Effect of Specific Macronutrients

On Competitive Golf Performance

by

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ABSTRACT

This study aimed to investigate the effects of specific macronutrient feedings on competitive golf performance and perceived levels of fatigue and alertness. Participants played three, nine hole rounds of golf, consuming an isocaloric beverage as a control (CON), with the addition of carbohydrate (CHO), or combination of protein and carbohydrate (COM). Physiological and performance measurements were taken before, during, and following each nine hole round. Performance measurements include driving accuracy (DA), driving distance (DD), iron accuracy (IA), chipping accuracy (CA), and putting accuracy (PA). Pre-golf hydration status (urine specific gravity [USG]) and Sweat Rate during golf performance showed no significant differences between trials. All nine hole rounds were performed in ~2 hours. Environmental conditions were similar for all three testing days (mean WBGT=10.946). No significant differences were seen in Driving Distance, Driving Accuracy, and Iron Accuracy for all nine holes between groups receiving different macronutrient feedings. Chipping Accuracy was significantly better in CON trial compared to CHO (p=0.004) and COM (p=0.019). No significant differences were seen in putting make percentages. COM trial significantly lowered Perceived Levels of Fatigue (p=0.019) compared to CON. The CHO trial showed significant improvements in DA compared to CON (13.7 vs. 44.1, p=0.012) and COM (13.7 vs. 33.6, p=0.004) in the first four holes. In the last five holes, the COM trial showed significant improvements in DA compared to CHO (17.5 vs. 29.7, p=0.007). Low Handicap golfers (3 +/- 3) performed significantly better than High Handicap golfers (14 +/- 3.6) in DD (265 vs. 241, p<0.001), DA (15.0 vs. 29.3, p=0.004), IA (15.2 vs. 25.2, p<0.001), CA (52.0 vs. 61.5, p=0.027), and PA 5ft (64% vs. 40%, p=0.003). High Handicap players showed no significant differences between the three trials for any golf performance measurements. Low Handicap players showed significant improvements in DA for COM trial compared to CON trial (13.6 vs. 27.6, p=0.003). The results suggest that carbohydrates at the start and a combination of carbohydrate and protein is beneficial at the second part of 9 holes to improve golf performance and maintain levels of fatigue, however, it needs to be investigated how this knowledge will relate to playing more holes.

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INTRODUCTION

Overview

In the United States, golf is a popular recreational sport. According to the National Golf Foundation, 33.5 million Americans aged six and older played golf in 2018 and 434 million rounds were played. Historically, golf has been and is still considered a sport that can be played by all athletic abilities. Strength and conditioning and diet have not traditionally been viewed as important factors that could impact performance. With the rise of Tiger Woods in the late 90s and throughout the 2000s, a trend started where golfers began to implement strength and conditioning regimes into their daily routines; studies began to look into the effects of strength and conditioning programs on golf performance (Fletcher and Hartwell, 2004; Doan et al, 2006; Lephart et al, 2007) Because of this, golf coaches have started to examine player's strength and conditioning programs with the purpose to increase club head speed and swing speed; meanwhile the effects of nutrition on golf performance is still undetermined and requires more research.

An 18-hole round of golf will typically take 4.5 hours to play and will cover approximately 8.5 km; during which, a golfer will need to balance a combination of mental, physical, and technical attributes to execute each shot (Smith et al, 2012). Due to the longevity of a round, when walking, golf can be considered an endurance sport; although the golf swing is a very short, powerful movement. While steady state ATP storage can be sufficient to get a player through one swing, the duration of one round which requires 70+ swings along with 100+ swings to warm up and 4+ hours spent walking the course may elicit some macronutrient need that might not be reached through feedings prior to a round. A vast amount of research has taken place to study the importance of feeding and proper fluid intake prior to, during, and following endurance exercises such as cycling and long-distance running (Ivy *et al,* 1979; Wright *et al,* 1991; Nicholas *et al,* 1999; Witard *et al,* 2011; Gibson and Green, 2002; Benton and Nabb, 2003; Ivy *et al*, 2003), yet there is limited research on the importance of nutrient intake and hydration for the game of golf. This may be due to the uniqueness of the sport; requiring both aerobic and anaerobic energy sources. Note that although the duration of a long-distance running can be compared to an 18-hole golf round, the oxidative response cannot. The American College of Sports Medicine has recommendations for endurance athletes which can be loosely applied to golfers during competition: 1) Athletes should start drinking early and at regular intervals in an effort to replace all water lost through sweating (Convertino *et al.,* 2000). This is an important factor that has to be considered in the central and southern Arizona, especially during the summer where temperatures consistently rise above 100F. 2) Fluids are flavoured to enhance palatability and promote fluid replacement. 3) Addition of proper amounts of carbohydrates and/or electrolytes to a fluid replacement solution is recommended for exercise events of duration greater than one hour since it does not significantly impair water delivery to the body and may enhance performance. 4) During intense exercise lasting longer than one hour, it is recommended that carbohydrates be ingested at a rate of 30-60 g/h to maintain oxidation of carbohydrates and delay fatigue (Convertino *et al.,* 2000). While some of these recommendations have been studied in golf performance, for example carbohydrates and/or electrolytes to assist fluid replacement (Stevenson et al, 2009), the recommendation for carbohydrate feedings of 30-60g has not.

An important factor that often gets overlooked in golf is the “mental” game. Bobby Jones, one of the most influential players in golf’s history was quoted “competitive golf is played mainly on a five-and-a-half-inch course, the space between your ears.” There have been a few studies that have assessed levels of alertness, fatigue and stress during a golf round (Mumford *et al,* 2016; Stevenson *et al,* 2009; Jager *et al,* 2007), and whether golf specific fatigue affected club head speed (an important variable closely related to how far the golf ball will travel) and shot consistency (Higdon *et al,* 2012). Findings from these studies suggest there is a need for macronutrient replacement during a round of golf to assist in restoring ATP storage. They were also effective in determining the importance of liquid feedings consisting of either caffeine, carbohydrates, or both on cognitive and motor performance (Stevenson *et al,* 2009). Based on these findings, the current study sought to monitor both motor and cognitive performance in golf. However, the applicability of certain measurements to the importance of lowering one’s golf score can be questioned. Monitoring statistics regarding club head speed, ball speed and total distance (Higdon *et al,* 2012; Ziegenfuss *et al,* 2015) may be appealing to the average golfer and they are increasingly being monitored by PGA Tour players. However, PGA players leading the statistics in these categories often are not the ones at the top of the world rankings. Players with leading statistics in putting accuracy along with scrambling (act of hitting one chip and one putt) and iron accuracy tend to rise to the top of the world rankings. It is important to note that while certain aspects of the game may be regarded as being more important, to be at the top level one must excel in virtually all categories. Most of the studies conducted to date have been lab based (Mumford et al., 2016; Smith et al., 2012; Stevenson et al., 2009), assessing distance and speed; therefore there is a need for field based research assessing multiple aspects of the game of golf. The main drawback of lab based experiments is how relatable they are to real life performance.

Although there is a limited body of research to provide evidence on what nutrients are best to consume on the golf course, there is sufficient research to suggest that there is a need for macronutrient replacement based off total energy expenditure (Zunzer SC *et al,* 2013; Murase Y, Kamei S, Hoshikawa T, 1989). The International Junior Golf Academy (IJGA) published a diet guide specifically for golfers that was developed by Matt Jones, sports nutritionist. It discusses the “6-hole meal plan” in which it prescribes nutrient intake based on what hole the player is on. For example holes 1-6, suggestions are to consume low carbohydrate foods with a low glycemic index which have slow sugar release to assist in sustained energy; examples on what golfers should consume are apples, pears, oranges and berries paired with nuts (Mehring, 2016). In the mid section of a golfers round, food and snacks that help maintain energy levels are needed, mentioning a balance in protein, carbohydrates and fats. In the latter parts of the round, concentration levels typically deteriorate, high carbohydrate snacks assisting in spikes in blood sugar to assist in raising alertness levels (Mehring, 2016). The current study seeks to address some of the measurement gaps, such as driving, iron, chipping, and putting accuracy, and to see if the timings of specific liquid macronutrient feedings play a role in the cognitive and motor functions of competitive golfers.

Purpose of Study

The purpose of this study is to investigate the effects of specific isocaloric macronutrient feedings and a zero kcal reference feeding during simulated competitive round on golf performance. The first aim was to collect further information that will determine which macronutrients a golfer should consume on the golf course and if the timing of specific macronutrients can aid in maintaining golf performance and perceived energy levels. Based on the current literature, a prediction can be made that the feeding group consisting of carbohydrates and proteins would elicit the best performance.

Definition of Key Terms

Alertness. Sensation of being wide awake and attentive.

Chipping. Short shots played around the green with any golf club in the bag. The idea is to get the ball rolling on the green as soon as possible so it rolls like a putt to help judge how far the ball will go.

Drive. Also known as a tee shot, is typically a long distance shot played from the tee box to advance the ball the greatest distance down the fairway.

Fatigue. Tiredness felt from either mental or physical exhaustion.

Iron. Typically a shorter club than a driver and the rest of the woods. Ranging from a 1 iron to a 9 iron, players will often carry 6 irons (4-9) which consist of different lofts and lengths to allow a variance in trajectory and distance.

Putt. A golf shot made on the putting green to cause the ball to roll into or close to the hole

Chapter 2

REVIEW OF LITERATURE

What Golfers Eat Now

What golfers eat on the course varies dramatically. Eating habits not only vary from country to country but they also vary depending on the ability level of the golfer. Another important factor that comes into place when analyzing what golfers eat on the course is the preparation they put in before a competitive round. While the amateur golfer will arrive 30 minutes prior to their tee time and maybe buy some snacks from the beverage/snack cart or pro shop, professional golfers along with their nutritionists look into what could most benefit them at any given time pre, during and post round. Even with nutritional experts assisting them in their meal prep, a professional golfer’s diet still varies from person to person. A wide range of snacks and meals being consumed such as trail mix, fruit, and peanut butter sandwiches, jerky, and popcorn; all of these varying in macronutrient percentages and nutritional content. That being said, while there are few studies that have looked into the effects of macronutrient feeding and golf performance, a number of different endurance and anaerobic sports that can be compared to that of a competitive golf round had to be assessed.

Physiological Responses to Playing Golf

Golf is a sport like none other. The physiological responses to walking 18 holes of golf can be difficult to compare to another sport. It requires the endurance to walk 18 holes which can take up to 4.5 hours and cover 8.5 km; however, the energy and muscular requirements during the golf swing are completely different. Not only does golf have specific motor performance requirements, it also has an intense cognitive side that can separate the best players in the world from the above average. The average heart rate response to an 18 hole round of golf has been measured at 108 beats/min, which corresponded to 38% VO2 max (Murase Y, Kamei S, Hoshikawa T, 1989). Similarly, a golf study looking into the physiological demands of golfers while walking found the average heart rate was 103.5+/-13.2

bpm and the percent of Heat Rate max using similar aged subjects as prior was 55.2+/-7.4 (Gabellieri, 2011). When comparing the physiological demands of golf between sexes and differences between hilly or flat courses, results showed that energy expenditure did not vary between hilly and flat courses (Zunzer SC *et al,* 2013). Relative energy expenditure between sexes showed no significant differences, however male golfers expended significantly greater energy than female players (926 +/- 292 vs. 556 +/- 180kcal)(Zunzer SC *et al,* 2013). The caloric cost of golf is 4-6 kcal/min and total energy expenditure was estimated as more than 960 kcal during 18 holes (Murase Y, Kamei S, Hoshikawa T, 1989).

