8	Hot	2.03	1.1	1.0	621	1527	620	0	0	0	1342	48.5	210	23
	Mod	1.78	0.3	0.5	474	918	0	0	0	0	1364	0	0	0
9	Hot	2.05	1.0	1.4	[b]	1878	0	234	95	23	2734	0	0	0
	Mod	1.76	1.3	0.7	747	507	0	0	0	0	2597	0	0	0
10	Hot	1.88	-0.9	0.3	[b]	1228	570	0	0	0	807	252	98	24
	Mod	1.56	2.1	0.9	853	115	0	0	0	0	850	0	0	0
11	Hot	2.28	1.5	1.6	1382	2125	674	37.9	120	24	1590	337	1240	212
	Mod	1.85	-0.2	1.0	1149	2012	0	0	0	0	3129	0	0	0
12	Hot	1.28	2.1	1.4	534	479	0	0	0	0	513	0	0	0
	Mod	1.20	2.2	1.1	518	217	0	0	0	0	578	0	0	0

[a]In the first two rows values are expressed as M ± SD based on finishers and non-finishers. Rescue Water (RW): Water provided to participants from researchers upon request, for safety measures. EE: Energy Expenditure. [b]Values could not be calculated due to missing heart rate data. [c]Includes personal fluids consumed and RW used. [c] Participant left food in lab, technically consuming after hike was completed. Hiker 1, Hiker 2, and Hiker 4 were not included in individual reports as they did not complete the HOT hike and did not return for the MOD hike. *Hiker 3 only completed 3 climbs on the HOT hike.

Furthermore, a comparison of personal fluids brought, amounts of fluid consumed, and each participant's calculated fluid needs for the HOT and MOD hikes can be found in *Figure 3* and *Figure 4*, respectively. An additional interpretation of these amounts can be found in flowchart *Figure* 5. For the HOT hike, under half (42%) of the participants did appear to plan well regarding their hydration (brought enough fluids to meet their calculated needs). Then on the MOD hike, just over half (56%) appeared to plan well regarding their hydration. On the HOT hike only two participants (17%) actually consumed enough fluids to meet their calculated fluid needs one participant doing so with the use of RW water. Then, on the MOD hike, only 33% actually consumed enough fluids to meet their calculated fluid needs.

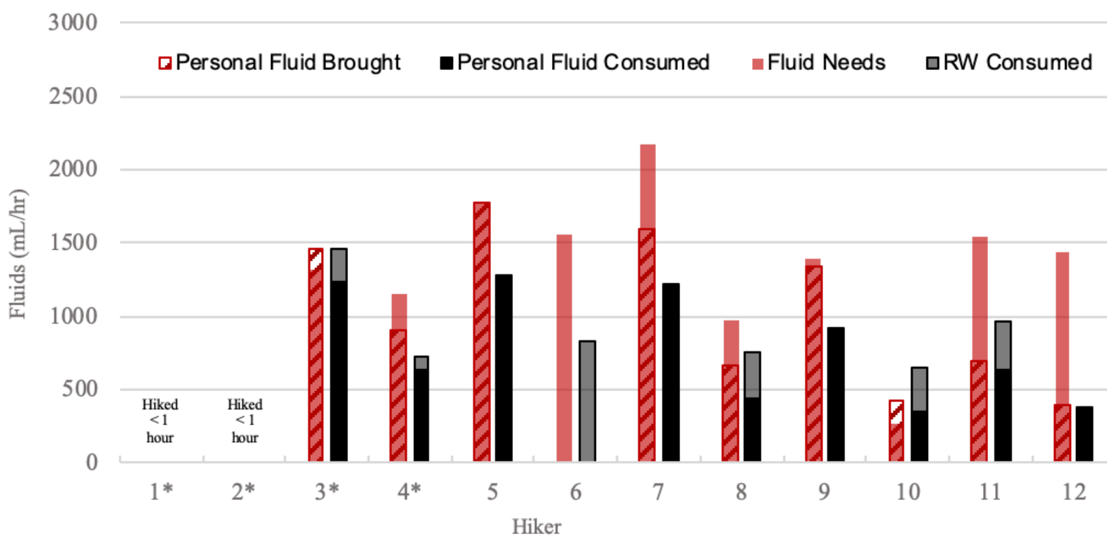

Figure 3. HOT Hike Fluid Behavior
RW= Rescue water was extra water provided to participants from researchers upon request for safety measures. Values for Hiker 1 and Hiker 2 are not displayed as they hiked less than 1 hour, completing only 1 climb and deciding to withdraw. Hiker 3 and Hiker 4 only completed 3 and 3.5 climbs, respectively, before withdrawing.

