

Effects of Steady State and High-Intensity Exercise on Compensatory Eating Behavior

Original Research

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Abstract

Introduction: Studies have shown differences in weight loss between high-intensity interval training (HI) and moderate continuous training (SS) potentially due to compensatory eating behaviors. The aim of this study is to observe the differences in eating behaviors HI and SS exercise.

Methods: Nine lean, college-aged individuals and participated in this study. Subjects completed three trials in a randomized order. During HI, subjects completed 16 intervals alternating between 90% and 50% $\text{VO}_{2\text{max}}$ (1:1). During SS, subjects ran at 70% $\text{VO}_{2\text{max}}$. Subjects sat quietly during the control trial. Food logs were collected 24 hours before and after exercise bouts. Data was analyzed using one-way repeated measures ANOVA. All data are presented as mean \pm SE.

Results: Caloric intake was not different between trials (CON: 1558 ± 172 kcal, HI: 1851 ± 150 kcal, SS: 1683 ± 143 kcal, $p=0.23$). Carbohydrate was not different between trials (CON: 186 ± 25 g, HI: 225 ± 24 g, SS: 201 ± 23 g, $p=0.41$). Fat was not different between trials (CON: 55 ± 8 g, HI: 73 ± 9 g, SS: 63 ± 5 g, $p=0.16$). Protein was not different between trials (CON: 78 ± 28 g, HI: 69 ± 10 g, SS: 70 ± 14 g, $p=0.64$).

Conclusions: Acute HI exercise did not lead to different compensatory eating behaviors compared to SS exercise. Practitioners may feel confident to recommend any exercise model without concern for compensatory overeating.

Key Words: Caloric expenditure, macronutrients, eating behaviors

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Introduction

Exercise plays a critical role in the management of body weight and obesity-related comorbidities. Exercise is often prescribed, along with dietary modifications, to those wishing to decrease weight and/or change their body composition. Often, the implementation of a diet and exercise regimen does not lead to favorable changes in weight or body composition. Though responses to weight management programs are highly individualistic, responsiveness can be attributed to several factors; one such factor could be compensatory eating after exercise.

Exercise, acute and chronic, has been shown to influence appetite by increasing anorexigenic hormones cholecystokinin (CCK), polypeptide YY (PYY), and glucagon like peptide-1 (GLP-1) and decreasing appetite stimulating hormones such as acylated ghrelin (AG) in the gastrointestinal tract¹. This provides an intriguing concept in weight management; theoretically, individuals will benefit from the caloric expenditure from the exercise itself and

eat less after the exercise is completed. This further supports the inclusion of exercise in weight management programs. However, this does not always occur in reality.

The research evaluating this concept has been mixed. Numerous studies found that exercise did in fact lead to increases in energy intake in some individuals following exercise^{2,3} yet others found the opposite to be true^{4,5}. A recent study found that the desire to eat approached significance ($p=0.07$) following high-intensity exercise in overweight and obese men⁶. A cross-over study conducted by Martins⁷ observed the acute effects of vigorous intensity continuous cycling, high-intensity intermittent cycling, and short-duration high-intensity intermittent cycling on appetite-related hormones. Each exercise intensity produced similar responses by reducing levels of appetite-related hormones such as AG and increasing GLP-1 and PYY. Energy intake was not observed post-exercise during this study⁷.

To date, few studies have considered the acute effects of compensatory eating in trained, healthy individuals. Furthermore, the effect of exercise intensity on compensatory eating behaviors and macronutrient selection is also unclear. Therefore, the purpose of this study was to evaluate eating behaviors after high intensity intermittent and vigorous intensity steady state exercise in trained, healthy young men and women.

Scientific Methods

Participants

Nine subjects volunteered for the present study (3 males and 6 females). Subjects were recruited from the East Stroudsburg University community through word of mouth. Subjects were young (23.6 ± 1.3 years old) and recreationally active ($\text{VO}_{2\text{max}}$: 47.0 ± 2.9 ml/kg/min). All subjects were non-obese (height: 66 ± 1 in, weight: 148 ± 7 lb, body mass index: 24 ± 0.7 kg/m²; body fat: $20 \pm 2\%$) and weight stable for the past 6 months. Subjects were non-smokers, did not take dietary supplements, and free of cardiovascular, metabolic, and renal disease and did not have any condition that would interfere with exercise. This study was approved by the Internal Review Board at East Stroudsburg University.

