The Effects of Carbohydrate, Protein, and Carbohydrate with Protein Solutions on 200-Meter Sprint Speed

THE EFFECTS CARBOHYDRATE, PROTEIN, AND CARBOHYDRATE WITH PROTEIN SOLUTIONS ON 200-METER SPRINT SPEED

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ABSTRACT

Title: The effect of carbohydrate, protein, and carbohydrate with protein solutions on 200-meter sprint speed. (Under the direction of DR. DAN BENARDOT)
Purpose: To investigate the differential effects of solutions providing varying concentrations of carbohydrate and/or protein ingested between 200-meter sprints on sprint time. **Subjects:** Recruitment was from the Georgia State University track and field team. **Methods:** The study protocol was approved by the Georgia State University IRB. Ten subjects, 18 to 21 years of age, consented to be included in the study. Nine subjects (7 females; 2 males) completed trial 1, six subjects (5 females; 1 male) completed trial 2, and three subjects (2 females; 1 male) completed the final trial. Each trial consisted of a 200-meter sprint followed by the immediate ingestion of a post-exercise recovery beverage within the first fifteen minutes of a one-hour recovery period. Following the one-hour of recovery, subjects sprinted a second 200-meter sprint. Beverage solutions were formulated to contain 1.2 g of protein (PRO), 1.2 g carbohydrate (CHO), or 1.2 g carbohydrate with protein (CHO/PRO) per kg of subject body weight. Using a single blind, non-randomized design, subjects received the same recovery beverage in each trial. Each trial consisted of either PRO (trial 1), CHO (trial 2), or CHO/PRO (trial 3), with one week separating trials. Sprint times were recorded in seconds and ten hundredths of a second using a manual, digital stopwatch. **Results:** During PRO, two subjects sprinted faster (x= -.25 sec), three subjects saw no change in sprint time, and four subjects sprinted slower (x= +.98 sec). During CHO, two female subjects sprinted faster between sprints (x= -.85 sec); and all other subjects (n=4) sprinted slower (x= +.73 sec). During CHO/PRO, no subjects sprinted faster from sprint 1 to sprint 2 (x= +.33 sec) **Conclusions:** Post-exercise nutritional supplementation effects varied among subjects, with some subjects performing better following PRO, while others experiencing improvements with CHO. In general, subjects performed better following consumption of the CHO beverage. Of those who ran faster between sprints, the CHO beverage resulted in an average improvement of -.85 sec, while the PRO beverage resulted in an average improvement of -.25 sec. On average, CHO resulted in faster 2nd sprints (x= +.20 sec) than the PRO beverage (x= +.47 sec) or the CHO/PRO beverage (x= +.33 sec). Continued research in this population is necessary for elucidation of study results. This investigation may serve as the foundation for future, related studies.

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LIST OF ABBREVIATIONS

ATP	ADENOSINE TRIPHOSPHATE
BPM	BEATS PER MINUTE
°F	DEGREES FAHRENHEIT
CHO	CARBOHYDRATE
CrP	CREATINE PHOSPHATE
FAT	FULLY AUTOMATIC TIMING
FFA	FREE FATTY ACID
G	GRAM
GI	GASTROINTESTINAL
GLY	GLYCOGEN
HR	HEART RATE
IAAF	INTERNATIONAL ASSOCIATION OF ATHLETICS FEDERATION
KG	KILOGRAM
L	LITER
ML	MILLILITER
MMOL	MILLIMOLES
NCAA	NATIONAL COLLEGIATE ATHLETIC ASSOCIATION
PRO	PROTEIN
RER	RESPIRATORY EXCHANGE RATIO
SEC	SECONDS
SD	STANDARD DEVIATION
VO^2	OXYGEN CONSUMPTION
w	WATTS
x	MEAN
Δ	CHANGE IN TIME

CHAPTER I

INTRODUCTION

Track and field competitions can last six to eight hours in a single day with sprint athletes usually competing in multiple events. Throughout the day, these athletes are continuously pushing their bodies to the limit to defeat the competition, even if only by fractions of a second. This type of energy consuming activity, will at some point, deplete energy reserves in muscles. During high intensity, short duration sprinting, creatine phosphate (CrP) and muscle glycogen (GLY) are the primary energy contributing substrates (1, 2, 3). Complete restoration of muscle GLY can occur within 24 hours when sufficient dietary carbohydrate is consumed. However, when an athlete is competing in multiple events throughout the day, they may only have one to two hours to recover and insufficient carbohydrate intake, making GLY restoration unattainable in this short period of time (3). Insufficient recovery from maximal effort exercise can lead to the early onset of fatigue, poor performance or performance plateaus, and injury (6).

In the author's experiences as a 4-year NCAA Division I sprinter, there are limited nutritional resources available at track meets for athletes to consume a balanced post-competition meal to replenish muscle GLY and proteins that may have been depleted and/or catabolized during competition. Usually, athletes travel to competitions as a team, do not have their own transportation, and cannot leave the track for food. As a result, they may have to choose from "junk food" available at concession stands, snacks supplied by the coach or trainer, or simply eat whatever is in close proximity to the track. In some cases, athletes will choose to eat nothing at all. These circumstances may inhibit the athlete's ability to replenish important energy yielding nutrients, and impede their ability to be ready to compete at optimal levels in subsequent races. The following sections will discuss how post-exercise skeletal muscle metabolism is an important consideration for recovery from exercise and physical activity.

Skeletal Muscle Metabolism during Exercise

Skeletal muscle must generate adenosine triphosphate (ATP) for any form of muscular movement. ATP is an immediate source of energy, which activates the excitation-contraction coupling reaction that leads to calcium ion release and the cross-bridge actin-myosin interactions needed for muscle contractions (1, 6). However, intramuscular concentrations of ATP are limited, and cannot sustain physical activity lasting more than a few seconds. Therefore, the ongoing resynthesis of ATP is necessary for continual muscular movement. For ATP supplied beyond the intramuscular pool, alternate metabolic pathways must be activated. For short-duration, high intensity exercise, anaerobic glycolysis is the primary ATP generating pathway. For long-duration, lower intensity exercise, oxygen is supplied in an aerobic pathway for ATP production.

Ament and Verkerke (2009) have expressed the idea that exercise alters the equilibrium of the environment within the muscle cells (6). When exercise is initiated, the contracting muscle generates mechanical heat energy along with inorganic phosphates, protons, lactate, and magnesium ions, which all accumulate inside the cell. The production of heat energy and metabolites stresses the skeletal muscle and changes its cellular environment. In order to restore a steady state to the skeletal muscle cellular environment, there are increases in blood circulation and gas exchange within the cell (6). Increased blood flow allows for an increase in musculo-cellular metabolism and transport of metabolites into and out of the cell to restore homeostasis. Evidence shows that during exercise there are increases in the glucose uptake, insulin sensitivity, GLY synthesis, increased fatty acid oxidation, and increased protein synthesis within the muscle (7). The surge of these metabolic activities during exercise gives rise to the idea that providing ample substrate during this increase in skeletal muscle anabolism will result in a quicker, more efficient recovery of muscle metabolites and physiological restoration from exercise.

