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Adequate Carbohydrate Intake And Hydration Status In Female Division I Collegiate Soccer Players

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ADEQUATE CARBOHYDRATE INTAKE AND HYDRATION STATUS IN FEMALE DIVISION I COLLEGIATE SOCCER PLAYERS

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ABSTRACT

The purpose of this study was to discern whether total grams of carbohydrate (CHO) consumed is associated with next day urine specific gravity (USG). Twenty-four Division I female collegiate soccer players with a mean age of 19.6 (SD=1.15) who were part of the team during pre-season summer training camp in August of 2019 volunteered to participate in this research. Athletes recorded food intake for six days during pre-season summer training camp. Food records were verified by a Board-Certified Specialist in Sports Dietetics and analyzed using NDSR. Athletes' hydration statuses were evaluated using a daily assessment of USG, via spontaneous urine collection. A two-tailed Pearson correlation evaluated the impact of total grams of CHO intake per day on next day USG. Results indicated no significant relationship exists between total grams of CHOs consumed and changes in next day USG status ($r = -0.131$, $p = 0.177$, $n = 107$). Additionally, our study found that none of the athletes met their CHO needs on any given day. Within this sample of female NCAA Division I soccer players, no evidence of significant correlation was seen between total grams of CHO consumed and the next day's USG. It may be beneficial for sports nutrition education strategies to focus on CHO's benefits on hydration maintenance in the acute timeframe of 1-4 hours. Certainly, that does not mean to dismiss the encouragement of consuming the recommended amount of CHOs on a daily basis, but now we see that in terms of hydration we may not need to be as concerned about the previous day's CHO intake.

LIST OF ABBEVIATIONS AND SYMBOLS

CHO	Carbohydrate
USG	Urine specific gravity
BW	Body weight
TGI	Gastrointestinal temperature

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I. INTRODUCTION

When air temperature and humidity reach levels that affect the quality of performance for athletes, their bodies use more water and energy to stay cool while exercising (Lopez et al., 2011; O'Connell et al., 2018; Sawka et al., 2007). As such, it is important to monitor the hydration status and food intake in athletes under these conditions. The following will summarize the existing literature about hydration and CHO relationship in athletes.

Currently, many discrepancies exist regarding CHOs due to the oversaturation of non-evidence-based recommendations. Far too often, CHOs are scrutinized for being the cause of unintentional weight gain (Shriver, Betts, & Wollenberg, 2013). Coupling that misinformation with societal norms that are placed on women regarding body image and what a healthy woman, or female athlete, should look like, may be one reason behind the large deficit of CHO intake seen in this population. Nutrition professionals have a duty to continuously develop, learn, and educate evidence-based research to dispel misconceptions and/or improper nutrition behaviors that a client/athlete may have (Abood et al., 2004; Thomas, Erdman, & Burke, 2016).

Previous studies have seen that female athletes are notorious for not meeting CHO needs (Shriver, Betts, & Wollenberg, 2013). Additionally, empirical data posits that a significant percentage of female athletes begin exercise in a hypohydrated state (Volpe, Poule, and Bland, 2009). Note that hypohydrated is not the same as term as dehydrated. While the term dehydrated describes the process of losing bodily fluids, hypohydrated means the subject is presently in a significant fluid deficit. Prior studies have evaluated the amount of fluid loss during exercise at which symptoms of hypohydration occur. Scholars agree that in a hot climate a 2% loss of BW is typically where first signs of hypohydration occur (Brendon et al., 2017; Garth & Burke, 2013; Goulet, 2012; Jeukendrup, Carter & Maughan, 2015; Lopez et al., 2011; O'Connell et al., 2018; Sawka et al., 2007; Shirreffs & Sawka, 2011). Signs and symptoms of hypohydration share numerous similarities with those of a CHO deficit affecting areas regarding mental processes, gastrointestinal and metabolic functions, and performance (Armstrong et al., 2012; Bartlett, Hawley, & Morton, 2014; Brendon et al., 2017; Cermack & van Loon, 2013; Kenefick & Cheuvront, 2012; Lopez et al., 2011; MacLeod & Sunderland, 2012; Sawka et al., 2007; Spriet, 2014; Thomas, Erdman, & Burke, 2016; Volpe, Poule, & Bland, 2009; Walsh et al., 1994). Exploring the shared symptoms of CHO deficiency and hypohydration could allow researchers to expand our knowledge of this relationship. Another relational finding between CHOs and water is that of glycogen's potential to influence cellular osmotic pressure (Philp, Hargreaves, & Barr, 2012). Dietary methods to increase muscle glycogen have been thoroughly evaluated to better understand the optimal CHO intake strategies at various stages of exercise. CHO intake recommendations for female athletes at several different levels of exercise intensity demonstrate the vast amounts of CHOs that high-intensity female athletes require (Burke, Hawley, Wong, & Jeukendrup, 2011). While high-CHO diets have shown to improve muscle glycogen synthesis, it has also been seen that the rate of CHO absorption in the intestine becomes a limiting factor for this process (Jentjens & Jeukendrup, 2003). When comparing the recommended amounts with actual amounts of CHO intake, empirical research has found that 75% of female athletes do not meet their CHO needs (Shriver, Betts, & Wollenberg, 2013).