Carbohydrate and Performance

There is an abundance of research looking into the effects of carbohydrate feedings on sports performance; however the research looking into the effects of carbohydrate feedings on golf performance is minimal. A study looking into the effect of a carbohydrate-caffeine sports drink on golf performance hypothesized that due to the duration of a golf round, homeostasis could be challenged through either hypoglycemia or hypohydration resulting in impaired motor skill or cognitive performance (Stevenson *et al,* 2009). They found that the consumption of 1.6 mg.kg-1 body mass of caffeine and 0.64 g.kg-1 body mass of carbohydrates consumed prior to, and twice during the round on holes 6 and 12, improved both motor performance, measured through 2m and 5m putts, and cognitive performance; self-rated scores of alertness and fatigue (Stevenson *et al,* 2009). Due to the lack of research on the effects of macronutrients on golf performance, a wider search had to take place looking into the effects of specific macronutrients on sports performance more generally. As golf requires both aerobic and anaerobic systems, it was important to research sports that contained similar oxidative responses to not only the golf swing but also the duration of a golf round.

Ingestion of approximately 90g of glucose polymer during the first 90 minutes of exercise in trained cyclists had no effects on total work production or VO2, however, it was effective in reducing the rate of fatigue over the last 30 min (Ivy *et al,* 1979). A study looking into the effects of carbohydrate feedings prior to, during and in combination compared to no carbohydrates found that when carbohydrates were consumed, the rate of carbohydrate oxidation was significantly higher throughout exercise compared to the no carbohydrate feeding group. Total work produced during exercise was 19-46% higher when carbohydrates were consumed. Time to exhaustion was also significantly greater, with the combination of feedings prior to and during exercise eliciting the best results (Wright *et al,* 1991). While these studies looked into trained cyclists, it is important to note that the consumption of carbohydrates prolonged time to exhaustion and prolonged the rate of fatigue. The ACSM position statement on "exercise and fluid replacements" stated that for exercise lasting longer than 1 hour, it is recommended that carbohydrates be ingested at a rate of 30-60 g/h to maintain oxidation of carbohydrates and delay fatigue (Convertino *et al,* 2000). As a golfer's round continues, their physical and mental fatigue increases (Doan *et al,* 2007). If a golfer experiences fatigue in the latter part of their round and carbohydrates has been known to offset or delay the sensation of fatigue in endurance athletes, an assumption can be made that the consumption of carbohydrates during a golf round can extend alertness to minimize motor and cognitive error.

Carbohydrates, along with fats, are the two primary sources of energy oxidized by the skeletal muscle. Which fuel sources are used is mainly dependent on exercise intensity and duration. While an average 18 hole round of golf is 4.5 hours, and intensity is around 40% VO2 max (Murase Y, Kamei S, Hoshikawa T, 1989), the intermittent bouts of intense, anaerobic exercise (the golf swing) require higher levels of muscle glycogen compared to when the golfers are walking between shots. A study looking into the effect of a carbohydrate-electrolyte drink compared to a non-carbohydrate placebo in intermittent high-intensity running on muscle glycogen utilization (MGU) found that MGU was reduced by 22% when compared to the control condition (Nicholas *et al,* 1999). When analyzing blood glucose levels during golf performance, golfers' blood glucose levels dropped anywhere between 10-30%, with the elderly being the latter (Broman *et al,* 2004). This drop in blood glucose has been related to poor decision making which in turn can affect an individual's performance (Brooks *et al,* 2000). In other endurance sports where blood glucose may drop more dramatically than in golf, the decision making requirements may not be quite as important.

Golfers have to assess a number of environmental factors before hitting each shot, for example when putting, a golfer has to determine green speeds, slope, grain, and possibly the high and low points of a golf course that can further affect how the golf ball may roll. If the cognitive performance of a golfer deteriorates, they may forget or misread specific aspects of the golf course that could lead them to taking one or two more shots. Although the oxidation rate may not be as high in golf as it is in other, more intense endurance sports, the consumption of carbohydrates during a golf round is still advised to help offset any symptoms of fatigue (Toms, 2017).

Accuracy of the golf shot is one of the most commonly reported statistics in golf. Fairways in regulation, greens in regulation, and putts per round are the three most reported statistics from the everyday golfer. The effects of macronutrients on accuracy have been investigated in other sports. For example, in a study of rifle shooting performance, researchers compared shooting accuracy pre-exercise (rest), post-exercise hike with a backpack (10.4km with a 21kg pack), and post-run (rock climb and 700m uphill run). What is interesting about this study is the post-backpack hike can be compared to that of carrying a golf bag 36 holes, and the post-run consisted of short sprints, an anaerobic exercise which can be loosely compared to a golf swing. The researchers found that accuracy did not significantly differ between the carbohydrate drink and the placebo and water drink, however, marksmanship accuracy was reduced in the post-backpack hike, which leads to the question of whether the consumption of a carbohydrate drink will affect golf performance. However, all participants after the three testing days were in a caloric deficit, with the water and placebo group being in a greater deficit (Tharion *et al,* 1997). Tharion et al. also noted that the effects of carbohydrate-electrolyte drink and its ability to combat the effects of exercise-induced fatigue on marksmanship should be researched in the future.

Protein and Performance

The Routledge International Handbook of Golf Science states that golfers should aim for approximately 2 g of protein per kg of body mass per day, and this should be split evenly across 4-5 meals, including eating some protein during the round (Toms, 2017). Depending on how much protein a golfer consumes on a regular day, there may be a need to increase the consumption of protein to enhance muscle development (Lemon, 2012) and decrease sensations of fatigue. A study comparing the effects of a milk-protein concentrate to a placebo in experienced weight lifters increased endurance, allowed quicker recovery from fatigue and increased their performance (Dragan *et al*, 1985). While most golfers are not trained weight lifters, the movement and strength used in weight lifting can be compared to that of a golf swing; extremely quick movements requiring a specific technique but also strength and power to carry out the exercise movement. While there is a vast amount of research that has looked into the benefits of consuming protein following endurance performance to aid in muscle recovery and development, there are some potential anabolic effects of pre-exercise protein consumption which could aid performance (Tipton, 2007). As mentioned earlier, the average caloric deficit of a golfer when walking 18 holes is ~960 kcal. With this in mind, the consumption of carbohydrate and protein will help maintain body weight, as well as replenishing glycogen stores, and provide satisfactory amounts of protein to build and repair tissue (Rodriguez, 2009). Along with some of the benefits protein has shown to have on motor performance, additional protein added to an endurance athlete's diet (3g/kg of body mass vs. 1.5g/kg of body mass) showed that this may reduce symptoms of psychological stress (Witard *et al,* 2011).

Carbohydrate/Protein Combination and Performance

After reviewing the past two topics, feedings of mainly carbohydrates or proteins elicit some beneficial outcomes that make these feedings appealing to the trained and untrained endurance and strength training athlete. However, they both have been shown to produce negative side effects that can hinder performance. Carbohydrate-rich, protein-poor meals can be sedating and anxiolytic; protein rich meals may be arousing, improving reaction time but also increasing unfocused vigilance (Gibson and Green, 2002). Gibson and Green go on to state that the consumption of a high carbohydrate meal can increase the amino acid tryptophan/large neutral amino acid ratio which could be responsible for feelings of sleepiness and calm, diminished alertness, and increased fatigue (Gibson and Green, 2002). This ratio, with the assist of additional protein, can be brought to a balance and manipulated through meal composition (Benton and Nabb, 2003). An equal carbohydrate-protein ratio (1:1) has been shown to result in better overall reaction time, cognitive performance, and improved levels of arousal (Fischer, Colombani, Langhans, and Wenk, 2002). Playing golf at a high level demands a player to be calm and relaxed, but also focused. The combination as explained by Gibson and Green could give the golfer the focus they need when performing intricate tasks such as reading a green but will also allow them to stroke the putt freely without any jitter sensations. Studies so far have shown that the consumption of carbohydrates and proteins together may decrease muscle damage to some degree (Valentine *et al,* 2008). A study comparing performance in 8 trained cyclists found that the combination of carbohydrate (0.8g/kg/h) and protein (0.4g/kg/h) compared to 1.2g/kg/h of carbohydrate increase plasma glucose, insulin, and branch chained amino acids, whereas the carbohydrate only group increased glucose and insulin (Rustad *et al,* 2016). A meta-analysis was performed looking into the effects of carbohydrate-protein ingestion on sports performance compared to carbohydrate only and placebo. One of the studies mentioned in this meta-analysis describes comparing the effects of carbohydrate-protein beverage to a carbohydrate only and placebo beverage in trained cyclists. While the percent VO2 in cyclists cannot be compared to golfers, the duration of cycling can help develop some initial hypotheses and ideas on dosage of each of the feedings. In 180 minutes of varied intensities, participants consumed 47 grams of carbohydrates and 12 grams of whey protein (if in carbohydrate/protein group). Results showed that the carbohydrate/protein group rode 36% longer to exhaustion compared with the carbohydrate trial (Ivy *et al*, 2003).

Alertness and Fatigue and Its Effect on Golf Performance

It is well known that golf can be a very mentally draining game, especially at the competitive level. The vast amount of research that has focused on golf performance mainly focuses on the effects of fatigue and what can reduce tiredness and increase perceived levels of alertness. One study sought to establish whether golf related fatigue had an effect on the biomechanics (body position, weight transfer, and pelvis trunk rotation) of the swing, and in turn, could affect the golfers score on a given hole. The results showed that golf related fatigue had a small effect on the intermediate biomechanical aspects of the golf swing (Higdon *et al,* 2012). However, the study did note that there are many other biomechanical aspects to the golf swing that can affect the golf swing that were not studied, so further research is needed. A further study looked to investigate whether elite golfers' putting scaling strategies altered when fatigued (Grealy and Mathers, 2014). Scaling strategies refers to how a golfer produces putts of different distances. The study showed that the number of putts successfully holed decreased due to fatigue and there were significant changes in the scaling strategies used, along with a trend for increasing the putter head velocity at ball impact (Grealy and Mathers, 2014). They went on to conclude that even when putts were successfully holed, there were moderate levels of fatigue influencing the consistency of their performance (Grealy and Mathers, 2014).

