Original Article

Metabolic biomarkers following a short and long bout of high-intensity functional training in recreationally trained men

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ABSTRACT

Glucose regulation is a fundamental process of metabolic function, and is acutely altered by physical activity. High-Intensity Functional Training (HIFT) is a form of exercise performed using combinations of various modalities and durations. It is unknown if the metabolic responses to HIFT are similar to more commonly studied modalities (e.g., cycling and treadmill exercise), or if exercise duration will influence glucose regulation. The purpose of this study was to determine the effect of a Short (< 5-min) and Long (15-min) bout of HIFT on plasma metabolic biomarkers. Ten apparently healthy males (28.11 ± 5.09yrs) participated in this study. Two HIFT sessions (SHORT and LONG) were performed in a crossover fashion. Blood plasma was collected at four time points: PRE, POST, 1HR, and 3HR in order to examine glucose (GLU), insulin (INS), epinephrine (E), and norepinephrine (NE) responses. No trial dependent difference between the SHORT and LONG bouts in GLU ($p=0.054$), INS ($p=0.671$), E ($p=0.078$), and NE ($p=0.194$). A time effect was observed in both bouts only at POST for GLU ($p<0.001$), INS ($p=0.011$), E ($p<0.001$), and NE ($p<0.001$). All times returned to baseline values ($p>0.05$), except for lowered 3HR E ($p=0.007$). This study demonstrated that both SHORT and LONG bouts of HIFT elicited GLU, INS, E, and NE responses similar to those reported in response to high-intensity treadmill and cycling exercise, and that duration of the HIFT bouts may not be a determining factor in glucose regulation in healthy individuals. **Key words:** METABOLISM, HIT, GLUCOSE, INSULIN, CATECHOLAMINE.

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INTRODUCTION

Short duration high-intensity exercise training has been shown to be both an attractive and effective tool for improved regulation of metabolic biomarkers (Babraj et al., 2009). Studies have shown that the plasma biomarkers glucose, insulin, and catecholamines, are elevated following bouts of high-intensity exercise as an attempt to meet metabolic demands and to maintain homeostasis in bioenergetics (Babraj et al., 2009; Adams, 2013). This metabolic response has been observed in a variety of populations ranging from sedentary to trained individuals (Whyte et al., 2013; Henriksson, 1995; Babraj et al., 2009). Traditionally, these studies have examined bouts that are of short duration and high-intensity, while utilizing single modality intervals such as cycling or running (Adams, 2013). Despite the capacity of this type of exercise to improve fitness and metabolic function (Karstoft et al., 2014; Shaban et al., 2014; Little et al., 2011; Mitranun et al., 2014), this style often lacks appeal for participant adherence (Gillen and Gibala, 2013). Recently, trends in fitness have gravitated towards a style of exercise described as High-Intensity Functional Training (HIFT)(Thompson, 2016).

HIFT is a style of exercise focused on general preparedness and performance rather than specific aspects of fitness providing a level of competitiveness, which has contributed to improved adherence (Heinrich et al., 2014). The major components of this style are comprised of several modalities such as Olympic weight lifting, bodyweight calisthenics, gymnastics, and aerobic modalities. These modalities generally differ based on variations in their prescribed sequence, resistance, and repetition scheme, with a goal of creating a high-intensity bout of exercise. Additionally, these bouts typically vary in duration between 5-minutes and 20-minutes (Sibley, 2012).

HIFT and short duration high-intensity exercise is an appealing form of exercise due to reduced time requirements. However, it is unknown if a bout of HIFT would elicit similar post exercise changes in metabolic biomarkers as those associated with commonly-studied single-modality interval exercise. Furthermore, due to the wide range of options for HIFT bout duration, it is unknown if acute metabolic responses to a short bout will differ significantly from those induced by a longer duration bout. Therefore, the purpose of this study was to examine whether or not a short bout of HIFT (i.e. < 5min) would elicit a similar metabolic biomarker response as a long bout of HIFT (i.e. 15 min). We hypothesize that the short bout would elicit similar metabolic biomarker responses.