Understanding the effects that a CHO deficit has on an athlete; research was conducted on the use of CHO-dense sports foods/beverages to enhance hydration maintenance throughout exercise (O’Connell et al., 2018). Relative to consuming water-alone, when consumed 1-4 hours before exercise, sports beverages containing glucose, fructose, or both have led to enhanced hydration maintenance throughout exercise (Burke & Cato, 2015; Jeukendrup, 2010; O’Connell et al., 2018; Thomas, Erdman, & Burke, 2016). Speculations as to why this improvement in hydration maintenance take place include: (1) the present glycogen is spared by the additional exogenous CHOs, thus, overcoming the intestinal absorption rate-limiting factor. Ultimately, this allows for the glycogen to maintain hydration via its aptitude for positively influencing osmotic pressure. (2) The intestinal absorption rate-limiting factor is overcome by short-chain fatty acids being produced during the fermentation process of the provided CHO substrates (O’Connell et al., 2018). Previous research has evaluated acute, or same-day, effects of CHO intake on hydration maintenance in athletes mostly finding increased CHO intake to be beneficial (Balsom et al., 1999; Hawley et al., 1997; Jentjens & Jeukendrup, 2003; Ormsbee, Bach, & Baur, 2014; Thomas, Erdman, & Burke, 2016). However, a gap in research exists regarding CHO’s effects on the following day’s hydration status. Therefore, the purpose of this study is to determine if a relationship exists between CHO intake and the next-day’s hydration status in female collegiate soccer players.

II. REVIEW OF LITERATURE

To comprehensively evaluate the current literature regarding the relationship of CHO intake and hydration, first a specific assessment of each nutritional component will be conducted. Once an understanding of each potential influencing factor is attained, previously studied relationships amongst CHO intake and hydration will be synthesized.

The Effects of Hydration on Performance and Physiological Functions

The increase of metabolic heat during exercise can further the rate at which hydration status declines. This can potentially lead to hypovolemia and possibly induce cardiovascular stress, increased glycogen usage, heightened body/gastrointestinal temperature, and altered metabolic and central nervous system function (Brendon et al., 2017; Kenefick & Cheuvront, 2012; Lopez et al., 2011; Sawka et al., 2007; Volpe, Poule, & Bland, 2009). Hypohydration in exercise may present as decreased performance intensity, decreased rate of recovery, degraded mood, and increased perception of task difficulty (Armstrong et al., 2012; Brendon et al., 2017; MacLeod & Sunderland, 2012; Walsh et al., 1994). Moreover, a hot climate exacerbates the amount of water needed to maintain euhydration during exercise (Kenefick & Cheuvront, 2012; Sawka et al, 2007). Thus, hydration status should be evaluated on an individual basis with consideration of the contributing factors: BW, USG, athlete's perception of hydration/thirst (Figure 1), the environment, and the type of exercise (Kenefick & Cheuvront, 2012; Thomas, Erdman, & Burke, 2016). Acute changes in BW are typically caused by body water displacement, therefore evaluating hydration status by measuring BW upon waking and directly after voiding is one means of measuring hydration status (Figure 1; Kenefick & Cheuvront, 2012; Thomas, Erdman, & Burke, 2016). Sweating is vital to maintaining homeostasis and TGI control during exercise (Lopez et al., 2011; O'Connell et al., 2018; Sawka et al., 2007).

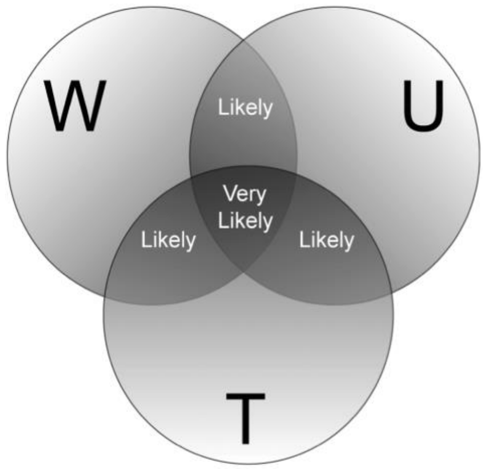

Figure 1. Venn diagram showing the likelihood of dehydration related to certain conditions. Abbreviations: W, weight; U, urine; T, thirst. From Cheuvront and Sawka (2005) (public domain).

Additionally, an altered TGI may adversely affect the rate of glucose absorption. (Jentjens & Jeukendrup, 2003; Lopez et al., 2011; Thomas, Erdman, & Burke, 2016). Water loss occurs from normal metabolic functions and is furthered when sweating (Thomas, Erdman, & Burke, 2016), with metabolic functions in consideration, sweat loss may be predicted by using the difference between pre- and post-exercise BWs (Figure 1; Sawka et al., 2007). Hypohydration symptoms typically becomes evident after an acute loss of ~2% BW while exercising in hot climates (Brendon et al., 2017; Garth & Burke, 2013; Goulet, 2012; Jeukendrup, Carter & Maughan, 2015; Lopez et al., 2011; O'Connell et al., 2018; Sawka et al., 2007; Shirreffs & Sawka, 2011). In cool climates, performance is typically affected more so within the range of 3% to 5% acute BW loss (Sawka et al., 2007; Shirreffs & Sawka, 2011).

Volpe, Poule, and Bland (2009) observed that 28% of female collegiate athletes are hypohydrated when they arrive to practice. With the goal being to prevent more than a 2% BW loss from sweat during exercise, athletes should begin fluid intake 2 to 4 hours prior to exercise and continue until 5-10ml/kgBW is achieved (Goulet, 2012; Sawka et al., 2007; Thomas, Erdman, & Burke, 2016). In spite of recommendations, athletes needing to meet a certain weight, or those given less than 8 hours between fuel demanding exercise in the heat, may start exercises already in a hypohydrated state (Garth & Burke, 2013; Goulet, 2012; Sawka et al., 2007; Shirreffs & Sawka, 2011).