Feedings and Alertness/Fatigue

Feedings high in carbohydrate and low in protein can induce feelings of tiredness and decreased alertness. The incorporation of protein into feedings assists in lowering the amount of tryptophan being absorbed into the brain, and therefore less serotonin being synthesised (Gibson and Green, 2002). Gibson and Green hypothesised that the serotonin may be responsible for the feelings of sleepiness and calm and therefore blocking this response would lead to perceived increases in alertness. Studies that specifically looked into feedings and their effects of fatigue on golf performance generally used caffeine or a caffeine-carbohydrate sports drink as their dependent variable. Mumford *et* al assessed golf measurements such as driving accuracy, fairways and greens in regulation along with perceived ratings of energy and alertness. The results showed that total score (76.9 +/- 8.1 vs. 79.4 +/- 9.1, *p*=0.039), greens in regulation (8.6 +/- 3.3 vs. 6.9 +/- 4.6, *p*=0.035), and drive distance (239.9 +/- 33.8 vs. 233.2 +/- 32.4, *p*=0.047) were statistically better during the caffeine condition compared with those during the placebo (Mumford *et al,* 2016). The study also reported more energy (*p*=0.025) and less fatigue (*p*=0.05). A further study using a caffeine-carbohydrate drink compared to a no-energy, flavour matched placebo drink looked into comparing putting performance from two separate distances (2m and 5m). The drinks were consumed prior to the round and on the 6th and 12th hole; they also assessed mood every third hole. Results showed that there were improvements in both 2m and 5m putting success rate with the consumption of the caffeine-carbohydrate drink along with perceived alertness (Stevenson *et al,* 2009).

While there is a large body of research assessing macronutrient feedings and athletic performance from a number of different aerobic and anaerobic sports, there is limited research assessing golf performance. From the golf research that has been done, some general recommendations have been made for the consumption of protein and carbohydrates pre, during, and post round. However, specific consumption timings have not been identified along with the combination of carbohydrate and protein. This study sorts to find whether macronutrient feedings will positively affect golf performance and perceived levels of fatigue/alertness and if these different feedings will have positive effects on golf performance at different times of the round.

Chapter 3

METHODS

The purpose of this study was to examine the effects of specific macronutrient feeding during a competitive round on golf performance. A Latin Square Design was used to examine the effects of specific macronutrient feedings of high carbohydrate and a 50/50 carbohydrate/protein combination compared to a flavoured control. Fantomalt and Protifar produced by Nutricia allowed us to study the effects of an almost entirely carbohydrate liquid feeding and exact 50/50 combination (fantomalt 96g carb per 100g, protifar 87g protein per 100g). In the Latin Square Design, each player was randomly assigned a participant ID. This ID was paired with a specific treatment order. Once all subjects had been given an ID number, the Latin Square Design was used to assure that there were an equal number of subjects in each treatment for every 9 hole round. This was done to account for any sequencing effects that could be seen from subjects' individual improvements (Figure 1). No counterbalancing was used; however, the study design assured that each treatment occurs equally each day. It was planned that each study day would have a minimum split of 7 days to ensure the effects from previous days are washed out; course availability would not permit this. The effects of each level of nutrient intake on driving, iron, chipping, and putting accuracy, and perceived levels of fatigue and alertness will be examined.

Figure 1. *Latin Square Design and random assignment*

Participant	Day 1	Day 2	Day 3
1	1	2	3
2	2	3	1
3	3	1	2
4	1	3	2
5	3	2	1
6	2	1	3
7	2	1	3
8	1	3	2
9	3	2	1
10	2	3	1
11	3	1	2
12	1	2	3
13	3	1	2
14	1	2	3
15	2	3	1
16	3	2	1
17	2	1	3
18	1	3	2
19	1	2	3
20	2	3	1

1 = Control group recieving 0 calorie sports drink
2 = High Carbohydrate drink
3 = 50/50 Carbohydrate/Protein drink

Participants

Participants were males from the Scottsdale, Tempe, or Phoenix area and had a USGA handicap lower than 18. Participant inclusion criteria was limited to males, 14-65 years of age, with a USGA handicap lower than 18 (capable of regularly scoring below 90on an 18 hole round). Participants were excluded if they had any food allergies related to the study, if they smoked, or consumed alcohol 24 hours prior to testing. Informed consent forms from all parents with participants under 18 and informed consent forms from participants who are 18 and over were obtained; assent from those participants under 18 was also required. The research protocol was reviewed and approved by the International Review Board of Arizona State University: STUDY00010405.

Recruitment

A convenience sampling procedure was used. A recruitment survey was sent to local high school athletic directors, coaches, and parents of potentially eligible participants. Meetings were also held with pro/amateurs tours in the Scottsdale/Tempe/Phoenix area along with posters through a number of golf clubs and emails to members of those golf clubs. Emails were also sent to all golf club athletes at Arizona State University. The parents of those recruited in high school were instructed to print and complete screeners and consent forms then scan and email back completed forms; these forms detailed what will be involved in the study and whether their children fall into the correct criteria. All participants over 18 printed and completed screeners and consent forms then scanned and emailed back the completed forms to participate in the study. We attempted to recruit 20 participants for this study; with 3 trials, this assured that each trial could be performed in a random sequence. Each participant took part in three, nine hole rounds of golf and received at least a $15 incentive. To make it competitive, those who finished with the best stats in driving, iron, chipping, and putting received a higher incentive of $25 and those who finished second in each of the four measurements would receive $20. The results were stored separately from the initial study.

Procedures

Initial Screening. The athletic directors and coaches of Scottsdale, Tempe, and Phoenix High Schools were emailed the IRB approved screening questionnaire and consent forms asking for any students that may be eligible for the study. The parents and students were given a four week period to complete the questionnaire and consent form and email it back. Screeners and consent forms were also sent to Arizona State University club golfers along with club members of golf courses in the area. Once the four week period was over, all screeners and consent forms that had been completed were reviewed, and all those that qualified for the study were notified. Prior to the first testing day, all participants were emailed instructions for pre test meals the night prior to, and fasting the morning of the testing day. Participants were asked to arrive a minimum of 45 minutes prior to the first testing day with their full set of clubs with carrying straps. On arrival for the first testing day at Papago Golf Course, the purpose and requirements of the study were explained including a description of all the measurements that would be taken each day of testing. Following this explanation, the participant's height, weight, and weight of their golf bag were taken. There were three measurement days that included three similar series of measurements with different feeding interventions. Urine samples were taken pre before body weight measurement, during (if participants needed to go) and post, again before body weight measurement. The urine samples were weighed and measured for urine specific gravity (USG) to better understand hydration status and fluid balance of the participants on testing days.

Testing Days. It was originally planned for there to be three testing days spread out evenly over 3 weeks (every Sunday) at Papago Golf Course in the City of Phoenix. Due to golf course availability, the three days were completed on the following dates; November 24th, November 30th, and December 1st. The black tees on the back 9 of Papago Golf course were used (See Figure 2 for course scorecard and Figure 3 for hole layouts) for each of the three testing days. Black coloured tee boxes were used for the three testing days; total yards for back 9 was 3612 yards.

Figure 2. Scorecard

	10	11	12	13	14	15	16	17	18	IN	TOT	HCP	NET
PLAYER	525	187	322	402	442	585	442	243	464	3612	7333		
	505	158	304	376	393	545	416	232	441	3370	6771		
	491	146	293	365	360	508	402	214	407	3186	6382		
	18	14	16	6	10	12	2	8	4				
	5	3	4	4	4	5	4	3	4	36	72		
	421	123	293	347	360	483	338	140	337	2842	5777		
	421	123	256	347	318	483	338	140	337	2763	5404		
	4	14	12	6	16	2	8	18	10				

Figure 3. Course Layout

(Top Row from left to right holes 10, 11, 12, 13, 14 Bottom Row from left to right holes 15, 16, 17, 18)

Hole locations were not controlled, as per a regular tournament. The participants were, however, instructed to apply the same strategy to aim directly at the target; this includes for their tee shot or drive, their approach shot, their chip, and their putts. Typically, Fairways in

Regulation and Greens in Regulation are the statistics measured on the professional tours; this statistic informs the player of how many fairways they hit and how many greens they hit. This however does not provide the player with any information on how close to centre they were, or how close to the pin. For this study there was an interest in the displacement in distance from the centre of fairway and hole location. Prior to the test, all the subjects were instructed to consume a pre test meal (dinner night before), and asked to come to the testing days fasted, assuring pre testing procedures remained consistent. The subjects were randomized to a sequential order to receive the three clinical trials. This was done to prevent any sequencing effects that could be seen through gradual improvements in a subject's ability from practice and reduce within-group variances. Each participant received a set caloric intake of between 100-110 calories per feeding containing carbohydrates, or a mixture of protein and carbohydrates. The control treatment would be the only time they will receive zero calories. Each subject completed the three testing days which consisted of (1) a control group that consumed a zero calorie sports drink during the 9 hole competitive round, (2) a high carbohydrate feeding group receiving a 30 gram carbohydrate powder mixed into 355ml zero calorie sports drink administered right before the first tee shot and following the completion of every third hole during the 9 hole competitive round, and (3) a 50/50 carbohydrate/protein feeding group receiving 15 grams of protein powder, 15 grams of carbohydrate powder mixed into 355ml zero calorie sports drink administered right before the first tee shot and following the completion of every third hole during the 9 hole competitive round. Golf performance was measured against these two independent variables and the control group. To control for alcohol, caffeine, caloric intake, participants were asked to complete a questionnaire and record their night meal. The questionnaire highlighted whether participants consumed alcohol and the study protocol stated not to consume alcohol 24h prior to each testing day. Participants were not excluded if they consumed alcohol, therefore this was not fully controlled. By recording their nightly meal and asking participants to consume a similar meal prior to each test day, we were attempting to control their caloric and macronutrient intake 12h prior. Times were recorded when wind speeds exceed 10mph and the data collected during these times were excluded. Environmental descriptives are broken up per test day.

Measures

Golf performance was measured with 6 tests that included driving distance, driving, iron, chipping, and putting accuracy and perceived levels of alertness and fatigue.

Demographics. The initial data collected included age, sex, year in high school (if applicable), golf handicap, height and weight, any food allergies the participants may have, alcohol and drinking habits. Their hydration status and sweat rate were calculated by taking urine samples pre, during, and post along with weight and height. Weight was measured prior to and following each of the 9 hole test days.

Driving Accuracy. Driving Accuracy (DA) was used to measure shot deviation, left or right, from the center of the fairway. For fairways that are dog legs (curve left or right), center was assumed to follow the shape of the hole allowing equal distance left and right of the fairway. The center of the fairway will be defined by a yellow rope and is outlined by the longer grass which surrounds the fairway. Distance of the drive was measured to compare to other studies. Subjects were asked to use their driver on every par 4 and 5, which is generally defined by the longest club in the bag with the largest clubface. At Papago Golf course, the back nine consists of two par 5's, five par 4's, and two par 3's, therefore the driver was used seven times each day. The results recorded consisted of how far from the centre of the fairway the participants hit their ball by using an extended measuring tape/range finder and how far they hit the ball from the tee. A TACKLIFE rangefinder (Laser Range Finder 900 yard-MLR01) will be used to ensure accuracy of measurements that extend farther than the measuring tape (Gergley et al, 2009). Time, convenience, and outdoor conditions were considered when choosing the correct measurements. After each week of testing, individual averages in distance from the centre of the fairway were calculated; following the three test days, medians and interquartile ranges were calculated to compare between and within group differences per hole and per round.