METHODS

Participants

Fifteen physically fit males participated in this study; participant characteristics are expressed in mean ± SD and can be seen in Table 1. Participants were recruited via word of mouth and through the use of flyers at local fitness establishments. Inclusion criteria required a minimum of three months experience with high-intensity exercise and must have performed 30 clean and jerks at 61.4kg in less than 5-minutes one time prior. Participants were free of any orthopedic problems as well as any cardiovascular, pulmonary, or metabolic condition. Study inclusion criteria were determined through the completion of a PAR-Q and Health History Questionnaire. The inability to perform any of the required movements or any symptom or contraindication of health resulted in exclusion from the study. Each participant reviewed and signed the informed consent before participating in the current study. For each visit, participants were required to abstain from alcohol for 24-hours prior and caffeine for 12-hours. Prior to the first visit, participants were asked to fast for a minimum of four hours and abstain from exercise for 24-hours. Preceding each HIFT trial participants were asked to eat a moderate breakfast before their arrival in order to avoid post exercise hypoglycemia.

Additionally, participants were asked to repeat this meal for consistency between trials and to abstain from exercise for 48-hours before each session.

Measures

Anthropometric Measurements & Graded Exercise Test

During the first visit participant aerobic capacity (VO_2max) was assessed through a modified ramp protocol graded exercise test (GXT) on a treadmill (Woodway USA, Waukesha, WI). Treadmill speed was self-selected and increased in elevation (percent grade) of one percent (1%) occurred every minute until completion of the test. A portable metabolic system (Cosmed K4b^2, Concord, Ca) was used to sample expired gas fractions. VO_2max test completion criteria require two of the following: RER > 1.10, HR within 10 bpm of age-predicted heart rate max, lactate concentration ≥ 8 mmol/dL, volitional fatigue, or a plateau in VO_2 with increasing workload. Baseline and peak effort lactate levels (mmol/dL) were collected before and after the GXT using a portable lactate analyzer (Lactate Plus, Nova Biomedical, Waltham, MA).

An electronic physicians scale (Tanita WB 3000, Arlington Heights, IL) was used to determine height (cm) and weight (kg). Body composition analysis (percent body fat and fat free mass) was assessed using dual-energy x-ray absorptiometry scan (GE Lunar iDXA). Participant characteristics and body composition data are presented in Table 1.

Blood Sample Collection and Storage

In order to assay for biomarkers of metabolism, blood plasma samples were collected at the following time points: pre-exercise (PRE), immediately post-exercise (IPE), 1-hour post (1H), and 3-hours post (3H). Participants underwent a venipuncture procedure while in a seated position. Samples were collected through 12mL-heparinized tubes using the antecubital vein. Following collection, tubes were inverted based on manufacture recommendations, and immediately centrifuged at 2500 rpm for 15 minutes. Plasma aliquots were stored in ultra-low freezer -80°C until subsequent assay. All periods of blood collection was accompanied by a finger stick in order to obtain hematocrit and hemoglobin (Alere Hemopoint 2). The study design can be seen in figure 1.

Metabolic Biomarkers

The biomarkers selected for metabolic regulation were insulin, glucose, and catecholamines (epinephrine [E], norepinephrine [NE]). Plasma insulin (INS) was assayed using a commercially available ELISA kit (DRG, Germany), protocols followed assay kit instructions and reported as $mU \cdot L^{-1}$. Plasma catecholamine E and NE was assayed using a commercially available dual purpose ELISA kit (ABNOVA, Taiwan). A single kit analyzed both E and NE; protocols used followed manufacturers instructions and reported in nmol/L. Plasma glucose (GLU) was measured using a Medtronic Contour glucometer (Bayer, Pittsburgh, PA), ran in duplicate and presented as $mg \cdot dL^{-1}$.

Procedures

Experimental Approach to the Problem

The University Institutional Review Board approved all testing protocols and procedures of this study. All methods and procedures were performed in the Universities Exercise Physiology Laboratory (EPL). Participants were asked to arrive at the EPL on three separate occasions, each visit taking place within one week of each other and occurring at the same time of day. Participant visits were scheduled between the hours of 6 AM and 11 AM. During the initial visit, participants were provided the opportunity to review the procedures, sign the informed consent, complete the health history questionnaire, and perform the GXT. The SHORT and LONG bouts of HIFT were performed in a crossover fashion for the remaining visits.