Protocol

Prior to participation, subjects completed a written informed consent; subjects were blinded to the true purpose of the study to not influence food selection before and after exercise. Subjects were told that the study they were participating in was to evaluate heart rate (HR) response to various exercise program structures. Subjects also completed a Physical Activity Readiness Questionnaire (PAR-Q), weight and activity history to confirm inclusion criteria was met.

Weight was assessed on a physician's scale while shoeless with minimal clothing (Detecto, Webb City, MO). Height was assessed, using a wall-mounted stadiometer. Body composition was then assessed via air-displacement plethysmography using the BOD POD® (COSMED, Concord, CA). $\text{VO}_{2\text{max}}$ tests were administered to each subject using a Quinton® TM55 motorized (Cardiac Science; Waukesha, WI) and utilized the Bruce protocol. Expiratory gases were collected and analyzed using the Parvo Medics TrueOne 2400 metabolic cart (Sandy, UT). HR was continually monitored using a Polar T-31 HR monitor (Polar Electro Inc., Lake Success, NY). Following familiarization, subjects completed the $\text{VO}_{2\text{max}}$ until self-determined volitional fatigue. A $\text{VO}_{2\text{max}}$ test was considered valid when the following criteria were met: VO_2 increased < 50 ml/min with increasing workload, rate of perceived exertion reached 17 or higher on the Borg Scale, and HR surpassed 85% of age-predicted max.

After preliminary assessments were complete, and at least 24 hours prior to the first exercise session, investigators calculated each subject's exercise treadmill running speed for each workload (50%, 70%, and 90% of predetermined $\text{VO}_{2\text{max}}$) using metabolic equations from the American College of Sports Medicine for running and walking⁸. All calculations were completed using a 0% grade. Following running speed calculations, the order that subject would complete the trials was randomized. Subjects were not told beforehand which trial would take place on a given day. Metabolic calculations were also used to determine the energy expenditure (EE) of each exercise session for each subject. Resting VO_2 was assumed to be 3.5 ml/kg/min.

Each subject completed each of the following exercise trials: continuous, vigorous-intensity steady state exercise (SS), high-intensity, intermittent exercise (HI), and a control trial. During the SS trial, subjects ran for 33 minutes at a speed corresponding to 70% of their predetermined $\text{VO}_{2\text{max}}$. During the HI trial, subjects ran for 34 minutes, alternating between 1 minute of running at 90% of their predetermined $\text{VO}_{2\text{max}}$ and 1 minute of walking at 50% of their predetermined $\text{VO}_{2\text{max}}$. During the control trial, subjects sat quietly on a chair for 34 minutes. During both exercise

trials, subjects were not able to view their running speeds; in all trials, the subjects were not aware of their precise trial time as they were not permitted to have any time keeping device on hand.

Subjects were asked to refrain from strenuous exercise 24 hours prior to each exercise session which was verbally confirmed upon arrival to each exercise session. Subjects reported to the laboratory, in an 8-10 hour fasted state, between 6:00 and 8:00am. Upon arrival, subjects consumed 20oz of orange or fruit punch flavored original Gatorade® (PepsiCo, Purchase, NY). The Gatorade® included 140kcal, 36g carbohydrate, 0g fat, and 0g protein. Subjects had 10 minutes to finish the beverage, then sat quietly in the laboratory for 60 minutes. Subjects then completed a 5-minute warm-up on the treadmill at a speed corresponding to 50% of their predetermined $\text{VO}_{2\text{max}}$. Subjects completed their assigned exercise protocol (discussed in previous paragraph) followed by a 5-minute cool-down on the treadmill at a speed corresponding to 50% of their predetermined $\text{VO}_{2\text{max}}$. HR was monitored throughout the exercise session and recorded each minute; RPE was recorded every two minutes throughout the exercise session. Subjects completed the remaining exercise sessions on the same day of the week, the following 2 weeks.