During exercise, sweat output may be 0.3 to 2.4 L per hour contingent upon exercise type, intensity and duration, the athlete's fitness, and the athlete's environmental acclimation (Figure 1; Kenefick & Cheuvront, 2012; Koehle, Cheng, & Sporer, 2014; Mountjoy et al., 2012; Sawka et al., 2007). When alternate variables that may affect BW, such as acute substrate loss during prolonged events, are dismissed, 1 kgBW lost has been attributed to ~1 L sweat/fluid loss (Figure 1; Kenefick & Cheuvront, 2012; Sawka et al., 2007; Thomas, Erdman, & Burke, 2016). For most athletes, fluid consumption at 0.4 to 0.8 L per hour during exercise is enough to maintain performance; however, individualizing hydration plans is optimal as it helps to account for each athlete's specific needs. This may be especially true when calculating the benefits associated with the drinks containing glucose and other nutrients (Burke & Cato, 2015; Jeukendrup, 2010; O'Connell et al., 2018; Philp, Hargreaves, & Barr, 2012; Sawka et al., 2007). Post-exercise, most athletes are dehydrated (Garth & Burke, 2013; Sawka et al., 2007), therefore the hydration goal is to exceed the fluid loss, measured in BW change. A ratio of 1:1.25-1.5 (kg: L) is suggested (Kenefick & Cheuvront, 2012; Sawka et al., 2007). Additionally, it is recommended that athletes consume sodium with the water, doing so at a tolerable rate until the proper previously mentioned fluid amounts are met (Shirreffs & Sawka, 2011).

A hydration status assessment that is more objective than acute change in BW is a process called USG. USG is the analysis of the concentration of solutes in a urine sample (Armstrong et al., 1994; Brendon et al., 2017; Kavouras, 2002; Popowski et al., 2001; Ross & Neely, 1983; Stover et al., 2006; Stuempfle & Drury, 2003; Thomas, Erdman, & Burke, 2016; Volpe, Poule, & Bland, 2009). USG is useful due to its practicality, easily discernable metrics, and ability to accurately assess acute changes in hydration. It is recommended that the sample of USG be collected during the first urine voidance of the day using a midstream urine collection and analyzed through refractometry (Armstrong et al., 1994; Brendon et al., 2017; Casa et al., 2000; Kavouras, 2002; Kenefick & Cheuvront, 2012; Ross & Neely, 1983; Thomas, Erdman, & Burke, 2016). Some studies suggest, however, a spontaneously voided urine collection directly before exercise may also be used (Stuempfle & Drury, 2003; Volpe, Poule, & Bland, 2009), as no differences in USG were found to be caused by variation in time of day or climate (Stover et al., 2006). Cheuvront, Kenefick, and Zambraski dispute the credibility of spontaneous urine collections finding that the added variables of fluid intake, exercise, and food intake may hinder USG accuracy (Cheuvront, Kenefick, & Zambraski, 2015). A USG of <1.020 (Armstrong et al., 1994; Brendon et al., 2017; Kavouras, 2002; Popowski et al., 2001), or perhaps <1.025 to account for individual variability, indicates euhydration (Kenefick & Cheuvront, 2012; Thomas, Erdman, & Burke, 2016). There is no discernible correlation among USG and plasma osmolality, plasma sodium, or hematocrit; suggesting that USG may be more accurate when measuring acute hydration status rather than hematological determinants (Armstrong et al., 1994). Also, USG was not found to be altered by differences in menstrual cycle phases among female collegiate athletes

(Volpe, Poule, & Bland, 2009). USG was not significantly impacted beyond a 3% BW loss (Popowski et al., 2001), albeit, in hot climates, other indicators of hypohydration are already apparent at ~2% (Sawka et al., 2007; Shirreffs & Sawka, 2011). Often associated with fluctuations in plasma osmolality, thirst sense is another notable indicator of the progressing need for fluids (Figure 1; Goulet, 2012). Similar to thirst sense (Figure 1; Goulet, 2012), is "mouth sensing", rinsing the oral cavity with a CHO solution during CHO-restricted exercise may allow for muscle adaptation to take place without performance being hindered (Bartlett, Hawley, & Morton, 2014).

A mindful and accurate incorporation of hydration, diet, and sleep are effective in reducing muscle fatigue and expediting recovery (Nédélec et al., 2013). Muscle cramps typically occur from muscle fatigue, or muscle glycogen stores depleted due to prolonged exercise (Philp, Hargreaves, & Barr, 2012, Sawka et al., 2007; Thomas, Erdman, & Burke, 2016). Glycogen is best known as a muscle substrate; however, glycogen may also be indirectly significant in the regulation of muscle adaptation during exercise (Philp, Hargreaves, & Barr, 2012). Once adapted to exercise, muscle glycogen amounts and localization can alter the surrounding physical, metabolic, and hormonal homeostasis, especially in prolonged bouts of limited exogenous, and especially endogenous, CHO availability (Bartlett, Hawley, & Morton, 2014; Thomas, Erdman, & Burke, 2016). Interestingly, muscle cramps may also be a consequence of hypohydration (Sawka et al., 2007; Thomas, Erdman, & Burke, 2016). Adding milk to a meal with CHOs and protein has been effective in refortifying substrate stores and muscle-damage repair (Jentjens & Jeukendrup, 2003; Nédélec et al., 2013; Thomas, Erdman, and Burke, 2016). Furthermore, hydration may be affected by glycogen depletion, hypoglycemia, and disturbances to acid-base balance (Philp, Hargreaves, & Barr, 2012; Santos et al., 2014; Thomas, Erdman, & Burke, 2016).