***Iron Accuracy*.** Iron Accuracy (IA) was used to assess shot deviation, left, right, short and long, of a randomized pin location. Subjects hit the club of their choosing from distances of 165 yards; the club selection may vary due to elevation change and wind direction although any data where wind speeds exceed the limit will be excluded. A distance of 165 yards led to participants using between a 9 and 6 iron, similar to most experienced male golfers as the size and ability of the player can vary club selection. Although green size average on the PGA Tour is roughly 6000 square feet, green in regulation was not recorded as the focus was on distance from the pin. As stated before, participants were instructed to aim directly at the target. Often in competitive rounds, players will favour a side of the hole to allow them the best chance to convert the putt; as players will not be completing the hole, this will not matter. The pin will be randomly located each day to simulate tournament conditions. The results recorded were distance measured from the pin, regardless if the ball was on the green, using a measuring tape (Komelon SL2825 Self Lock 25-Foot Power Tape) or a TACKLIFE rangefinder for those distances that are outside of the measuring tape parameters. Measuring tapes were laid flat on the grass from the front of the cup to the front of the ball. After each week, the subject's average distance from the pin was calculated and following the three days of testing, medians and interquartile ranges of each trial were compared.

***Chipping Accuracy*.** Chipping Accuracy (CA) tested how close the participant can hit the ball to the hole location from a predetermined location 3 yards off the green. As there are a number of clubs that could be used around the green for chipping, the subjects were told to use a club of their choosing; this best simulates what would occur in a competitive round. When choosing a chipping location, a flat and straight surface would allow the results throughout the nine holes to be compared to one another and control for any environmental factors such as slope. A stimpmeter was used to measure green speeds to assure consistency throughout the weeks of testing. A measurement (inches) from the front of the cup to the front of the ball was taken using a measuring tape laid flat on the grass. Following the completion of 9 holes, each subject's average distance from the hole was calculated. Once the three days of testing had been completed, median and interquartile ranges of each trial were compared.

Putting Accuracy. Putting Accuracy (PA) was measured by the percentage of putts each participant made from three designated distances (5ft, 10 ft, and 15ft). These distances were chosen to assess three different lengths of putts; short, medium, and long. Each subject used their putter and completed these three putts on each hole of the nine holes in order from shortest to longest. An attempt was made to make each putt straight and flat, making it easier to determine that the player missed due to their putting stroke (performance) rather than misreading the green (controlling for confounding variables). Again a stimpmeter was used to assess each of the green speeds throughout the three testing days. Following each testing day, nine putts from 5, 10, and 15ft were collected per participant, and a make percentage of each distance was calculated for each subject participating in the three trials. Once the three study days had been completed, median and interquartile ranges of each trial were compared.

Perceived Levels of Alertness and Fatigue. An adapted two-item visual analogue scale questionnaire was used to measure self-perceived levels of alertness (PLA) and self-perceived levels of fatigue (PLF) (Mumford et al, 2016). A horizontal scale from 0-10 was used, where 0 and 10 were anchored; 0 being labelled "very low" alertness and fatigue, 10 being labelled "very high". Each participant was measured prior to their drives on each hole. Participants were instructed to mark a vertical line through the horizontal scale on how they felt in that moment (Mumford et al, 2016). By instructing participants to score a vertical line rather than a numeric scale, the participants could make no comparisons to previous scores; by asking them to score how they felt in the moment, variances could be seen from hole to hole.

Green Speeds. Green speeds were measured with the use of a stimpmeter. A stimpmeter measures the speed of a green by applying a known force to the golf ball and measuring the distance the ball rolls. It is a 36-inch grooved aluminium bar. A notch in the groove is used to support a ball until one end is lifted to an angle of 20 degrees. The distance the ball rolled is measured and repeated twice more going in the same direction. This was then done in the opposite direction to assure a flat surface was used for the measurement.

Wind Speeds. An anemometer was used to measure wind speed. Wind speeds were recorded every minute throughout the study and the study team received notifications any time wind exceeded the limit (10mph). If they did, data collected during these times were excluded.

Hydration Status. Acute hydration status measured as sweat rate will be calculated using difference in pre and post body mass, accounting for any liquid consumption and urine excretion. An adaptation of the formula used by McDermott et al. (2017) calculated sweat rate: sweat rate (ml/h) = (pre exercise body mass – post exercise body mass + fluid intake – urine output) / exercise duration. To measure chronic hydration status (i.e. hydration status reflecting the last 24-hour), participants will provide an "all out" urine void pre- and post-test on each of the testing days as well as the informational meeting. USG measurements as well as osmolality will be conducted in all the urine samples; a 30ml sample at standard room temperature (20°C) (PEN-refractometer, ATAGO, Tokyo, Japan). USG values exceeding 1.020 g/ml is considered hypohydrated (McDermott et al., 2017).

Statistical Analysis

A visual inspection of histograms was conducted to test for normal distribution and outliers along with the Shapiro Wilks test (chosen because the sample size was less than 30). Following this, the planned repeated measures ANOVA statistical analysis had to be replaced with Friedman and Wilcoxon signed rank test. Therefore data will be represented in Median and Interquartile Ranges. A correlation coefficient will be used to examine the size and the direction of the relationship between the variables. Eta-Squared was calculated to examine effect size between all 3 trials (small=0.01-<0.08, medium=0.08-0.26, large=>0.26). Effect sizes comparing two feedings were based on Wilcoxon Signed rank test where $r = \frac{Z}{\sqrt{N}}$;0.1-<0.3 represents small effect size, 0.3-<0.5 represents medium effect size, and >0.5 represents a large effect size. *P*-value was set at ≤0.05 for all statistical tests. The data was analyzed using the SPSS Statistics 26 (IBM Corp. Released 2018. IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp.).

Chapter 4

RESULTS

The purpose of this study was to examine the effects of specific isocaloric macronutrient feedings on competitive golf performance. The three feedings consisted of; a control (CON) 330ml 0 calorie Gatorade drink, a carbohydrate (CHO) 30g of carbohydrate powder mixed with 330ml 0 calorie Gatorade drink, and a carbohydrate/protein combination (COM) 15g of carbohydrate powder with 15g of protein powder mixed with 330ml 0 calories Gatorade drink. Primary measured dependent variables include: Driving Accuracy (DA) yards, Driving Distance (DD) yards, Iron Accuracy (IA) yards, Chipping accuracy (CA) inches, Putting Accuracy (5ft, 10ft, 15ft), and perceived levels of fatigue and alertness using an adopted analogue scale. Secondary individual outcomes measured include Sweat Rate and Hydration Status (USG).

Subject and Environmental Descriptives

Fourteen participants (all male) were expected for the first day of the study, but only ten participated on the first day. Following the next two days, a further four participants dropped out due to not showing up or injuries received at home, meaning six completed all three rounds. For the purpose of this study, participants included in the final statistical analysis had complete data; descriptives can be seen in Table 1 (6 male; mean age 23.8 +/- 4.45). However, due to last minute cancellations and no shows, the order in which the participants consumed their feedings throughout the three days maintained the same; the table below depicts the participants ID along with the order in which they consumed the macronutrient feedings. This was based on the Latin Square Design described above.

Figure 4. *(Latin Square Design remaining participants)*

Participant	Day 1	Day 2	Day 3
4	1	3	2
5	3	2	1
6	2	1	3
7	2	1	3
9	3	2	1
10	2	3	1

1 = CON
2 = CHO
3 = COM

Table 1. *Participant Descriptives during CON, CHO, and COM trial*

	CON	CHO	COM
Subjects	6	6	6
Subject Age (y)	23.8 [4.45]	23.8 [4.45]	23.8 [4.45]
Handicap	8.5 [6.72]	8.5 [6.72]	8.5 [6.72]
Weight (kg)	81.5 [11.86]	81.1 [12.44]	81.4 [11.94]
Golf Bag Weight (kg)	12.6 [0.98]	12.4 [0.90]	12.4 [1.25]

Values are expressed as means [SD]. Handicap based of USGA home club.

The original dates were scheduled one week apart but due to Golf Course availability, one of the dates had to be moved, and therefore the week split was not seen from Day 2 to Day 3. Golf bag weight was measured each day to account for any differences in carrying weight; CON (12.6 +/- 0.98), CHO (12.4 +/- 0.90), COM (12.4 +/- 1.25).

There was no statistical significance between trials for USG or Sweat Rate. Although the USG median is lower in the COM (1.0205) trial compared to CON (1.0210) and CHO (1.0227), there were a higher percentage of individuals considered to be hydrated (<1.02 USG) in CON. Participants' Sweat Rate are expressed as positive (M=0.189 L/h) meaning post body weight and fluid intake were greater than pre body mass and urine output. Although all 3 feedings had a positive Sweat Rate, temperatures were low (M=12.1°C) for Phoenix during the time in which data was collected. Environmental conditions remained fairly consistent throughout the three days (Table 3). Wind speeds did not exceed the max set prior to the study (<10mph). Greens speeds did not differ significantly between the three days.

Table 2. *USG and Sweat Rate for CON, CHO, and COM trial*

	CON	CHO	COM	*p*
USG	1.0210 (1.0180-1.0253)	1.0227 (1.0200-1.0266)	1.0205 (1.0120-1.0235)	0.438
Sweat Rate (L/h)	0.172 (0.122-0.254)	0.175 (0.094-0.227)	0.221 (0.137-0.309)	0.607

Values are expressed at Median (25^{th}-75^{th} percentile)

Table 3. *Environmental Descriptives for each trial day*

	Day 1 (11/24/2019)	Day 2 (11/30/2019)	Day 3 (12/01/2019)
Temperature (C)	14.1 [2.40]	9.1 [1.95]	13.1 [3.07]
Wind Speed (mph)	0.4 [0.57]	2.0 [0.91]	0.5 [0.60]
Relative Humidity (%)	59.0 [9.92]	69.8 [7.71]	48.3 [10.28]
Stimpmeter (ft)	10	10.5	10.5

Values are expressed as means [SD]. Environmental measures were taken from the start of the first golfers' tee shot to the final golfers' putt. Note on the final day there was an hour delay due to frost.