The HIFT trials consisted of one of the following trials: SHORT or LONG. Regardless of trial, pre-exercise and post-exercise measurements of heart rate (HR) collected through a heart rate monitor were taken. Additionally, pre-exercise and post-exercise of metabolic makers; glucose, insulin, and catecholamines (epinephrine [E], norepinephrine [NE]), were obtained through plasma analysis. Lastly, pre-exercise and post-exercise lactate was measured in order to gauge exercise intensity. Following the acquisition of resting heart rate (RHR), blood samples were collected from each participant. After baseline samples were obtained, participants engaged in a 5-minute self-selected warm-up followed by the exercise bout of SHORT or LONG. After the completion of the bouts, designated blood draws and HR markers were collected. Experimental design can be seen in Figure 1. Participants were not allowed to eat until 2-hours following the exercise bout.

Hift bouts

The SHORT bout chosen for this study was the CrossFit® named workout named "Grace." The workout "Grace" consists of 30 power clean & jerks at 61.4kg using an Olympic barbell. The beginning of the movement starts with the barbell on the ground, a power clean is performed, followed by a shoulder to overhead movement (i.e. jerk). Full extension was necessary at the end of the movement for the repetition to count. These movements and standards were repeated for 30 repetitions at a self-selected pace to complete the workout as fast as possible. Participants were allowed to self-select their rest periods. In addition, resting lactate (mmol/dL), hemoglobin (g/dL) and hematocrit (Alere Hemopoint 2, Waltham, Massachusetts), and pre-exercise blood draws were taken. Upon completion of the workout, participants were placed in a seated position and post-exercise blood draws were taken at designated time points.

The LONG bout chosen for this study was a 15-minute circuit created by a Level I certified CrossFit® Coach. This circuit consisted of a 250-meter row on a rowing ergometer (Concept 2), 20-kettlebell swings at 16kg, and 15-dumbbell thrusters with two 13.6kg dumbbells. The objective of the workout was to complete as many repetitions as possible within the 15-minutes. For scoring purposes, every 10-meters on the rowing ergometer was counted as one repetition. The standard resistance for the rowing ergometer was for the damper to be set at six. Kettlebell swings began with the kettlebell at the starting position between the legs and off the ground. The kettlebell is then swung overhead until achieving an upright position with the kettlebell directly overhead with arms in the locked position. The dumbbell thruster consisted of holding the dumbbells in the front rack position, completing a full front squat into an overhead press with hips open and arms locked at the end of the movement. The participant could not continue onto the next movement until all prescribed repetitions were completed. All movements had to be completed within the standards in order for the repetition to be counted. Prior to exercise, resting lactate, hemoglobin and hematocrit, and pre-exercise blood draws were taken. Upon completion of the workout, participants were placed in a seated position and post-exercise blood draws were taken at designated time points.

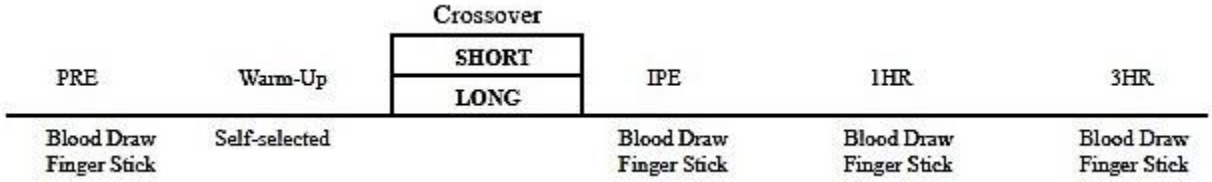

Figure 1. Study design

Statistical analysis

Plasma concentrations of INS, E and NE, and GLU data was entered into statistical software program SPSS (Version 24). A 2 (trial) x 4 (time) repeated measures ANOVA was used in order to assess differences

between resting biomarker concentrations and post-exercise concentrations between both HIFT trials (SHORT and LONG). A paired samples t-test was run in order to further assess differences between same trial-time points. The statistical significance was set to an alpha of < 0.05. The data is presented in the mean ± standard error of the mean (SE).