Skeletal Muscle Recovery

Muscle GLY and CrP is broken down to fuel high intensity exercise (1, 2, 3). When these substrates, along with oxygen, are not supplied in sufficient amounts to support the needs of exercise and are no longer available to energize the muscles, lactate, a by-product of anaerobic metabolism, builds up in the muscle causing feelings of pain and fatigue. Recovery from GLY depleting exercise requires the removal of lactate from the muscles and the replenishment of muscle GLY stores. The degree to which a person has resynthesized GLY and catabolized lactate influences their capacity to perform any subsequent exercise bout (3, 4). For many athletes, training and competition involves frequent maximum effort, muscle GLY depleting, muscle protein catabolizing workouts. Daily depletion and catabolism require daily resynthesis and replenishment of muscle GLY stores and proteins to continue training and competing at a high level (3, 8, 9). When training is frequent, maximizing recovery rates is the priority. Studies have shown that post-exercise nutritional intake is important for efficient recovery from high intensity exercise (4, 10).

Post-exercise Nutritional Intake and Skeletal Muscle Metabolism

Following exercise, the body is in a potentially anabolic state, where available nutrients support increased rates of synthesis and transport of glucose and amino acids to support restoration of GLY and proteins that were catabolized during exercise. An exercise induced reduction of muscle GLY leads to a faster rate of GLY re-synthesis post-exercise. This enhanced nutrient metabolism that occurs following exercise provides a means by which post-exercise nutrition can be manipulated to maximize recovery (3, 4).

There are two defined phases of recovery, a rapid phase and a slow phase (11). The rapid phase occurs 30 to 60 minutes post-exercise and stimulates glucose transport and uptake without the presence of insulin (11). In the slow phase, insulin becomes significant and there is increased insulin sensitivity for muscle glucose uptake and GLY synthesis (1). Post-exercise increases in insulin sensitivity can last more than 48 hours (9, 12, 13). Nutrient provision in the rapid phase is most important for those who have recovery periods of less than eight hours (12). When recovery time is short, immediate post-exercise nutrition is essential for maximal replenishment of energy substrates. A recent review paper has determined guidelines for nutrient provision post-exercise including that nutrients should be supplied within two hours of exercise (14).

Purpose

Nutrient timing, frequency, and macronutrient composition have all been investigated to identify a strategy that uses the post-exercise increase in metabolism to maximize recovery rates. However, little has been done to evaluate the efficacy of post-exercise recovery supplementation in track and field sprinters who have limited recovery time. The goal of this study is to investigate which nutritional beverage composition may enable sprinters to have optimal performance on repeated sprints when there is limited time for muscle recovery. Post-exercise nutritional supplementation techniques demonstrated to affect muscle recovery in athletes through GLY restoration rates, muscle protein synthesis rates, and athletic performance are used to determine how a recovery solution composed of 1.2 $g \cdot kg^{-1}$ protein (PRO), 1.2 $g \cdot kg^{-1}$ carbohydrate (CHO), or 0.8 $g \cdot kg^{-1}$ carbohydrate with 0.4 $g \cdot kg^{-1}$ protein (CHP/PRO) given immediately following a 200-meter sprint will affect sprinting speed on a subsequent 200-meter sprint bout.

Hypothesis

Between-sprint consumption of a recovery beverage containing 4% carbohydrate and 2% protein will improve sprint time in the 2nd 200-meter sprint better than either a 6% carbohydrate beverage or a 6% protein beverage.

Null Hypothesis

Between-sprint consumption of a recovery beverage containing 4% carbohydrate and 2% protein will not improve sprint time in the 2nd 200-meter sprint better than either a 6% carbohydrate beverage or a 6% protein beverage.

Study Rationale

Subject population, nutrient composition, nutrient timing, and exercise protocol vary between studies evaluating the effects of post-exercise nutrient supplementation on muscle recovery and can make the results of these studies difficult to apply. There is not much evidence to support post-exercise nutrient supplementation in women or in younger athlete populations. In addition, beyond cycling and resistance training, other modes of exercise, such as running or sprinting, have not been thoroughly investigated. Perhaps expanding investigations to evaluate a variety of athlete populations will lead to further elucidation of appropriate post-exercise nutrition practices. The potential for increased recovery rates and better performance are especially important in a collegiate population. Collegiate athletes have to balance school along with a rigorous training and competition schedule, and are the future of professional athletics. Although nutritional enhancement of post-exercise metabolism has been demonstrated through strategies using nutrient composition and nutrient timing, the subject populations and exercise modes used in these studies have been limited, and therefore these practices may or may not be valid across the athlete spectrum. Recovery is an important aspect of training in all athletic populations and athletes of all sports can struggle with the consumption of adequate nutrition post-exercise. All athletes could stand to benefit from defined, evidence-based recovery nutritional strategies that aim to enhance training and competition performances.

CHAPTER II

REVIEW OF LITERATURE

Although there are few studies that have investigated the effects of post-exercise nutrition on muscle recovery in sprint athletes, there are studies that have assessed post-exercise nutritional supplementation on muscle recovery (2-5, 8-17). In the following studies, muscle recovery is evaluated based on the effects of post-exercise nutritional strategies on muscle GLY restoration and muscle protein synthesis.

Post-Exercise Nutrient Supplementation

Glycogen Synthesis

Glycogen is a primary source of energy during high intensity exercise. Increased pre-exercise GLY status is related to increased performance capacity while reduced levels of muscle GLY stores are related to fatigue. It is ideal for most athletes to maximize GLY storage capacity, GLY stores, and GLY synthesis rates (5, 9, 11, 12). Several studies have reported increased rates of muscle GLY synthesis, glucose transport, and skeletal muscle insulin sensitivity during post-exercise recovery (9, 11, 12). After only a single bout of exercise, skeletal muscle GLY synthase activity and GLY synthesis are increased (9, 12); there is increased translocation of GLUT-4 receptors and increased glucose uptake into the muscle cells (9, 11, 12); and there is an increase in insulin action on glucose and increased insulin receptor signaling (9, 12). All of these processes occur to help facilitate GLY restoration and glucose homeostasis.

