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Original Research Article

Acute Effect of Sprint Interval Cycling vs. Continuous Moderate Intensity Cycling on Postprandial Insulin Sensitivity

Michael Braun[1-2], Bryant Stamford[1]

[1]Kinesiology and Integrative Physiology Program, Hanover College, Hanover, IN, USA

[2]High Altitude Exercise Physiology Program, Western Colorado University, Gunnison, CO, USA

Abstract

Aim: The purpose of this study was to examine the effect of exercise intensity on postprandial glucose uptake. **Methods:** In a crossover experimental design, eight college aged male athletes completed separate bouts of continuous moderate-intensity (CMIE) exercise on the cycle ergometer and maximum effort sprint repeats of the Wingate test (SIE), each followed by an oral glucose tolerance test (OGTT). Glucose area under the curve (AUC) served as a proxy for acute postprandial insulin sensitivity. Total work output was kept constant between the CMIE and SIE sessions **Results:** Compared to control, both intensities were able to significantly reduce AUC, ΔAUC, and glucose concentrations at several time points during the OGTT. No statistically significant difference, aside from ΔBG at the 15-minute mark, was found between the two exercise conditions. **Conclusions:** Both CMIE and SIE improve acute postprandial insulin sensitivity in healthy young males.

Key Words: Glucose Clearance, Exercise Intensity, Sprint Interval Training, Moderate Intensity Exercise.

Introduction

In 2017, the economic cost of diabetes in the U.S. reached an all-time high of $327 billion, and this rising cost is expected to continue[1]. Individuals with type-2 diabetes are also at increased risk for developing the number one cost of healthcare in the U.S.—heart disease. With the high prevalence and cost to diabetes and pre-diabetes, interventions are necessary to address this. Evidence has shown a strong relationship between exercise and improved insulin sensitivity, a risk factor for developing type-2 diabetes. Understanding the relationship between insulin sensitivity and exercise may allow for non-pharmaceutical treatment options, potentially improving patient outcomes, and reducing medical cost. It has been previously established that low to moderate aerobic exercise can improve insulin sensitivity[2], but adherence to such programs tends to be low[3]. Therefore, the American Diabetes Association (ADA) currently recommends all adults get at least either 150 minutes of moderate-intensity exercise or 90 minutes of vigorous-intensity exercise per week in an effort to better control or prevent type-2 diabetes[4]. While this dual prescription gives individuals more options for exercise, it is not well understood how prevention may vary based on which of these recommendations someone follows. Therefore, we sought to examine the acute relationship between exercise intensity and insulin sensitivity in young healthy subjects.

It has been previously suggested that intense exercise does not improve insulin sensitivity more than moderate exercise[3,5,6]. However, the intense exercise of these early studies did not go beyond the lactate threshold. When exercise rises above the lactate threshold, the body is in a fundamentally different state than during moderate-intensity exercise; insulin secretion decreases minimally, glucose utilization rises by 3-4-fold and there is a 14-18-fold rise in plasma catecholamines[7]. Due to its fundamental differences, exercise above the lactate threshold (LT) must be looked at separately than exercise below the LT. Recent studies comparing low or moderate intensity exercise to exercise above the LT have suggested that this type of exercise may result in greater improvements in insulin sensitivity[7,8]. Sprint interval exercise (SIE), with interval durations of 30 seconds or less have been previously shown to be a practical mechanism for training well beyond the lactate threshold[9,10], and has been shown to improve acute insulin sensitivity in pre-diabetics[7] and adolescences[11]. Therefore, the purpose of this study was to compare the effects of SIE and moderate intensity continuous exercise (CMIE) on postprandial glucose uptake when matched in total work output in healthy college aged males.

Methods

Participants

Eight male participants volunteered to partake in this study. Participants were all current athletes at the club or division III level (3 track, 2 baseball, 2 ultimate frisbee, 1 rugby), aged 19-22 y (M = 20.6 y, SD = 1.3), and in apparent good health. Subjects were required to be currently exercising a minimum of three days a week, including exercise above the lactate threshold and resistance training. This study was approved by the Institutional Review Board at Hanover College. All participants completed an informed consent in advance of their participation in the study. The physical characteristics of participants are presented in Table 1.