Golf Performance Variables

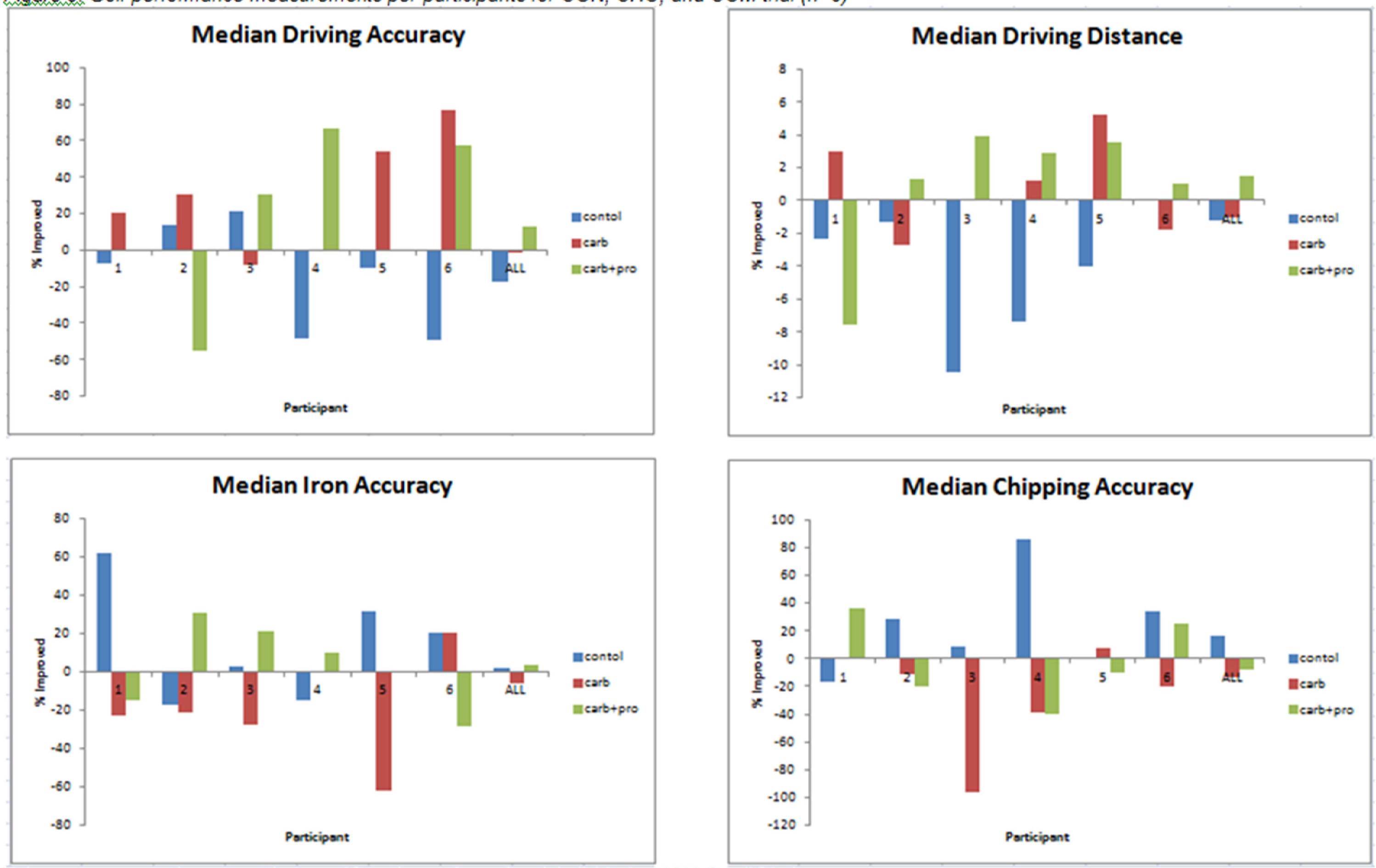
Between CON, CHO, and COM, there was no significant difference in Driving Distance, Driving Accuracy, Iron Accuracy and Chipping Accuracy respectively (p>0.05) (Table 4). While no significant improvements were seen in these measurements, the COM trial was statistically lower in DD, DA, and IA compared to CON and CHO (Table 4). Even though the results assessing the entire nine holes may not be significant, a trend can be seen in which the feedings are having a positive effect. CA (inches) was significantly better in the CON trial compared to CHO (p=0.004) and COM (p=0.019) trials. This may be due to more participants partaking in the control trial on the third day leading to some familiarization on green speeds, firmness, and slope. Specifically, the two best players in the study took part in the control trial on the third day. After removing these players from the data set, there were no significant differences seen in CA (p=0.216). Additionally, when data was assessed from the first day including all 10 participants (n=3 CON, n=3 CHO, and n=4 COM) no differences were seen between COM trial and CON trial for CA and significant improvements in CA were seen in the COM trial compared to CHO (p=0.028*)*. This suggests that if participation numbers were maintained throughout the three days, the COM trial may have produced improvements in CA as well. Although the Latin Square Design helped to control for randomization and familiarization, due to unexpected absences and drop outs, the number of participants partaking in each feeding per day could not be fully controlled. DD, DA, IA, and CA graphs can be seen below split by individual. When analyzing Putting Accuracy (PA), the percentage of putts made can be reported from the three measured distances (5ft, 10ft, and 15ft). There was no significant difference between CON, CHO, and COM from 5ft (50%, 56%, and 50%, p=0.779), 10ft (31%, 20%, and 33%, p=0.250), and 15ft (17%, 13%, and 20%, p=0.607), respectively. Again, while there was no significant difference between the three feedings, the COM trial showed a tendency to perform better at 10 ft and 15 ft, with the CHO trial performing better at 5 ft. Individual improvements per feeding show that the intervention feedings of CHO and COM have a positive effect on Driving Accuracy and Driving Distance (Figure 5) for all nine holes.

Table 4. *Golf Performance measurements for CON, CHO, and COM trials (median and IQR)*

	CON	CHO	COM	
	Mdn (25th-75th)	Mdn (25th-75th)	Mdn (25th-75th)	*p*
Driving Distance (yards)	251.5 (221.0-274.0)	252.0 (230.0-277.5)	258.4 (230.0-277.3)	0.807
Driving Accuracy (yards)	30.8 (13.5-46.0)	25.6 (11.9-32.2)	22.7 (11.8-38.0)	0.109
Iron Accuracy (yards)	18.4 (8.95-28.65)	20.0 (12.38-36.00)	18.1 (13.00-25.45)	0.185
Chipping Accuracy (inches)	48.3 (29.69-68.88)	65.0 (35.63-119.00)	61.6 (31.44-119.25)	0.065
Putting Accuracy (5ft)	50%	56%	50%	0.779
Putting Accuracy (10ft)	31%	20%	33%	0.25
Putting Accuracy (15ft)	17%	13%	20%	0.607

Values are expressed as Medians (25^{th} percentile-75^{th} percentile). Putting Accuracy values expressed as putts made percentage. *P* values from post hoc analysis using Friedman comparing all three groups.

Figure 5. *Golf performance measurements per participants for CON, CHO, and COM trial (n=6)*

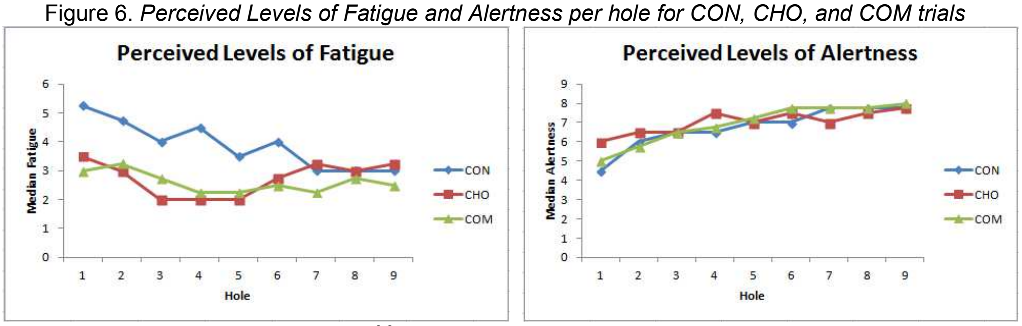


Values are expressed as percent improved from the medians of each individual and ALL for all 9 holes.
DA, IA, and CA, improved = more accurate (closer to hole/centre of fairway). DD, improved = longer drive.

Perceived Fatigue and Alertness

Perceived level of fatigue was significantly lower in COM, 2.5 (0.75-3.63), compared to CHO, 3.0 (1.50-4.25) (*p*=0.046), and CON, 4.0 (2.88-6.50) (*p*<0.001). Perceived level of fatigue was also significantly lower in CHO compared to CON (*p*=0.014). PLA did not significantly differ between CON 7.0 (5.75-8.00), CHO 7.0 (6.00-8.50), and COM 7.5 (5.00-9.00) trials (*p*=0.252) (Table 5 and Figure 6).

Figure 6. *Perceived Levels of Fatigue and Alertness per hole for CON, CHO, and COM trials*



Median levels of fatigue and alertness throughout nine holes.

Table 5. *Perceived Levels of Fatigue and Alertness for CON, CHO, and COM trials*

	CON	CHO	COM	
	Mdn (25th-75th)	Mdn (25th-75th)	Mdn (25th-75th)	*p*
Perceived Level of Fatigue	4 (2.88-6.50)	3 (1.50-4.25)	2.5 (0.75-3.63)	0.019
Perceived Level of Alertness	7 (5.75-8.00)	7 (6.00-8.50)	7.5 (5.00-9.00)	0.252

Values are expressed as Median (25^{th} percentile-75^{th} percentile).