Research Strategies and Results

Van Loon et al. (2000) explored maximizing post-exercise GLY synthesis by evaluating eight trained, male cyclists. Each cyclist rode to exhaustion using an established muscle GLY depleting protocol developed by the study's investigators. Muscle biopsies were taken immediately post exercise, followed by the immediate ingestion of a carbohydrate ($0.8\ g \cdot kg^{-1} \cdot h^{-1}$CHO), carbohydrate-protein ($0.8\ g \cdot kg^{-1} \cdot h^{-1}$ CHO + $0.4\ g \cdot kg^{-1} \cdot h^{-1}$PRO), or a high carbohydrate ($1.2\ g \cdot kg^{-1} \cdot h^{-1}$CHO) beverage. Five hours later, another muscle biopsy was taken. When comparing immediate post-exercise muscle biopsies to the 5-hour post-exercise muscle biopsy sample, the researchers found that carbohydrate-protein and the high carbohydrate beverages produced higher insulin responses compared to the carbohydrate group. However, no significant difference in insulin response was noted between the high carbohydrate and carbohydrate-protein groups (11). Ivy et al. (2002) also rode trained, male cyclists (n=7) to GLY depletion (plasma glucose less than $3.89\ mmol \cdot L^{-1}$). In this study, either a carbohydrate-protein (80 g CHO, 28 g PRO, 6 g fat), low carbohydrate (80g CHO,6g fat), or a high carbohydrate (108 g CHO, 6 g fat) supplement was taken either immediately or two hours post-exercise. Muscle GLY status was greater with the carbohydrate-protein supplement, but there were no significant differences in muscle GLY effects between the high and low carbohydrate groups (3). Jetjens et al. (2001) conducted a study in which eight male cyclists performed a graded Wmax ($Wmax = W_{out} + [t/180] * 35$) exercise test of maximal power output to GLY depletion and exhaustion. In the Wmax exercise test, heart rate (HR) and oxygen consumption (VO_2) were monitored while subjects rode a cycle ergometer against increasing amounts of resistance (35 W every 3 minutes) until the subjects met two of the following criteria: 1) no further increases in VO_2 with increasing resistance, 2) HR within ten beats/minute (BPM) of predicted maximum for age, and 3) a respiratory exchange ratio (RER) greater than 1.05. Post- exercise, carbohydrate (1.2 $g \cdot kg^{-1} \cdot h^{-1}$) or carbohydrate-protein (1.2 $g \cdot k^{-1} g \cdot h^{-1}$ CHO + 0.4 $g/kg^{-1} \cdot h^{-1}$ PRO) supplements were given at 30-minute intervals during a 3-hour recovery period. Muscle biopsies and blood samples showed no significant differences between the carbohydrate and carbohydrate-protein groups in plasma glucose or rate of muscle GLY synthesis.

Summary

The effects of post-exercise nutrition on GLY synthesis rates and related glucose metabolism have been evaluated through a variety of exercise protocols, including several nutrient compositions, and at various timing intervals. Strategies in post-exercise supplement timing involved studies providing the supplement in a bolus amount immediately post-exercise, and others provided an initial bolus amount with additional supplementation hours later (3, 14), or at 15-minute (8) or 30-minute intervals (2, 4, 10, 13) during the post-exercise recovery period. Post-exercise beverages have included varying amounts of carbohydrate, protein, and fat, and spanned the range from 0.8 g to 1.67 g per kg of body weight for the subjects. Most studies have shown that there are no significant differences in GLY synthesis rates between the nutrient compositions of the recovery supplement solutions when the supplements provided are isocaloric.

Muscle Protein Metabolism

Muscle Protein Breakdown and Synthesis

Exercise promotes both muscle protein synthesis and muscle protein breakdown (16). During exercise, skeletal muscle proteins are broken down for energy metabolism and force production (17). In the post-exercise recovery process protein synthesis increases and the muscle is repaired. It is proposed that resistance exercise stimulates protein metabolism through increases in the localized production of IGF-I in the muscle and/or through contraction induced signaling events, specifically, the protein kinase B transduction pathway (18). The continued skeletal muscle breakdown from exercise and repair during recovery results in skeletal muscle growth and strength gains. These can be considered training effects. Without efficient recovery from exercise, training benefits may be limited.

Muscle Protein Balance

Although both muscle protein synthesis and breakdown are stimulated following exercise, post-exercise net muscle protein balance is negative (16). If athletes do not restore catabolized skeletal muscle proteins from one exercise bout to the next, they will continue to exercise in a negative protein balance resulting in higher risks of overtraining and skeletal muscle injuries. Therefore, it is important for an athlete to restore a positive energy balance following exercise.

Research Strategies and Results

Roy et al. (1998) found that the provision of a carbohydrate beverage ($1 \text{ g} \cdot \text{kg}^{-1}$) post-exercise compared to a placebo showed no difference in muscle protein synthesis rates, but that carbohydrate did decrease muscle protein breakdown and urinary urea excretion which resulted in an improved (but still negative) nitrogen balance (16). However, it was determined that 50 g of carbohydrate provided post-exercise resulted in a negative energy balance, but the addition of 33 g protein to the supplement resulted in increased rates of whole body protein synthesis, lower protein breakdown rates, and a net positive protein balance. The addition of the amino acid leucine (16.6 g) to the carbohydrate-protein supplement resulted in further increases in protein synthesis, lowered protein oxidation rates, and a positive protein balance (19). In a recent study, isocaloric supplements of carbohydrate ($1.6 \text{ g} \cdot \text{kg}^{-1}$) and carbohydrate-protein (1.2 g CHO, 0.4 g PRO), and a lower carbohydrate beverage ($1.2 \text{ g} \cdot \text{kg}^{-1}$) were given post-exercise (17). The researchers found that whole body net protein balance was only positive in the carbohydrate-protein supplement group. With carbohydrate-protein supplementation, muscle protein breakdown was decreased while protein synthesis rates were increased when compared to both carbohydrate only beverages (17).

In the studies reviewed, the exercise protocols, supplement timing, and nutrient composition all varied. The one consistent variable was that they were all done using populations of healthy, untrained, recreationally active men. Exercise protocols included lower body resistance training (19), resistance exercise on one unique muscle group (16), and a cycling bout (17). Supplements were provided at intervals post-exercise (17, 19), or given immediately post-exercise and then one hour later (16). Nutrient provision included some variation of carbohydrate or protein/amino acid formulation. All studies determined that nutrient supplementation post-exercise resulted in a more positive muscle protein status when compared to the absence of post-exercise nutrient supplementation.

