



Original Research

Repeated Plyometric Exercise Attenuates Blood Glucose in Healthy Adults

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ABSTRACT

International Journal of Exercise Science 10(7): 1076-1084, 2017. Plyometric exercise is popular in commercial exercise programs aiming to maximize energy expenditure for weight loss. However, the effect of plyometric exercise on blood glucose is unknown. The purpose of this study was to investigate the effect of relatively high intensity plyometric exercise on blood glucose. Thirteen subjects (6 females age= 21.8 ± 1.0 yrs.; height= 163.7 ± 7.8 cm; mass= 60.8 ± 6.7 kg and 7 males age= 22.0 ± 2.6 yrs.; height= 182.3 ± 3.6 cm; mass= 87.4 ± 12.5 kg) volunteered to participate. Subjects completed two random conditions on two separate days, consisting of either five sets of 10 maximal effort countermovement squat jumps (SJ) with 50 seconds' rest between sets or quiet sitting (SIT) for the time equated to the SJ duration (~4min). Immediately after each condition, subjects drank 75g of anhydrous glucose (CHO) in 100ml of water. Blood glucose measurements were taken via finger prick pre and immediately post SJ or SIT, and 5, 15, 30, and 60 min post. A 2x6 (condition x time) ANOVA revealed a significant interaction where SJ blood glucose was lower at 15 (114.0 ± 14.6 mg/dl) and 30 (142.1 ± 22.5 mg/dl) min compared to SIT (15min 130.8 ± 14.0 mg/dl and 30min 159.3 ± 21.0 mg/dl). The current plyometric protocol attenuated CHO-induced blood glucose at 15 and 30 min. This may be due to increased physiological stress applied to the muscles, thus increasing muscular glucose uptake.

KEY WORDS: Glycemic control, jump, diabetes, interval training

INTRODUCTION

The prevalence of diabetes in the United States in 2012 was 14.3%, which has increased from 10% in 1999 (8). Impaired glucose metabolism is the underlying mechanism in diabetes (25). Carbohydrates are substrate macronutrients that release energy for cellular demands. Carbohydrates broken down in the gut lead to elevated blood glucose concentrations. The body stores the excess blood glucose in adipose, muscle, or liver tissue (21). Fasting blood glucose at or below 99 mg/dl indicates normal glucose metabolism (2, 4, 21, 25, 34) while a

value above 100 mg/dl is considered pre-diabetic or diabetic (2, 4, 21, 25, 34). Exercise is on the forefront of treatment options for glucose metabolic diseases due to its low price and effectiveness. Exercise prescription with high intensity, short duration and/or Type II muscle fiber recruitment increases glycogenolysis (21). This causes an elevation in glycogen synthase, which increases blood glucose uptake and replenishes glycogen concentrations in the resting muscle (21).

Aerobic exercise commonly involves low intensity, long duration bouts. Walking is a modality of aerobic exercise that decreases blood glucose in Type 2 diabetic individuals, with an additive effect if they walk at a higher intensity (13). Running type interventions based on heart rate and or oxygen consumption have shown both positive (7, 36) and no relationships (6, 9, 10) in controlling blood glucose. However, exercise adherence is a limiting factor in these interventions designed to regulate blood glucose (6, 7, 9-11, 13, 17, 23, 24, 28, 33, 36).

Resistance training is variable, utilizing moderate to high intensities and low to high volumes. It has been shown to be effective at decreasing blood glucose immediately post exercise (24), and after 12 (23, 33), and 16 weeks (28), but has also been shown to have no effect (30). Physiological blood glucose adaptations to resistance training have been shown to be similar to aerobic training (3, 12, 15, 22, 27, 29, 37), while reducing total workout time. A dilemma with resistance training for affecting blood glucose is that there is no standardized protocol to follow relative to intensity and duration, thus the mixed results. High intensity, interval training structured in a short duration model have been shown to decrease blood glucose (3, 12, 15, 22, 27, 29, 37). Jump plyometrics are a form of short duration, high intensity exercise that normally involve low repetitions, thereby reducing fatigue and maximizing the storage and release of kinetic energy (32). Furthermore, plyometric exercise training duration has been shown to be significantly less than resistance or aerobic exercise training (20). One limiting factor for current short duration, high intensity protocols is the necessary use of technical equipment (e.g. cycle ergometer), which are not practical for the lay person due to their expense.

