

*Original Research*

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**Effect of an Acute Bout of Kettlebell Exercise on Glucose Tolerance in Sedentary Men: A Preliminary Study**

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**ABSTRACT**

*International Journal of Exercise Science* 9(4): 524-535, 2016. Impaired glucose tolerance can have significant health consequences. The purposes of this preliminary study were to examine whether a single session of kettlebell exercise improves acute post-exercise glucose tolerance in sedentary individuals, and whether it was as effective as high-intensity interval running. Six sedentary male subjects underwent a two-hour oral glucose tolerance test following three different conditions: 1) control (no exercise); 2) kettlebell exercise (2 sets of 7 exercises, 15 repetitions per exercise with 30 seconds rest between each exercise); or 3) high-intensity interval running (10 one-minute intervals at a workload corresponding to 90% VO<sub>2</sub>max interspersed with one-minute active recovery periods). Blood glucose and insulin levels were measured before (0 minutes), and 60 and 120 minutes after glucose ingestion. Both kettlebell and high-intensity interval running exercise significantly lowered blood glucose 60 minutes after glucose ingestion compared with control. However, there was no significant difference in blood glucose between the two exercise conditions at any time point. In addition, there were no significant differences in insulin concentration between high intensity interval running, kettlebell, and control conditions at all time points. Results indicate that an acute bout of kettlebell exercise is as effective as high intensity interval running at improving glucose tolerance in sedentary young men.

**KEY WORDS:** Insulin sensitivity, type 2 diabetes, glycemic control

**INTRODUCTION**

The incidence of type 2 diabetes (T2D) has increased significantly over the last several decades (24, 42), and management of the disease presents a significant health challenge. T2D is characterized by elevated fasting blood glucose and insulin insensitivity, and can lead to many health complications, including the development of cardiovascular disease (8). Exercise is recommended as a therapy for the prevention and management of T2D (26).

The American College of Sports Medicine (ACSM) recommends 150 minutes/week of moderate intensity aerobic exercise conducted over 5 days/wk or more, along with moderate to vigorous-intensity resistance training at least 2-3 days/wk (8). Acutely and chronically, resistance and aerobic exercise have been shown to improve glucose uptake and insulin action (2, 13, 17, 18, 20, 23, 27, 31-33).

In spite of the known health benefits of exercise, most Americans do not meet the

recommended amounts of exercise, in part due to a lack of time (5). Recent studies have examined the effects of high intensity interval training in an attempt to reduce the necessary time commitment while simultaneously improving health (3, 7, 21). For example, sprint interval training (SIT) in young volunteers results in significant improvements in muscle oxidative capacity (6, 7), exercise performance, fat oxidation (28, 30), endothelial function (29), and glucose tolerance (i.e., ability to maintain normal blood glucose) (3). Although use of SIT induces significant physiological and functional improvements from only 2-3 minutes of exercise per workout, the total workout time commitment remains close to 30 minutes due to the prolonged rest period between each work interval. Thus, in terms of time commitment, SIT is no more effective than traditional aerobic training. Perhaps more important, SIT employing the Wingate protocol is conducted at supramaximal intensity and is potentially unsafe for sedentary middle-aged and older adults, especially if they have not undergone proper medical evaluation for determination of exercise safety (1).

Consequently, other HIT protocols have been developed that utilize a lower intensity than SIT and also requires less time. For example, Little et al. (21) utilized a protocol consisting of ten 1-minute exercise intervals at a workload ~ 90-100%  $VO_{2max}$  interspersed with 60" recovery periods with a total workout time (excluding warm-up and cool-down) of ~ 20 minutes. Use of this training strategy has been shown to significantly increase skeletal muscle GLUT-4 protein content (21) and lower 24-hour glucose in type 2 diabetics (21). Moreover, because of the 1-minute recovery periods, the metabolic

cost, heart rate response, and rating of perceived exertion are similar to continuous steady state running at 70%  $VO_{2max}$  (11).