Athletic Performance

Muscle recovery is defined by GLY restoration and net protein balance, which directly influences athletic performance. Several investigations put this assumption to the test by assessing the effects of post-exercise nutrient supplementation on various dimensions of athletic performance. A study that evaluated the effects of isocaloric carbohydrate (CHO) and carbohydrate-protein (CHO-PRO) beverages given post-exercise on same day cycling performances (subjects completed time trials in which they cycled as far as they could in 60 minutes) showed that in the subsequent cycling bout (6 hours later) cycling performances were reduced in comparison to the initial cycling performance for both groups. Yet, when the CHO group was compared to the CHO-PRO group, the subjects given the CHO-PRO beverage had significantly lower performance and power decreases from the first to second cycling bout (20). The CHO group had a mean reduction in power of x=16.50 (± 6.74) W (watts) compared to the x=3.86 (± 6.47) W reduction in the CHO-PRO group. The CHO traveled .75 km less than the CHO-PRO group in the 60-minute period. In a different study on exercise performance, post-exercise nutrient supplementation using either carbohydrate (4.6% CHO) or carbohydrate-protein (3.6% CHO, 1% PRO) was provided post-exercise and over a 2-week period. Rather than subjects being evaluated in the same day, based on one day of supplementation, performances were evaluated on consecutive day cycling exercise bouts (5). It was determined that the carbohydrate-protein beverage reduced muscle damage, decreased fatigue, and maintained exercise performance when compared to consumption of the carbohydrate beverage. By contrast, when cyclists were fed mixed diets during a 4-hour post-exercise recovery period with one group having a larger percentage of calories from protein (218 g PRO, 435 g CHO, 79 g FAT) and the other having more carbohydrate calories (34 g PRO, 640 g CHO, 79 g FAT), the effects on next day sprint power performance were unclear. However, ratings of perceived exertion indicated by the subjects immediately after sprints for the categories of sensation of tiredness, limb soreness, ability to sprint, level of effort during the sprint, and feeling of nausea reveal that there was a reduction in tiredness and muscle soreness during the sprints with the enhanced protein meal (21).

Research Strategies and Results

When muscle recovery is based on aspects of muscle GLY restoration, muscle protein metabolism, and exercise performance, post-exercise nutrition is likely to be a determining factor. Studies that have assessed the influence of post-exercise nutrition and GLY re-synthesis rates most often found no distinction between post-exercise nutrient composition as long as the caloric load of the supplements were equivalent. However, when one evaluates muscle protein metabolism and restoration of a positive muscle protein balance, regardless of caloric equivalence, to support muscle protein anabolism some variation of protein and/or amino acids need to be added to a carbohydrate solution. Carbohydrate with protein elicited better results for performance studies as well. Performance, as well as muscle fatigue and soreness, was improved with post-exercise nutrition provided from a carbohydrate-protein supplement rather than from carbohydrate alone.

CHAPTER III

METHODS

Development of Protocol and IRB Approval

This protocol was developed based on the experiences of the writer as a track and field athlete for the Georgia State University women's track and field team, in combination with a review of current research related to post-exercise nutrient supplementation involving carbohydrate and protein solutions. A written format of the thesis protocol was submitted to the thesis committee for review in April 2008. Following committee review and collaboration with committee chair, Dr. Dan Benardot, this protocol was revised and submitted to the IRB in December 2008.

Subject Recruitment

Subjects were recruited from the Georgia State University track and field team. The subject recruitment presentation and information session was held before the start of strength training practice, as requested by the coach. Included in the presentation was information about the purpose of the investigation, the importance of the investigation for track and field sprinters, the methods, their role as subjects, and the risks involved with participation. Following the presentation, subjects were invited to participate by reading and signing the informed consent forms (see Appendix B). Athletes unable to provide maximal effort during the sprint due to injury or lack of sprint training were excluded from participation in the study. Ten subjects, eight females and two males, provided consent and participated in the study.

Recovery Beverage Preparation

Beverages were prepared at the Georgia State University Food Science Laboratory. On the day before each trial, the recovery beverage solution was prepared in bulk and hand mixed using a wire whisk in a large plastic container. The protein beverage consisted of a 6% solution (780 g) of instantized whey protein isolate (Proven 292 provided by Glanbia Nutritionals, Inc. Monroe, WI); the carbohydrate beverage was composed of a 6% sucrose solution (780 g); and the carbohydrate-protein beverage was a 4% carbohydrate, 2% protein solution. All solutions included 109.6 grams of Crystal Light® (used for flavoring purposes) and approximately 12,110 g of water to make a total mass of 13,000 g of recovery solution. Large measuring cups and measuring jugs were used to determine the mass of the beverage. Digital and mechanical food scales were used to measure the solute mass. The solution was stored in the laboratory refrigerator at 38° F overnight. The amount of the solution consumed depended on the amount required to provide each participating subject $1.2 \text{ g} \cdot \text{kg}^{-1}$ solution.

On the day of the trials, the bulk beverage solution was removed from the refrigerator, re-stirred for uniformity, and poured into individual jugs for the subjects.

Measuring jugs were filled to reach the mass necessary for the beverage composition required by each athlete's measured body mass (1.2 g ·kg $^{-1}$). Subject body weight was measured and recorded on the day before each trial. Beverages were transported approximately 10 miles from the Food Science Laboratory by automobile to the track. (For data on the composition of each solution, see Appendix C; Table 1)

Sprinting Trial Procedures

Subjects were asked to participate in three weeks of experimentation, during which they completed three trials. The goal was for the experimental trials to imitate track meet competition situations where athletes have minimal time for recovery. Subjects were allowed to warm up and stretch before sprinting as they would before any sprint workout or competition. The trials were held on a standard, 400-meter running track with a rubberized surface. Runners began the race on a three-command start from a standing running position (without starting blocks). Each trial was completed at least one week apart and consisted of two 200-meter sprints with a recovery period of 60 minutes between sprints. During the recovery period, subjects had 15 minutes immediately following completion of their first 200-meter sprint to ingest the prescribed recovery beverage. Trial 1 provided 1.2 g ·kg $^{-1}$ protein (PRO), trial 2 provided 1.2 g · kg $^{-1}$ carbohydrate (CHO), and trial 3 provided .40 g · kg $^{-1}$ protein with .80 g · kg $^{-1}$ carbohydrate (CHO/PRO). In this single-blind investigation, subjects were unaware of the composition of their solutions and did not know whether their solutions were different or the same as the other subjects. Following the one hour of recovery, the participants sprinted 200 meters again. The completion times, in seconds and hundredths of seconds, were recorded with a handheld stopwatch (Seiko S149) capable of recording and printing multiple race times. Because of his experience with recording times using a handheld stopwatch, the track and field coach recorded sprint times during each trial. Sprint times were recorded in compliance with the International Association of Athletics Federations (IAAF) 2010-2011 competition rules, which states that for all hand-timed races, times shall be read and recorded as follows: For races on the track, unless the time is an exact 1/10th of a second, the time shall be read and recorded to the next longer 1/10th of a second.