RESULTS

Ten of the original fifteen participants completed pre and post measures for this study; two participants did not return due to injury that occurred outside of the study, two participants experienced vasovagal responses to the phlebotomy procedure, and one due to a scheduling conflict. Participant characteristics are presented as means and standard deviations and can be observed in table 1. GXT, SHORT, and LONG outcomes measures are presented as means and standard deviations and can be found in table 2. Markers of metabolic activity are presented as GLU (figure 1a), INS (figure1b), E (figure 2a), NE (figure 2b).

Table 1. Participant Characteristics

Characteristic	Values ± SD
Age (y)	28.1 ± 5.4
Height (cm)	176.1 ± 8.0
Weight (kg)	88.0 ± 9.9
Body Fat (%)	17.9 ± 5.0
VO_2 max ($mL \cdot kg^{-1} \cdot min^{-1}$)	43.5 ± 5.2
GXT Max HR ($b \cdot min^{-1}$)	186.3 ± 11

*N = 10; mean ± SD.

Metabolic Markers

Repeated measures ANOVA showed no trial-dependent differences in plasma GLU, INS, or E, NE concentration between the SHORT and LONG bouts of HIFT ($p = 0.054$, $p = 0.671$, $p = 0.078$, $p = 0.194$), respectively. However, a main time-dependent effect was observed at IPE for all markers ($p < 0.001$, $p = 0.011$, $p < 0.001$, $p < 0.001$), respectively. GLU, E, NE all returned to baseline by 1-HP ($p > 0.05$, $p = 0.532$, $p = 0.287$) respectively, while INS was significantly lower than PRE values ($p = 0.020$). All times returned to baseline values ($p > 0.05$), except for 3-HP E, which significantly lowered ($p = 0.007$).

Table 2. Performance Measures

Measures	GXT	SHORT	LONG
Lactate (mmol/L)	11.64 ± 2.4	14.3 ± 2.0	13.74 ± 1.5
Average HR (bpm)	186.3 ± 11	172.4 ± 6.3	170 ± 9.5
Score (seconds)		206.4 ± 60.2	
Score (repetitions)			274 ± 48.6

*N = 10; mean ± SD.

DISCUSSION AND CONCLUSIONS

The purpose of this study was to examine the influences of a short (i.e. < 5min) and a long bout of HIFT (i.e. 15 min) on plasma glucose along with regulatory metabolic biomarkers INS and E/NE. The primary findings of this study demonstrated significant time-dependent differences, with all of the measured metabolic biomarkers being significantly elevated immediately following both exercise bouts and returning to baseline or below by 1-HP. Interestingly, no trial dependent differences were observed between the SHORT and LONG bouts.

These findings support previous research suggesting that metabolic responses to high-intensity exercise differ from those associated with moderate-intensity activity (Marliss and Vranic, 2002; Adams, 2013). Specifically, where insulin is a key regulator of plasma glucose during sustained moderate-intensity exercise, catecholamines appear to be the dominant regulators during vigorous activity. Although most previous studies examined more common forms of exercise (i.e., treadmill or cycle ergometry), our findings show that the response to vigorous whole-body exercise appears to be similar to those induced by other modalities. Furthermore, there was no difference between responses to the LONG and SHORT bouts selected, suggesting that the metabolic disturbance attributable to intense activity can be induced with even brief bouts, so long as the intensity is sufficiently vigorous.