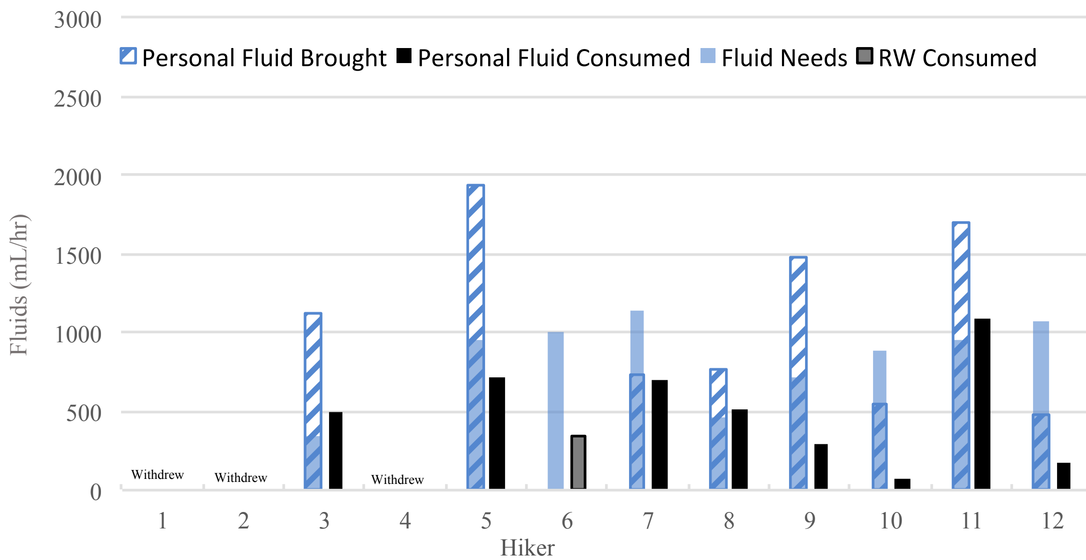

Figure 4. MOD Hike Fluid Behavior

RW: Rescue water was extra water provided to participants from researchers upon request for safety measures. Hiker 1, Hike 2, and Hiker 4 withdrew from the study before the MOD hike day.

For the HOT hike, six participants (50%) used RW and five of them still did not meet their calculated fluid needs. One of those six that used RW could have met their needs solely with the use of their own water but did request RW at the end of their hike. This could possibly be due to the participant wasting some of their water (pouring over self or spitting out). The only participant that used RW on the MOD hike still did not meet their needs even with the use of RW. The amount of RW used was statistically significant (p=0.010) with a mean difference between HOT and MOD hike days of 334 ± 358 mL and the greater amount consumed being on the HOT hike day (Table 6). Group averages on HOT and MOD hike days were 391 ± 479 mL and 57 ± 170 mL, respectively.

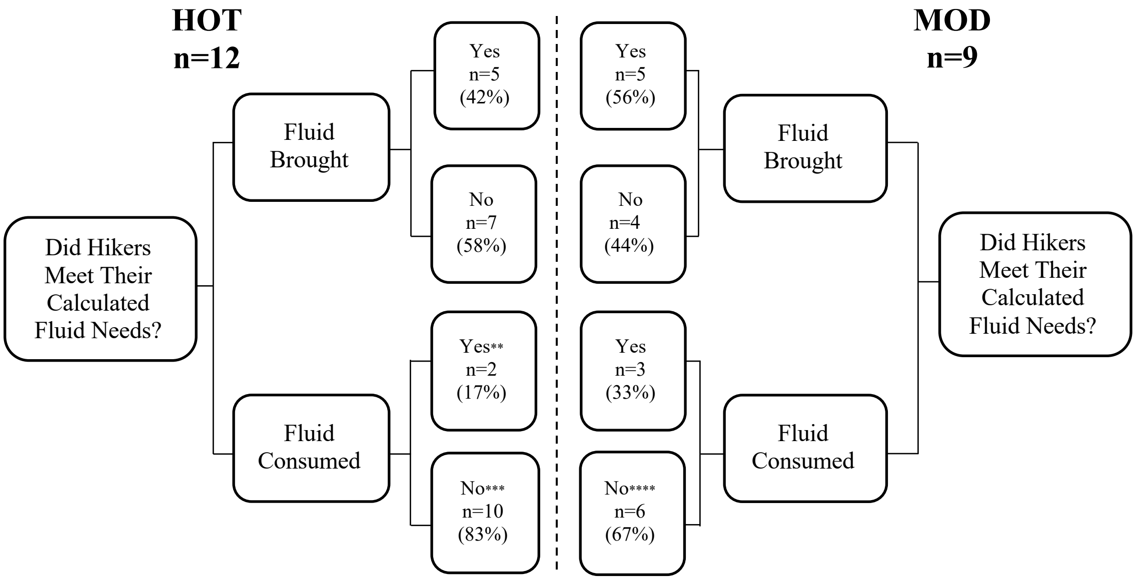

Figure 5. Fluid Behavior Compared to Calculated* Fluid Needs for Both Hikes (Finishers and Non-Finishers)

*Calculated fluid needs were calculated individually based on sweat rate and compared to their respective individual amounts consumed and brought.

**On the HOT hike, of the 2 hikers that consumed enough fluids to meet their calculated fluid needs, 1 hiker did so with the use of RW.

***On the HOT hike, of the 10 hikers that did not consume enough fluids to meet their calculated fluid needs, 5 hikers used RW and still did not meet their needs.

****On the MOD hike, of the 6 hikers that did not consume enough fluids to meet their calculated fluid needs, 1 hiker used RW and still did not meet their needs.