Sprinting times were compared to evaluate whether time was increased, decreased or maintained and compared to the subject's best time recorded during the track and field season in which the trials occurred. Subjects were expected to provide maximal effort during sprints, and comparing their sprint time during the trials to their best performance will help determine the level of effort the subjects were able to provide during sprinting. Evidence has shown that hand times produce faster times when compared to electronic, automatic timing. For conversion of hand time to fully automatic time (FAT), as a rule .24 seconds is added to the recorded time. Involving minimal human error, FAT timing is the most accurate system for recording race times and is considered the gold standard in track and field competition.

Data Analysis:

Data analyses were performed using SPSS for Windows, version 11.0. It was the investigator's original intent to analyze the data collected for differences significant at *p-values* less than 0.05. However, due to subject attrition, the resulting number of subjects resulted in the data having low statistical power. Therefore, the data were analyzed descriptively as a qualitative investigation that focused on of each subject's performance.

CHAPTER IV

RESULTS

A total of ten subjects participated in the sprinting trials. Nine subjects (7 females; 2 males) completed trial 1, six (5 females; 1 male) completed trial 2, and three (2 females; 1 male) completed the final trial. Data on subject age, height, and weight are displayed Appendix C (reference Table 2).

Mean subject age was 19.10 (± 0.88) years; mean female subject age was 19.25 (± 0.89); and mean male subject age was 18.50 (± 0.71). Mean subject height was 165.60 cm (± 9.18); mean female height was 162.24 cm (± 6.57), and mean male height was 179.07 cm (± 1.79). The mean mass (weight) of the subjects equaled 62.27 kg (± 8.07), 60.32 kg (± 8.31), and 62.57 kg (± 10.62) in trials 1 (PRO), 2 (CHO), and 3 (CHO/PRO) respectively.

Recovery Beverages

In trial 1 the PRO solution was given to the subjects, in trial 2 CHO was provided during recovery, and in trial 3 CHO/PRO was given to the subjects. For data on the composition of the beverage solution for each subject in each trial, please reference Appendix C (see Table 3).

Changes in 200-meter Sprint Time

Trial 1: PRO

The PRO recovery solution was administered to nine subjects (2 male, 7 female). Mean initial sprint time for the group was 26.12 sec (± 1.46), with the male mean at 24.45 sec (± 0.92) and the female mean at 26.60 sec (± 1.23). Post recovery phase, the mean group time increased by .47 (± 0.61) seconds. The male mean time decreased by 0.05 sec (± 0.07) while the female mean time increased by 0.61 sec (± 0.62). Two subjects increased speed post-recovery beverage supplementation. Post-supplementaton, Male 2 sprinted faster by -.10 second and Female 1 sprinted faster by -.40 seconds. Three subjects (Female 3, Female 5, and Male 1) experienced no changes in sprint time. The other four subjects sprinted slower from sprint 1 to sprint 2. (Subject sprint data for trial 1 can be found in appendix C; see Table 4)

Trial 2: CHO

The CHO trial included six subjects (2 male, 4 female). Mean initial sprint time for the group was 27.60 (± 1.48). The female mean was 28.14 sec (± 0.73). Only one male (Male 1) participated in this trial. His initial sprint time was 24.90 sec. Post recovery phase, the mean group time increased to 27.80 (± 1.74) sec. Female mean sprinting time increased by 0.10 (± 0.95) sec during the second sprint. Following supplementation male 1 increased sprint time by 0.70 sec. In the group, two female subjects sprinted faster post supplementation while all other subjects experienced an increase in sprint time. Female 1 sprinted faster with a change in sprint time of -1.4 sec and Female 2 sprinted faster with a change in sprint time of -.30 seconds. (Subject sprint data for trial 2 can be found in appendix C; see Table 5)

Trial 3: CHO/PRO

CHO/PRO was administered to three subjects (1 male, 2 females). Mean initial sprint time for the group was 26.37 (± 1.91) sec. Post-recovery phase the mean group time increased by 0.33 (± 0.12) sec. Initial female mean sprint time was 27.25 (± 1.63) sec and the increased by 0.30 (± 0.14) sec following supplementation. Male 1 completed trial 3 (CHO/PRO) with an initial sprint time equaling 24.60 sec. The male sprinter also sprinted slower with an increase in sprinting time of 0.40 sec. No subjects experienced a decrease in sprinting time following ingestion of CHO/PRO. (Subject sprint data for trial 3 can be found in appendix C; see Table 6)

<u>Individual Subject Analyses</u>

Females

Female 1

Female 1 completed trials 1 (PRO) and 2 (CHO). She was a seasoned sprinter on the team and one of the top performers for the University. Although, her level of effort may not have been consistent throughout trials, her changes in sprint time resulted in increases in sprinting speed post supplementation during both the PRO and CHO trials. Female 1 was the fastest female sprinter of the subject population and experienced the most significant reduction in sprint time (-1.40 sec) with the consumption of CHO. She remained among the fastest of female sprinters throughout the trials. As with most subjects, female 1 did not enjoy drinking PRO. She found it difficult to consume the PRO beverage within the 15 minutes allotted for ingestion, and her abdomen was visibly distended following ingestion. She also needed to "use the restroom" following supplementation with the PRO beverage. The subject was unable to complete trial 3 because she missed the shuttle that transports the athletes back and forth to the track.

Female 2

Female 2 completed all trials. Similar to Female 1, she was among the fastest sprinters and experienced a decrease in sprint time (-0.30 sec) with consumption of CHO. The worst performance was experienced following PRO ingestion (+.60 sec). The subject also experienced abdominal distension and difficulty finishing the PRO recovery beverage in the specified time.

Female 3

Female 3 completed all trials. While she was not among the fastest of the subjects, she experienced no change in sprint time during trial 1 (PRO) from sprint 1 to sprint 2. In both trials 1 and 3, she saw the least change in time from the initial to second sprints compared to other subjects. The fastest times for both sprints 1 and 2 occurred in trial 1 where she also had the smallest differences in sprinting time between sprints. This means that she was able to maintain a faster sprinting speed with PRO. Carbohydrate alone supplementation resulted in the highest increase in sprint times for the subject.

Female 4

Female 4 only participated in trial 2 (CHO). The subject missed practice on the day of the initial trial and had no further interest in participating beyond trial 2. This was possibly related to the preference of having a shorter practice. Those who were not participating in the study did not have to stay at the track. The 1-hour recovery time called for participating subjects to remain at the track longer than a typical practice.

Female 5

Female 5 was among the three subjects who experienced no change in sprinting time from sprint 1 to sprint 2 during trial 1 (PRO). Immediately following the second 200- meter sprint of the sprinting trials, the subjects completed subsequent sprints as part of their training regimen outlined by their coach. Female 5 was able to complete these sprints without becoming quickly fatigued and outperformed other sprinters in her group. The subject called the recovery beverage a "magic potion" and expressed feeling "good" during the workout. However, following completion of the workout Female 5 vomited unexpectedly, although having no preceding gastrointestinal (GI) symptoms.