In spite of these recent findings, HIT may not be feasible for many individuals due to various reasons including, but not limited to, the costs associated with exercise testing, prescription, and supervision. Kettlebell training has existed for several years and is known to result in significant improvements in muscular strength (e.g. back squat) and power output (e.g. vertical jump) (25). It can differ considerably from traditional resistance training in that exercises may be performed at a significantly lower percentage of 1 repetition maximum, and with less recovery time between exercises. In many respects, kettlebell training is similar to circuit training and represents a hybrid of traditional endurance and resistance training. Most kettlebell exercise routines require the use of only one or two kettlebells and can be performed in the home. It is considered a more cost-effective means of exercise, as it does not require expensive equipment or monthly fitness membership. In spite of the significant functional improvements associated with kettlebell training, the effects of kettlebell exercise on selected health markers such as glucose tolerance have yet to be investigated.

The purpose of this preliminary study was to examine whether or not a single session of kettlebell exercise impacts glucose tolerance in healthy, but sedentary individuals. A secondary objective was to evaluate the average oxygen cost of the kettlebell workout employed in this study. We hypothesized that immediately following a bout of kettlebell exercise,

glucose tolerance would be significantly improved compared to control. We also hypothesized that a bout of kettlebell exercise would be as effective at improving glucose tolerance compared with a bout of HIT similar in duration.

**METHODS**

*Participants*

Inclusion criteria included healthy individuals who were sedentary (exercised  $\leq 2$  day/week), had a body mass index  $< 30$ , and had a normal blood glucose response during a two-hour oral glucose tolerance test (OGTT) (i.e., did not display impaired glucose tolerance or type 2 diabetes). Exclusion criteria included individuals who were active (exercised  $> 2$  times/week), had a BMI  $\geq 30$ , took glucose or lipid lowering medication, smoked, or had any medical condition where exercise was contraindicated. Six healthy sedentary males with a mean age of 23.8 ( $\pm 1.8$ ) years and a mean BMI of 26.5 ( $\pm 0.5$ ) kg•m<sup>2</sup> completed the study. The University at Buffalo Institutional Review Board approved all procedures. All subjects provided informed consent prior to participation in the study.

*Protocol*

To test our hypothesis, a repeated measures design was used. Following a screening OGTT and determination of maximal oxygen consumption (VO<sub>2</sub>max), subjects underwent three different experimental conditions. Each visit was separated by a minimum of 5 and maximum of 7 days. All procedures except the graded treadmill test were performed between 0600-0900 hours following an overnight fast ( $> 8$  hours). Subjects were asked to refrain from any vigorous physical activity and to maintain

their normal diet throughout the study. Condition test order was randomly assigned for each subject. The independent variable was the experimental condition whereas the major dependent variables included blood glucose and insulin concentrations.

A timeline of the study appears in Figure 1. During the screening visit, each subject underwent a baseline OGTT to ensure normal glucose tolerance. Blood was obtained from an ear stick before (0 minutes), 30, 60, 90, and 120 minutes after rapidly consuming 75 gm of glucose (100 ml volume, Glucose Orange Drink 075, Azer Scientific, Morgantown, PA). Blood glucose was measured using a commercially available glucose meter (Accu-Chek glucose meter, Aviva, Roche Diagnostics, Indianapolis, IN) that meets the International Organization for Standardization requirements (35). Any subject with a fasting blood glucose  $> 100$  mg•dL<sup>-1</sup> or with a two-hr OGTT blood glucose concentration  $> 140$  mg•dL<sup>-1</sup> was excluded from the study. After completing the OGTT, subjects were familiarized with the equipment and procedures to be used throughout the study.