Fluid Balance and Hydration Status

Group averages for sweat rate (L/hr) were found to be statistically significantly different (p=0.010) when comparing the HOT and MOD hiking days (HOT: 1.4 ± 0.5 L/hr; MOD: 0.8 ± 0.3 L/hr), with higher rates reported on the HOT day (Table 4). The amount of sweat lost was also statistically significant (p=0.006) with group averages for the HOT day of 2269 ± 910 mL and 1280 ± 390 mL for the MOD day.

Body weight loss and % body weight loss were not found to be significantly different on the HOT and MOD days with a group average of % body weight loss on the

HOT day of 1.1 ± 1.0% and 1.0 ± 0.8% on the MOD day. It is important to note that on the HOT day eight of twelve participants (~67%) exhibited body weight losses ≥ 1%, indicating a level of dehydration that can begin to affect performance. Only one participant exhibited a body weight loss of 2%. Furthermore, on the MOD day, five of nine participants (56%) exhibited a body weight loss ≥1%. No participants had a body weight loss ≥ 2 % on the MOD day. One participant actually gained weight on the HOT hike, likely due to fluid consumption as they did consume fluids in excess of their calculated needs. One other participant also showed weight gain on the MOD hike, which appeared to also likely be due to fluid consumption as their fluid consumption was indeed greater than their calculated needs.

Individual pre-hike and morning-after USG values as well as group means can be found in Table 7 and an individual level hydration status interpretation of them are in Table 8. On average, the groups pre-hike USG for the HOT day was 1.016 ± 0.010 and the MOD day was 1.010 ± 0.008 indicating on a group level, hikers were arriving euhydrated for both hikes. However, on an individual level 50% of hikers arrived for the HOT hike in a dehydrated state and 89% arrived for the MOD hike in a dehydrated state, which are similar to results reported earlier in the Phoenix area (Olzinksi, 2019). Morning-after USG was 1.022 ± 0.007 for the HOT day and 1.019 ± 0.009 for the MOD day indicating on a group level, hikers did not rehydrate well throughout the rest of the day/night after the HOT hike but did rehydrated well after the MOD hike. On an individual level, 75% of hikers did not rehydrate well after the HOT hike and 67% of hikers did not rehydrate well after the MOD hike. Neither the HOT pre-hike compared to the MOD pre-hike (p=0.085) and HOT morning-after compared to the MOD morning-after (p=0.387) USG values were statistically significant. However, when comparing the pre-hike USG samples to the morning-after USG samples within each HOT and MOD day, both were statistically significant at a p-value < 0.05. The mean difference and SD (p-value) for those HOT values were 0.006 ± 0.009 (p=0.047) and for the MOD values were 0.010 ± 0.010 (p=0.026).

Table 7. *Individual Pre-Hike and Morning-After USG Values for Both Hikes*

		Pre-Hike USG	**Morning-After Hike USG**
M ± SD	Hot	1.016 ± 0.010	1.022 ± 0.007
	Mod	1.010 ± 0.008	1.019 ± 0.009
1	Hot	1.021	1.021
	Mod	--	--
2	Hot	1.023	1.021
	Mod	--	--
3	Hot	1.004	1.009
	Mod	1.003	1.011
4	Hot	1.002	1.017
	Mod	--	--
5	Hot	1.010	1.021
	Mod	1.005	1.023
6	Hot	1.023	1.022
	Mod	1.028	1.021
7	Hot	1.007	1.016
	Mod	1.008	1.011
8	Hot	1.004	1.029
	Mod	1.008	1.023
9	Hot	1.022	1.024
	Mod	1.008	1.002
10	Hot	1.028	1.022
	Mod	1.006	1.025
11	Hot	1.014	1.021
	Mod	1.004	1.026
12	Hot	1.030	1.033
	Mod	1.019	1.031

USG classification for dehydration was set at ≥ 1.020. (--) Indicates hiker withdrew from the study. Mod Pre-hike USG was not normally distributed, but results were found to be statistically significant with both parametric and nonparametric tests so were reported with M ± SD for consistency in reporting.

According to USG values, of the nine participants that hiked both the HOT and MOD hikes, five of the same participants (~56%) were euhydrated when arriving for both hikes, one participant was dehydrated when arriving to both hikes, and three of the same participants were not consistent with hydration levels when arriving to both hikes. For morning-after hydration status, only two of the same participants rehydrated well-enough after both hikes, while six of the same participants (~67%) did not re-hydrate well after both hikes. Only one participant was inconsistent with their morning-after hydration levels.