Current literature has focused on performance adaptations to plyometric exercise (16, 17, 19) with clear implications for strength and conditioning. Physiological adaptations such as, increased bone mineral density (14, 18, 26), muscle strength (16, 31), neuromuscular function (1, 5), and cardiorespiratory function (38) have been reported with plyometric exercise. In this manner, plyometrics fit the short duration, high intensity profile and should elicit similar responses in acute blood glucose, but have not been investigated.

Current effective protocols at increasing blood glucose regulation are limited by time, equipment, and expense making them impractical to prescribe on a scale that matches the prevalence of glucose metabolic diseases. Plyometric exercise is a more practical form of short duration, high intensity exercise. Therefore, the purpose of this study was to investigate the acute effect of plyometric exercise on blood glucose.

METHODS

Participants

Assuming an effect size f of 0.25, a power of 80%, and a correlation of $r=0.80$ between repeated measures, a power analysis estimated a sample size of 12 subjects. Thirteen recreationally resistance trained participants, (age range 19-29; 6 females age= 21.8 ± 1.0 yrs.; height= 163.7 ± 7.8 cm; mass= 60.8 ± 6.7 kg and 7 males age= 22.0 ± 2.6 yrs.; height= 182.3 ± 3.6 cm; mass= 87.4 ± 12.5 kg) with no lower body injuries within the last year were recruited from within a University Kinesiology program. Inclusion criteria were to be currently engaged in habitual plyometric exercise (≥ 1 plyometric exercise per week for the past 6 months) and resistance training (>3 resistance training days per week for the past 6 months). Additional inclusion criteria was the ability to achieve 80% of age predicted max heart rate (APMHR) following the plyometric exercise. Participants read and signed a University IRB approved informed consent form before testing began.

Protocol

Familiarization: Height and mass were recorded using a scale (ES200L; Ohaus Corporation Pinebrook, NJ, USA) and stadiometer (752KL, Seca; Ontario, CA) on day one. They then performed a dynamic warm-up consisting of walking knee hugs, reverse lunges, single leg hamstring bows, and side lunges twice for 10 meters. Participants were then familiarized with the squat jump protocol by standing inside a four-square foot box with their feet slightly wider than hip width. They extended their arms over head with a slight bend in the elbows followed by squatting down and swinging their arms to perform a counter movement maximal effort jump. Participants performed three jumps with maximal effort for familiarization. They were instructed and encouraged to perform these maximal effort counter movements jumps 10 times. Participants were also familiarized with a finger prick blood draw. They returned for days two and three after an eight-hour fast. Additionally, they were asked to refrain from resistance training or alcohol consumption for 48 and 24 hours, respectively.

Plyometric or Control Intervention: Days 2 and 3 were randomized where participants performed either squat jumps (SJ) or quiet sitting (SIT). Whichever one they did not do on day two was completed on day three. Participants could work quietly for the hour of blood glucose measurements post SJ or SIT.

Participants arrived on both day two and three and sat for 10 min. They then performed the same warm up as day one. After the warm up they either performed SJ or SIT conditions. For SJ they were instructed to stand inside a four-square foot box and perform five sets of 10 maximal effort counter movement jumps with 50 seconds of standing rest. For SIT they sat for a time that was equated to the SJ condition which was predetermined by the time of the 10-maximal effort counter movement jumps on day one multiplied by four with 200 seconds added (~4min).