Subjects were asked to keep their dietary intake as normal as possible. All subjects logged their food 24 hours prior to exercise and 24 hours after each exercise session. Food intake was logged using the MyFitnessPal (Under Armour, Baltimore, MD) mobile application and website. Subjects were asked to provide photographs of all of the food and drink they consumed to verify their food logs. Daily caloric intake, carbohydrate (CHO), protein (PRO), and fat (FAT) was analyzed.

Statistical Analysis

A one-way analysis of variance (ANOVA) was used to assess differences in EE, RPE, and HR during exercise across exercise sessions. A one-way ANOVA was also used to assess daily caloric and macronutrient intake before and after exercise. Bonferroni post-hoc analysis was used to evaluate findings of significance. Cohen's Guidelines were used to determine effect size of clinically significant findings. Statistical significance was accepted at $p \leq 0.05$ (SPSS version 24.0, IBM Corporation, Armonk, NY). All data was reported as mean \pm SE.

Results

Exercise

Sessions

Each subject completed all three sessions of exercise (control, SS, HI). EE was significantly lower during the control session (77 ± 10 kcal) compared to the HI (321 ± 73 kcal) and SS (345 ± 73 kcal) exercise sessions ($p < 0.001$). There was no difference in EE between HI and SS ($P = 0.49$). RPE was significantly lower during the control session (6 ± 0) compared to the HI (14 ± 3 ; $p < 0.001$) and SS (14 ± 1 ; $p < 0.001$) exercise sessions. There was no difference in RPE between HI and SS ($p = 0.81$). HR was significantly lower during the control session (68 ± 10 bpm; $p < 0.001$) compared to the HI (156 ± 22 bpm) and SS (157 ± 21 bpm) exercise sessions. There was no difference in HR between HI and SS ($p = 0.67$).

Food

Intake

Each subject submitted completed food logs for all requested days. Daily caloric intake was not different the day before and the day following exercise in between groups ($p = 0.42$). Effect sizes were not notable for the CON ($d = -0.13$) or SS ($d = 0.26$). Effect size was medium-large ($d = 0.74$) in the HI group. A summary of energy and macronutrient intake can be seen in Table 1.

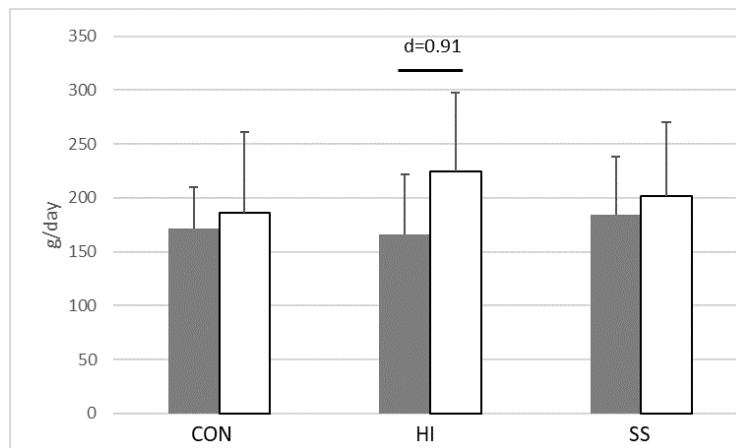
Table 1. Caloric and macronutrient intake the day before (Pre) and 24-hours following (Post) HI, SS, and CON are summarized. Data is presented as Means \pm SE

	CON (n=9)		HI (n=9)		SS (n=9)	
	Pre	Post	Pre	Post	Pre	Post
Caloric Intake (kcal)	1614 \pm 106	1557 \pm 172	1553 \pm 114	1850 \pm 150	1567 \pm 158	1683 \pm 143
Carbohydrate (g)	172 \pm 13	186 \pm 25	166 \pm 19	225 \pm 24	185 \pm 18	201 \pm 23
Protein (g)	68 \pm 10	57 \pm 5	40 \pm 6	61 \pm 6	73 \pm 12	72 \pm 8
Fat (g)	66 \pm 9	63 \pm 5	65 \pm 8	73 \pm 9	62 \pm 10	66 \pm 9

Carbohydrates

Daily CHO intake was not different the day before and the day following exercise in between groups ($p=0.66$). Effect sizes were not notable for the CON ($d=-0.24$) or SS ($d=0.27$). Effect size was large-very large ($d=0.91$) in the HI group. A graphical representation of daily CHO intake can be seen in Figure 2.