Table 8. *Pre-Hike and Morning-After Hydration Status for Both Hikes*

Euhydration = USG value < 1.020 Dehydration = USG value ≥1.020	**HOT n=12**		**MOD n=9**	
	n	%	n	%
Pre-Hike				
Euhydrated	6	50	1	11
Dehydrated	6	50	8	89
Morning-After				
Euhydrated	3	25	3	33
Dehydrated	9	75	6	67

CHAPTER 5

DISCUSSION

This research further demonstrates the increased physiological effects that activity in the heat can have on individuals and reinforces the observation of increased heat stress indicators when compared to activity in a more moderate climate. Those findings: fluid consumption, total hiking time, sweat rates, core temperatures and RPE scores being higher hiking in the heat compared to when hiking in moderate temperatures was expected, but added to new literature specific to recreational mountain hiking, which was previously lacking. Furthermore, hikers on average, as a group, began both hikes in a euhydrated state but did not appear to rehydrate well following the HOT hike as they were dehydrated the morning after. Hikers were asked to prepare for the hikes as they normally would in regard to food and fluids brought and on average, amounts brought and consumed on both hikes were actually in line with general activity fluid recommendations of 0.5–1.0 L/hr. However, their individual calculated fluid needs for the HOT hike were not in agreement with those general recommendations and on average proved to be slightly higher (by ~0.4 L on the HOT hike) ultimately resulting in them not meeting their needs. This gives an additional insight into recreational mountain hiker's hydration status and their food and fluid behaviors, adding more to the limited research on recreational hiking specifically in a hot, dry environment.

Effect of Heat Stress

A common assumption about most Phoenicians, those who live in Phoenix, Arizona, are that they are acclimatized to the heat, however it is curious if this is true or not. Because of the process to become acclimatized and the “use it or lose it” characteristic, many Phoenicians probably are not truly acclimatized for outdoor activity in the summer months as they likely stay in air-conditioned buildings, homes, cars, and fitness centers. That reality along with tourists from cooler states, and the connections between acclimatization, dehydration, and performance probably play an integral role in the hiker rescues of the area (Pandolf et al., 1998; Shapiro et al., 1998; Aldridge et al., 2005). The majority of the variables that can be connected to heat stress in this study (hike time, core temperature, RPE scores, and sweat rates) (Nybo et al., 2014; Cheuvront et al., 2010; Baker et al., 2016) were all statistically significantly higher on the HOT hike compared to the MOD hike as expected, but are now corroborated, providing literature on recreational mountain hikers.

Nybo and colleagues (2014) wrote in a review that a 0.4 ºC mean rise in core temperature can be expected in heat stress environments between 25-40 ºC compared to 12-23 ºC moderate environments. This present study found an even greater rise in core temperatures of 0.7 ºC between the HOT versus MOD hikes. Additionally, it is interesting to note that baseline core temperatures were already 0.3 ºC higher on the HOT hike compared to the MOD hike, also supporting Nybo’s reports (Nybo, Rasmussen, & Sawka, 2014). Furthermore, overall average RPE scores and peak RPE scores were significantly higher on the HOT day versus the MOD day, which was also expected as a result of heat stress on an individual (Cheuvront, Kenefick, Montain, & Sawka, 2010).

Sweat rate is a useful tool that allows individuals to fine-tune their personal hydration needs in order to compensate for fluid loss during activity. However, Baker and colleagues (2016) reported how the variation of sweat rates between individuals is large across and even within populations. This indicates that general fluid recommendations probably should not be based on greater sweat rate data, but that fluid recommendations may need to be tailored towards the individual using their personal sweat rate. Their reported average sweat rates for adult athletes was 1.37 ± 0.71 L/hr which was measured and averaged across both moderate and hot conditions (Baker et al., 2016). This present study found average sweat rates for just the HOT day to be 1.38 ± 0.53 L/hr. Although, according to this study, on the HOT hike even though 42% of individuals brought enough fluids to compensate for their sweat rate (fluid needs), whether intentionally or not, only 17% of individuals actually consumed enough of those fluids to meet their needs, defined as 100% compensation of their estimated loss. This raises the question that although more detailed hydration recommendations are needed, maybe a detailed consumption plan, or prescribed drinking, should also be recommended when hiking in the heat. This might be an interesting and valuable question for future research to provide specific fluid consumption recommendations.

Fluid Intake Behavior and Hydration Status

The fluid behavior data gathered in this research indicates that almost half (42%) of recreational hikers appeared to plan well when bringing fluid (compared to their calculated fluid needs) for their HOT hikes and over half (56%) for the MOD hike. However, there was a disconnect when they chose to actually consume those fluids because less than 20% of hikers actually consumed enough fluids during their HOT hike to make up for the amounts lost through sweating and only 33% did during their MOD hike. Data from this study shows that on average, hikers lost at least 1% body weight on both hikes, which has been reported many times as a level detrimental to performance (Aldridge et al., 2005; Casa et al., 2005; Benton et al., 2016). Krake and colleagues (2003) reported on the health hazards that park rangers at Grand Canyon National Park face. In their study, park rangers, preventative search and rescue volunteers, and other park employees lost on average between 1.0 - 1.3% body weight when hiking between 3-10 miles, depending on the trail their work was assigned to (Krake, McCullough, & King, 2003). Although those individuals were not recreational hikers, their job duties had similar basic energetic costs and physical demands and observing similar % body weight losses supports the generalizability of these results to other occupations like park rangers and rescue crews.

