The Effect of a 12 Week High Intensity Interval Training Program on Glycosylated Hemoglobin A1c in Patients with Type II Diabetes

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Chapter I

The Problem and Its Scope

Introduction

Diabetes is the seventh leading cause of death in the United States, killing over 231,400 people annually and costing the United States 174 billion dollars each year. It is estimated that 25.6 million people age 20 and older are affected by diabetes in the United States, with the highest prevalence among Caucasians. Diabetes may lead to serious complications including hypertension, blindness and eye problems, kidney disease, nervous system disease, amputations, dental disease, pregnancy complications, diabetic ketoacidosis, and hyperosmolar (nonketotic) coma (Centers for Disease Control and Prevention, 2011b). Furthermore, diabetes was identified as a key risk factor for development of cardiovascular disease (Murphy, Xu, & Kochanek, 2010), the leading cause of death among both men and women in the United States (Centers for Disease Control and Prevention, 2011a).

Treatment goals for diabetics include managing blood glucose, blood pressure, and lipid levels (Centers for Disease Control and Prevention, 2011b). Physical activity has been proposed as a preventative measure against diabetes, reducing the risk of developing type II diabetes by 30-50% (Bassuk & Manson, 2005; French et al., 2008). One proposed mechanism by which exercise protects against type II diabetes is by improved glycemic control (Alizadeh, Bijeh, & Hakak Dokht, 2012; Boulé, Haddad, Kenny, Wells, & Sigal, 2001; Figueira et al., 2013; Kennedy et al., 1999). It is widely accepted that aerobic and resistance exercises improve glycemic control in patients with type II diabetes (Alizadeh et al., 2012; Figueira et al., 2013; Gordon, Bird, MacIsaac, & Benson, 2013).
Despite the health benefits, only 39% of diabetics are physically active (Morrato, Hill, Wyatt, Ghushchyan, & Sullivan, 2007). Diabetic patients report lack of time and discomfort during exercise as the top barriers to physical fitness (Egan et al., 2013). Recent studies suggest that high intensity interval training may provide the same or superior results in glycemic control compared with traditional aerobic and resistance training (Babraj et al., 2009; Burgomaster et al., 2007; Gillen et al., 2012; Kjaer et al., 1990; Little et al., 2011; Nybo et al., 2010; Richards et al., 2010; Sandvei et al., 2012; Whyte, Gill, & Cathcart, 2010). This exercise model may be appealing to patients with type II diabetes the time commitment and perceived exhaustion are less (Gillen et al., 2012; Kjaer et al., 1990; Little et al., 2011).

**Purpose of the Study**

The purpose of this study was to determine if a significant difference existed in glycosylated hemoglobin A\(_1c\) (HbA\(_1c\)) in type II diabetic patients following a 12 week high intensity interval training program.

**Null Hypothesis**

There is no significant difference in HbA\(_1c\) levels in patients with type II diabetes following a 12 week high intensity interval training program.

**Significance**

As the prevalence of type II diabetes rises, cost-effective treatment approaches are highly valuable in a clinical setting. The role of high intensity interval training in improving glycemic control is not well researched. Specifically, there is little published research on the effect of high intensity interval training on HbA\(_1c\), a diagnostic marker for pre-diabetes and diabetes (Cox & Edelman, 2009). Results from this study will provide information about the role of high intensity
interval training in protection against type II diabetes. A better understanding of this may provide novel and practical approaches to prevention and treatment of type II diabetes.

**Limitations of the Study**

1. Participants were recruited from the PeaceHealth St. Joseph Medical Center Nutrition and Diabetes Clinic which assists with lifestyle management. The lifestyle management assistance may have affected the results of this study.

2. Variations in body weight and fat mass may have impacted the results. For example, obese individuals may have been less metabolically healthy.

3. Health status of each subject may have changed from pre to post test, impacting HbA1c levels.

4. Use of diabetic medication was not controlled for, as individual medical needs differed.

5. Participants entered the study with varying physical fitness levels and diet. Subjects were asked not to change their exercise or diet habits during the study, but this was difficult to control in all subjects.

6. It was assumed that maximal effort was utilized by participants during training and testing sessions.

7. The study was carried out with type II diabetic patients. The results may not be generalizable to patients with type I or gestational diabetes.

8. The study did not compare HIIT to other modes of exercise. More research is needed to evaluate HIIT in comparison with other exercise programs.

