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Section: Original Research

Article Title: Post-exercise Glycogen Recovery and Exercise Performance is Not Significantly Different Between Fast Food and Sport Supplements

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POST-EXERCISE GLYCOGEN RECOVERY AND EXERCISE PERFORMANCE IS NOT SIGNIFICANTLY DIFFERENT BETWEEN FAST FOOD AND SPORT SUPPLEMENTS

SIMILAR OUTCOMES FOR SPORT SUPPLEMENTS AND FAST FOOD

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Abstract

A variety of dietary choices are marketed to enhance glycogen recovery after physical activity. Past research informs recommendations regarding the timing, dose, and nutrient compositions to facilitate glycogen recovery. This study examined the effects of isoenergetic sport supplements (SS) vs. fast food (FF) on glycogen recovery and exercise performance. Eleven males completed two experimental trials in a randomized, counterbalanced order. Each trial included a 90-minute glycogen depletion ride followed by a 4-hour recovery period. Absolute amounts of macronutrients (1.54 ± 0.27 g•kg^{-1} carbohydrate, 0.24 ± 0.04 g•kg fat^{-1}, and 0.18 ± 0.03g•kg protein^{-1}) as either SS or FF were provided at 0 and 2 hours. Muscle biopsies were collected from the vastus lateralis at 0 and 4 hours post exercise. Blood samples were analyzed at 0, 30, 60, 120, 150, 180, and 240 minutes post exercise for insulin and glucose, with blood lipids analyzed at 0 and 240 minutes. A 20k time-trial (TT) was completed following the final muscle biopsy. There were no differences in the blood glucose and insulin responses. Similarly, rates of glycogen recovery were not different across the diets (6.9 ± 1.7 and 7.9 ± 2.4 mmol•kg wet weight^{-1}•hr^{-1} for SS and FF, respectively). There was also no difference across the diets for TT performance (34.1 ± 1.8 and 34.3 ± 1.7 minutes for SS and FF, respectively. These data indicate that short-term food options to initiate glycogen resynthesis can include dietary options not typically marketed as sports nutrition products such as fast food menu items.

Introduction

It is common knowledge that muscle glycogen stores can be significantly replenished when dietary carbohydrate (CHO) sources are ingested following a glycogen depleting bout of exercise (Bergstrom & Hultman, 1966). The positive relationship between initial muscle glycogen stores and work time to exhaustion (Ahlborg et al., 1967) has led to the present dogma that exercise performance necessitates an emphasis on muscle glycogen.Research has continued to demonstrate that regular CHO feedings after glycogen depletion enhance muscle glycogen resynthesis (Rotman et al., 2000; Tarnopolsky et al., 1997) and endurance performance (Ivy et al., 2003). Additional emphasis has been placed on macronutrient composition/ratios (Blom et al., 1987; Burke, Collier, & Hargreaves, 1993;; Zawadzki, Yaspelkis, & Ivy, 1992), the amount of macronutrient (Ivy, Lee, et al., 1988;), and timing of ingestion (Ivy et al., 2002;) to assist athletes, clinicians, and coaches in exercise recovery and performance efforts.

Carbohydrate composition (glucose, fructose, and sucrose) and varying levels of glycemic index (GI) have demonstrated subtle impact on overall rates of muscle glycogen resynthesis (Beavers & Leutholtz, 2008; Blom et al., 1987; Burke, Collier, & Hargreaves, 1993; R. Jentjens & Jeukendrup, 2003). Collectively, these data have emphasized the concept of sports supplements as the preferred nutritional approach to facilitate glycogen recovery. In contrast, the use of chocolate milk has gained recognition as an alternative to traditional sport supplement products for glycogen recovery (Karp et al., 2006; Roy, 2008; Shirreffs, Watson, & Maughan, 2007; Thomas, Morris, & Stevenson, 2009).

While fast food is often viewed as a barrier to the prevention and treatment of obesity in children (Bonnet et al., 2014), sensible menu items may offer a more economical approach to glycogen recovery compared to costly sports supplements. Moreover, there appears to be two major stigmas associated with fast food. The first links fast food to unhealthy eating, childhood obesity, and poor nutritional choices while the second categorizes fast food ingredients as low quality. In contrast, the nutritional value and ingredient quality of sports supplemental food items goes mostly unchallenged because of marketing perceptions and a link to regular physical activity/exercise training.