Furthermore, morning-after USG samples in this research, on an individual level indicated that 75% of hikers were dehydrated even the morning after their HOT hike (likely already dehydrated at hike completion as seen through weight loss values) and indicating they were unable to compensate for fluid loss even through the rest of the evening after their hike. Not consuming enough fluids inevitably leads to dehydration which has negative effects on cognition, performance, heart rate, core temperatures, and perceived exertion (Aldridge et al., 2005; Casa et al., 2005; Benton et al., 2016). This could all potentially lead to injury, especially in a mountainous environment. Ainslie's hiking research (2002) measured and reported impairments in psychomotor functioning and jump test performance in those who were dehydrated. Additionally, like this present study their hikers were allowed to eat and drink ad libitum and were found to become dehydrated throughout their hike (Ainslie et al., 2002). Interestingly, Boore's research on hiker preparedness (2013) reported that respondents of previous rescue incidents commented that if they had enough water, their rescues might have been minimized. In this present study extra water was available upon request and labeled as "rescue water" (RW), which was needed and requested significantly more on the HOT hike versus to the MOD hike. This further demonstrates the additional strain on hikers hiking in hot temperatures and the importance of planning enough fluids for an intended hike. However, in regard to increased needs while hiking in the heat, the amount of fluids someone may need might be more than they can or are willing to carry during their hike. This could create a gap between adequate recommendations and actual behavior of hikers, maybe a topic for future research to explore.

Estimated Sweat Rate and Percent Body Mass Loss

For the HOT hike, sweat rates and % body weight loss were also calculated without the inclusion of rescue water (w/o RW), predicting the potential effect on the individual in a real-life setting where extra water was not readily available. For the six participants that used rescue water on the HOT hike, averages for estimated sweat rates (w/o RW) was 0.84 ± 0.48 L/hr and for estimated % body weight loss (w/o RW) was 1.7 ± 1.4 %. For those RW users, 33% would be under 1% body weight loss, 67% would be above 1% body weight loss and 50% would be above 2% body weight loss when the RW is not included in the calculation. There was a significant difference found when comparing estimated sweat rate (w/o RW) to original sweat rate ($p=0.042$). The estimated % body weight loss (w/o RW) was at a performance affecting level (> 1%) (Aldridge et al., 2005; Casa et al., 2005; Benton et al., 2016) and when compared to original % body weight loss, there was also a statistically significant difference ($p=0.016$). These results, although predictive, indicate that if researchers did not provide that extra rescue water, those hikers could have developed a larger fluid loss becoming even more dehydrated and resulting in a likely higher amount of negative heat stress symptoms, possibly leading to the discontinuation of their hike before completion (dropping-out) or having to be removed by researchers for safety protocol if they had reached a core temperature exceeding 39.5 ºC.

Energy Intake Behavior While Hiking

Ainslie's hiking research (2002) did estimate energy intake data, although their hike was double the length (8-miles) of this study and was in moderate temperatures. Their reported energy intake was 5.6 ± 0.7 MJ (M ± SE) equating to almost 1,340 kilocalories while in the present study, no participants had any energy intake during the moderate temperature hike. Ainslie's reported energy intake was during a prolonged break for lunch, which is logical and common to plan on an 8-mile hike, especially in moderate weather (Ainslie et al., 2002). Overall insight into food behavior was limited in this present study, but not without any value. There was some insight gathered for hiking in the heat as only three hikers consumed food during their hike of the seven that even brought any food (total hikers $n=12$) with a mean intake of 117 ± 32 kilocalories. This may have been due to the continuous exposure of heat making stopping for breaks to eat, likely the behavior of a recreational hiker, undesirable as they would have prolonged the heat exposure. Additionally, it has been proposed and studied that exercising in the heat decreases appetite and therefore could be a factor of decreased energy intake (Herman, 1993; Shorten, Wallman, & Guelfi, 2009). This brings to light an important possible chain of events. A low energy intake likely leads to negative energy balance while hiking coupled with the fact that for each gram of glycogen in the body, at least 3g of water is present (Fernandez-Elias, et al., 2015), therefore both (negative energy balance and dehydration) could contribute to a decline in physiological and psychological functioning, again potentially resulting in accident and injury (Casa et al., 2005; Ainslie et al., 2002). This can bring about possible updated guidelines as the current *Take a Hike. Do it Right.* campaign does not mention food or energy intake. A possible solution to both issues could be the recommendation of consuming a CHO containing beverage when hiking in the heat in order to provide additional energy while limiting the need to stop for a break and eat solid foods. Also, potentially prescribed eating (like prescribed drinking) might be an effective recommendation for hiking in the heat as well as providing breakfast/pre-hike recommendations. Pre-hike meal details for this study will be discussed in the following section.