The Effects of Available Glycogen on Physiological and Cognitive Processes

Glycogen synthesis, via intake of CHOs, is not only required for physical performance but also for fueling the central nervous system, thus the availability of glycogen is more rapidly diminished during periods of continuous exercise (Thomas, Erdman, & Burke, 2016). While the muscle adaptation does occur in periods of low CHO intake, evidence that suggests it improves performance remains lacking (Bartlett, Hawley, & Morton, 2014). On the contrary, similar to symptoms associated with hypohydration, glycogen depletion shares some commonalities: mental and physical fatigue, decreased levels of sustained exercise intensity, impaired perception of fatigue, decreased motor skills (Bartlett, Hawley, & Morton, 2014; Cermack & van Loon, 2013; Spriet, 2014; Thomas, Erdman, & Burke, 2016), cardiovascular stress, tachycardia, impairments in metabolic function (Brendon et al., 2017; Kenefick & Cheuvront, 2012; Lopez et al., 2011; Sawka et al., 2007; Volpe, Poule, & Bland, 2009), decreased rate of recovery (Brendon et al., 2017; MacLeod & Sunderland, 2012; Walsh et al., 1994), degraded mood, and increased perception of task difficulty (Armstrong et al., 2012). Furthermore, the increased glycogen usage from being in a hypohydrated state (Brendon et al., 2017; Kenefick & Cheuvront, 2012; Lopez et al., 2011; Sawka et al., 2007; Volpe, Poule, & Bland, 2009), and the potential conjoining of decreased cellular osmotic pressure from lack of glycogen (Philp, Hargreaves, & Barr, 2012), could perpetuate the hydration and glycogen deficits. Just from withholding CHOs for several hours (<1.2 gCHO/kgBW/hr) post-exercise, rates of muscle glycogen synthesis may decrease by ~50% (Jentjens & Jeukendrup, 2003). As such it is recommended that athletes participate in training sessions in which high CHO availability is provided so that their performance, health, and CHO oxidation ability is not compromised (Bartlett, Hawley, & Morton, 2015; Jentjens & Jeukendrup, 2003; Nédélec et al. 2013; Thomas, Erdman, & Burke, 2016).

	Situation	Carbohydrate targets	Comments on type and timing of carbohydrate intake
DAILY NEEDS FOR FUEL AND RECOVERY: *these general recommendations should be fine-tuned with individual consideration of total energy needs, specific training needs, and feedback from training performance*			
Light	• Low-intensity or skill-based activities	3–5 g · kg^{-1} of athlete's body mass per day	• Timing of intake may be chosen to promote speedy refuelling, or to provide fuel intake around training sessions in the day. Otherwise, as long as total fuel needs are provided, the pattern of intake may simply be guided by convenience and individual choice • Protein- and nutrient-rich carbohydrate foods or meal combinations will allow the athlete to meet other acute or chronic sports nutrition goals
Moderate	• Moderate exercise programme (i.e. ~1 h · day^{-1})	5–7 g · kg^{-1} · day^{-1}	
High	• Endurance programme (e.g. moderate-to-high intensity exercise of 1–3 h · day^{-1})	6–10 g · kg^{-1} · day^{-1}	
Very high	• Extreme commitment (i.e. moderate-to-high intensity exercise of >4–5 h · day^{-1})	8–12 g · kg^{-1} · day^{-1}	
ACUTE FUELLING STRATEGIES: *these guidelines promote high carbohydrate availability to promote optimal performance in competition or key training sessions*			
General fuelling up	• Preparation for events <90 min exercise	7–12 g · kg^{-1} per 24 h as for daily fuel needs	• Athletes may choose compact carbohydrate-rich sources that are low in fibre/residue and easily consumed to ensure that fuel targets are met, and to meet goals for gut comfort or lighter "racing weight"
Carbohydrate loading	• Preparation for events >90 min of sustained/intermittent exercise	36–48 h of 10–12 g · kg^{-1} body mass per 24 h	
Speedy refuelling	• <8 h recovery between two fuel demanding sessions	1.0–1.2 g · kg^{-1} · h^{-1} for first 4 h then resume daily fuel needs	• There may be benefits in consuming small regular snacks • Compact carbohydrate-rich foods and drinks may help to ensure that fuel targets are met
Pre-event fuelling	• Before exercise >60 min	1–4 g · kg^{-1} consumed 1–4 h before exercise	• The timing, amount, and type of carbohydrate foods and drinks should be chosen to suit the practical needs of the event and individual preferences/experiences • Choices high in fat/protein/fibre may need to be avoided to reduce risk of gastrointestinal issues during the event • Low GI choices may provide a more sustained source of fuel for situations where carbohydrate cannot be consumed during exercise
During brief exercise	• <45 min	Not needed	
During sustained high-intensity exercise	• 45–75 min	Small amounts including mouth rinse	• A range of drinks and sports products can provide easily consumed carbohydrate
During endurance exercise including "stop and start" sports	• 1.0–2.5 h	30–60 g · h^{-1}	• Opportunities to consume foods and drinks vary according to the rules and nature of each sport • A range of everyday dietary choices and specialised sports products ranging in form from liquid to solid may be useful • The athlete should practice to find a refuelling plan that suits their individual goals including hydration needs and gut comfort
During ultra-endurance exercise	• >2.5–3.0 h	Up to 90 g · h^{-1}	• As above • Higher intakes of carbohydrate are associated with better performance • Products providing multiple transportable carbohydrates (glucose:fructose mixtures) will achieve high rates of oxidation of carbohydrate consumed during exercise

Figure 2. Summary of guidelines for carbohydrate intake by athletes. From Burke, Hawley, Wong, & Jeukendrup (2011). (public domain).