Female 6

Female 6 experienced uncomfortable bloating during trial 1 from ingestion of PRO dropped out of the study after the first trial. She experienced one of the greatest differences in sprint time during trial 1. She had the 4^{th} fastest initial sprints during the PRO trial but dropped down to one of the slowest in the post-supplementation sprint.

Female 7

Female 7 experienced GI upset related to the consumption of the PRO beverage and dropped out following trial 1 (PRO). This subject had the greatest difference in sprinting time compared to any other subject (1.80 sec). The GI distress was so great in this subject that she was unable to sprint the entire 200 meter distance. Her efforts had been reduced to a jog before the end of the sprint.

Female 8

Female 8 was one of the 3 subjects that dropped out of the study after trial 1 (PRO). The subject had the second fastest initial sprint time, but following consumption of the PRO beverage the subject found it difficult to complete the second sprint. She had the second largest increase in sprinting time (0.90 sec) in trial 1 (PRO).

Males

Male 1

Male 1 was one of two males, and the only male to complete all three trials. Male 1 experienced no change in sprint time following supplementation with the PRO beverage. Although this subject found it difficult to complete the beverage in the time given, he did not complain of GI discomfort. His largest increase in sprinting time was following consumption of the CHO beverage (+.70 sec).

Male 2

This subject increased sprint speed from sprint 1 to sprint 2 in the PRO trial. He also had the fastest times of the two male sprinters. It was revealed that the subject had been taking protein supplements in the form of liquid "protein shakes" prior to the investigation. The fact that this subject was able to tolerate a bolus ingestion of protein and improve sprinting performance may be related to him already being accustomed to this type of solution. Male 2 was able to participate in the initial trial only. He sustained an injury that prevented him from completing the study. It was determined by the team's head coach that the subject not engaged in maximum effort sprinting.

Results Summary

Subjects generally performed better during trial 2 (CHO). In trial 1 (PRO), male 2 sprinted faster in the second sprint by 0.10 sec and Female 1 sprinted faster by .40 seconds (x= -.25 sec), but in trial 2 (CHO), two females, female 1 and female 2, sprinted faster by 1.40 sec and 0.30 sec respectively (x= -.85 sec). The fastest female had their best results with the CHO beverage. The slowest sprinters in trial 1 (female 3 and female 5) did better following PRO supplementation and experienced no increases in sprint time between first and second sprints. In this subject sample, subjects experienced better results with either the CHO solution or the PRO solution. No subject sprinted faster post CHO/PRO supplementation.

CHAPTER V

DISCUSSION AND CONCLUSIONS

Subject Drop Out

The study sprint trials began with 10 subjects and ended with three. Subject drop out was related to unpleasant reactions to supplementation, time needed to be involved in the study, scheduling conflicts, and injury. After trial 1 (PRO), because of the GI effects, some subjects did not want to continue. Several subjects complained of bloating, abdominal discomfort and needing to "use the restroom". Subjects who experienced GI distress had increases in sprinting time and ultimately dropped out of the study. Other reasons for subject drop out include that study participation required subjects to be at the track for longer time and some athletes lacked interest in the study and just did not want to stay (Female 4). In addition, subjects who began sprint trials and desired to continue the study were unable to complete participation because they simply could not make it to the track. Before the study trials began, three additional athletes consented to participation in the study but were not able to. One female was unable to participate due to an injury sustained prior to the initial trial, and two other female athletes were not able to participate because of class schedule conflicts during the time of the study. The low number of subjects ultimately reduced the significance of the study results, and made the use of probability statistics impossible. For data on subject attrition and related causes, reference Appendix C (see Table 7).

Gender Differences

When looking at the mean change in sprint time for males (Table 5), the carbohydrate beverage trial resulted in the highest increase (0.70 sec) in time differences between sprints. Overall, males performed better following PRO supplementation, which showed a mean increase in sprint time (x= 0.05 ± 0.07 sec). Due to injury, male 2 only completed the initial trial; however, the fact that he was actually able to reduce sprint time with protein supplementation is important. The exact opposite holds true for females. Females saw the smallest change in sprint time from sprint 1 to sprint 2 in the carbohydrate trial (x= .10 ± 95). Generally, performance was worse with protein supplementation in females. There are two proposed explanations for these outcomes. The first reason is that previous studies have shown that muscle protein anabolism occurs most rapidly with a post-exercise supplement that includes protein when compared to carbohydrate alone (15, 16, 17). Males generally have a larger muscle mass than females and may have responded better to the protein supplementation supporting net protein anabolism. Net protein anabolism may have enhanced their ability to recover and allowed for maintenance of subsequent sprint speed. The second possible reason is that energy metabolism is more efficient during recovery when using nutrients that are more frequently consumed as calories by a subject. For example, a person on a higher protein diet would have a better recovery response metabolically with a higher protein post-exercise beverage solution. During the protein trial, six of the female athletes complained of bloating and GI discomfort after consumption of the protein beverage. Their reaction could be related to their bodies not being accustomed to an intake of this volume of protein. Data from the most recent National Health and Nutrition Examination Survey, 2003-2004, shows that males consume a higher percentage of total calories from protein (22). Male subjects most likely had a higher protein intake than females and may have already been using protein supplements prior to participation in the study. Because their bodies are used to higher protein consumption, the males may not have been affected by the bolus protein solution. One male subject (Male 2) was confirmed as taking protein supplements. This male subject was the only subject to decrease sprint time following protein supplementation

Studies agree that gender differences in protein metabolism do exist, with males metabolizing protein more efficiently when compared to females, but further investigations are needed to elucidate these findings. Tipton (2001) suggests that, at the basal level, there are no significant differences in protein metabolism between genders (23). However, during exercise gender differences in protein metabolism do occur. Tarnopolsky et al. (1990) reported that during moderate-intensity, long-duration exercise, females demonstrated decreased protein utilization compared to equally nourished (subjects followed a controlled diet) similarly trained males (24). A subsequent investigation of gender differences in protein metabolism showed that when a primed continuous infusion of the amino acid leucine was administered to equally trained male and female subjects, males oxidized a greater amount of leucine during the infusion than females (25). This study suggests that gender differences in protein metabolism in endurance-trained athletes may have relevance in sprint athletes as well.

Weight Trends and Performance

Subjects tended to lose weight as the study progressed. It is important to note that those athletes who gained weight throughout the study experienced better subsequent sprint performance with PRO supplementation. Sixty-six percent of those who lost weight during the study had better sprint performances with the CHO beverage. For this group, there could be an association with the way protein was metabolized and a capacity for weight gain. For data on weight trends and changes in sprint time, reference Appendix C (Table 8).