Estimated CHO Utilization

Estimated CHO utilization was predicted for participants based on their average relative intensity (%HRmax) using a predictive table of corresponding energy source percentages from O'Neill, however it may be noted that his table is only a rough guide (O'Neill et al., n.d). The average estimated percent CHO oxidation for the group was 59% on the HOT hike day and 54% on the MOD hike day. This resulted in an estimated whole hike CHO need for the HOT and MOD hikes of 126 ± 105 g and 95 ± 81 g, respectively. Average pre-hike CHO intake before the HOT hike was 90 ± 25 g and before the MOD hike was 66 ± 10 g. Only a small number of participants (n=3) actually consumed CHO during the hike HOT (total hikers n=12) with an average consumption of 23.5 ± 14.3g. Therefore, on average, participants that did consume any CHO during the hike, consumed less than the estimated CHO needs throughout the hike. Although, this use of O'Neill's predictive table did not take into account that consumed CHO utilization is decreased in the heat compared to cooler temperatures (Jentijens, Wagenmakers, & Jeukendrup, 2002). An additional limitation to this predictive process is that normal body glycogen reserves were not taken into account, which can be an estimated 300-700g daily (Farrell, Joyner, & Caiozzo, 2011) and likely to be on the lower end of the spectrum (~300g) for this age group of recreational hikers. Muscle glycogen specifically would be an important energy source for CHO oxidation during activity. This study did not collect participant's dietary intake data leading up to the hikes besides the standardized pre-hike meal and additional breakfast suggestion compositions. Although, NHANES reports the average CHO consumption for men and women 20 years and older to be between 47-50% of their total calories with almost 18% coming from breakfast (NHANES, 2015-2016). This results in an estimated 245g of CHO per day. Additionally, the recommendation for fueling before activity is to consume 1-4 g/kg of CHOs 1-4 hours before starting and this study's pre-hike standardized meal contained 65g CHO and was instructed to be consumed two hours prior to hike start time (Thomas et al., 2016). Therefore, based on the average American diet and the standardized meal provided before the hikes, it is expected that CHO utilization for the hikers was a mixture of glycogen and endogenous

CHO oxidation and were likely sufficient enough to fuel the hike. Although the hikers on a group level likely had sufficient carbohydrate availability from of their standardized pre-hike meal, the during activity recommendation to consume 30-60 g/hr of CHO was not met (Thomas et al., 2016). Future research accurately measuring energy source oxidation for hikers in a hot, dry environment would be very interesting and valuable to recommendations given by preventative rescue and hiker safety campaigns.

Strengths and Limitations

Strengths. Even though there was no randomization and additional variables such as food and fluid intake were not controlled, one of the foundational strengths of this study was the simulation of actual hiker food and fluid behavior. Hikers were allowed to bring whatever they wanted and were allowed to eat and drink ad libitum. This allowed the researchers to gain an insight into how recreational hikers plan for their hikes (the amounts and types of food and fluid brought) as well as when and how much of each they consume while on their hikes.

An additional strength of this study was the use of the intestinal core temperature tracking capsules. These allowed real time monitoring of all participant's core temperatures. Continuous monitoring of these temperatures held important implications for overall heat stress and safety protocols, especially on the HOT hike as several participants were reaching core temperatures where exertional heat illnesses begin to manifest.

Limitations. One of the most important limitations in this study was the small sample size. The participant count was already at the minimum amount when beginning (n=12) and then an additional three hikers withdrew from the study between the HOT and MOD hikes, leaving only nine participants with data for both hikes. Furthermore, activity tracking data was not recorded for two additional hikers during the HOT hike, which limited the sample size even further for comparisons of variables such as EE, METs, and average intensity. Additionally, four hikers on the HOT hike did not complete all four climbs and were not included in those comparisons as their activity tracking data was incomplete. However, those four hikers were already meeting the maximum core temperatures allowed before the researchers would have had to remove them from the hike and were also exhibiting negative heat stress symptoms when they decided to discontinue their hike.

Another limitation to this study, in regards to food behavior, again was affected by a small sample size and even further by the amount of participants in that sample who actually brought food (n=7/12 for HOT and n=2/9 for MOD) and an even smaller amount that actually consumed food (n=3 for HOT and n=0 for MOD). These results do give us some insight into food behavior for hiking in a HOT versus MOD condition, although more data would have undoubtedly been even more insightful especially on types and macronutrient compositions. Additionally, adding to this limitation was the request that hikers try not to stop and take breaks outside of the already designated measuring stations. This design allowed data to be given at a steadier state, especially when reviewing total hike times. This was limiting to the other design aspect of simulating actual hiker food and fluid behavior as a recreational hiker might stop to take breaks more often, eating at that time and/or stop at the peak of the mountain for up to 30 minutes and eat at that time.

Conclusion and Application

Vast literature exists on the effect of activity in the heat, but these results expand that to a previously under studied population, recreational mountain hikers. These results demonstrate that hikers did not consume enough fluids to meet their needs while hiking, especially in the heat as well as demonstrating the effects of heat stress on the physiological and performance measures of hikers. These results also have the potential to expand to occupations where individuals are required to work in the heat and are not necessarily elite athletes, although because of the high demands of this hike generalizing to recreational athletes/sports is also fitting. These other occupations can include park rangers, wildland firefighters, search and rescue teams, construction crews, and even military personal (although maybe closer to an elite athlete than the others).

As previously mentioned, the issue of hiker rescues, especially in the greater Phoenix area needs more and/or updated preventative solutions in order to decrease prevalence while keeping hikers safe. The *Take a Hike. Do it Right.* campaign would benefit from more detailed hydration recommendations, the addition of detailed food/energy recommendations, and possibly educating more on the interconnectedness of heat stress (and acclimatization) dehydration, and energy balance when hiking in the heat.