The purpose of this study was to investigate the efficacy of fast food dietary sources for glycogen recovery compared to common sport supplement foods/beverages. We hypothesized that commonplace fast food options can provide adequate macronutrient needs to restore muscle glycogen and that the potential benefits will not be different from an approach using sport supplement products.

Methods

Participants

Eleven recreationally active male participants (n = 11) completed this randomized cross-over study design. Participants were healthy, injury-free and familiar with moderate to high intensity exercise (27.7 ± 6.3 years, 180 ± 8 cm, 76.8 ± 10.2 kg, 10 ± 5% fat, 4.2 ± 0.4 $LO_2 \bullet min^{-1}$, 309 ± 32 $watt_{max}$). Prior to data collection, each participant completed a Physical Activity Readiness Questionnaire (PAR-Q) and provided informed consent. All procedures were approved by the University Institutional Review Board.

Preliminary Testing

All preliminary testing was completed during the same initial visit after a minimum 4-hour fast. Body composition was estimated using hydrodensitometry. Underwater weight was measured using an electronic strain-gauge scale (Exertech, Dreshbach, MN) with estimated residual lung volume (Goldman & Becklake, 1959). Body density was calculated using underwater weight and transposed to body composition using the Siri equation (Siri, 1993).

Peak oxygen uptake (VO_{2peak}) and maximal power output (W_{max}) were determined in the laboratory on a cycle ergometer (Velotron, RacerMate Inc., Seattle, WA). Participants completed a graded exercise protocol starting at 95 watt, increasing 35 watt every 3 min until volitional fatigue. Expired gases were analyzed using a calibrated metabolic cart (ParvoMedics, Inc., Salt Lake City, UT). VO_{2peak} was determined as the highest fifteen second average oxygen uptake during the test. Maximum power output was calculated by adding the power output (watt) of the last completed stage to the time in the stage volitional fatigue was achieved multiplied by 35 watt. For example, each minute of each stage was assumed to be equivalent to 11.67 watt (35•0.334 = 11.67).

In addition to the measure of VO_{2peak}, participants completed two practice (PTT) 20km time trials (TT) on the same cycle ergometer on two separate days to ensure TT competency prior to the completion of the experimental trials. Participants were verbally instructed to complete the distance as quickly as possible and were allowed the flexibility of shifting gears electronically. Distance and time were measured using the RacerMate Inc. software. (RacerMate, Inc., Seattle, WA).

Experimental Design

Participants completed two trials with seven days between each trial in a randomized crossover design. Trials included the consumption of sport supplement products (SS) or fast food menu items (FF) during a 4-hour recovery period after a glycogen depletion ride. A 20km TT followed the recovery period to evaluate exercise performance. Participants were instructed to abstain from exercise and keep a dietary record of all food and drink consumed 24-hours prior to each trial. Participants were instructed to duplicate this diet for the second trial to minimize differences in resting muscle glycogen levels. The morning of each trial, participants arrived at the lab following a 12-hour fast. Each participant completed the 90-minute glycogen depleting exercise using the above mentioned cycle ergometer. The protocol included a 10-minute warm up at 55% W_{max} followed by a series of 10 intervals (2-minutes at 80% W_{max} followed by 4-minutes at 50% W_{max}). After the interval series, participants completed 8-minutes at 60% W_{max} followed by a final 12-minutes at 50% W_{max}. Water consumption was ad libitum. Following the 90-minute cycling trial, participants rested in a reclined/seated position during a 4-hour recovery period and adhered to a prescribed feeding schedule. Following the 4-hour recovery period, participants completed the 20km TT on the same cycle ergometer as described above.

Feeding Strategy

Participants consumed absolute amounts of macronutrients as either SS or FF at 0 and 2-hours of recovery. All food items were weighed for accuracy in conjunction with nutrition label serving sizes. Participants consumed the same food items, which

amounted to 1.54 ± 0.27, 0.24 ± 0.04, and 0.18 ± 0.03 g•kg^{-1} for carbohydrate, fat, and protein, respectively. Table 1.1 and 1.2 illustrate the detailed menu items.