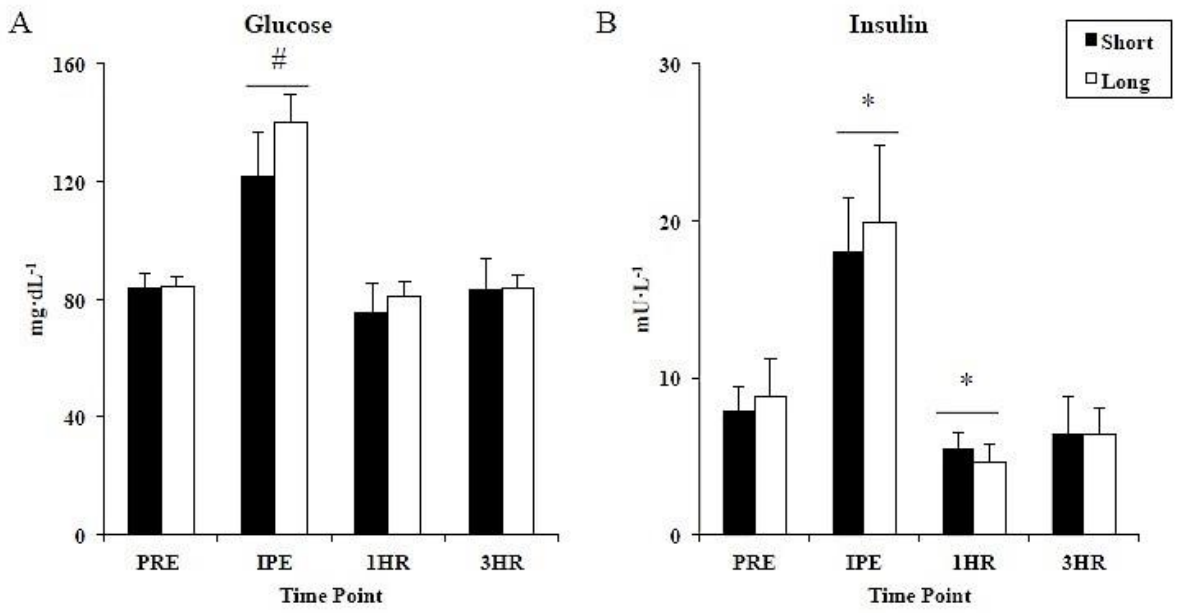

Figure 2. Biomarkers of metabolism. A) Plasma glucose (GLU) concentration presented as means ± SE. B) Plasma insulin (INS) concentration presented as means ± SE.
* = Significantly different from PRE ($p < 0.05$), # = Significantly different from PRE ($p < 0.001$)