9. There were not enough bicycle ergometers for all participants to train at the same time. Participants completed training at different times which may have affected results.
**Definition of Terms**

Diabetes: A group of disease characterized by high blood glucose levels. Diabetes may result from defects in insulin production, insulin action, or both (Centers for Disease Control and Prevention, 2011b).

Glycemic control: physiological regulation of blood glucose (Centers for Disease Control and Prevention, 2011b).

HbA1c test: a diagnostic blood test that presents information about a patient’s average blood glucose levels over the last three months. The HbA1c test is used for diabetes management and research (Gillett, 2009).

High intensity interval training: there is no universal definition of HIIT, but it usually refers to exercise comprised of short bursts of vigorous exercise (>90% VO$_2$max) separated by short recovery periods (Gibala & McGee, 2008).

Pre-diabetes: a condition in which patients have elevated blood glucose or HbA1c levels, but the levels are not elevated enough for a diagnosis of diabetes. Pre-diabetic patients have an increased risk for type II diabetes and cardiovascular disease (Centers for Disease Control and Prevention, 2011b).

Type II diabetes: typically begins as insulin resistance, a disorder in which insulin is not properly used by the cells. The need for insulin increases and the pancreas slowly loses the ability to produce insulin. This type of diabetes is also known as non-insulin-dependent diabetes mellitus (NIDDM) or adult-onset diabetes and is associated with age, obesity, family history, impaired glucose metabolism, physical inactivity, and ethnicity (Centers for Disease Control and Prevention, 2011b).
Chapter II

Review of Literature

Introduction

Type II diabetes typically begins with insulin resistance, a disorder in which insulin is not properly used by the cells. As the need for insulin increases, the pancreas slowly lose the ability to produce insulin. This type of diabetes is associated with age, obesity, family history, impaired glucose metabolism, physical inactivity, and ethnicity (Centers for Disease Control and Prevention, 2011b; Hu, 2011). The estimated risk for developing diabetes is 32.8% in males and 38.5% in females (Narayan, Boyle, Thompson, Sorensen, & Williamson, 2003).

Management of diabetes is important as serious complications such as cardiovascular disease, stroke, hypertension, blindness, kidney disease, nervous system disease, amputations, dental disease, pregnancy complications, diabetic ketoacidosis, and hyperosmolar coma may occur (Centers for Disease Control and Prevention, 2011a; Centers for Disease Control and Prevention, 2011b). Treatment goals for diabetics include managing blood glucose, blood pressure, and lipid levels (Centers for Disease Control and Prevention, 2011b). Physical activity is used as a preventative measure, reducing the risk of developing type II diabetes by 30-50% (Bassuk & Manson, 2005).

Aerobic and resistance training help manage type II diabetes by improving glycemic control (Alizadeh et al., 2012; Figueira et al., 2013; Gordon et al., 2013). Exercise recommendations for patients with diabetes consist of 150-210 minutes of moderate intensity combined aerobic and resistance exercise spread between 3-5 sessions a week (Bhattacharyya,
Despite the benefits of exercise, only 39% of diabetics are physically active (Morrato et al., 2007).

Lack of time and discomfort during exercise are reported as major barriers to physical fitness (Egan et al., 2013). High intensity interval training (HIIT) may provide the same or enhanced glycemic control compared with aerobic and resistance training (Babraj et al., 2009; Burgomaster et al., 2007; Gillen et al., 2012; Kjaer et al., 1990; Little et al., 2011; Nybo et al., 2010; Richards et al., 2010; Sandvei et al., 2012; Whyte et al., 2010). HIIT may appeal to type II diabetics because the time commitment and perceived exhaustion levels are less compared with traditional aerobic and resistance exercises (Gillen et al., 2012; Kjaer et al., 1990; Little et al., 2011).