Results broken down for holes

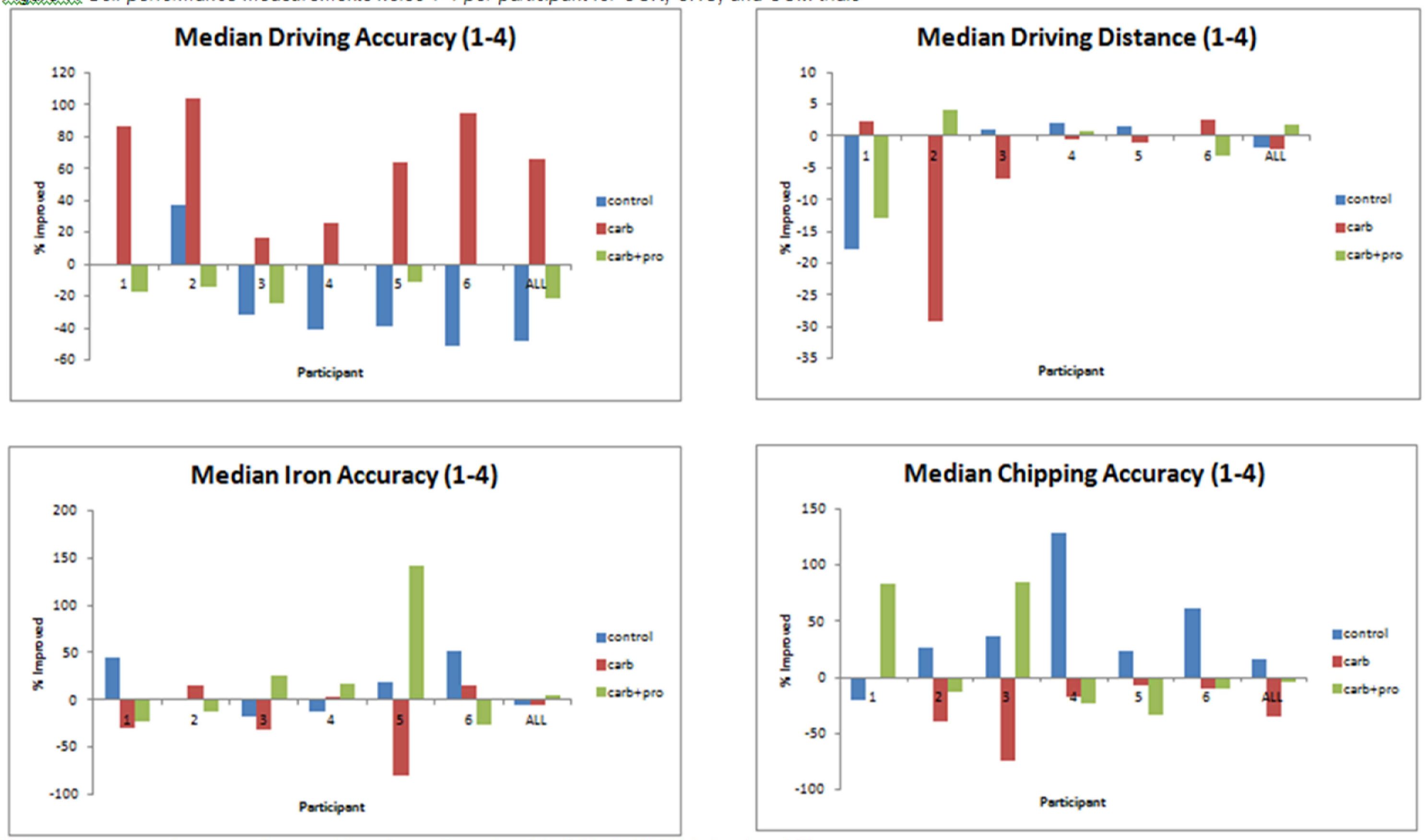
In the course of the data analysis, a difference was observed in PLF, splitting the analysis comparing holes 1-4 between CON and the other two feedings and on holes 5-9 between CHO and COM. Therefore, an additional analysis was conducted stratifying by portion of round. On holes 1-4, DA improved significantly in the CHO trial (13.7, 10.00-26.40) compared to both the CON trial (44.1, 21.85-50.03, *p*=0.012) and COM trial (33.6, 13.53-48.88, *p*=0.004) trial. This was based on post-hoc analyses using the Wilcoxon signed rank test. No significant differences were seen in DD and IA, differences in CA have been explained (Table 6 and Figure 7). Medium to large (0.3-<0.5) effect sizes were seen between CHO and CON (r=0.42), and CHO and COM (r=0.48). While DA improved significantly in the CHO trial compared to the other two trials, CA was significantly higher in CON trial (50.9, 29.06-78.63) compared to the CHO trial (85.0, 56.88-154.38, *p*=0.007) but not compared to the COM trial (62.3, 28.13-125.38, p=0.175). No differences were seen in putting performance from 5ft, 10ft, or 15ft (Table 6). PLF was significantly lower in both the CHO trial (2.5, 1.5-5.0, p=0.014) and COM trial (2.8, 0.3-4.8, p=0.006) compared to CON trial (4.0, 3.0-6.5) trial. No significant differences were seen between the three trials in PLA (Table 6).

Table 6. *Golf performance measurements and perceived levels of fatigue and alertness holes 1-4 for CON, CHO, and COM trials*

Holes 1-4				
	CON	CHO	COM	
	Mdn (25th-75th)	Mdn (25th-75th)	Mdn (25th-75th)	*p*
Driving Distance (yards)	251 (220.75-269.75)	250 (229.00-270.00)	260 (229.75-268.00)	0.678
Driving Accuracy (yards)	44.1 (21.85-50.03)	13.7 (10.00-26.40)	33.6 (13.53-48.88)	0.006
Iron Accuracy (yards)	19.6 (7.75-36.40)	19.5 (13.03-30.80)	17.7 (11.65-27.88)	0.582
Chipping Accuracy (inches)	50.9 (29.06-78.63)	85.0 (56.88-154.38)	62.3 (28.13-125.38)	0.167
Putting Accuracy (5ft)	58%	63%	50%	0.627
Putting Accuracy (10ft)	25%	13%	25%	0.325
Putting Accuracy (15ft)	17%	17%	13%	0.895
Perceived Level of Fatigue	4.0 (3.0-6.5)	2.5 (1.5-5.0)	2.8 (0.3-4.8)	0.163
Perceived Level of Alertness	6.0 (4.0-7.4)	7.0 (4.0-8.5)	6.5 (3.3-9.0)	0.326

Values are expressed as Medians (25^{th} percentile-75^{th} percentile). Putting Accuracy values expressed as putts made percentage. *P* values from post hoc analysis using Friedman comparing all three groups.

Figure 7. Golf performance measurements holes 1-4 per participant for CON, CHO, and COM trials



Values are expressed as percent improved from the medians of each individual with ALL being the addition.
DA, IA, and CA, improved = more accurate (closer to hole/centre of fairway). DD, improved = longer drive.

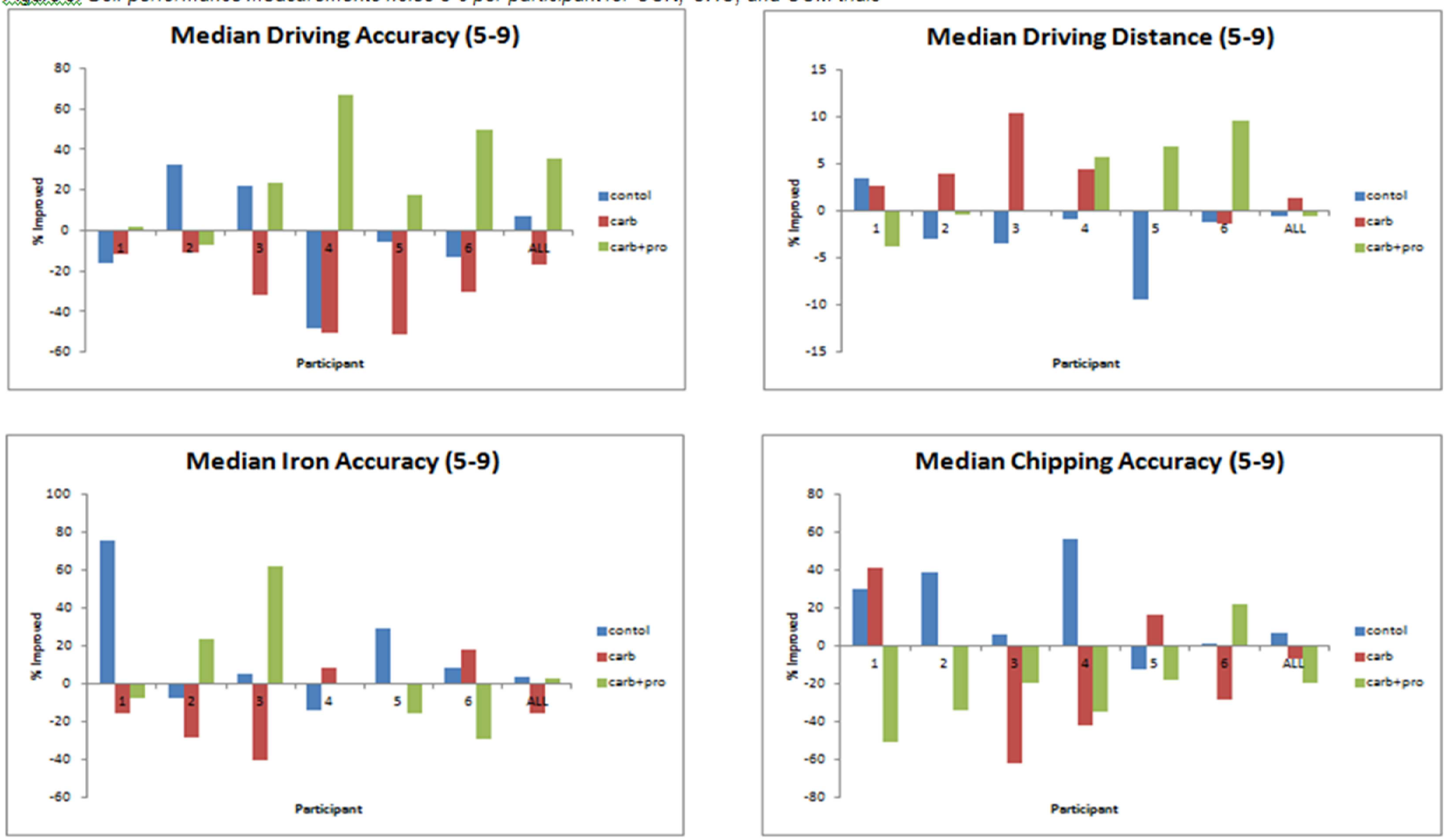
After running statistical analysis on holes 5-9 using Friedman and Wilcoxon ranked tests, DA again was positively affected by the feedings. While no significant findings were found between the three feedings, a trend could be seen with the positive effects of feedings on Driving Accuracy (Figure 8), therefore Wilcoxon signed ranked test was used to determine any differences between two feedings. Results showed significant improvements in COM trial (17.5, 8.58-27.90) trial compared to CHO trial (29.7, 15.05-37.00, p=0.007) but interestingly not significant compared to CON trial (23.4, 10.85-36.60, p=0.076). There were no significant differences in trials for DD and IA (Table 7). A medium to large effect size was seen between COM and CHO (r=0.39). Although the CHO trial significantly improved DA holes 1-4, the same effect was not seen in holes 5-9; however with the addition of protein (COM), DA saw significant improvements. Eta-Squared was calculated to examine effect size between all 3 trials (small=0.01-<0.08, medium=0.08-0.26, large=>0.26). This helps determine how big an effect was seen in feedings regardless of sample size in golf measurements where significance was seen. Driving Accuracy for the first four holes showed a medium to large effect size (n2=0.21). DA for the last five holes showed a small to medium effect size (n2=0.08). Similar to the previous findings for holes 1-4 and all holes, CA was significantly better in the CON trial (47.3, 30.38-60.88) compared to COM trial (61.6, 32.56-118.25, p=0.050). Significance was not seen between CON and CHO trial (54.3, 15.19-91.13, p=0.159). While there were again no differences between the three trials in PLA, (p=0.843), PLF was significantly lower in the COM trial compared to both the CON trial (p=0.004) and CHO (p=0.021) (Table 7). Visually, the graphs show improvements in DA and DD with the CHO and COM feedings, while again CA remained the best in the CON trial.