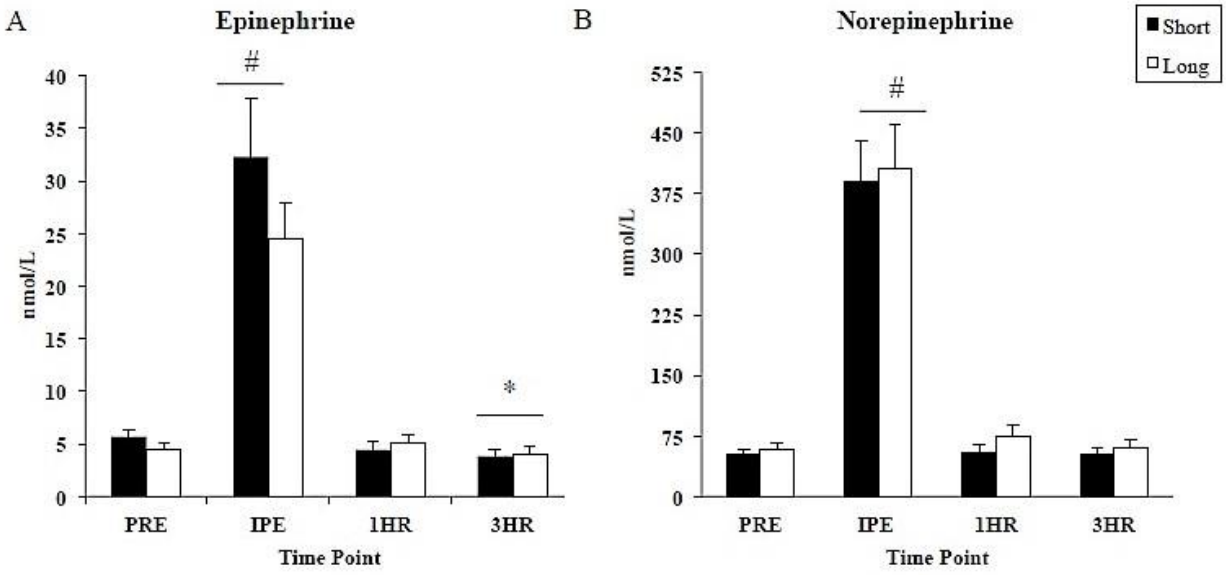

Figure 3. Plasma Catecholimines. A) Plasma Epinephrine (E) concentration presented as Means ± SE B) Plasma Norepinephrine (NE) concentration presented as Means ± SE . Values
* = Significantly different from PRE ($p < 0.05$), # = Significantly different from PRE ($p < 0.001$)

These findings suggest that HIFT may be efficacious in helping those with type 2 diabetes mellitus (T2DM) manage plasma glucose. Previous studies have shown that high-intensity interval exercise that elicits metabolic and autonomic responses similar to those associated with the protocols employed in this investigation can improve glucose control. Gillen et al. (Gillen et al., 2012) reported that an acute bout of exercise comprised of ten, 60-second bouts of cycle ergometer exercise at approximately 90% of maximal workload separated by 60 second rest periods resulted in lower post-prandial and all-day plasma glucose in a group of adults with T2DM. Likewise, Mitranun et al. (Mitranun et al., 2014) reported that 12 weeks of treadmill exercise training comprised of 6, 1-minute intervals at approximately 85% of peak VO_2 separated by 4-minute recovery intervals at approximately 60% of peak VO_2, performed three times per week resulted in improved fasting glucose, homeostasis model assessment for insulin resistance (HOMA-IR) scores, and reductions in glycosylated hemoglobin (HbA1c) in adults with T2DM. Mechanisms whereby interval exercise enhances glucose control in this population include how intramuscular fat is partitioned (i.e., triacylglycerol vs diacylglycerol) (Schenk and Horowitz, 2007), enhanced insulin signaling, (Karstoft et al., 2014) improved defenses against oxidative stress, (Mitranun et al. 2014) and reductions in inflammatory activity (Samaan et al., 2014). Although the participants in this study were young and healthy, the similarity of the responses elicited by both SHORT and LONG HIFT with those induced by more traditional modes of exercise makes it reasonable to suggest that responses in those with T2DM would also be similar, though further investigation is necessary to confirm this. Moreover, responses were the same to both doses of HIFT utilized in the current investigation, suggesting that even short bouts of HIFT may be sufficient to improve metabolic function in persons with T2DM. This would especially be of interest to clinicians and exercise specialists working with diabetic patients, as lack of time remains one of the most common reasons cited for not exercising. While it may be difficult to accumulate 150 minutes of moderate intensity exercise on a weekly basis, perhaps it would be less of a challenge for many to complete five minutes of exercise, three or four times per week.

In summary, the results of this investigation show that the autonomic and metabolic responses to HIFT are similar to those associated with high-intensity running and cycling exercise, and furthermore, that the response to a vigorous five-minute bout were similar to the response to a 15-minute bout. Much like what has been found utilizing other modes of exercise, these findings suggest that HIFT may be efficacious in helping those with T2DM manage plasma glucose. Though the time commitment associated with the this type of exercise is relatively short, it is an important consideration for whom time availability is a barrier to exercise.