Optimal CHO needs for athletes depend upon a multitude of factors including the athlete's total energy requirements, specific training needs, feedback from the exercise, and intensity of exercise (Burke et al., 2011). Athletes exercising 1-3 hours/day at moderate to high-intensity are recommended to receive 6-10gCHO/kgBW/day (Figure 2). If adequate CHO intake is maintained and muscle damage is not extreme, glycogen stores can be rejuvenated with an accompanying 24 hours of reduced training (Burke, Kiens, & Ivy, 2004). Exercises such as soccer promote extreme prolonged muscle fatigue (>90 minutes) and may warrant CHO loading (Figure 2). High amounts of CHO intake may enhance muscle glycogen synthesis (Jentjens & Jeukendrup, 2003), increase glycogen stores, and improve athletic performance (Balsom et al., 1999; Hawley et al., 1997; Ormsbee, Bach, & Baur, 2014; Thomas, Erdman, & Burke, 2016). Acute pre-event CHO intake protocol for exercise >60 minutes consists of 1 to 4 gCHO/kgBW consumed 1 to 4 hours before the exercise, this may further increase body glycogen stores and act as a source of gut glucose during exercise (Burke, Kiens, & Ivy, 2004). Type of CHO may be left to the preference of the athlete as long as the CHO intake needs for the athlete are met (Burke, Kiens, & Ivy, 2004; Burke et al., 2011).

Those who formulate individualized pre-exercise CHO intake plans should also consider nervousness, timing uncertainties, and the athlete's rate of CHO digestion in which a liquid meal supplement may be beneficial (Thomas, Erdman, & Burke, 2016). With these factors in mind, athletes typically benefit most from pre-event CHO intake when the foods contain low-fat, low-fiber, and moderately low protein as these foods are less likely to upset the gut and promote gastric emptying (Nédélec et al., 2013; O'Connell et al., 2018; Rehrer et al., 1992). Furthermore, especially for athletes with predispositions to CHO metabolism, insulin response per individual should be evaluated and reflected upon because a reduction in fat mobilization may occur accompanied by increased CHO use (Ormsbee, Bach, & Baur, 2014). In some athletes, this insulin response has the potential to induce premature fatigue (Foster, Costill, Fink, 1979). Pre-exercise recommendations that may remedy the insulin response include promoting an intake of at least 1gCHO/kgBW to potentially buffer the increased rate of CHO oxidation, stimulating hepatic gluconeogenesis during pre-exercise warm up via several high-intensity movements, and consuming CHOs during the exercise (Coyle, 1991). Furthermore, including certain amino acids and/or protein with the CHOs may enhance the insulin response (Coyle, 1991; Jentjens & Jeukendrup, 2003); which could be the cause for increased muscle glycogen synthesis (Jentjens & Jeukendrup, 2003; Nédélec et al., 2013). Nevertheless, during post-exercise, if CHO intake is consumed at regular intervals and is ≥1.2 gCHO/kgBW per hour, continuing to increase the insulin concentration via additional amino acids and/or proteins will no longer enhance the rate of muscle glycogen synthesis (Jentjens & Jeukendrup, 2003).

While the recommendations are consistent regarding CHO intakes, 75% of female athletes do not consume the recommended amount of CHO, 36% claim to have less than 5 meals/day; and, only 16% monitor hydration status and most regularly skip breakfast (Shriver, Betts, & Wollenberg, 2013). Recognizing individual differences, the intake of CHOs during exercise may benefit athletes by sparing glycogen, providing exogenous muscle substrates, maintaining glycemic equilibrium, and stimulating reward neurotransmitters (Cermak & van Loon, 2013) via processes like “mouth sensing” (Burke & Maughan, 2014). Each of these effects is linked to the timing, amount, and type of CHO (Burke et al., 2011; Stellingwerff & Cox, 2014). Since muscle glycogen synthesis rates are highest when large portions of CHOs are provided (Jentjens & Jeukendrup, 2003), the amount of CHO intake must be proportional to exercise intensity (Figure 2). Timing of intake should also be syncopated with the rate of glycogen resynthesis (~5% per hour) resulting in a recommended ~1 to 1.2 gCHO/kgBW per hour, at 15 minute intervals, in the initial 4 to 6 hours post-exercise (Figure 2; Burke, Kiens, & Ivy, 2004; Jentjens & Jeukendrup, 2003). Finding types of interventions that will prompt the athletes to form better eating habits is vastly important (Shriver, Betts, & Wollenberg, 2013). Factoring in the athlete's individual preferences and experiences, the guidelines represented in Figure 2 must be made practical to be of use in a performance situation (Thomas, Erdman, Burke, 2016). Practical options may include ready-to-eat foods, sports foods (e.g. bars, confectionery, gels), and sports beverages (Burke & Cato, 2015; Jeukendrup, 2010). Sports foods/beverages are beneficial in instances where whole food consumption is difficult, however, the ease of accessibility of these products may lead to their unnecessary use and/or their use in unsuitable amounts (Burke and Cato, 2015).