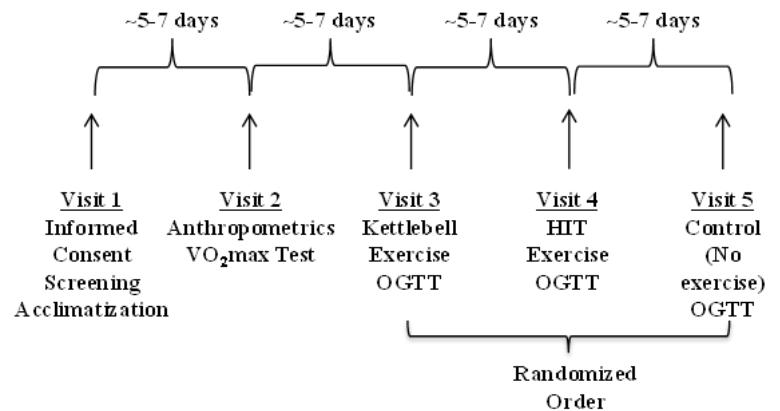


Figure 1. Study Timeline

On the second visit, body composition was assessed using volume plethysmography (BodPod, Cosmed, Chicago, IL). Subjects then underwent a graded exercise test on a treadmill for determination of  $\text{VO}_2\text{max}$ . During the treadmill test, subjects ran at an initial self-selected speed between 8.0 – 12.9  $\text{km}\cdot\text{h}^{-1}$  at 0% grade. The grade remained constant throughout the test, but the speed was increased 0.8  $\text{km}\cdot\text{h}^{-1}$  every two minutes. Subjects were given a three-minute warm-up period (4.8  $\text{km}\cdot\text{h}^{-1}$  at 0% grade) prior to the test and a three-minute cool-down period (3.2  $\text{km}\cdot\text{h}^{-1}$  at 0% grade) following the test. The exercise test was terminated when the subject could no longer continue (volitional exhaustion). Prior to the test, an ear stick was performed to obtain baseline blood lactate (Lactate Plus, Nova Biomedical, Waltham, MA) levels. Oxygen consumption was measured breath by breath throughout the test (Viasys Vmax, Carefusion, San Diego, CA). Heart rate was measured at each stage using a Polar heart rate monitor (Polar USA, Lake Success, NY) via a chest strap, whereas perceived exertion was measured using the standard 6-20 Borg scale. Heart rhythm was also monitored using an electrocardiograph (MAC 550, GE Healthcare, United Kingdom). Blood glucose and lactate were again measured immediately upon test termination.

The subjects underwent three different conditions. Each condition was separated by ~ one week (5-7 days), and the order of conditions was randomized for each subject. Each condition was followed by a two-hour OGTT. Condition 1 was a control visit (quiet sitting for 2 hours during the OGTT) where no prior exercise was performed. Condition 2 consisted of a kettlebell workout (~25 minutes). Subjects

used either a 9 or 11.3-kg kettlebell for the workout depending on their ability. Kettlebell ability was based on whether a subject could complete an exercise with an 11.3 kg kettlebell. If the subject deemed the kettlebell too heavy and was unable to complete the 15 repetitions, a 9-kg kettlebell was provided for that exercise. The workout consisted of seven exercises (squat and press, chest press, one-arm kettlebell swing, bent over row, front squat, sit-up press-up, and kettlebell swing) in sequence targeting the muscles of the legs, arms and core. Fifteen repetitions per exercise were performed with 30 seconds of standing recovery between each set. After completion of the seven exercises, subjects were given one-minute standing recovery followed by a second circuit of the aforementioned exercises. The workout was preceded by a warm-up consisting of five sets of 20 kettlebell swings. Heart rate was measured at the end of each exercise whereas rating of perceived exertion (RPE) was measured following each circuit. Condition 3 consisted of high-intensity interval running (HIT) on a motor driven treadmill with a 1:1 work-to-rest ratio. Following a three-minute warm-up period at 4.8  $\text{km}\cdot\text{h}^{-1}$ , subjects performed 10 one-minute intervals at a running speed corresponding to 90%  $\text{VO}_2\text{max}$ . Each exercise interval was interspersed with a one-minute active rest period (5.6  $\text{km}\cdot\text{h}^{-1}$ ). After the 10<sup>th</sup> interval, a three-minute cool down was provided. Heart rate and RPE were recorded throughout the condition. To determine the effect of the HIT and kettlebell workouts on blood glucose and lactate, blood was obtained via ear stick before and immediately following the exercise protocols.