Muscle Biopsies

Muscle biopsies of the vastus lateralis muscle were performed at 0 and 4-hours of recovery using the percutaneous biopsy needle technique with the aid of suction (Evans, Phinney, & Young, 1982). One milliliter of 1% lidocaine was injected directly beneath the skin to anesthetize an area approximately 2 cm^2, then an additional 2-3 ml of 1% lidocaine preparation was injected near the location of the fascia. Adrenaline was not used in combination with the lidocaine. Following the lidocaine injection a small (approximately 0.5 cm) incision was made through the skin and muscle fascia. The Bergstrom biopsy needle was then inserted through the incisions into the belly of the vastus laterals muscle, removing approximately 30mg of tissue. Excess blood, fat, and connective tissue were immediately removed. Tissue samples were frozen in liquid nitrogen and stored in a freezer at -80^{0}C for later muscle glycogen analyses. The 4-hour biopsy was taken from a site approximately 2 cm proximal to the initial 0-hour biopsy location. Second trial biopsies were taken from the opposite leg and leg order was randomized across trials.

Blood Sampling

Blood samples were obtained from an antecubital arm vein using a venipuncture technique at scheduled intervals of 0, 30, 60, 120, 150, 180, and 240 min of recovery (n=10). Samples were allowed to clot then spun at 4000 rpm for 15 minutes in a refrigerated centrifuge (4°C) (Jouan Inc., MR22i). Serum was aliquoted into tubes and

stored at −30°C for later glucose and insulin analyses. Whole blood samples were collected at 0 and 4 h of recovery and sent to Providence St. Patrick Hospital in Missoula, MT for lipid analyses.

Questionnaire

Participants completed gastrointestinal discomfort questionnaires assessing feelings of hunger, fullness, sickness, and stomach discomfort at 0, 1, 2, 3, and 4-hours of recovery. A second post-meal questionnaire was administered at 0 and 2-hours of recovery assessing meal satisfaction, taste, and acceptability. Questionnaires were designed on a 150mm visual analogue scale (VAS) with "Not at all" on the left and "Extremely" on the right end points. Participants placed an X along the continuum in response to each question. Scores were reported as the distance from "Not at all" in mm divided by 150mm. This technique has been previously used to evaluate dietary impacts (Kissileff et al., 2003).

20km Time Trial

After recovery, participants performed a 20km TT on the same cycle ergometer as described above (Velotron, RacerMate Inc., Seattle, WA). Participants were instructed to complete the distance as quickly as possible and were allowed to shift gears electronically. Verbal encouragement was not provided during any of the TT testing segments.

Tissue and Blood Analysis

Two separate muscle samples (12.7±3.0 mg, obtained at the same time point) were each analyzed in duplicate to determine muscle glycogen concentrations using an

enzymatic spectrophotometric method (Ruby et al., 2005). Samples were weighed and placed in 0.5 ml of 2N HCl solution. Sample solutions were weighed, incubated in an oven for two hours at 100°C, then re-weighed and re-constituted to their original weight using distilled water. To normalize pH, 1.5 ml of 0.67 M NaOH was added. Then 100 µl of the muscle extract solution was added to 1 ml of infinity glucose (HK) liquid stable reagent (ThermoTrace Ltd.) and read on a spectrophotometer at 340 nm. Muscle glycogen concentration was calculated using the extinction co-efficient of NADH. Muscle glycogen concentrations are expressed in $mmol \bullet kg^{-1}$ wet weight of muscle.

Blood samples were analyzed for glucose in triplicate using Infinity glucose (HK) liquid stable reagent (ThermoTrace Ltd.) and read on a spectrophotometer at 340 nm. Blood glucose concentration was calculated using the extinction co-efficient of NADH. Samples were analyzed for insulin in duplicate using an enzymatic spectrophotometric ELISA method (EIA-2935, DRG International). Serum lipid analyses were performed by the laboratory at Providence St. Patrick Hospital (Missoula, MT). Samples were allowed to clot for 30 minutes in serum separating tubes then spun at 2500G in a refrigerated centrifuge (Beckman Coulter INC). Samples were then placed in a chemistry analyzer for reading (Dimension Vista 500, Siemens). Mean intra-assay coefficient of variation for muscle samples, glucose, and insulin was less than 5%.