During post-exercise, non-exercise-related tissue glucose absorption, along with intake of glucose amounts >1 g/min, may cause intestinal glucose absorption to become a rate-limiting factor for muscle glycogen synthesis (Jentjens & Jeukendrup, 2003). To combat this, sports beverages are intended to enhance the total intestinal absorption of CHOs by providing glucose, and perhaps additional fructose (Jeukendrup, 2010; O'Connell et al., 2018). Possibly this may be attributed to the binding capabilities of glycogen positively influencing the osmotic pressure in muscle cells (Philp, Hargreaves, & Barr, 2012). Alternatively, the enhancement of intestinal absorption may be due to the production of short chain fatty acids during the fermentation of CHO substrates (O'Connell et al, 2018). A mixture of glucose with fructose may be more beneficial than water alone (O'Connell et al., 2018; Thomas, Erdman, & Burke, 2016). When given a high amylose maize starch and glucose solutions, soccer players in high-heat training conditions proved to retain fluids better and have lower hematocrit scores than when provided only water (O'Connell et al., 2018). Notwithstanding the evidence supporting the benefits of high CHO intake on performance (Balsom et al., 1999; Hawley et al., 1997; Ormsbee, Bach, & Baur, 2014; Thomas, Erdman, & Burke, 2016), research regarding optimal ingredient proportions in sports foods/beverages and their benefits on performance is considered limited (Garth & Burke, 2013; O'Connell et al., 2018; Thomas, Erdman, Burke, 2016).

Given the current information in the literature regarding hydration status and CHO intake recommendations, the purpose of this investigation was to determine whether CHO intake is related to next-day hydration status in female soccer players. Thus, my hypothesis is that the amount of CHO intake in grams relates to variations in next-day USG.

III. METHODS

Participants

Participants included twenty-four Division I female collegiate soccer players with a mean age of 19.6 (SD=1.15) who were part of the team during preseason summer training camp in August of 2019. The camp was located in the southeastern region of the United States of America. Verbal consent was requested and confirmed by each participant. Athlete information was kept confidential as part of the athlete's medical record. Additionally, collected data was stored in compliance with HIPPA requirements and, upon collection, data was de-identified for the remainder of the study.

Procedures

Dietary assessment

Each athlete kept 24-hour food records for three consecutive days during both weeks of the pre-season camp which were verified by a Board-Certified Specialist in Sports Dietetics. Dietary intake data were collected and analyzed using Nutrition Data System for Research software version 50, (2019) developed by the Nutrition Coordinating Center (NCC), University of Minnesota, Minneapolis, MN (Schakel, 2001). Each athlete's total grams of CHO intake were assessed for each day during the data collection period.

Urine Specific Gravity

Athletes' hydration statuses were assessed using a daily assessment of USG. Each athlete provided a daily, spontaneous urine sample and an Atago PEN-Urine S. G. digital refractometer was used to determine USG. Athletes were deemed hypohydrated if their USG was above 1.020 (Kenefick & Cheuvront, 2012; Thomas, Erdman, & Burke, 2016). It was determined that USG would be affected primarily by the previous day's CHO intake, thus the USG data from the day subsequent to that of each food record was used.

Statistical Analysis

Using SPSS statistical software version 26, a two-tailed Pearson correlation between daily CHO intake in grams and changes in USG.

IV. RESULTS

None of the athletes met their CHO needs on any given day. Analysis of USG values showed, 29% (n=34) of the female collegiate athletes were below a USG of 1.020 (mean USG = 1.024 ± 0.0028), symptomatic of hypohydration; 61% (n=81) of athletes were euhydrated (mean USG = 1.010 ± 0.005); and the team's average USG was 1.014 ± 0.0076 (n=114) (Figure 3).

Pearson correlation analysis indicated no significant relationship between total grams of CHO consumed and USG (r= -0.131, p= 0.177, n= 107) (Figure 4). If an athlete's USG data or CHO intake data was not available, that athlete's data for that day was not used in statistical analysis. One day was eliminated from the study completely due to no USG collections taking place.