Experimental Design

In order to determine the immediate effects exercise had on postprandial glucose disposal, each participant went thought three separate exercise conditions. This exercise was followed by one hour of seated recovery and then an oral glucose tolerance test followed. The three conditions were as follows: Sprint interval exercise (SIE) performed as repeat bouts of the Wingate test, moderate-intensity continuous cycling (CMIE), and a non-exercise control. After each condition, subjects were given one hour to recover before the OGTT. In order to prevent residual effects from previous trials and minimize possible ordering effect, each session was administered a minimum of three days apart. Because the duration of the CMIE trial was dictated by the total work output of the SIE, the CMIE had to be administered sometime after the SIE; the order of the trials was otherwise randomized. The study timeline is outlined in Figure 1 below.

Table 1. Subject characteristics

Characteristic	N=8
Age (y)	20.6±1.3
Height (cm)	180±8.5
Weight (kg)	81.8±11.5
Fasting blood glucose (mg/dl)	97.1±4.5

All values presented as mean ± SD.

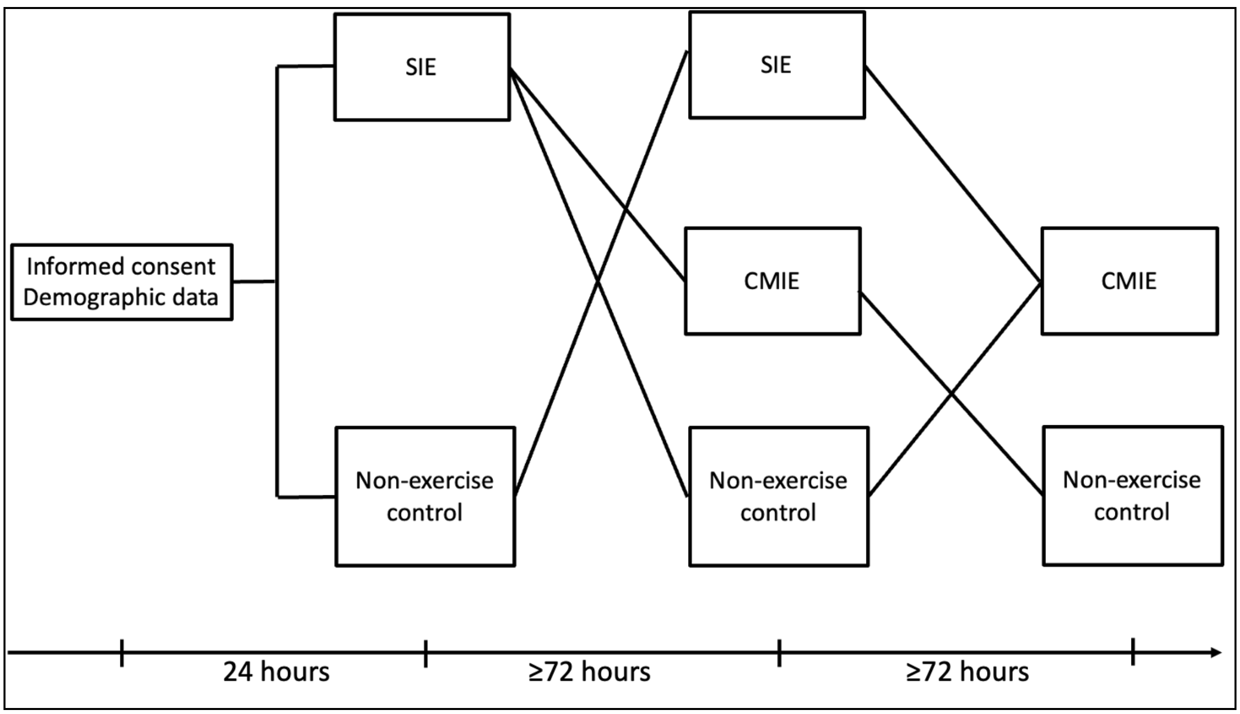

Figure 1. Experimental flowchart. All exercise conditions were followed by a one-hour seated recovery period and then a one-hour OGTT. (SIE=sprint interval exercise) (CMIE= continuous moderate intensity exercise) (OGTT=oral glucose tolerance test).