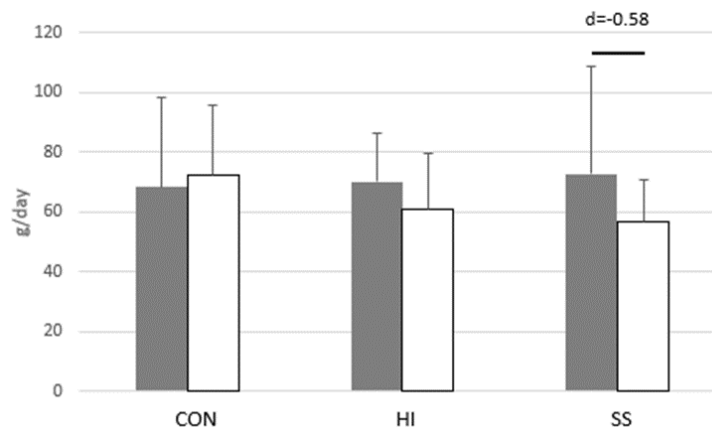
Figure 2. Carbohydrate intake the day before (grey bar) and 24-hours following (white bar) HI or SS exercise and CON. There were no statistically significant findings between days and exercise sessions for carbohydrate intake though the increase in carbohydrate intake in after HI exercise was large-very large. Data is presented as means \pm SE.



Protein

Daily protein intake was not different the day before and the day following exercise in between groups ($p=0.82$). Effect sizes were not clinically notable for the CON ($d=-0.01$) or HI ($d=-0.21$). Effect size was medium-large ($d=-0.58$) in the SS group. A graphical representation of daily protein intake can be seen in Figure 3.

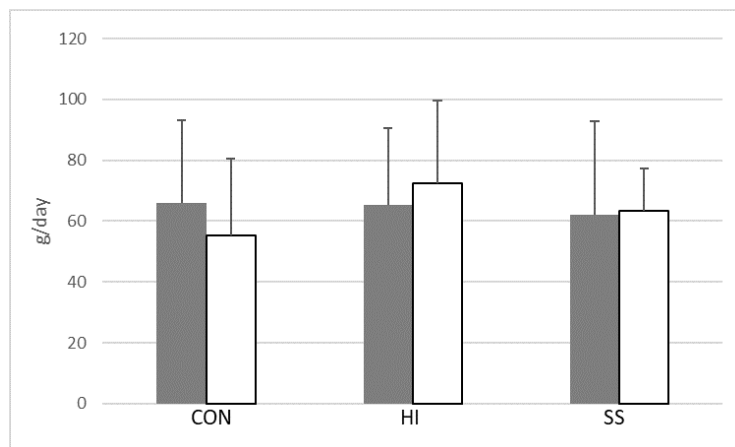
Figure 3. Protein intake the day before (grey bar) and 24-hours following (white bar) HI or SS exercise and CON. There were no statistically significant findings between days and exercise sessions for protein intake though the decrease in protein intake in after SS exercise was medium-large. Data is presented as means \pm SE.



Fat

Daily fat intake was not different the day before and the day following exercise in between groups ($p=0.30$). Effect sizes were not notable for the CON ($d=-0.41$), HI ($d=-0.28$), or SS groups ($d=0.05$). A graphical representation of daily fat intake can be seen in Figure 4.

Figure 4. Fat intake the day before (grey bar) and 24-hours following (white bar) HI or SS exercise and CON. There were no statistically significant findings between days nor were there any notable effect sizes in any exercise session. Data is presented as means \pm SE.