Approximately five minutes following each condition, 7mL of blood was withdrawn from the antecubital vein into EDTA lined vacutainer tubes (16X100 Lavendar, BD, Franklin Lakes, NJ). This blood draw was referred to as time 0. Subjects then rapidly consumed a glucose drink as described above. Subsequent blood draws were performed 60 and 120 minutes after glucose consumption. Blood obtained from the venipunctures was used for measurement of insulin and glucose. Blood glucose was also measured at each draw using the portable glucose meter as previously described. Plasma insulin was measured in duplicate using an enzyme-linked immunosorbent assay (ELISA) kit (ab100578, ABCAM, Cambridge, England) per the manufacturer's instructions. The ELISA kit was read at 450 nm wavelength using a microplate reader (iMark, BIO-RAD, Hercules, CA).

During a separate visit after completion of the three experimental conditions, a subset of five subjects came into the lab for measurement of the oxygen cost of the kettlebell workout. Subjects performed the same kettlebell workout previously described while oxygen consumption and respiratory exchange ratio (RER) was continuously monitored (TrueOne, Parvo Medics, Sandy, UT).

#### *Statistical Analysis*

Glucose and insulin data were analyzed using a two-way (group \* time) repeated measures ANOVA (Sigma Stat). The Holm-Sidak method was used for post-hoc multiple pair-wise comparisons. Post-exercise blood lactate data was analyzed using a paired t-test.  $P < 0.05$  was considered statistically significant. All data

were normally distributed, and values are expressed as mean  $\pm$  SE (n = 6).

## RESULTS

Subject characteristics appear in Table 1. A total of twelve subjects were recruited for the study. Six subjects were not included in the data analysis. One subject withdrew from the study because they did not wish to have any further venipuncture. A second subject was eliminated from the study because of nausea following ingestion of the glucose drink. A third subject was unable to complete the kettlebell workout and was therefore eliminated. Another subject was eliminated due to a display of reactive hypoglycemia following the HIT workout. The final two eliminated subjects displayed abnormal glucose tolerance during the screening visit.

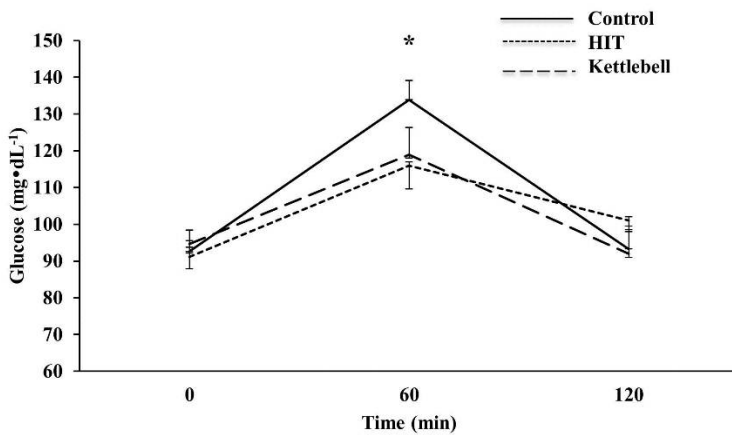
Data collected during graded maximal exercise testing appears in Table 1. Values obtained for blood lactate ( $> 8.0 \text{ mmol}\cdot\text{L}^{-1}$ ) or RER ( $\geq 1.15$ ) at the end of the test indicated that all subjects achieved  $\text{VO}_2\text{max}$ .