Statistical Analysis

A two-tailed, paired t-test was used to compare rates of muscle glycogen recovery (Microsoft Excel, Microsoft Corp., Redmond, WA). PTT and TT performance times were analyzed using a one-way ANOVA with repeated measures (SPSS Inc., Chicago, IL). Muscle glycogen, blood glucose, serum insulin, blood lipids, and

questionnaire data were analyzed using a two-way ANOVA (trial × time) with repeated measures (SPSS Inc., Chicago, IL). A probability of type I errors less than 5% was considered significant ($p<0.05$). All data are reported as mean ± SD.

Results

Muscle Glycogen

We were unable to detect a statistically significant difference in muscle glycogen concentration post-exercise when comparing SS and FF trials at 0 and 4-hours of recovery ($p>0.05$). There was a main effect for time, demonstrating an overall increase in muscle glycogen concentrations following the 4-hour recovery period ($p<0.05$, $n=11$) (Figure 1). Similarly, the calculated rate of muscle glycogen recovery was not different between diets (6.9 ± 1.7 and 7.9 ± 2.4 mmol•kg wet weight^{-1}•hr^{-1} for the SS and FF trials, respectively ($p>0.05$, $n=11$).

Blood Glucose

There was no difference for blood glucose concentrations between SS and FF trials at 0, 30, 60, 120, 150, 180, and 240 minutes of recovery ($p>0.05$, $n=10$) (Figure 2). There was a main effect for time, as blood glucose was elevated at 30 and 150 minutes compared to time 0 ($p<0.05$, $n=10$).

Serum Insulin

There was no difference for serum insulin concentrations between SS and FF trials at 0, 30, 60, 120, 150, 180, and 240 minutes of recovery ($p> 0.05$, $n = 10$) (Figure 2). There was a main effect for time, with serum insulin elevated at 30, 60, 150, and 180 minutes compared to time 0 ($p < 0.05$, $n = 10$).

Blood Lipids

There was no difference between SS and FF trials for total cholesterol, high-density, low-density lipoproteins, and triglycerides at 0 hours and 4 hours post-exercise (Table 2). There was a main effect for time, which demonstrated that CHOL, HDL, and LDL were lower 4 hours post-exercise compared to time 0 ($p<0.05$, n=10)

20k Time Trial

There was no difference in TT performance between PTT and the experimental trials (34.3 ± 2.1, 34.5 ± 1.9, 34.1 ± 1.8, and 34.3 ± 1.7 minutes for PTT1, PTT2, SS, and FF trials, respectively, $p>0.05$, n = 11).

Questionnaire

There was no difference for feelings of sickness and discomfort between the trials observed at 0, 1, 2, 3, and 4 hours of recovery ($p>0.05$, n=11). Hunger displayed a main effect for time with scores of 42 ± 8, 64 ± 6, 28 ± 6, 53 ± 7, and 72 ± 6 millimeters at 0, 1, 2, 3, and 4 hours of recovery, respectively. ($p<0.05$, n = 11). Hunger was higher at 4 hours compared to time 0 hours of recovery. Participants reported being more full during the SS compared to FF immediately after the 2-hour feeding (108 ± 33 vs. 75 ± 42mm, respectively, interaction effect, $p<0.05$, n=11). No difference was observed for perceived meal taste and acceptability after 0 and 2-hour feedings ($p>0.05$, n=11). There was no difference between the diets for feelings of satiety after 0 and 2 hour feedings, but the FF meal was more satisfying at 2 hours compared to the initial 0 hour FF meal (78 ± 32 vs. 52 ± 27mm, respectively, interaction effect, $p<0.05$, n=11).

Discussion

This protocol was designed to evaluate the impacts of non-traditional sport nutritional choices on recovery, specifically glycogen recovery, and subsequent exercise performance. This was accomplished by matching macronutrient composition from fast food menu items with commercially available sport nutrition products used for the 0 and 2 hour post-exercise feedings. Primary findings demonstrate that muscle glycogen recovery and exercise performance were not different when comparing products created specifically for sport recovery and traditional fast food. These data are novel in demonstrating effective glycogen recovery benefits from fast food menu items comparable to products most often advertised as a practical option to optimize glycogen recovery.