REFERENCES

1. Adams, P. (2013). The Impact of Brief High-Intensity Exercise on Blood Glucose Levels. *Diabetes Metab Syndr and Obes: Targets and Therapy,6*, 113–22.
2. Babraj, J.A., Vollaard, N.B.J., Keast, C., Guppy, F.M., Cottrell, G., Timmons, J.A. (2009). Extremely Short Duration High Intensity Interval Training Substantially Improves Insulin Action in Young Healthy Males. *BMC Endocr Disord, 9*, 3.
3. Gillen, J.B., Little, J.P., Punthakee, Z., Tarnopolsky, M.A., Riddell, M.C., Gibala, M.J. (2012). Acute High-Intensity Interval Exercise Reduces the Postprandial Glucose Response and Prevalence of Hyperglycaemia in Patients with Type 2 Diabetes. *Diabetes Obes Metab.,14*(6), 575–77.
4. Gillen, J.B., Gibala, M.J. (2013). Is High-Intensity Interval Training a Time-Efficient Exercise Strategy to Improve Health and Fitness? *Appl Physiol Nutr Metab.,39*(3), 409–12.
5. Heinrich, K.M., Patel, P.M., O'Neal, J.L., Heinrich, B.S., (2014). High-Intensity Compared to Moderate-Intensity Training for Exercise Initiation, Enjoyment, Adherence, and Intentions: An Intervention Study. *BMC Public Health.,14*, 789.

6. Henriksson, J. (1995). Influence of Exercise on Insulin Sensitivity. *J Cardiovasc Risk.,2*(4), 303–9.
7. Karstoft, K., Winding, K., Knudsen, S.H., James, N.G., Scheel, M.M., Olesen, J., Holst, J.J., Pedersen, B.K., Solomon, T.P.J. (2014). Mechanisms behind the Superior Effects of Interval vs Continuous Training on Glycaemic Control in Individuals with Type 2 Diabetes: A Randomised Controlled Trial. *Diabetologia, 57*(10), 2081–93.
8. Little, J.P., Gillen, J.B., Percival, M.E., Safdar, A., Tarnopolsky, M.A., Punthakee, Z., Jung, M.E., Gibala, M.J. (2011). Low-Volume High-Intensity Interval Training Reduces Hyperglycemia and Increases Muscle Mitochondrial Capacity in Patients with Type 2 Diabetes. *J Appl Physiol., 111*(6), 1554–60.
9. Marliss, E.B., Mladen, V. (2002). Intense Exercise Has Unique Effects on Both Insulin Release and Its Roles in Glucoregulation." *Diabetes, 51 (suppl 1)*, S271–83.
10. Mitranun, W., Deerochanawong, C., Tanaka, H., Suksom, D. (2014). Continuous vs Interval Training on Glycemic Control and Macro- and Microvascular Reactivity in Type 2 Diabetic Patients. *Scan J Med Sci Sports., 24*(2), e69–76.
11. Samaan, M.C., Marcinko, K., Sikkema, S., Fullerton, M.D., Ziafazeli, T., Khan, M.I., Steinberg, G.R. (2014). Endurance Interval Training in Obese Mice Reduces Muscle Inflammation and Macrophage Content Independently of Weight Loss. *Physiol Reports, 2*(5), e12012.
12. Schenk, S., Horowitz, J.F. (2007). Acute Exercise Increases Triglyceride Synthesis in Skeletal Muscle and Prevents Fatty Acid–induced Insulin Resistance. *J Clin Invest.,117*(6), 1690–98.
13. Shaban, N., Kenno, K.A., Milne, K.J. (2014). The Effects of a 2 Week Modified High Intensity Interval Training Program on the Homeostatic Model of Insulin Resistance (HOMA-IR) in Adults with Type 2 Diabetes. *J Sports Med Phys Fitness.,54*(2), 203–9.
14. Sibley, B.A. (2012). Using Sport Education to Implement a CrossFit Unit. *J Phys Educ Recreat Dance., 83*(8), 42–48.
15. Thompson, W. Worldwide Survey of Fitness Trends for 2017: ACSM's Health & Fitness Journal, 2016. Available at: http://journals.lww.com/acsm-healthfitness/Fulltext/2016/11000/WORLDWIDE_SURVEY_OF_FITNESS_TRENDS_FOR_2017.6.aspx; Accessed 11.21.2016
16. Whyte, L.J., Ferguson, C., Wilson, J., Scott, R.A., Gill, J.M.R. (2013). Effects of Single Bout of Very High-Intensity Exercise on Metabolic Health Biomarkers in Overweight/Obese Sedentary Men. *Metabolism, 62*(2), 212–19.