**Table 1:** Subject characteristics and graded maximal exercise test data (mean  $\pm$  SE).

Age (years)	24.3 $\pm$ 4.1
Height (cm)	174.5 $\pm$ 7.4
Weight (kg)	80.7 $\pm$ 10.2
BMI ( $\text{kg}\cdot\text{m}^{-2}$ )	26.3 $\pm$ 1.4
Body Fat (%)	19.7 $\pm$ 7.8
$\text{VO}_2\text{max}$ ( $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ )	43.9 $\pm$ 8.7
HR max ( $\text{beats}\cdot\text{min}^{-1}$ )	189.7 $\pm$ 6.8
Blood Lactate max ( $\text{mmol}\cdot\text{L}^{-1}$ )	10.5 $\pm$ 0.9
RPE max	18.9 $\pm$ 0.9
RER max	1.12 $\pm$ 0.05

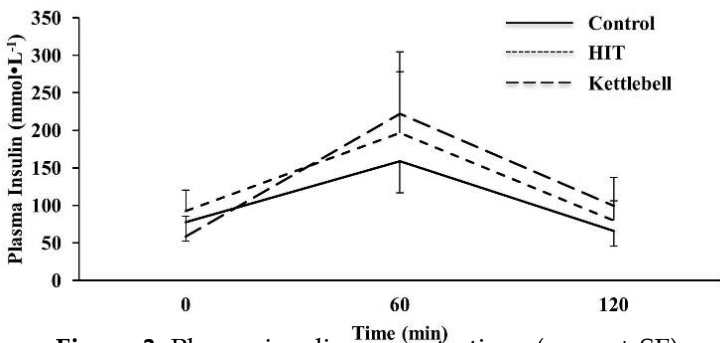
Glucose values obtained during a two-hour OGTT after the three experimental conditions appear in Figure 2. There was a

significant effect for time ( $P < 0.001$ ) and interaction ( $P = .028$ ). There were no significant differences in blood glucose levels at 0 or 120 minutes between all three conditions. However, 60 minutes after glucose ingestion, blood glucose was significantly lower following HIT ( $p < 0.001$ ) and kettlebell ( $p = 0.003$ ) exercise when compared to control.



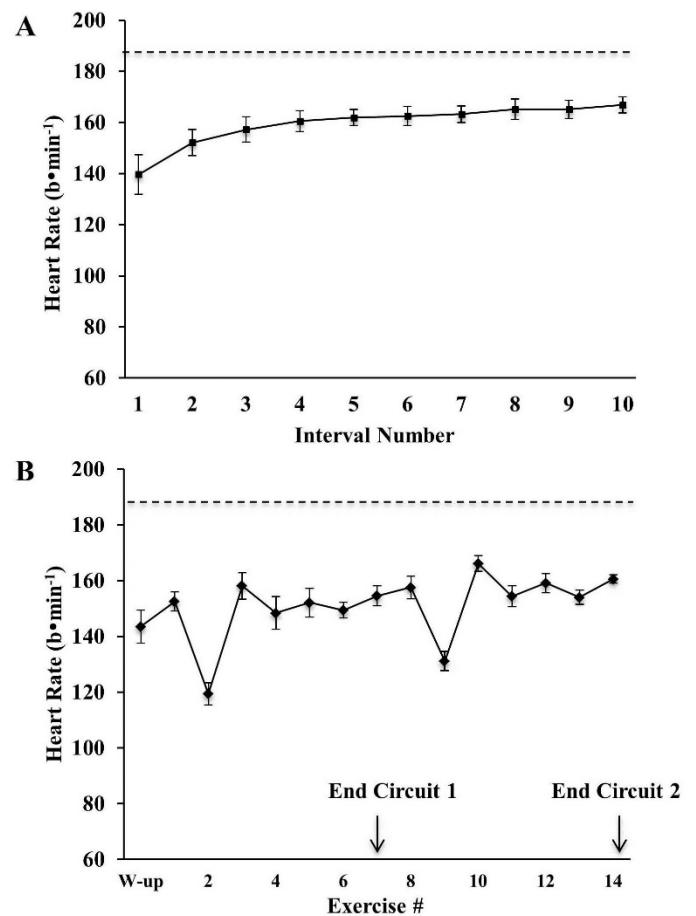
**Figure 2.** Blood glucose concentration (mean  $\pm$  SE) during a 2-hour OGTT following a control visit, HIT workout, and kettlebell workout. \* - denotes significant difference between groups at 60 minutes.