A wide range of feeding strategies have been implemented (macronutrient composition, amount, and timing of ingestion) so as to develop specific suggested guidelines to enhance immediate glycogen resynthesis (Ivy, 1998; Ivy et al., 2002; Ivy, Katz, et al., 1988; R. Jentjens & Jeukendrup, 2003; Reed et al., 1989). Optimal glycogen recovery recommendations are 1.2g•kg^{-1} CHO every hour, ingested in regular intervals of ≤30 minutes (R. Jentjens & Jeukendrup, 2003; van Loon et al., 2000). This study chose to utilize a 2-hour interval feeding strategy as suboptimal, real-world application of recovery strategies where environment, nutrient source availability, and total amount of nutrient source ingestion may hinder adherence to optimal recovery recommendations. Administration of CHO immediately after exercise has been shown to improve glycogen recovery by 45% versus delayed feedings and is further enhanced with the addition of a 2-hour feeding (Ivy, Katz, et al., 1988). However, if feeding is

provided prior and during extended exercise, the inclusion of a carbohydrate/protein recovery product immediately post-exercise does not enhance rates of glycogen recovery compared to a 2-hour delayed feeding (Reinert et al., 2009). Carbohydrate amount used in the present study of 1.54 ± 0.27g·kg^{-1} was in accordance with previous studies suggesting a plateau of glycogen recovery between feedings of 0.7 and 3.0g·kg^{-1} administered in two hour intervals (Blom et al., 1987; Ivy, Lee, et al., 1988; R. L. Jentjens et al., 2001; Reinert et al., 2009). In addition, muscle glycogen recovery rates of 6.9 ± 1.7 and 7.9 ± 2.4 mmol·kg wet weight^{-1}·hr^{-1} for SS and FF, respectively, are comparable to previous research of 4.1-10.6 mmol·kg wet weight^{-1}·hr^{-1} given a variety of modalities, environments and feeding strategies (Gillum, Dumke, & Ruby, 2006; Naperalsky, Ruby, & Slivka, 2010; Reinert et al., 2009; Ruby et al., 2005).

While the presence of protein in the form of essential amino acids (EAA) enhances muscle glycogen recovery in conjunction with a moderate amount of CHO (approximately 0.8g•kg^{-1}•hr^{-1}), protein added to a high CHO supplement (≥1.2g•kg^{-1}•hr^{-1}) does not further increase glycogen recovery rates (R. L. Jentjens et al., 2001). Although the inclusion of additional protein and/or novel amino acids may alter short-term rates of glycogen recovery (Ivy et al., 2002; Ruby et al., 2005), the present data demonstrate that the sources of carbohydrate and protein (1.54 ± 0.27 and 0.18 ± 0.03 g•kg^{-1} respectively) from fast food result in comparable rates of glycogen synthesis.

The present blood response data demonstrates a rapid rise in blood glucose and insulin 30-minutes following each feeding with a concomitant return to baseline by 60-minutes post feeding. This is comparable to prior research using varied strategies in the carbohydrate dose (Ivy, Lee, et al., 1988), feeding intervals (Ivy, Katz, et al., 1988),

and type of feedings (Ivy et al., 2002). The near identical response patterns for glucose and insulin with the two diets highlight the lack of difference between diets in terms of digestion, absorption and ultimately CHO delivery to the muscle.

While it is commonly hypothesized that the chronic consumption of fast food choices have a negative effect on dyslypemia, cardiovascular risk, and obesity (Grundy & Denke, 1990), the acute consumption has received little attention in the literature when applied to young, active individuals. Furthermore, fast food sources matched isoenergetically to sports supplements can provide for basic recovery needs of the muscle and may offer a convenient and economical approach to glycogen recovery under some circumstances.

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Authors' Contributions

MJC participated in conception, design, data acquisition, assisted in muscle glycogen, blood parameter, questionnaire, and TT analysis and interpretation of data, and wrote the manuscript. CLD participated in conception, design, assisted in muscle glycogen, blood parameter, questionnaire, and TT analysis and interpretation of data, and aided in the drafting and revising of the manuscript. JSC participated in conception, design, data acquisition, analysis and interpretation of data, and aided in the drafting and revising of the manuscript. WSH participated in conception, design, data acquisition, analysis and

interpretation of data, and aided in the drafting and revising of the manuscript. BCR participated in conception, design, and data acquisition, assisted in analysis and interpretation of data, and aided in the drafting and revising of the manuscript. All authors have read and given final approval of this version of the manuscript for publication.