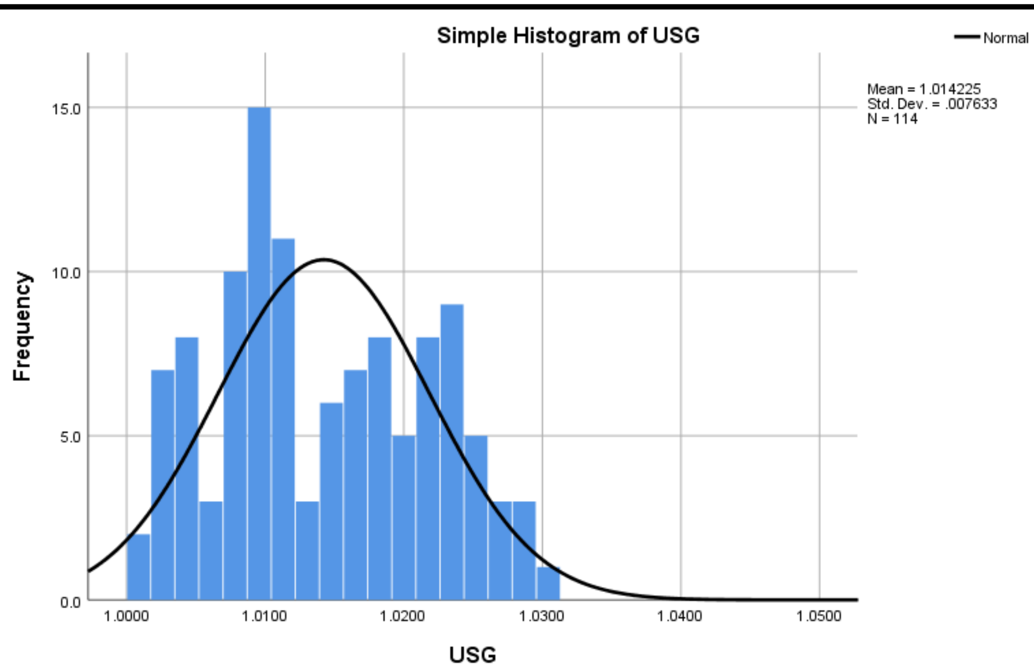

Figure 3. Simple Histogram of USG

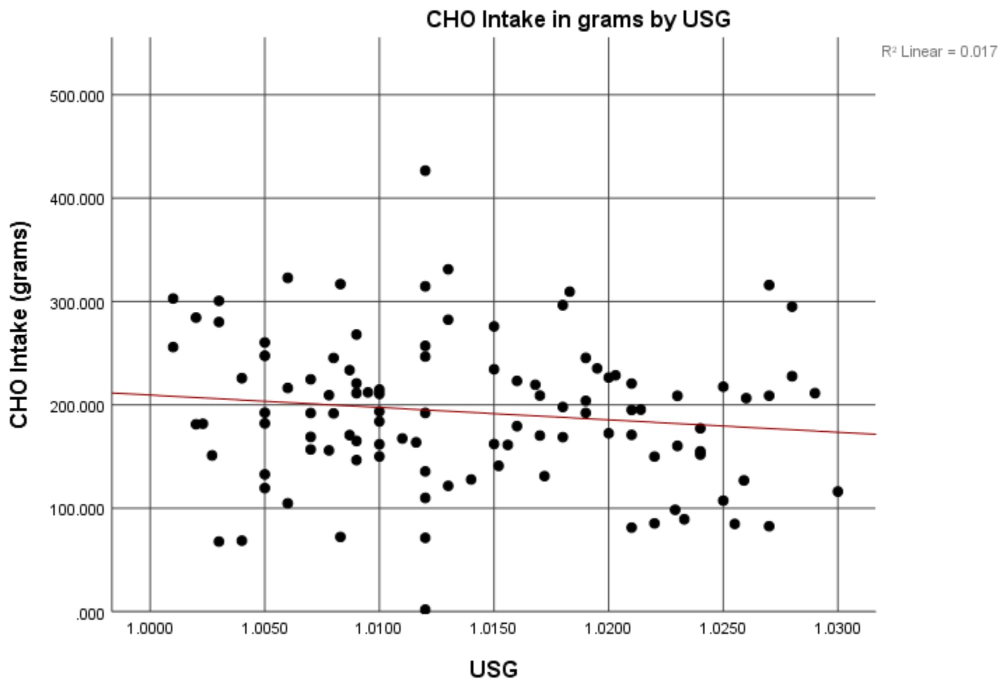

Figure 4. CHO intake in grams by USG.

V. DISCUSSION

The purpose of this study was to determine whether a correlation existed between CHO intake, measured in grams, and next-day hydration status in female NCAA Division I soccer players undergoing pre-season training in a hot climate. Leading to my hypothesis being, the amount of CHO intake in grams relates to variations in next-day USG; H_0: r =0; H_1: r < ±0.05.

In this population, our findings fail to reject the null hypothesis, since total grams of CHO consumed has no significant correlation with next day USG (r =-0.131). Having no athletes meet CHO requirements may have compromised the quality of the study, nonetheless, it displays an apparent low correlation between these two variables. This unexpected result was not unprecedented, along with previous research that suggests 75% of female athletes do not meet CHO requirements (Shriver, Betts, & Wollenberg, 2013), our study implies that this population could benefit from education regarding CHO consumption. During dietary assessments, very few athletes claimed to consume sports beverages, of which contain large quantities of CHOs and are intended to increase intestinal glycogen production (Jeukendrup, 2010; O'Connell et al., 2018). Instead, if the athletes in our study wanted a sports beverage they would rather opt for an electrolyte-based solution, of which contain limited CHOs. Empirical data suggest that CHO-dense solutions may be more beneficial than water alone (O'Connell et al., 2018; Thomas, Erdman, & Burke, 2016). O'Connell et al. (2018) concluded hydration maintenance was improved when male soccer players in hot climates were provided CHO-dense solutions, opposed to when provided only water. With this evidence, it appeared that results of our study would yield similar results, but this is not the case here. Minding the evidence that suggests just

16% of female athletes monitor hydration status (Shriver, Betts, & Wollenberg, 2013), our study resulted in a 29% rate of hypohydration among the female soccer team, corresponding well with the findings of Volpe, Poule, and Bland (2009) who concluded 28% of female collegiate athletes were hypohydrated upon the beginning of exercise. Females have a higher capacity to regulate gastrointestinal temperature (Lopez et al., 2011; Lopez et al., 1994), potentially causing decreased susceptibility to hypohydration (Volpe, Poule, & Bland., 2009). Thus, CHO needs may not need to be met in order to maintain adequate hydration status due to this innate physiological characteristic in women.