Applying past literature, current recommendations and these results, the following recommendations are proposed. First, fluid needs are individually based so it would be advised to measure body weight regularly before and after activity in order to monitor if more than 1-2% of body weight is being lost during activity. This will give hikers a better idea of their fluid needs compared to their consumption across various activities. While hiking in a hot, dry environment, consuming between 1-2 L/hr of fluids would be recommended. For hikes more than one hour in duration, it would also be recommended to consume CHO containing food/snacks that provide 30-60 g/hr. Particularly, snacks that are also salty would be beneficial for providing electrolytes. Easy to carry salty snacks (trail mix, whole wheat crackers, pretzels) would be a good idea to allow the hiker to eat and hike simultaneously, limiting heat exposure on breaks. Although, another option is to consume a CHO and electrolyte containing beverage (sports drink) which would allow for the easy, concurrent consumption of needed fluids, CHOs, and electrolytes while hiking. Example food and fluid recommendations for a 4-mile hot hike taking on average 1.5–2 hours to complete are provided below (ranges are relative to hike time):

1. Pack and drink up to 1.5-4 L of water, pack and eat salty snacks (such as trail mix) that will provide between 45-120g CHO (30-60 g/hr).
2. Pack and drink up to 1.5-4 L of a sports drink that will provide between 45-120g CHO (30-60 g/hr) and electrolytes (watch for sugar-free flavors, as they do not contain CHOs).
3. Pack and consume a mixture of the above recommendations based on personal taste preferences. This could look like a) water, sugar-free sports drinks (electrolytes), and CHO snacks, b) sports drink, water, and snacks.

These recommendations help to provide more detailed food and fluid consumption guidelines for hikers when hiking in the heat and would likely benefit any educational campaigns for hiking in the heat.

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APPENDIX A

INSTRUCTIONS FOR CAM STUDY PARTICIPANTS

<u>CAM Participant Instructions</u>

Thank you for volunteering to participate in our research! Below are some things to remember before coming in for your scheduled hike:

- **<u>2 days prior to hike</u>**: Cease supplement intake. Let us know if this is not possible.
- **<u>Night prior to hike:</u> Fast-** Do not eat or drink after 9:00 pm (water is okay).

  [Morning of Hiking Day: Controlled food intake and no physical activity]

- **<u>12 to 4 hours prior to hike</u>**: Ingest the CorTemp capsule **(hike will start at roughly 12 pm (HOT) and 11am (MOD) so take it sometime between 11 pm the night before and 7 am the morning of the hike)**.
  (Too early and you may "pass" the capsule before the hike. Too late, and we will get poor data as cool fluids will change the temperature of your stomach.) **(**<u>Do not</u> ingest the long, small magnet that is packaged with the pill)
  - Do not store the capsule close to metal objects or in extreme hot or cold environments.
  - Do not remove the capsule from the package until ready to be consumed.
  - A text will be sent at as a final reminder to consume the CorTemp capsule with a glass of water.
  - The capsule will pass through the body with regular digestion time.
- You may consume a light breakfast (before our standardized meal). Please choose out of the following options and **take a picture before you start and after you've finished your meal**. In the picture, please include a coin or an object to give perspective to plate sizes/amounts. This allows us to see what you ate and in case you did not consume all the foods we can estimate the actual consumed amount.

Option 1	Option 2	Option 3	Option 4	Option 5
1 Plain Bagel + 1 oz Cream Cheese	4 oz Greek Yogurt + ½ cup Granola	1 Slice of Toast + 1 TBSP Peanut Butter + 1 Banana	1 Granola Bar ~200 calories (NOT protein bar) + 1 cup of 2% Milk or Soy Milk	1 Fried Egg *(w/ 1 tsp cooking oil)* + 2 Slices of Toast + 1 TBSP Jam

- Please eat <u>all</u> of the provided study meal (cereal & milk/alternative) **between 9:45 – 10:15 am (HOT) and 8:45 - 9:15 am (MOD).**
  - If you are unable to finish the meal, take a photo of what is leftover to share when you arrive for your hike.
- Do not consume anything but plain water until you come into the lab. No caffeine!
- **<u>Prepare for a 4 mi hike</u>** (e.g. Camelback/Piestewa) and bring whatever you normally would (e.g. food, water, daypack, sunscreen, etc.). The research team will have emergency supplies only, so do not expect provisions.
- Dress appropriately (usual workout attire for a hike) and **bring an extra change of light dry clothes** (**NOT** the ones you'll be hiking in) for weight measurements. The extra pair may be stored in our secure lab during the hike.

APPENDIX B

HUMAN SUBJECTS RESEARCH APPROVAL

Certificate of Action

Investigator Name: Floris Wardenaar, PhD	**Board Action Date:** 06/28/2018
Investigator Address: 425 N. 5th Street Phoenix, AZ 85004, United States	**Approval Expires:** 06/28/2019 **Continuing Review Frequency:** Annually
Sponsor: Arizona State University **Institution Tracking Number:**	**Sponsor Protocol Number:** None **Amended Sponsor Protocol Number:**
Study Number: 1187205	**IRB Tracking Number:** 20181336
Work Order Number: 1-1088121-1	**Panel:** 3
Protocol Title: Climbing A-Mountain Study	

THE FOLLOWING ITEMS ARE APPROVED:
Investigator
Advertisement – Presentation – Climbing A-Mountain Athleat Field Lab #17835700.0 - As Submitted
Advertisement - Wanted Hikers 18-40 Y/O #17835698.0 - As Submitted
Exertional Heat Illness Policy #17835701.0 - As Submitted
Pre-screening Questionnaire #17835699.0 - As Submitted
Protocol (04-27-2018) Ver 1.0
Research Test Result #17835702.0 - As Submitted
Consent Form [IN0]

Please note the following information:
The Board requires that all subjects must be able to consent for themselves to be enrolled in this study. This means that you cannot enroll incapable subjects who require enrollment by consent of a legally authorized representative.