Funding and Conflicts of Interest

The authors declare that they have no competing interests in access to these data or associations with companies involved with products used in this research.

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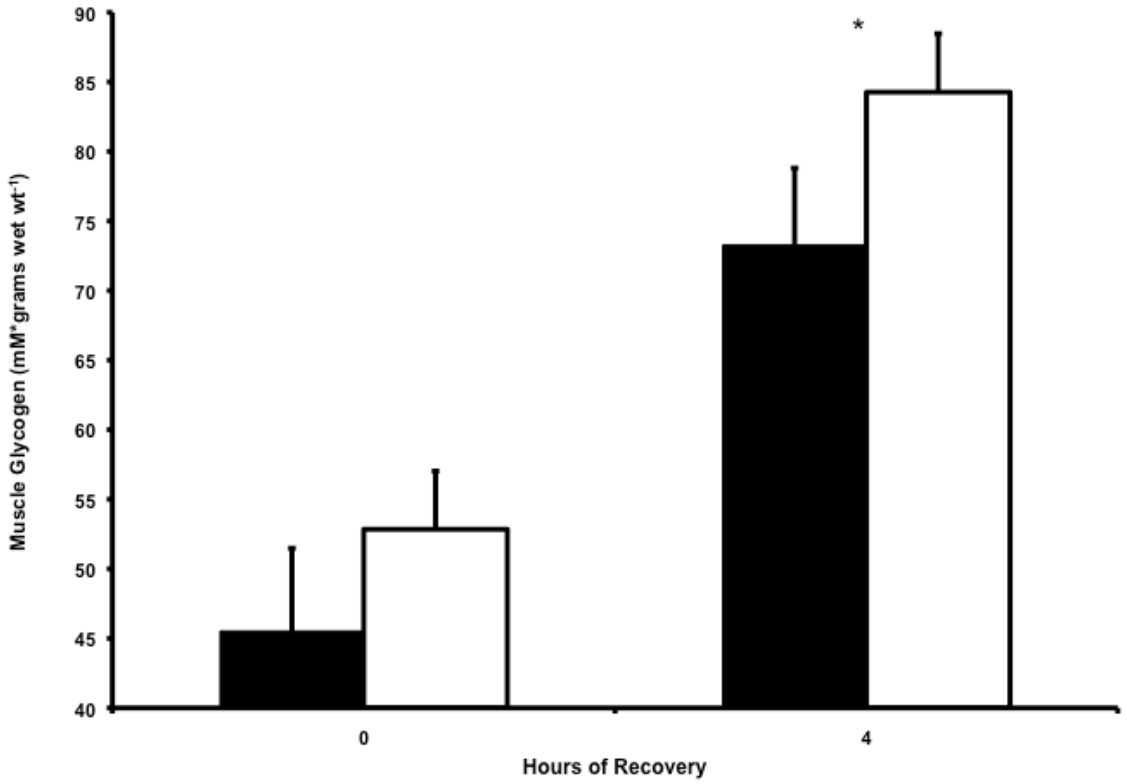

Figure 1. Muscle glycogen concentration during recovery.