Considerations for Improvements

Environmental Influences

Temperatures varied considerably between trials. Temperatures during trial 1 got up to 70° F while during trial 2, temperatures were at a cool 56°F, and trial 3 temperatures were at a moderate 63°F. Inconsistent weather patterns of these trials may or may not have factored into the sprinting outcomes. Future studies should consider doing trials on an indoor track to control climate and other environmental influences.

Study Design and Protocol

To decrease the effects of attrition, recruitment of a larger sample is desirable and conducting the study during the off-season to have more control over the trials so less interference could have occurred. Randomization of beverages within trials may have given a better picture of the results of post-exercise supplementation and lessened the influence of factors such as weather and attrition resulting from GI complications with the PRO beverage. Giving different beverages within trials was considered, but storage space was not able to accommodate three different tubs of beverages in the refrigerator at a single time. However, keeping beverages consistent within trials may have actually turned out as being for the best for this investigation due to the attrition rate. Subject drop out may have caused a beverage to be eliminated from a trial. For example, in trial 3 two subjects may have ended up with the same recovery beverages meaning that one of the beverages would not have been included in that trial.

Every sprinter performed an individualized warm-up and some may not have been as ready to sprint as others. Warm-up is an important part of race preparation and an incomplete or insufficient warm-up could negatively affect sprint performance. Subjects may have warmed up better in sprint 1 compared to sprint 2 resulting in an inaccurate base for comparison between sprints. Original intentions of the investigation were for it to assimilate the actual conditions of a track meet where an athlete would warm-up independently. However, for a more controlled investigation, subjects should have done the same warm-up prior to both sprints.

In the future, a trial of water only should be considered. This was decided against initially because of the literature that has shown that any caloric beverage is better than water (or placebo) for recovery (10). However, because this recovery time is minimal, it would be of interest to see if there are any differences.

Including a survey and questionnaire on how the subjects were feeling mentally and physically before, during, and after the sprints to see how being able to overcome fatigue mentally plays a role should be considered. Consideration of how the subjects felt while engaged in sprinting would help to see if nutrient supplementation affects not just performance but how the subject feels physically. Usually if an athlete feels good physically, they compete well, however, if the athlete is sore and in pain, this can manifest as poor performance.

Conclusions

Post-exercise nutritional supplementation effects varied among subjects, with some subjects performing better following PRO, while others experiencing improvements with CHO. In general, subjects performed better following consumption of the CHO beverage. Of those who ran faster between sprints, the CHO beverage resulted in an average improvement of -.85 sec, while the PRO beverage resulted in an average improvement of -.25 sec. On average, CHO resulted in faster 2nd sprints (x= +.20 sec) than the PRO beverage (x= +.47 sec) or the CHO/PRO beverage (x= +.33 sec). However, there was considerable variation between trials and between individual subjects in sprint times following consumption of the different beverages. Some subjects performed better following PRO supplementation while other subjects found improvements with CHO post-exercise supplementation. These variations suggest that the most appropriate recovery supplement may be based on the unique metabolic response of the individual athlete rather than a single strategy for all sprint athletes. Repeated use of supplement beverages may be needed to adequately understand individual responses to a beverage. This investigation serves as a foundation for future, related studies as further research in this population is necessary for elucidation of conclusions. Although the results of this investigation do not consider statistical significance of the changes in sprint times post-supplementation, these results do have strong practical significance. An athlete who is able to blunt a slowing of sprint speed during a subsequent high-intensity sprint by using a unique recovery nutrition strategy is in a better position to compete favorably during competition. Even small changes, at the level of tenths of seconds, in sprinting time are critically important in track and field performances, and could mean the difference between winning and losing.

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APPENDIX A

APPENDIX B

TABLES

Table 1: Solution Composition and Percent Nutrient Concentration [Weight (g) /Weight (g)]

	Trial 1	Trial 2	Trial 3
Carbohydrate (Sucrose)	0 g	780 g (6%)	468 g (4%)
Protein (Proven 292)	780 g (6%)	0 g	312 g (2%)
Crystal Light®	109.6 g	109.6 g	109.6 g
Water	12, 110 g	12, 110 g	12, 110 g

Table 2: Subject Characteristics

	Subject Age (yr)	Height (cm)	Trial 1 Weight (kg)	Trial 2 Weight (kg)	Trial 3 Weight (kg)
Female 1	20	152.40	50.00	49.54	did not participate
Female 2	19	152.40	54.54	54.22	54.00
Female 3	21	162.56	58.63	59.20	59.27
Female 4	19	162.56	did not participate	63.91	did not participate
Female 5	19	167.64	62.36	61.45	did not participate
Female 6	19	165.10	63.27	did not participate	did not participate
Female 7	18	165.10	55.00	did not participate	did not participate
Female 8	19	170.18	64.27	did not participate	did not participate
Male 1	19	177.80	73.36	73.59	74.45
Male 2	18	180.34	75.25	did not participate	did not participate
Female Mean	19.25 (.89)	162.24 (6.57)	59.26 (5.64)	57.66 (5.78)	56.64 (3.73)
Male Mean	18.50 (.71)	179.07 (1.79)	74.31 (.34)	74.98 (n/a)	74.45 (n/a)
Total Mean	19.10 (.88)	165.60 (9.18)	62.27 (8.07)	60.32 (8.31)	62.57 (10.62)

Values in Parentheses = Standard Deviation

Table 3: Subject Beverage Composition Information by Trial

Subject	Weight (kg)	Nutrient (g)	Total Solution (g)	Calories
TRIAL 1 (PRO)				
Female 1	50.00	60.00	1,000	240.00
Female 2	54.54	65.45	1,090	261.80
Female 3	58.63	70.36	1,172	281.44
Female 5	62.36	74.83	1,247	299.32
Female 6	63.27	75.92	1,265	303.68
Female 7	64.27	77.12	1,285	308.48
Female 8	55.00	66.00	1,100	264.00
Male 1	73.36	88.03	1,467	352.12
Male 2	75.25	90.30	1,504	361.2
Mean (SD)	61.85 (8.45)	74.75 (9.73)	1,237 (168.87)	296.89 (40.56)
TRIAL 2 (CHO)				
Female 1	49.54	59.45	991	237.80
Female 2	54.22	65.06	1,084	260.24
Female 3	59.20	71.04	1,184	284.16
Female 4	63.91	76.69	1,278	306.76
Female 5	61.45	73.74	1,229	294.96
Male 1	73.59	88.31	1,472	353.23
Mean	60.32 (8.31)	72.38 (9.97)	1,206 (166.04)	289.52 (39.87)
TRIAL 3 (CHO/PRO)				
Female 2	55.54	64.80	1,080	259.16
Female 3	59.27	71.12	1,185	284.48
Male 1	74.45	89.28	1,488	357.12
Mean (SD)	62.57 (10.62)	75.01 (12.71)	1,251 (211.87)	300.25 (50.85)