Our study hypothesized an association between CHO intake and next-day hydration status due to prior research finding that high CHO intake may improve muscle glycogen synthesis and increase glycogen stores; additionally, glycogen's potential influence over cellular osmotic pressure and enhanced hydration maintenance after provision of CHO-dense beverages (Balsom et al., 1999; Hawley et al., 1997; Jentjens & jeukendrup, 2003; Ormsbee, Bach, & Baur, 2014; Philp, Hargreaves, & Barr, 2012; Thomas, Erdman, & Burke, 2016). Perhaps, however, CHO's effects on water only have a limited window of action. For example, just after several hours, muscle glycogen synthesis can drop by ~50% (Jentjens & Jeukendrup, 2003), therefore, the osmotic pressure of cells would already be compromised in conjunction. Seeing as our study used USG from the day subsequent to that of which CHO intake was recorded, CHOs were already in the body for an extended amount of time, ultimately leading to a decline in cellular osmotic pressure. Additionally, it may be that CHOs only affect hydration status when in their non-storative state. Such is the case, for when CHO-dense sports beverages are provided (O'Connell et al., 2018; Thomas, Erdman, & Burke, 2016). Our study, instead, sought to observe the effects of the athlete's endogenously- stored CHOs, glycogen. To my knowledge, no studies have conducted research regarding previous day CHO intake in comparison with hydration status on the day of exercise. Consequently, our study cannot be compared directly with previous studies and further research is needed to properly assess the parameters of our study.

Application of Results

The unexpected finding that all (n =24) athletes in our study did not meet CHO requirements on any of the 6 days of dietary assessment displays the significant prevalence of inappropriate eating behaviors among this population. So often non-evidenced based sources portray CHOs as the cause of excessive weight, which may lead female athletes concerned with weight gain to avoid them. Furthermore, among female athletes, only 16% report that they monitor hydration status, 36% claim to have less than 5 meals/day, and most regularly skip breakfast (Shriver, Betts, & Wollenberg, 2013). Nutrition education should be made a regular part of training and dismissing non-evidence-based nutrition recommendations should be commonplace. Abood et al. (2004) found by implementing an 8-week education intervention, nutrition knowledge, self-efficacy, and overall dietary improvements are possible among female athletes. Providing athletes with their individualized recommended amounts of CHO intake, and the knowledge to properly estimate their daily CHO intake, could lessen the occurrence of inadequate CHO intake. Athletes should provide feedback on their preferred CHO sources and a fueling strategy should be developed to account for the athlete's preferences and needs alike. This is especially true in team sports, like soccer, in which exercise intensity is varied into intervals of maximal exertion, lower-intensity, and rest (Burke & Hawley, 1997). These interval levels of intensity have been linked to high losses of body water (Burke & Hawley, 1997) and large variations of body water loss between athletes (Shirreffs et al., 2005; Volpe, Poule, & Bland, 2009). While CHO needs being met does not appear to be relative to next day hydration status, this is a test involving pre-exercise CHO intake. Evidence does, however, still support the hydration maintenance in exercise when CHO-dense sports beverages are provided during or directly before to (Burke & Cato, 2015; Jeukendrup, 2010; O'Connell et al., 2018; Thomas, Erdman, & Burke, 2016).

Limitations

Since this study was conducted during the summer pre-season training camp, it is important to consider that perhaps the athletes had not yet reincorporated the dietary habits that they associate with being an in-season collegiate athlete. In other words, the athletes may have still been eating in amounts associated with the decreased levels of activity that accompany their time away from college. This reinforces the notion that this population could benefit from frequent reminders and education regarding CHO needs and fluid intake.

One must also consider a potential limitation being that our study used spontaneous urine collection and therefore may have been subject to extraneous variables such as recent voidance, incorrect collection procedure, and/or recent consumption of CHOs in an uncertain number of athletes. This consideration would lead to a breach in reliability; however, the samples were collected as early in the day as possible and spontaneous urine collection has been seen to be just as valid as first voidance collection (Stover et al., 2006; Stuempfle & Drury, 2003; Volpe, Poule, & Bland, 2009). We used spontaneous urine collection because it was more practical for the athletes and coaching staff, also we assumed we would have more collections via this method, opposed to if we would have relied on the athletes to consistently collect their first urinary voidance each morning. Nevertheless, this was still included as a limitation, because it is not the recommended urine collection method.

Additionally, there are limitations regarding food records among athletes. Food records may vary upon the athlete's willingness to cooperate, attention to detail, ability to record foods at time of consumption, ability to accurately measure food quantities, unintentional alteration of diet towards eating habits perceived as being more favorable, and the researcher's potential misinterpretation of the athlete's measurement when coding food into nutrient analysis software, like NDSR (Larson-Meyer, Woolf, & Burke, 2018).

Conclusions

Within this sample of female NCAA Division I soccer players, no evidence of significant correlation was seen between total grams of CHO consumed and the next day's USG. It may be beneficial for sports nutrition education strategies to focus on CHO's benefits on hydration maintenance in the acute timeframe of 1-4 hours. Certainly, that does not mean to dismiss the encouragement of consuming the recommended amount of CHOs on a daily basis, but now we see that in terms of hydration we may not need to be as concerned about the previous day's CHO intake.

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