■SS, □FF *p<0.05 (n=11) main effect for time vs 0 hours. Values are mean ± SEM

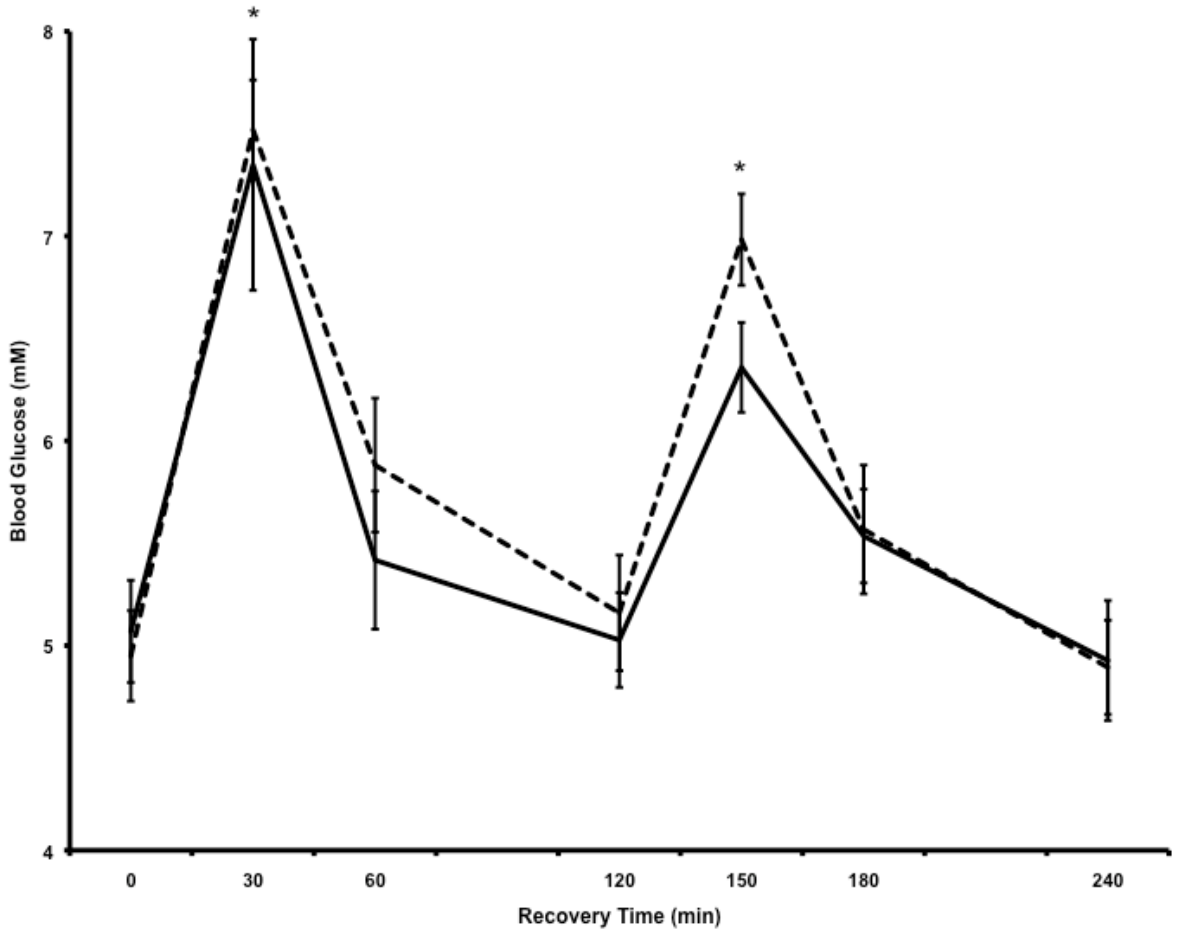

Figure 2. Blood glucose concentration during recovery.

----FF, —SS *p<0.05 (n=10) main effect for time vs 0 hours. Values are mean ± SEM