There was no difference between the two exercise conditions. Plasma insulin concentration during the OGTT appears in Figure 3. There were no significant differences in insulin concentration between conditions at any time point.



**Figure 3.** Plasma insulin concentrations (mean  $\pm$  SE) during a 2-hour OGTT following a control visit, HIT workout, and kettlebell workout.

Figure 4A illustrates the mean heart rate response following each interval throughout the entire HIT workout. Heart rate gradually increased with each successive interval throughout the workout. At the end of the 10<sup>th</sup> interval, HR averaged  $\sim 86\%$  of HR<sub>max</sub>. Figure 4B illustrates the mean heart rate response after each exercise throughout the entire kettlebell workout. The lowest heart rate was observed following the chest press exercise (2 and 9), whereas the highest heart rate was observed after the one-arm kettlebell swing exercise (3 and 10). Heart rate averaged  $\sim 81\%$  and  $\sim 84\%$  of HR<sub>max</sub> after the 1<sup>st</sup> and 2<sup>nd</sup> circuit, respectively.



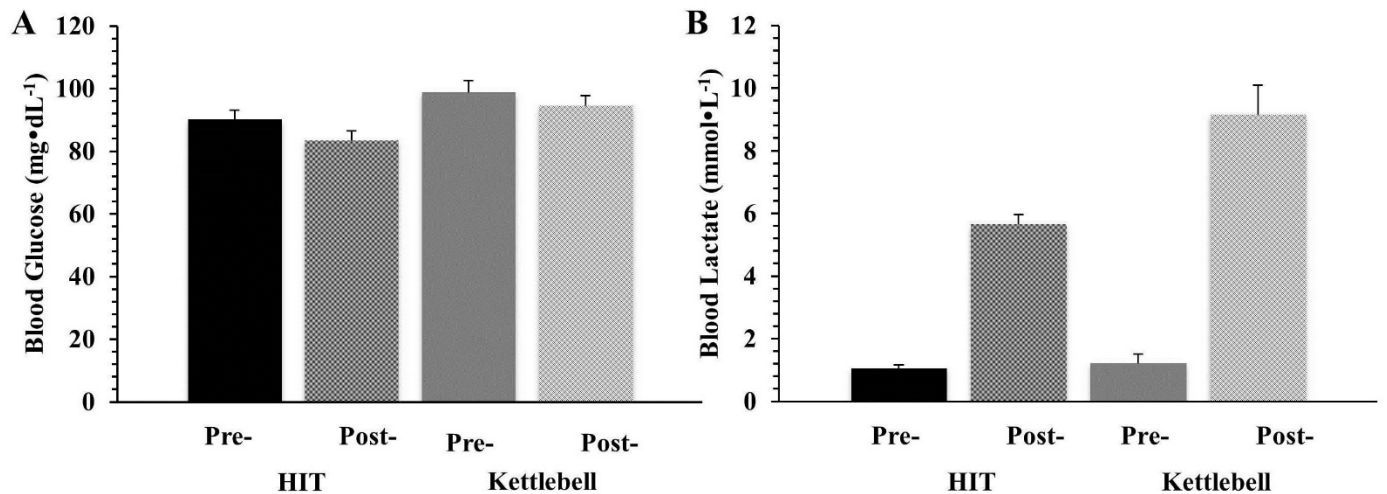
**Figure 4:** Mean heart rate ( $\pm$  SE) following each interval during the HIT workout (A) and following each exercise during the kettlebell workout (B).