Table 7. *Golf performance measurements and perceived levels of fatigue and alertness holes 5-9 for CON, CHO, and COM trials*

Holes 5-9	CON	CHO	COM	
	Mdn (25th-75th)	Mdn (25th-75th)	Mdn (25th-75th)	*p*
Driving Distance (yards)	252 (221.5-280.0)	257 (232.8-292.0)	252 (231.75-298.25)	0.453
Driving Accuracy (yards)	23.4 (10.85-36.60)	29.7 (15.05-37.00)	17.5 (8.58-27.90)	0.135
Iron Accuracy (yards)	18.1 (9.40-28.13)	21.9 (11.50-36.50)	18.3 (13.23-24.33)	0.301
Chipping Accuracy (inches)	47.3 (30.38-60.88)	54.3 (15.19-91.13)	61.6 (32.56-118.25)	0.238
Putting Accuracy (5ft)	47%	50%	50%	0.951
Putting Accuracy (10ft)	40%	27%	40%	0.467
Putting Accuracy (15ft)	17%	10%	27%	0.282
Perceived Level of Fatigue	3.0 (1.88-4.50)	3.0 (1.88-4.00)	2.5 (0.75-3.00)	0.044
Perceived Level of Alertness	7.5 (7.00-8.00)	7.3 (7.00-8.50)	7.8 (7.00-9.00)	0.843

Values are expressed as Medians (25^{th} percentile-75^{th} percentile). Putting Accuracy values expressed as putts made percentage. *P* values from post hoc analysis using Friedman comparing all three groups.

Figure 8. *Golf performance measurements holes 5-9 per participant for CON, CHO, and COM trials*



Values are expressed as percent improved from the medians of each individual with ALL being the addition.
DA, IA, and CA, improved = more accurate (closer to hole/centre of fairway). DD, improved = longer drive.

Breakdown of Handicaps

In the study protocol, participants were required to have a USGA handicap of 18 or below. This handicap was chosen to aid in recruitment of a diverse range of golfers but also to assure consistency and automation of the golf swing. However, while comparing the six participants, three would be considered to have low handicaps 3 +/- 3 and three to have high handicaps 14 +/- 3.6. Therefore data was split for high versus low handicap and then compared. Computing coefficient of variation per individual, variation was higher than expected for accuracy measurements but was good for distance. This suggests that maintaining distance for all levels of golfer is more feasible than to maintain accuracy. There was no significant difference in variation between Low Handicap and High Handicap. Another reason for breaking down the data between high and low handicaps is because of the Latin Square design which led to two players with the lowest handicaps competing in the CON trial on the third day. As these players are more experienced, their ability to adjust to the physical aspects of the green such as speed, firmness, slope, and grain will be quicker. For example, a high handicapped player who is either a beginner with no experience or experienced but not as skilled will take longer to learn how the ball reacts to the playing surfaces. A low handicap player is more likely to learn and adapt to the conditions.

As expected, Low Handicap performed significantly better than High Handicap (Table 9). While this finding was not surprising, it does aid in the discussion of what golf measurements should be taken to help determine if someone has improved as a golfer. Effect size for the significant differences between Low Handicap and High Handicap can be seen in Table 8. Effect sizes were based on the Wilcoxon Signed rank test where 0.1-<0.3 represents small effect size, 0.3-<0.5 represents medium effect size, and >0.5 represents a large effect size.

Table 8. *Effect Size Low Handicap vs. High Handicap*

Low Handicap vs. High Handicap Effect size	
Golf Measurements	r
Driving Distance	0.25
Driving Accuracy	0.32
Iron Accuracy	0.36
Chipping Accuracy	0.17
Putting Accuracy 5ft	0.23

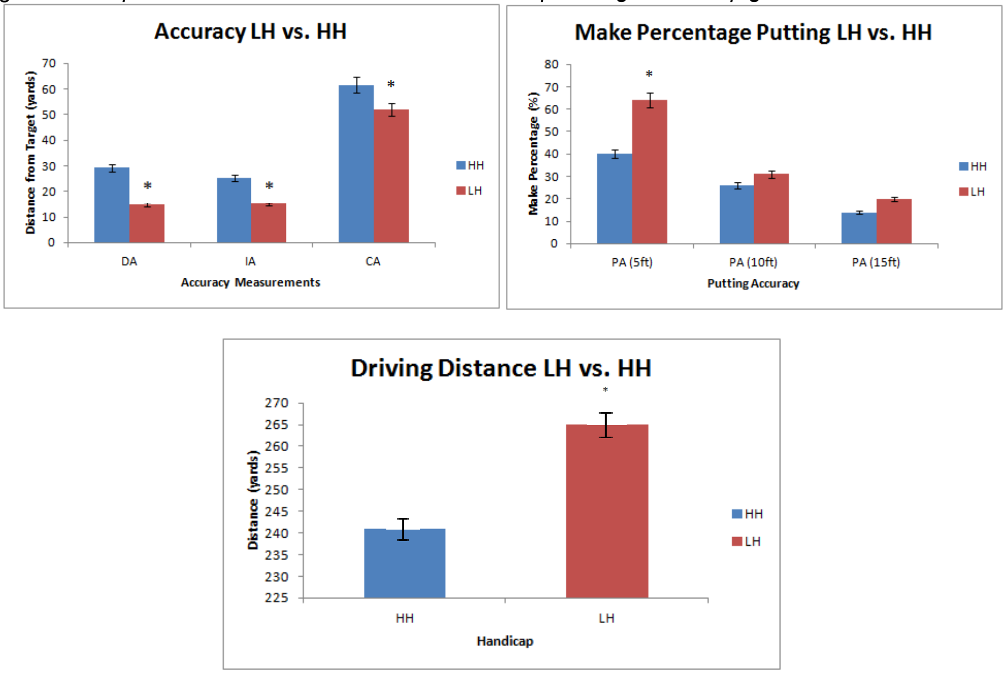
While most studies specifically look for improvements in one golf measurement e.g. driving, and provide statistics related to how improving a specific marker will improve one's game; these findings suggest that to achieve a lower handicap, all markers are important, and therefore should be researched.

Table 9. *Golf performance measurements Low Handicap vs. High Handicap golfers for all trials*

	HH	LH	
	Mdn (25th-75th)	Mdn (25th-75th)	*p*
Driving Distance (yards)	241 (223.0-267.0)	265 (241.0-295.0)	<0.001
Driving Accuracy (yards)	29.3 (15.30-45.00)	15.0 (10.00-32.40)	0.004
Iron Accuracy (yards)	25.2 (13.20-41.30)	15.2 (9.75-20.25)	<0.001
Chipping Accuracy (inches)	61.5 (34.75-41.30)	52.0 (27.88-90.00)	0.027
Putting Accuracy (5ft)	40%	64%	0.003
Putting Accuracy (10ft)	26%	31%	0.48
Putting Accuracy (15ft)	14%	20%	0.297

Values are expressed as Medians (25^{th} percentile-75^{th} percentile). Putting Accuracy values expressed as putts made percentage. LH - Low Handicap, HH – High Handicap. *P* values from post hoc analysis using Wilcoxon signed rank test comparing two groups.

Figure 9. *Golf performance measurements Low Handicap vs. High Handicap golfers for all trials*



Values are expressed as Medians. For measurements in accuracy, lower values signify desired outcome. For make percentage, higher values signify desired outcome. For measurement in distance, higher values signify desired outcome. LH - Low Handicap, HH – High Handicap.

When analyzing High Handicap golfers' accuracy and distance measurements, no significant differences were seen between the three trials. While no significant findings were found, there were improvements in DA (29.0 vs. 36.1), DD (238 vs. 227), and IA (21.0 vs. 25.7) in the COM trial vs. the CON trial. Similar to the findings above, the CON trial performed best in CA compared to both CHO and COM (58.8 vs. 83.5 vs. 61.5) respectively but again was not significant (p=0.633). However, when analyzing Low Handicap golfers', DA significantly improved in COM trial compared to CON trial (13.6 vs. 27.6, p=0.003) with a medium to large effect size (r=0.46). CA was significantly better in the CON trial vs. COM trial (35.3 vs. 61.8, p=0.006) trial and CHO trial (35.3 vs. 61.0, p=0.025). While only two of the seven measurements were significant, for Low Handicap golfers the COM trial performed better in DA, DD, and PA (5ft). These findings would suggest that High Handicap golfer's swings are not automated enough to where macronutrient feedings make a significant difference in playing performance.

Table 10. *Golf performance measurements High Handicap golfers for CON, CHO, and COM trials*

High Handicap				
	CON	CHO	COM	
	Mdn (25th-75th)	Mdn (25th-75th)	Mdn (25th-75th)	*p*
Driving Distance (yards)	227 (217.5-262.5)	252 (227.50-270)	238 (227.5-263.5)	0.717
Driving Accuracy (yards)	36.1 (13.20-45.80)	28.4 (17.00-37.00)	29.0 (17.25-47.65)	0.953
Iron Accuracy (yards)	25.7 (11.1-39.0)	29.3 17.20-45.00)	21.0 (13.30-34.40)	0.203
Chipping Accuracy (inches)	58.8 (40.50-99.00)	83.5 (26.00-159.50)	61.5 (32.00-129.90)	0.633
Putting Accuracy (5ft)	41%	44%	33%	0.662
Putting Accuracy (10ft)	26%	19%	33%	0.424
Putting Accuracy (15ft)	11%	11%	19%	0.695

Values are expressed as Medians (25^{th} percentile-75^{th} percentile). Putting Accuracy values expressed as putts made percentage. *P* values from post hoc analysis using Friedman comparing all three groups.

Table 11. *Golf performance measurements Low Handicap golfers for CON, CHO, and COM trials*

Low Handicap				
	CON	CHO	COM	
	Mdn (25th-75th)	Mdn (25th-75th)	Mdn (25th-75th)	*p*
Driving Distance (yards)	267 (239.0-288.5)	252 (230.0-295.0)	271 (252.5-304.0)	0.405
Driving Accuracy (yards)	27.6 (14.00-46.70)	13.3 (9.00-28.50)	13.6 (7.00-27.00)	0.013
Iron Accuracy (yards)	15.2 (7.10-20.60)	15.2 (10.00-20.00)	16.1 (11.50-20.00)	0.717
Chipping Accuracy (inches)	35.3 (20.50-55.00)	61.0 (39.00-112.00)	61.8 (31.25-118.00)	0.034
Putting Accuracy (5ft)	59%	67%	67%	0.81
Putting Accuracy (10ft)	37%	22%	33%	0.465
Putting Accuracy (15ft)	22%	15%	22%	0.735

Values are expressed as Medians (25^{th} percentile-75^{th} percentile). Putting Accuracy values expressed as putts made percentage. *P* values from post hoc analysis using Friedman comparing all three groups.