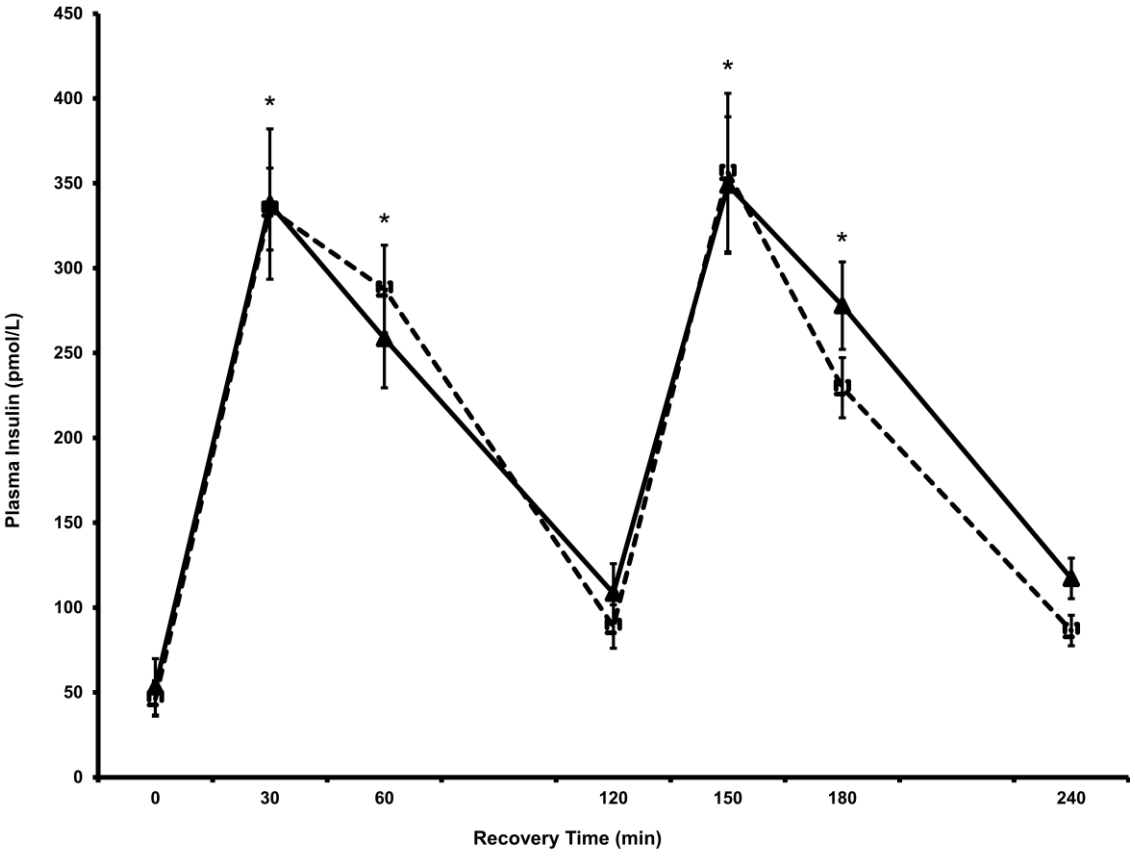

Figure 3. Serum insulin concentration during recovery.

----FF, —SS *p<0.05 (n=10) main effect for time vs 0 hours. Values are mean ± SEM

Table 2.1 Fast food feeding

Fast Food						
0 hr	**Energy (kJ)**	**Fat (g)**	**Cho (g)**	**Pro (g)**	**Qty**	**Sodium (mg)**
Hotcakes	1464	9	60	8	1	590
Hashbrown	628	9	15	1	1	310
Orange Juice (small)	628	0	34	2	1	0
Total	2720	18	109	11		900
2 hr						
Hamburger	1046	9	31	12	1	480
Coke (medium)	837	0	54	0	1	45
Fries (small)	962	11	29	3	1	160
Total	2845	20	114	15		685
4 Hour Total	5565	38	223	26		1585

Table 2.2 Sport supplement feeding

Sport Supplement						
0 hr	**Energy (kJ)**	**Fat (g)**	**Cho (g)**	**Pro (g)**	**Qty**	**Sodium (mg)**
Gatorade (20 oz)	544	0	34	0	1	270
Kit's Organic PB	837	11	25	6	2	95
Cliff Shot Bloks (1 blok)	139	0	8	0	4	17
Total	2775	22	116	12		527
2 hr						
Cytomax (1 scoop, 10 oz)	377	0	22	0	2	120
Power Bar Recovery PBCC	1088	10	30	12	1	180
Power Bar Energy Chews	837	0	46	3	1	30
Total	2678	10	120	15		450
4 Hour Total	5453	32	236	27		977

Table 3 Blood lipid profile for both trials (FF and SS) at the beginning (0 hour) and end (4 hour) of recovery

	FF		SS	
	0 hour	**4 hour**	**0 hour**	**4 hour**
CHOL(mg/dL)	173 ± 32	160 ± 34*	177 ± 28	164 ± 29*
TRIG(mg/dL)	106 ± 31	108 ± 53	112 ± 50	130 ± 102
HDL(mg/dL)	62 ± 15	56 ± 16*	62 ± 13	54 ± 12*
LDLc(mg/dL)	89 ± 27	83 ± 28*	93 ± 25	84 ± 29*

*$p<0.05$ (n=11) main effect for time vs 0 hours.