During the HIT workout, RPE after the first interval averaged 10.2 ( $\pm$  0.7). RPE gradually increased during the workout and averaged 15.7 ( $\pm$  0.9) after the last interval. During the kettlebell workout, RPE averaged 12.7 ( $\pm$  1.4) and 14.7 ( $\pm$  1.7) after the first and second circuits, respectively.

Blood glucose values were obtained immediately before and after the kettlebell and HIT workouts (Figure 5A). Pre- and post-exercise glucose values were not significantly different from one another for either condition. Moreover, there was no difference between the two exercise conditions. Blood lactate was also measured before and immediately following the kettlebell and HIT workouts

(Figure 5B). There was no difference in resting blood lactate levels before the HIT and kettlebell workouts. However, after exercise, blood lactate was significantly higher after the kettlebell workout ( $9.2 \pm 0.9$  mmol $\cdot$ l $^{-1}$ ) compared with HIT ( $5.7 \pm 0.3$  mmol $\cdot$ l $^{-1}$ ) (Figure 5B). The blood lactate values were  $\sim$  86% (kettlebell) and  $\sim$  53% of that reached during the VO<sub>2</sub>max test.

The oxygen cost of the kettlebell workout was measured in a subset of five subjects. VO<sub>2</sub> averaged 20.4 ( $\pm$  2.2) ml $\cdot$ kg $^{-1}\cdot$ min $^{-1}$  (46.5% VO<sub>2</sub>max) during the first circuit, and 21.1 ( $\pm$  2.0) ml $\cdot$ kg $^{-1}\cdot$ min $^{-1}$  (48.1% VO<sub>2</sub>max) during the second circuit. RER averaged 1.2 ( $\pm$  0.04) and 1.1 ( $\pm$  0.04) during the first and second circuit, respectively.



**Figure 5.** (A) Blood glucose concentration pre- and immediately post- HIT and kettlebell exercise. (B) Blood lactate concentration pre- and immediately post- HIT and kettlebell exercise.

**DISCUSSION**

In the present preliminary study, we investigated the effect of a single bout of kettlebell exercise on glucose tolerance in sedentary, but healthy male subjects. We also sought to compare kettlebell exercise with high-intensity interval running. The

kettlebell and HIT workouts (including warm-up and cool down) were similar in duration and averaged  $\sim$ 25 and 26 minutes, respectively. We found that immediately following a single session of kettlebell or HIT exercise, glucose tolerance during an OGTT was significantly improved at 60 minutes with no concomitant change in

insulin concentration. In addition, there was no difference between the two modes of exercise. These findings indicate that kettlebell exercise may serve as an alternative training strategy to HIT for improving glucose tolerance.

The mechanisms for improved glucose clearance post-exercise are complex and have not been completely elucidated. Immediately post exercise, increased glucose clearance can be due to both insulin-dependent and insulin-independent pathways. In a rat study by Hamada et al. (12), insulin-independent glucose uptake was increased when measured 40 minutes after a single 60-minute session of treadmill exercise and was associated with increased AMPK threonine phosphorylation. However, by 85-minutes post exercise, this AMPK effect had dissipated and the increased glucose uptake that persisted was likely due to insulin-dependent mechanisms. Interestingly, Akt phosphorylation did not differ between the exercise and control muscles. In human skeletal muscle post-exercise, Akt phosphorylation has been shown to increase (37) or not change (36, 39) during a euglycemic clamp with physiological insulin levels. In several other acute exercise studies, no changes were observed in insulin receptor binding or phosphorylation, sub-maximal insulin stimulation of the tyrosine phosphorylation of IRS-1 or sub-maximal insulin-stimulation of P13k (4, 14, 39-41). Regardless of the mechanism for the improved glucose uptake, GLUT-4 protein is known to increase after aerobic (9, 16, 32, 34), resistance (15, 19), and high-intensity interval (22) exercise. Results from these previous studies suggest that GLUT-4 is also increased after kettlebell exercise,

though definitive data are currently lacking.