Procedures

Pre-test

Prior to each testing session subjects were required to get a normal night's rest, abstain from exercise for at least six hours and not use any alcohol or tobacco products for the 24 hours preceding the session. Subjects were required to fast, no food or drink, for a minimum of three hours prior to the exercise trial. This shortened duration fasting protocol was used in lieu of a more typical eight- or ten-hour protocol due to the high intensity and poor subject tolerance in pilot testing. All trials for an individual subject were performed at the same time of day in effort to control for circadian fluctuations in insulin sensitivity[12].

Sprint Interval Training

After a five-minute warmup, 60 rpm with 1.5 kg of resistance (540kg/min), subjects performed five maximal efforts sprints with four minutes of passive recovery between bouts. Intervals were performed as 30 second repeat Wingate tests with a resistance equal to 7.5% of the subject's bodyweight. Repeat efforts of the Wingate test were chosen in order to find exercise beyond the lactate threshold without the need for a prior maximal exercise test (VO_2max) test. A similar training protocol was used by Babraj et al. which found improved insulin sensitivity after two weeks of this training[13].

Moderate Intensity Cycling

To ensure that the total work output was the same for both MICT and SIE, during the MICT the subject cycled at 60 rpm with 1.5 kg of resistance (540kgm/min) until work totaled that of the SIE trial (including warm up).

Oral Glucose Tolerance Test

Oral glucose tolerance tests were performed at the same time of day for all exercise conditions and one hour after the conclusion of the cycling session. The subject was asked to wash their hands, with soap and warm water, and then dry them. The subject then sat quietly for five minutes. Blood glucose measurements were taken using the following steps: First, the researcher cleaned the subject's finger using an alcohol wipe and allowed it to air dry. Next, the subject's ring finger, off center of the finger pad, was punctured using a unistik 2 lancet (Owen Mumford, Oxfordshire, UK). The ringer finger was used due to its lower amount of tactile use reducing the likelihood of calluses and cross-contamination. Finally, the finger stick sample was recorded and measured using an Accu-Check glucometer (Roche Diabetes Care, Indianapolis, IN). After an initial resting measurement, the subject consumed a 75g Sun-dex glucose supplement drink (Azer Scientific, Morgantown, PA). The subject sat for 1 hour with glucose reading taken every 15 minutes.

Statistical analyses

All data analyses were performed using Prism 9 (GraphPad Software, San Diego, CA). All basic subject characteristics were presented in terms of a mean ± SD. All dependent variables were compared using a repeated measures one way ANOVA with a Geisser-Greenhouse correction to determine statistical significance between treatment groups ($p<0.05$). Follow up Tukey comparisons were used to compare dependent variable means across exercise conditions.

Results

A total of 8 subjects participated in this study. Each subject completed all exercise conditions, serving as their own control. All subjects completed all exercise conditions and reported no adverse effects. A repeated measures one way ANOVA was conducted to evaluate the impact of SIE and CMIE on individual blood glucose measurements and the area under the curve (AUC) of the OGTT. Both exercise conditions resulted in a statistically significant decrease from control in mean blood glucose values at the 15- and 30-minute mark as well as AUC. SIE also significantly reduced blood glucose from control at the 45- minute mark. The mean blood glucose values during the OGTT after each exercise condition are presented in Table 2.

Table 2. Blood glucose values during OGTT post exercise conditions

Variable	CON	MICT	SIT
BG at T=0 (mg/dl)	97.1±12.7	96.1±9.8	88.0±4.3
BG at T=15 (mg/dl)	142.9±6.5	125.3±11.3*	133.3±7.7*
BG at T=30 (mg/dl)	157.5±8.6	141.9±12.2*	139.3±12.4*
BG at T=45 (mg/dl)	149.6±17.1	144.0±16.6	127.5±16.8*
BG at T=60 (mg/dl)	130.9±21.2	130.8±19.0	113.0±11.6
AUC (mg/dl/hour)	8460±521.3	7868.4±519.8*	7507.5±630.3*
ΔBG at T=15 (mg/dl)	45.8±9.3	29.1±11.5*+	45.3±6.8
ΔBG at T=30 (mg/dl)	60.4±13.5	45.8±13.0*	51.3±12.2*
ΔBG at T=45 (mg/dl)	52.5±22.2	47.9±21.9	39.5±16.0
ΔBG at T=60 (mg/dl)	33.8±20.2	34.6±23.6	25.0±10.6
ΔAUC (mg/dl/hour)	2632.5±705.8	2100.9±722.2*	2227.5±581.8*

Values presented as mean ± SD; * Within-group value is significantly lower than baseline, p < 0.05; +Within-group value is significantly lower than SIE p < 0.05; BG=blood glucose; T=time (in minutes post glucose ingestion), CON=control, CMIE= continuous moderate intensity exercise, SIE=sprint interval exercise.