Table 4: Trial 1 (PRO) Subject Sprint Data (Time in Seconds)

	Recorded Season Best (RSB)	Sprint 1 Hand Time	Sprint 1 FAT Conversion (RSBΔ%)	Sprint 2 Hand Time	Sprint 2 FAT Conversion (RSBΔ%)	Change in Sprint Time
Female Mean (SD)	25.62 (1.31)	26.60 (1.23)	26.84 (1.22)	26.84 (1.47)	27.34 (1.46)	.61 (.62)
Female 1	24.27	25.00	25.24 (+4%)	24.60	24.84 (+2%)	-.40
Female 2	24.45	26.00	26.24 (+7%)	26.60	26.84 (+9%)	.60
Female 3	27.69	27.80	28.04 (+1%)	27.80	28.04 (+1%)	0
Female 4	(Female 4 did not participate in Trial 1)					
Female 5	non recorded	28.10	28.34	28.10	28.34	0
Female 6	25.29	26.90	27.14 (+7%)	27.50	27.74 (+9%)	.60
Female 7	26.62	27.20	27.44 (+3%)	29.00	29.24 (+9%)	1.8
Female 8	25.42	25.20	25.44 (+1%)	26.10	26.34 (+3%)	.90
Male Mean (SD)	23.52 (.12)	24.45 (.92)	24.69 (.92)	24.40 (.99)	24.64 (.70)	.05 (.07)
Male 1	23.60	25.10	25.34 (+7%)	25.10	25.34 (+7%)	0
Male 2	23.43	23.80	24.04 (+3%)	23.70	23.94 (+2%)	-.10
Total Mean (SD)	25.10 (1.48)	26.12 (1.46)	26.36 (1.46)	26.30 (1.71)	26.74 (1.77)	.47 (.61)

Table 5: Trial 2 (CHO) Subject Sprint Data (Time in Seconds)						
	Recorded Season Best (RSB)	Sprint 1 Hand Time	Sprint 1 FAT Conversion (RSBΔ%)	Sprint 2 Hand Time	Sprint 2 FAT Conversion (RSBΔ%)	Change in Sprint Time
Female Mean (SD)	26.00 (1.89)	28.14 (.73)	28.38 (.73)	28.24 (1.53)	28.48 (1.53)	.10 (.95)
Female 1	24.27	27.80	28.04 (+13%)	26.40	26.64 (+9%)	-1.4
Female 2	**24.45**	**27.10**	**27.34 (+11%)**	**26.80**	**27.04 (+10%)**	**-.30**
Female 3	27.69	28.20	28.44 (+3%)	29.00	29.24 (+5%)	.80
Female 4	27.57	28.60	28.84 (+4%)	29.20	29.44 (+6%)	.60
Female 5	non recorded	29.00	29.24 (n/a)	29.80	30.04 (n/a)	.80
Female 6	(Female 6 did not participate in Trial 2)					
Female 7	(Female 7 did not participate in Trial 2)					
Female 8	(Female 8 did not participate in Trial 2)					
Male Mean (SD)	23.60 (n/a)	24.90 (n/a)	25.14 (n/a)	25.60 (n/a)	25.84 (n/a)	.70 (n/a)
Male 1	23.60	24.90	25.14 (+6%)	25.60	25.84 (+9%)	.70
Male 2	(Male 2 did not participate in Trial 2)					
Total Mean (SD)	25.52 (1.96)	27.60 (1.48)	27.84 (1.48)	27.80 (1.74)	28.04 (1.74)	0.20 (.89)

Table 6: Trial 1 (CHO/PRO) Subject Sprint Data (Time in Seconds)

	Recorded Season Best (RSB)	Sprint 1 Hand Time	Sprint 1 FAT Conversion (RSBΔ%)	Sprint 2 Hand Time	Sprint 2 FAT Conversion (RSBΔ%)	Change in Sprint Time
Female Mean (SD)	26.07 (2.29)	27.25 (1.63)	27.49 (1.63)	27.55 (1.48)	27.79 (1.48)	.30 (.14)
Female 1	(Female 1 did not participate in Trial 3)					
Female 2	24.45	26.10	26.34 (+7%)	26.50	26.74 (+9%)	.40
Female 3	27.69	28.40	28.64 (+3%)	28.60	28.84 (+4%)	.20
Female 4	(Female 4 did not participate in Trial 3)					
Female 5	(Female 5 did not participate in Trial 3)					
Female 6	(Female 6 did not participate in Trial 3)					
Female 7	(Female 7 did not participate in Trial 3)					
Female 8	(Female 8 did not participate in Trial 3)					
Male Mean (SD)	23.60 (n/a)	24.60 (n/a)	24.64 (n/a)	24.80 (n/a)	25.04 (n/a)	.40 (n/a)
Male 1	23.60	24.60	24.64 (+4%)	24.80	25.04 (+6%)	.40
Male 2	(Male 2 did not participate in Trial 3)					
Total Mean (SD)	25.25 (2.16)	26.37 (1.91)	26.54 (2.01)	26.63 (1.90)	26.87 (1.90)	.33 (.12)

Table 7: Subject Mortality (Attrition) and Proposed Causes			
Subject	Trial 1	Trial 2	Trial 3
Female 1	P	P	M
Female 2	P	P	P
Female 3	P	P	P
Female 4	M	P	N
Female 5	P	P	M
Female 6	P	G	-
Female 7	P	G	
Female 8	P	G	-
Male 1	P	P	P
Male 2	P	I	-
Post-Trial Attrition n (%)	-4 (44%)	-3 (50%)	n/a
Study Total	-7 (70%)		

P= Participated
M= Miscellaneous absence (n=2)
N= No longer interested in participating (n=1)
G= Gastrointestinal distress (n=3)
I= Injury (n=1)

Table 8: Weight Trends and Changes in Sprint Time*

	Trial 1 Wt (kg)	Trial 2 Wt (kg)	Trial 3 Wt (kg)	Total Weight (kg) Δ^1	Trial 1 Δ^2	Trial 2 Δ^2	Trial 3 Δ^2
Female 1	50.00	49.54	Did not Participate	- .46	.45	**-1.39**	Did not Participate
Female 2	54.54	54.22	54.00	- .54	.58	**.29**	.41
Female 3	58.63	59.20	59.27	+ .64	**.02**	.74	.23
Female 5	62.36	61.45	Did not Participate	- .91	**.02**	.71	Did not Participate
Male 1	73.36	73.59	74.45	+ 1.09	**.06**	.79	.23

*Data only includes subjects that completed more than one trial
Δ^1: Overall change in weight over the course of the study
Δ^2: Change in sprint time