Although the two exercise conditions were qualitatively different from one another, the heart rate response was similar. In addition, the end-workout perceived exertion was also similar, with RPE averaging ~16 and 15 for the HIT and kettlebell workout, respectively. In spite of these similarities, however, the blood lactate concentration was significantly higher following the kettlebell workout ( $9.2 \text{ mmol}\cdot\text{L}^{-1}$ ) when compared to the HIT workout ( $5.7 \text{ mmol}\cdot\text{L}^{-1}$ ). We hypothesize that the increased blood lactate concentration after the kettlebell workout is due to a higher reliance on glycolysis. Exercise order was constructed to alternate between different muscle groups during the workout, with each exercise lasting approximately 30 seconds followed by 30 seconds rest. In contrast, during the HIT workout, the same musculature was recruited during each interval, and the work interval was 60-sec in duration.

We did not measure the oxygen cost of the HIT workout in the present study. However, our previous work indicates that oxygen consumption for the workout employed reaches approximately 70% of  $\text{VO}_2\text{max}$  (11). During the kettlebell workout in the current study,  $\text{VO}_2$  averaged  $\sim 21.1 (\pm 4.9) \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ , or 48% of  $\text{VO}_2\text{max}$ . Farrar et al. (10) reported that the oxygen cost of kettlebell exercise was  $\sim 34.3 (\pm 5.7) \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ . In this latter study, subjects employed a significantly heavier kettlebell and were required to complete as many two-handed swings as possible in 12 minutes (10). The contrasting findings are therefore likely due to the different weight and workout characteristics employed in



the two studies. Utilizing a 10-exercise, 3 circuit design (30 seconds exercise, 15-sec recovery), Wilmore et al. reported that the oxygen cost of circuit weight training in men was approximately 41% of  $\text{VO}_2\text{max}$  (38).

Although blood lactate following the kettlebell workout approached that recorded at the end of the graded maximal exercise test and was significantly higher than that observed after HIT exercise, all subjects were able to complete this workout. Moreover, the subject's perception of effort at the end of kettlebell exercise was similar (~ 15, hard) to the HIT workout. The workout may require modification for older, higher risk individuals who do not tolerate such a high perception of effort. For example, the work-to-rest ratio during interval exercise is known to affect heart rate, lactate, and RPE responses (11). Thus, when prescribing kettlebell exercise to higher risk individuals, it may be desirable to lower the weight and/or increase the recovery period between exercises to attenuate these variables.

High intensity interval training has been studied extensively the last several years, and has been proposed as a time-efficient alternative to traditional aerobic training for the improvement of metabolic and cardiovascular health. In spite of the established health benefits, incorporation of a safe and effective HIT program into the daily routine of lay individuals will require laboratory testing and professional consultation. The cost associated with implementation of such a program, as well as other factors (e.g., availability of facilities, time and cost of driving, weather, etc.) may deter many individuals from

commencing a HIT exercise program. In contrast, the cost associated with kettlebell exercise is quite low, the exercises can easily be learned from web-based videos, and the workouts can be performed in the home or office. Limitations to the current study include the small sample size ( $n = 6$ ), the use of sedentary but healthy volunteers, exclusion of female subjects, age of the volunteers, as well as the use of only one exercise workout. Regardless, this preliminary study suggests that kettlebell exercise acutely improves glucose tolerance in young sedentary subjects, and that the changes are similar to that observed following a bout of high-intensity interval running. Thus, kettlebell exercise might serve as a suitable alternative to HIT or traditional aerobic training. However, future studies are required to determine the acute and long-term effectiveness of kettlebell training at improving metabolic health in pre-diabetic and diabetic individuals. Moreover, because individuals often cite lack of time as an excuse for not exercising regularly, further work is required to determine the minimal kettlebell exercise dose to improve glucose tolerance.

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