Discussion

The current study observed compensatory eating following an acute bout of HI and SS exercise. While no statistically significant differences in caloric or macronutrient intake were observed, effect sizes indicate potential increases in caloric intake and carbohydrate consumption following HI exercise. We observed medium-large effect size in the HI group indicating that subjects consumed more energy following HI compared to SS. Also, we observed a very-large effect size for increased carbohydrate consumption following HI exercise. Our results agree with previous studies that evaluated compensatory eating behaviors after continuous and interval-based acute exercise^{6,9}.

The exercise prescribed in this study has significant applicability as the protocol was derived from American College of Sports Medicine guidelines⁷ and allowed for the comparison of compensatory eating between a common exercise mode, intensities, and durations. High intensity interval training (HIIT) has emerged as a popular exercise program; HIIT was been listed in the top three Worldwide Fitness Trends since it first appeared on the list 2014¹⁰. Given HIIT's popularity, it is worth considering if this type of exercise program is beneficial for long-term weight management.

We observed an increase in energy intake of 297 kcal following HI exercise; the caloric expenditure of exercise was 321 kcal (24 kcal deficit was observed). This indicates that our subjects' nutritional compensation was close to their increased energy expenditure. Following steady state exercise, subjects consumed an additional 116 kcal while energy expenditure during exercise was 345 kcal (a 229 kcal deficit). We did not evaluate subjective appetite after exercise though Kawano et. al¹² observed suppressed appetite after weight-bearing exercise. Lower appetite may be responsible for the caloric deficit observed in our study. For those wishing to reduce body weight with the aid of exercise, steady state exercise may be a more effective manner for doing so, based on our results.

Previous research focused on acute exercise and compensatory feeding have found differing results that the present study. Sim et al¹¹ found that energy intake was lower following 30 minutes of high intensity and very high intensity exercise in overweight, sedentary men. However, subjects were provided a liquid meal immediately following exercise and given meal options 70 minutes after. Our study allowed participants to eat at will, on their schedule, according to their preferences representing free-living conditions.

Our protocol focused on acute exercise though long-term studies are important to observe compensatory eating behavior in response to chronic, repeated exercise bouts. The present study provides insight into behaviors that, if repeated over time, could lead to unfavorable results if exercise is used as a tool for weight loss. HIIT is regarded as an enjoyable, efficient exercise regimen¹³. The present study did not evaluate energy expenditure during the recovery period. It is possible that a larger deficit was created between energy expenditure and intake, but the post-exercise energy expenditure was not evaluated.

The present study included both males and females; hormonal changes throughout the menstrual cycle have been shown to impact appetite. A limitation of the present study is that menstrual cycle was not controlled nor were menstrual abnormalities addressed. Previous studies have found higher caloric, fat, and carbohydrate intake during the luteal phase of the menstrual cycle compared to the follicular phase^{14,15}. Others have found that increases in food consumption and macronutrient intake were only increased in women with premenstrual dysphoric disorder¹⁶; additionally, women with menstrual disturbances demonstrate altered appetite hormone levels¹⁷. Future studies should consider evaluating women and consider the effects of menstrual abnormalities on eating behaviors following exercise.

Lastly, another limitation of the present study evaluated non-obese, recreationally active young individuals. Obese individuals should be evaluated as appetite-regulating hormones differ compared to non-obese counterparts. Dietary induced obesity has been linked to leptin resistance¹⁹. Ghrelin is lower in obese individuals compared to lean¹⁹⁻²¹. Compensatory eating behaviors in sedentary individuals should also be considered in response to chronic exercise training (both steady state and interval-based programs) to elucidate the role that exercise intensities have on eating habits and hormonal responses. The present study found that acute, high-intensity, interval exercise may lead to increases in caloric intake in the 24 hours following exercise; it appears that this intake is specifically attributed to increased carbohydrate intake. When using high-intensity interval exercise programs for weight management purposes, special consideration should be given to potential increases in compensatory eating behaviors which may offset the caloric expenditure of a given exercise bout.

Conclusions

In summary, we did not observe statistically significant differences in eating behaviors following acute HI exercise when compared to isocaloric SS exercise.

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