Chapter 5

DISCUSSION

Our results suggest that the consumption of specific macronutrient feedings including carbohydrate and protein positively affects golf performance. While no significant differences were seen when analyzing all nine holes between the three trials, the COM trial improved five of the seven golf measurements compared to CHO and CON. Furthermore, the study did provide evidence that the consumption of CHO and COM reduces perceived levels of fatigue. While the significant finding of lowered perceived levels of fatigue were not matched with significant changes in golf performance, previous studies showed that the biomechanical aspects of the golf swing alter due to fatigue (Higdon *et al,* 2012) and although putts made may not alter due to fatigue, the consistency of the putting stroke can (Grealy and Mathers, 2014). The data does suggest the need for more research analysing a wider variety of golf measurements such as IA and CA, as Low Handicap golfers were significantly better in all categories (DA, DD, IA, CA, and PA).

Perceived Levels of Fatigue and Alertness

The main takeaway when comparing all nine holes is the positive effect both COM and CHO had on reducing PLF compared to CON (2.5 vs. 3 vs. 4) respectively. These findings are supported with previous research assessing fatigue with the consumption of a caffeine/carbohydrate drink (Stevenson *et al,* 2009). The initial findings also provide us with cause to separate data into first four holes and final five holes. We could hypothesize that if the study were over the standard 18 holes, fatigue would have risen further in the CON trial.

Post Hoc Analysis

The Friedman test was used to compare and determine if any of the three feedings had an effect on golf performance. Typically, if the Friedman test rejects the null hypothesis, a series of pariwise tests can be ran using the Wilcoxon signed rank test to assess which differences between the three feedings are significant. In statistics, you do not use the Wilcoxon signed rank test following a non significant Friedman test. While the Friedman test showed some significant data comparing all three, a number of data points did not. However, when analyzing the statistical results, differences could visually be seen between two groups. While both the Friedman test and the Wilcoxon signed rank test both rank the feedings, the Friedman test ranks all three feedings (1,2,3) whereas the Wilcoxon signed rank test only ranks two feedings (1,2). This could lead to the third feeding diminishing the significant differences between two. Therefore, the Wilcoxon signed rank test was used to compare two feedings for data where visual trends were seen, even if Friedman showed no significance. While the Wilcoxon signed rank test found significant data comparing two feedings, caution must be taken when applying these results.

Golf Performance

While the findings comparing CON, CHO, and COM may not differ significantly, the data does suggest that a feeding consisting of both carbohydrate and protein does improve golf performance. Surprisingly, CA was significantly better in the CON trial compared to both CHO and COM (48.3 vs. 65.0 vs. 61.6) respectively. This may be due to the two best participants consuming the CON trial on day 3 which would lead to some familiarization of green speeds. While all other accuracy measurements were improved with COM, they do not require the same level of judgement on green speeds, slope, grain, and firmness. The two previous days may have allowed the participants amp time to adjust. After removing these two participants from the CA data set, no significant differences could be seen in CA between CON, CHO, and COM (p=0.216) trials. Furthermore, when analyzing the data from day 1, including all 10 participants (n=3 CON, n=3 CHO, n=4 COM), CA was seen to be statistically better in the COM trial compared to the CHO and CON trials. These findings help support our hypothesis that familiarization of greens occurred, skewing data in CA for CON trial.

Following the separation of data to holes 1-4 and 5-9, significant differences were observed with respect to DA. The CHO trial showed a 30 yard improvement in DA compared to CON and 20 yard improvement in DA compared to COM for the first four holes. In the final five holes, the COM trial showed a 12 yard improvement in DA compared to CHO and a 6 yard improvement compared to CON. Caution must be taken when analyzing DA holes 5-9 as

Wilcoxon signed rank test was ran due to trends seen, rather than significant results from Friedman test. However, 12 yard improvement in DA may be considered sufficient by most golfers. A medium effect size was seen when comparing the three trails which helps support the significant findings regardless of sample size. These findings are in line with the suggestions by Matt Jones (2017) in which the golfer requires specific macronutrient feedings every 6 holes. Specifically, Jones suggests carbohydrate feedings at the start of the round, followed by feedings balanced in proteins and carbohydrates in the middle of a golfer's round which can be compared to our participant's holes 5-9, if they were to play 18 holes.

The results comparing Low Handicap golfers vs. High Handicap golfers showed that Low Handicap golfers performed significantly better in DA, DD, IA, CA, and PA (5ft) than High Handicap golfers. While this finding may not be surprising, it does create a case to study a wider variety of golf measurements including IA and CA as the findings support the claim that to lower a player's handicap, improvements in all aspects of the game need to improve. As far as feedings, High Handicap golfers showed no significant differences between the three trials; although the CHO trial or COM trial performed better than the CON trial in six of the seven golf measurements. Whereas Low Handicap golfers showed a significant improvement of 14 yards in DA for COM and CHO compared to CON. CA was significantly better in the CON trial compared to CHO and COM however as discussed previously, two of the three Low Handicap participants consumed the CON trial on the final day. The data suggests that when Low Handicap golfers are given adequate time to practice on a specific playing surface they will improve their judgement of green characteristics. This may also be why no significant differences were seen in IA and PA. Following this data analysis, further research should be conducted using Low Handicap players as the automation of High Handicap players may prevent showing any differences in feedings. How to determine what handicap is sufficient is still unclear. With regard to the marketability of certain nutrition products in golf, the results showed that fatigue was significantly impacted with the addition of a feeding. While the results of this study may not show any significant effect for High Handicap player's performance, other studies have shown that fatigue can negatively affect performance (Smith et al. 2012).

Hydration and Sweat Rate

Hydration status was measured prior to the start of each round. Participants were instructed to consume water as they usually would and consume the standardized CON, CHO or COM feedings every three holes. There were no significant USG differences between the three trials. While the mean USG measurement was lower prior to the COM feeding, the largest percentage of participants considered euhydrated prior to a trial was the CON trial. Future research should assess players over 18 and 36 holes. While no effects were seen in this study, over a longer time period and in hotter climates, acute hydration status may be challenged. Hydration has been shown to affect performance (Stevenson et al., 2009), however it is not known if solid feedings would affect hydration, specifically in golfer's if they were given freedom to drink throughout the round. Similar to hydration status, there were no significant differences in sweat rate between the three groups. These findings suggest that differences found between CON, CHO, and COM trials in golf performance were not due to hydration status or sweat rate. Hydration status was unlikely to affect performance between interventions. Results may change in seasons with higher temperatures; Phoenix temperatures during the summer exceed 40°C, which could cause an increase in Sweat Rate and fluid intake. As the two powders were plain tasting, the 0 calories sports drink was used as a flavoured placebo; while this controlled taste, texture of the drink changed. Therefore participants may have known if they were consuming the 0 calorie drink alone, but would not have been able to differentiate between the two feedings.

Environmental Variables

Golf is an outdoor sport; however the majority of studies that have taken place assessing golf performance were laboratory based. This was most likely done to control for external factors such as wind, temperature, and slope. Wind did not exceed 4mph in each of our three testing days; a max wind speed of 10mph was set for the study. These figures help suggest that wind played little to no effect on the golf ball or on the cognitive thought process of the participants. There were small differences in temperature and relative humidity; however there were no significant differences in participants' sweat rate which helps us propose that there were no environmental influences on participant's performance. Our study was in the minority with outdoor data collection which can be advantageous compared to other studies as it can be more closely compared to an actual tournament round. Future research could use Track man as a form of measuring club head speed, ball speed, along with tracking ball flight. This way, more specific figures could be seen and be compared to the devices and forms of measurement in this study. This method of data collection was not done due to cost restrictions.

Limitations

Once recruitment for the study had closed, each individual was assigned a specific feeding order. This feeding order was created using a Latin Square Design which has each feeding occur at a different time per three individuals. This originally led to an equal amount of participants receiving the CON, CHO, and COM trial each day. However, due to unexpected drop outs and no shows, the participation field dropped to six by the final day and feedings of each trial became imbalanced. Having a low number of participants will in turn affect the power of the study; however other golf studies using a low number of participants have been able to find significance in their data. Due to the imbalance of three feedings per day, more participants consumed the CON trial the final day which in turn could lead to improvements in performance due to familiarization rather than the feedings. As for the low number of participation, by calculating effect size, how large an effect can be established regardless of sample size. Specifically in DA, a small-medium to medium-large effect sizes in holes 1-4 and 5-9 was seen.

Handicaps for participation were limited to 18. This handicap was selected as participants with handicaps of 18 and below could be considered to have some level of automation in the golf swing. However, as mentioned in chapter 4, when handicaps were split to low handicap and high handicap, High Handicap participants showed no significant differences in golf performance between the three trials, yet the Low Handicap participants did. This data suggests that to assess whether specific feedings affect golf performance, a certain level of automation has to be achieved. Future research should use single digit handicap players. However, caution must be taken as golf courses vary in difficulty and two people with the same handicap may vary dramatically in ability.

Originally, participants being recruited were 14-18 years, however due to lack of participant recruitment the age limit was increased to 50. While participants were asked to consume no alcohol 24 hours prior to each study day, consumption of alcohol could not be fully controlled. This in turn may affect hydration status and perceived levels of fatigue and alertness. As evident in chapter 4, the mean USG was lower in the COM trial. This may be misleading as a higher percentage of participants were considered euhydrated in the CON trial compared to both CHO and COM based on a USG cut off value of 1.02. However, hydration measurements consisting of pre USG and sweat rate were sufficient in concluding that hydration was unlikely to affect performance.

After analysis of environmental factors such as wind, temperature and relative humidity, there were no significant differences between the three days and can conclude with some certainty that environmental factors had little effect on performance. However, on the third day, there was an hour of frost delay. Participants arrived at the same time each of the three days, which means they may have had extra time to warm up prior to starting their third round. Interestingly, temperatures were lowest on the second day, but there was no frost delay. Time spent on the course remained the same throughout the three days but due to the frost delay, subjects were present at the study for an extra hour and were on the golf course an hour later than the previous days.

Finally, pin locations per day did not remain the same. Due to using a golf course facility with regular play teeing off on the front nine, pin placements changed each day; this is similar to a regular four day competitive tournament. However due to the change in pin placements, IA, CA, and PA may have been affected. While distances to pin for IA, CA, and PA remained constant per day, slope and grain were harder to control. For CA and PA, shots were fairly straight and flat, however due to the layout of the course; this could not always be maintained.

Conclusions

The findings from this study contribute to the literature supporting macronutrient feedings during sports performance to improve performance and aid in fatigue. The results add to the limited literature for the need for macronutrient feedings in relation to golf performance and provide evidence for the consumption of carbohydrate or a combination of carbohydrate and protein during prolonged endurance exercise. While most golfers will see a benefit from consuming macronutrients during their round, the low handicap golfers are more likely to see improvements in playing performance. The study’s findings not only suggest that golfers’ need to consume energy containing feedings, but results may be impacted by feeding composition.

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