THE IRB HAS APPROVED THE FOLLOWING LOCATIONS TO BE USED IN THE RESEARCH:
Sun Devil Athletics, Arizona State University, 600 E Veterans Way, Tempe, Arizona 85281

ALL IRB APPROVED INVESTIGATORS MUST COMPLY WITH THE FOLLOWING:
As a requirement of IRB approval, the investigators conducting this research will:

- Comply with all requirements and determinations of the IRB.
- Protect the rights, safety, and welfare of subjects involved in the research.
- Personally conduct or supervise the research.
- Conduct the research in accordance with the relevant current protocol approved by the IRB.
- Ensure that there are adequate resources to carry out the research safely.
- Ensure that research staff are qualified to perform procedures and duties assigned to them during the research.
- Submit proposed modifications to the IRB prior to their implementation.
  - Not make modifications to the research without prior IRB review and approval unless necessary to eliminate apparent immediate hazards to subjects.
- Submit continuing review reports when requested by the IRB.
- Submit a closure form to close research (end the IRB's oversight) when:
  - The protocol is permanently closed to enrollment
  - All subjects have completed all protocol related interventions and interactions
  - For research subject to federal oversight other than FDA:
- No additional identifiable private information about the subjects is being obtained
- Analysis of private identifiable information is completed
- If research approval expires, stop all research activities and immediately contact the IRB.

This is to certify that the information contained herein is true and correct as reflected in the records of this IRB. WE CERTIFY THAT THIS IRB IS IN FULL COMPLIANCE WITH GOOD CLINICAL PRACTICES AS DEFINED UNDER THE U.S. FOOD AND DRUG ADMINISTRATION (FDA) REGULATIONS, U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES (HHS) REGULATIONS, AND THE INTERNATIONAL CONFERENCE ON HARMONISATION (ICH) GUIDELINES.

- Promptly report to the IRB the information items listed in the IRB's "Prompt Reporting Requirements" available on the IRB's Web site.
- Not accept or provide payments to professionals in exchange for referrals of potential subjects ("finder's fees.")
- Not accept payments designed to accelerate recruitment that are tied to the rate or timing of enrollment ("bonus payments") without prior IRB approval.
- When required by the IRB ensure that consent, permission, and assent are obtained and documented in accordance with the relevant current protocol as approved by the IRB.
- Promptly notify the IRB of any change to information provided on your initial submission form.

Consistent with AAHRPP's requirements in connection with its accreditation of IRBs, the individual and/or organization shall promptly communicate or provide, the following information relevant to the protection of human subjects to the IRB in a timely manner:

- Upon request of the IRB, a copy of the written plan between sponsor or CRO and site that addresses whether expenses for medical care incurred by human subject research subjects who experience research related injury will be reimbursed, and if so, who is responsible in order to determine consistency with the language in the consent document.
- Any site monitoring report that directly and materially affects subject safety or their willingness to continue participation. Such reports will be provided to the IRB within 5 days.
- Reports from any data monitoring committee, data and safety monitoring board, or data and safety monitoring committee in accordance with the time frame specified in the research protocol.
- Any findings from a closed research when those findings materially affect the safety and medical care of past subjects. Findings will be reported for 2 years after the closure of the research.

If your research site is a HIPAA covered entity, the HIPAA Privacy Rule requires you to obtain written authorization from each research subject for any use or disclosure of protected health information for research. If your IRB-approved consent form does not include such HIPAA authorization language, the HIPAA Privacy Rule requires you to have each research subject sign a separate authorization agreement. "

Federal regulations require that the IRB conduct continuing review of approved research. You will receive Continuing Review Report forms from this IRB when the expiration date is approaching.

Thank you for using this WCG IRB to provide oversight for your research project.

DISTRIBUTION OF COPIES:
Contact, Company
Floris Wardenaar, PhD, Arizona State University

COA Template 01-03-2018

ASU Knowledge Enterprise Development

Floris Wardenaar
Nutrition
(602) 827-2841
Floris.Wardenaar@asu.edu

Dear Floris Wardenaar:

On 6/28/2018 the ASU IRB reviewed the following protocol:

Type of Review:	Initial Study
Title:	Climbing A-Mountain: assessment of nutrient needs of desert mountain hikers.
Investigator:	Floris Wardenaar
IRB ID:	STUDY00007707

The review of the above-referenced protocol has been given local review and the ASU IRB acknowledges that oversight is deferred to the Copernicus Group WIRB, IRB tracking# 20181336

Sincerely,

Susan Metosky

Susan Metosky, IRB Administrator