Measuring Blood Glucose: Blood glucose was measured using a glucose meter (Accu-Chek Performa, Indianapolis, IN). Participant's blood was drawn with a lancing device (Accu-Chek

Softclix Plus, Indianapolis, IN) on the fourth and fifth phalange tip. Fasting blood glucose was measured after the initial 10 min of quiet sitting (pre) and immediately post the SJ or SIT conditions. They ingested a 75g load of anhydrous glucose (CHO) dissolved in 100 ml of water within two min of finishing SJ or SIT. Dosage amount is consistent with previous research (36, 37). Blood glucose was then measured at 5, 15, 30, and 60 min post the drink.

Statistical Analysis

Data were analyzed using a 2x6 (condition x time) analysis of variance (ANOVA). Main effects were followed up with pairwise comparisons. An alpha level of 0.05 was used to determine statistical significance, and SPSS version 23.0 software (SPSS, Inc., Chicago, IL, USA) was used for all analyses.

RESULTS

For blood glucose, there was a significant two-way interaction. This was followed up with two 1X6 ANOVAs for time, one for each condition.

Pairwise comparisons revealed that SJ and SIT at 5, 15, 30 and 60 min post were significantly greater than baseline (table 1). Also, SJ blood glucose was lower at 15 and 30 min post compared to SIT (table 1).

Table 1. Blood glucose (mean \pm SD mg/dl) between time and squat jump (SJ) and sitting (SIT) conditions.

	SJ	SIT
Baseline	93.8 \pm 8.8	94.9 \pm 8.7
Immediately Post	98.2 \pm 8.1	97.0 \pm 7.8
5m Post	106.1 \pm 9.5*	106.1 \pm 12.8*
15m Post	114.0 \pm 14.6*†	130.8 \pm 14.0*
30m Post	142.1 \pm 22.5*†	159.3 \pm 21.0*
60m Post	146.5 \pm 34.1*	144.6 \pm 19.1*

* = Significantly greater than baseline ($p < 0.05$). † = Significantly less than SIT value ($p < 0.05$)

DISCUSSION

The purpose of this study was to investigate the effect of plyometric exercise on blood glucose. Our results demonstrated there was a significant decrease in glucose at 15m and 30m following SJ exercise when compared to sitting rest. Therefore, it appears that an exercise protocol of five sets of 10 maximal effort counter movement jumps places enough physiological stress on recreationally resistance trained males and females to elicit an attenuated blood glucose response post CHO ingestion. A possible factor for this response could be a cardiovascular intensity of 80% APMHR providing adequate physiological stress to the muscles, thus increasing muscular glucose uptake.

Mul et al. conducted a review of current literature surrounding the role of exercise in glucose uptake (21). Skeletal muscle has energy substrates that originate from either glucose or triglyceride like compounds. Glycogenolysis, breakdown of glycogen, is increased by either increasing duration, intensity of the exercise, or utilizing Type II muscle fibers, followed by an

increase in glycogen synthase. However, the transportation process is the rate-limiting step for glucose utilization; hence, exercise promotes glucose uptake into the liver, skeletal muscle, and adipose tissue. Therefore, increasing intensity of the exercise may elicit better glucose regulation.

Intensity of exercise can be graded as low, moderate, or high and can be defined by heart rate, maximal effort, or % V_{O_2max} (3, 7). Dube et al, had participants cycle at 75% peak HR and found blood glucose uptake was increased greater when higher kilocalories were expended (7). Little et al. utilized 90% and 65% peak HR and found blood glucose was better regulated post exercise with higher intensity (15). Babraj compared a maximal effort Wingate protocol to continuous self-paced cycling and found a chronic adaptation of increased blood glucose regulation with the Wingate protocol (3). Intensity can also be graded by percentage of peak energy expenditure (pEE). Karlsoft et al. measured intensities of interval walking above and below 75% pEE, and continuous constant walking at 55% pEE (13). Steps per day did not differ between conditions. However, a decrease in body mass adiposity and lower blood glucose with an increase in VO_{2max} were only shown in interval walking. The present study varied intensity by heart rate with the same number of jumps and rest per participant. The inclusion of 80% APMHR fits within prior investigations that used 70-90% of peak HR (7, 13, 15). Similarly, the present study showed lower blood glucose following SJ at 15 and 30 min, possibly due to the relatively high intensity of the protocol. Glycogen utilization is dependent on exercise intensity and duration (21). Therefore, the current study exhibits exponential glycogen utilization with increased exercise intensity (35).