Since both exercise conditions resulted in a lower mean blood glucose at T=0 of the OGTT, the change in glucose from this starting point was examined in order to assess whether the exercise conditions resulted in better glucose clearance. Both exercise conditions resulted in a statistically significant reduction in ΔAUC as well as a significant decrease in mean Δ blood glucose values(ΔBG) at the 30-minute mark. MICT ΔBG was significantly lower than both baseline and SIE at the 15-minute mark. ΔBG curves are presented in Figure 2.

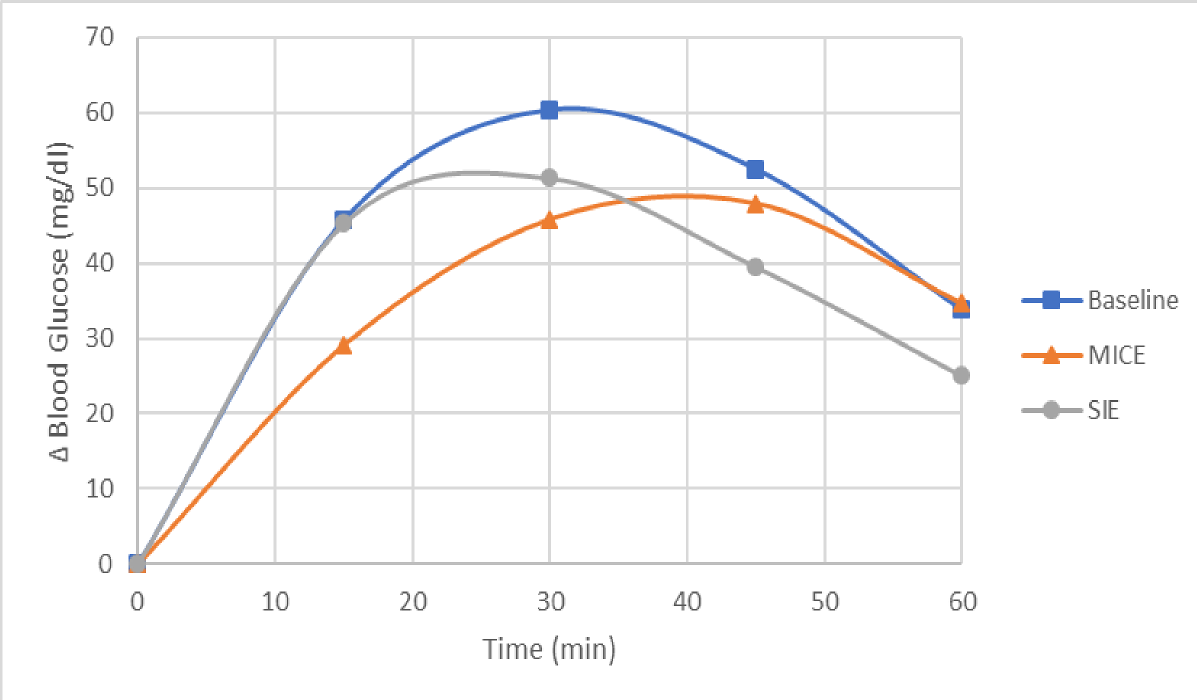

Figure 2. Mean change in blood glucose levels during one hour glucose tolerance test following each exercise condition.

Discussion

CMIE on improving glucose uptake

In the present study, CMIE significantly reduced the rise in blood glucose during the first half of the OGTT. This was marked by significantly lower blood glucose concentrations at the 15- and 30- minute mark and a significant reduction in AUC and ΔAUC. Moderate exercise has been shown to improve insulin sensitivity by increasing the quantity of GLUT-4 carrier proteins and their ability to translocate[14]. This is believed to occur because during exercise skeletal muscle relies on intramuscular glycogen stores as a source of energy, and the only way to replenish these stores is to uptake new glucose molecules from the bloodstream[14]. GLUT-4 is the primary transporter of glucose across the cell membrane. Previous studies have shown simple exercise prescriptions, such as walking 12 miles a week for six months, can improve insulin sensitivity by 85% for sedentary overweight individuals[3]. However, the current study demonstrated that the beneficial effect of CMIE on glucose clearance can occur immediately after exercise. This is in agreement with Ryders et al. They found a single bout of moderate exercise can improve insulin sensitivity by 51% with beneficial effects lasting 48-72 hours[1,7]. The duration of these benefits means from an exercise prescription standpoint, MICT should be administered roughly every two days for optimal benefit.

SIE on improving glucose uptake

Compared to control, SIE reduced blood glucose concentrations at the 15-, 30-, and 45-minute time points and significantly reduced AUC and ΔAUC. SIE is marked by a 14- to 18-fold increase in the concentration of several plasma catecholamines, including epinephrine and norepinephrine[15]. These hormones stimulate glycogenolysis and inhibit insulin secretion during exercise. This fight or flight response allows for ample glucose to fuel the exercise effort. However, typically the amount of glucose produced far exceed the exercise demand[15]. Recovery from exercise of these intensities is characterized by a rapid decrease in catecholamines which allows for a compensatory insulin response to bring blood glucose back to base levels. This mechanism may be the driving force behind the decreased glucose concentrations during the OGTT seen by both Rynders et al.[7] and this current study.

CMIE vs SIE

Both intensities were able to significantly reduce AUC, ΔAUC, and glucose concentrations at several time points during the OGTT. No statistically significant difference, aside from ΔBG at the 15-minute mark, was found between the two exercise conditions. Both forms of exercise provide similar benefits when it comes to acute insulin sensitivity in healthy young males. From a practical standpoint, both exercise intensities have distinct advantages. SIE has a significant advantage when it comes to time. The SIE trials had a total time commitment of approximately half of the CMIE trial and a working time of approximately 10%. Since "not enough time" is the most commonly listed barrier for regular exercise participation[16] SIE or similar high-intensity protocols (like high-intensity interval training or high-intensity functional training) may provide a time efficient option. CMIE protocols, like easy cycling or walking, have the advantage of being able to fit into the day without need for special equipment, location, or change of clothes. It can be easier to take a brisk walk during a lunch break or during a phone meeting than to carve out a specific exercise time. However, we are not limited to a single type/intensity of exercise. Bird et al. which found that a 13 week exercise prescription combining moderate intensity continuous training (MICT) + HIIT elicited greater improvements in VO2max and MetS z-score than standardized MICT alone[17]. Since both exercise intensities have different advantages and underlying mechanisms, both are recommended for the full practical, performance, and health benefits.

Practical Application

The paradigm of sprint interval exercise (SIE) provides an alternative exercise strategy for health promotion to CMIE. Our results indicate a similar improvement in acute insulin sensitivity despite the working exercise time of the SIE protocol only lasting 10% of the CMIE protocol. However, it is worth noting that while working time was substantially shorter in the SIE protocol total, time commitment was very similar across the two conditions. Previous research with high intensity protocols like SIE have been demonstrated to elicit comparable or superior improvements in CRF[18], MetS[19,20], and mental health[21] even with a lesser time commitment. Both forms of exercise can improve insulin sensitivity. Individuals should choose exercise intensity based on their preferences and time constraints.

Limitations

Limitations to the present study merit discussion. First, although participants were advised at the beginning of the study to maintain their regular dietary and physical activity habits, dietary intake and physical activity behaviors were not strictly controlled nor quantified during this investigation. This lack of diet and physical activity control may have influenced the findings. Second, the population of this study was quite uniform, and the total number of subjects was low. Further research with a larger sample size and a more diverse population is warranted.

Conclusions

These findings indicate that both CMIE and SIE improve acute postprandial insulin sensitivity. No statistically significant difference was found between the two conditions. The paradigm of SIE may provide an alternative exercise strategy for health promotion to CMIE. However, the differences in intensity and time demand likely do not affect the need for regular exercise participation. As exercise program adherence is paramount, individuals should choose exercise intensity based on their own preferences and time constraints.

Address for Correspondence

Michael Braun, MSc, High Altitude Exercise Physiology Program, 600 N. Adams St., Western Colorado University, Gunnison, CO, United States, 81231. Phone: 970-943-3095; Email: michael.braun@western.edu.

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