Exercise choice can be categorized by oxygen consumption, anaerobic, aerobic, force production, continuous or plyometric. Ortega et al. demonstrated increased acute blood glucose uptake at 30m, 24h, and 48h post-exercise with sprint and aerobic exercise compared to no exercise, and greater positive effects at 30 min' post with sprint training compared to aerobic training (22). Little et al. reported similar findings with blood glucose uptake being greater with sprint training compared to aerobic training (15). Andersen et al. utilized an exercise choice of soccer skills to elicit an increase in blood glucose uptake (2). The present study demonstrated lower blood glucose in the SJ condition at 15m and 30m. Plyometric exercise is dependent on reducing the amount of time spent on the ground and maximizing the time spent in the air, thus utilizing high force production and velocity to overcome gravitational forces. This force-velocity couple requires usage of Type II muscle fibers at high intensities that stimulates blood glucose uptake into the working muscles (21).

Exercise volume can be varied by duration, sets or repetitions. Little et al. varied volume by having subjects perform either 10 sets of one-min cycle sprints or 30 min of continuous cycling (15). Ortega et al. used either four sets of 30 second maximal effort cycle sprints, or 60, or 30 min of continuous cycling and found that the lower volume protocols increased blood glucose regulation greater than the higher volume protocols (22). The present study lasted less than five min overall, while work bouts were one min. The average duration of one set for the current plyometric protocol was 11 seconds whereas prior research has utilized no less than 30 seconds. However, there was a decrease in blood glucose with the current exercise

prescription. Plyometric exercise sets rarely last more than four – six repetitions in order to reduce fatigue and maximize storing and releasing of kinetic energy (1). The low volume prescription used in the present study may have been mediated by the high intensity. Increasing volume and intensity stimulates muscle glycogen depletion and decreases blood glucose. However, in a practical sense, volume directly relates to duration as greater volume takes a longer time to complete. In contrast, with increased intensity a low duration can be maintained, yet still stimulate blood glucose uptake.

Fitness level refers to an individual's physiological capabilities in relation to exercise. Young healthy sedentary or recreationally active men have shown an increase in blood glucose regulation when performing six sets of 30 second maximal effort sprints (3). However, when comparing trained, low BMI, and untrained, high BMI, participants with the same exercise protocol, lean participants had significantly less blood glucose uptake following exercise when compared to untrained participants (9). The current study demonstrated a decrease in blood glucose following SJ among recreationally resistance trained adults. Our population was healthy and able to achieve elevated heart rates with our protocol, eliciting enough physiological stress to stimulate change in blood glucose regulation. Trained populations may not show an effect with this protocol due to cardiovascular efficiency providing energy for maximal effort jumps with sub maximal heart rates, thus muscle glycogen would not deplete enough to increase blood glucose uptake.

Variance in fitness of the participants, exercise choice, volume or intensity may have played a role in the results of the present study. Future studies may want to investigate various exercise prescriptions that reach 80% APMHR with untrained and diabetic populations to further investigate the effect of plyometric exercise on blood glucose. Reaching 80% APMHR might be the desired physiological stress level to stimulate a change in blood glucose.

The present study demonstrated that an exercise protocol of five sets of 10 maximal effort counter movement placed enough physiological stress on recreationally resistance trained males and females to elicit an attenuated blood glucose response post CHO ingestion. However, this type of exercise may require skill and could possibly be unsafe for special populations, such as Type II diabetics, the elderly, low bone mineral density, etc. Future research should examine exercise selection with similar movement patterns, such as medicine ball slams, squats, kettle bell swings, etc. to elicit similar effects.

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