**Aerobic and Resistance Exercise**

Aerobic and resistance exercise have been shown to improve glycemic control as effectively as some anti-diabetic medications (Boulé et al., 2001; Snowling & Hopkins, 2006; Umpierre et al., 2011). Exercise may be an effective treatment for low-income patients, patients who dislike taking medications, or those who want additional glucose control. Some research indicates that both duration and intensity affect glycemic control (Umpierre et al., 2011), but there is considerable evidence that intensity may have more impact than volume on glycemic control (Babraj et al., 2009; Burgomaster et al., 2007; Gillen et al., 2012; Little et al., 2011; Mourier et al., 1997; Nybo et al., 2010; Richards et al., 2010; Sandvei et al., 2012; Whyte et al., 2010). The exact effects and mechanisms of glycemic control during high intensity exercise remains unknown. Investigation of the roles of aerobic, resistance, and high intensity interval training in glycemic control is clinically important for new prevention and treatment approaches.
Mechanism of Glucose Regulation during Aerobic and Resistance Exercise

Most of glucose uptake after eating is by skeletal muscle. Transport of glucose into muscle cells has been identified as a major limiting step in glucose metabolism (Houmard et al., 1991; Hughes et al., 1993). Much of glucose uptake into the muscle is carried out by glucose carrier proteins, such as GLUT4. Exercise and insulin promote the transfer of GLUT4 from the intracellular compartment to the plasma membrane and transverse tubules. At rest and after eating, glucose uptake is mediated by insulin-dependent pathways to restore muscle glycogen levels (Colberg et al., 2010).

During exercise, intramuscular glycogenolysis and glucose uptake are increased to meet metabolic demands for energy. GLUT4 transport is often impaired in type II diabetic patients. Exercise, however, has been shown to increased GLUT4 levels and translocation of GLUT4 to the plasma membrane. Therefore, more glucose can be taken into the skeletal muscle by a pathway which is not insulin dependent (Colberg et al., 2010). The resulting glucose uptake may be equal to normal glucose uptake in non-diabetics (Colberg et al., 2010; Kennedy et al., 1999).

In people who do not have diabetes, insulin levels are decreased with exercise and this is sensed by the liver which increases glucose production in response. The increased glucose uptake by skeletal muscle is balanced by an increase in hepatic production of glucose explaining unchanged blood glucose levels (Colberg et al., 2010; Marliss & Vranic, 2002). During exercise for patients with type II diabetes, skeletal muscle glucose uptake is usually higher than hepatic glucose production (Little, Safdar, Wilkin, Tarnopolsky, & Gibala, 2010), explaining the slight decrease in blood glucose levels in response to exercise. Despite the drop in blood glucose, hypoglycemia is not a pertinent concern during exercise because insulin levels decrease. This helps to balance the increased skeletal muscle glucose uptake (Colberg et al., 2010).
High Intensity Exercise

Models of high intensity interval training. There is no universal definition of HIIT, but it usually refers to exercise comprised of short bursts of vigorous exercise (>90% VO\(_2\)max) separated by short recovery periods (Gibala & McGee, 2008). The wingate test is a common model of HIIT performed on a cycle ergometer. It is preceded by 3-5 minutes of warm up. The test usually consists of 4-6 30 second “all-out” maximal effort cycling bouts against a standardized resistance. The cycling bouts are separated by 4 minute rest intervals. During the wingate test, a total of 2-3 minutes of maximal exercise is typically performed over 15-30 minutes (Little et al., 2010). The high intensity and short duration of the wingate test elicit mostly anaerobic power (Smith & Hill, 1991). The wingate test is very stressful and participants are usually supervised and verbally encouraged as a high level of motivation is needed to complete the test (Bayati, Farzad, Gharakhanlou, & Agha-Alinejad, 2011).

Altered HIIT programs comprised of longer sessions, more repetitions, and shorter rest periods may be a better option for studies with diabetic participants (Bayati et al., 2011). Recent studies have shown that interval training programs using decreased intensity and increased duration have shown similar benefits compared with more intense programs. The less intense model of interval training may be more realistic for nonathletic participants. Such programs may consist of 6-10 cycling bouts of 30 seconds at 125% of power at VO\(_2\)max separated by 2 minute rests between each cycling bout (Bayati et al., 2011; Burgomaster, Hughes, Heigenhauser, Bradwell, & Gibala, 2005).

Glucose metabolism during high intensity interval training. Exercise of >80% VO\(_2\)max utilizes glucose as the exclusive muscle fuel, greatly impacting glycemic control (Marliss & Vranic, 2002). Unlike moderate intensity exercise, research has shown a significant
rise in catecholamine levels during high intensity exercise. This stimulates a 7-8 fold increase in glucose production and a 3-4 fold increase in glucose uptake. The resulting increase in blood glucose seen in diabetic patients during HIIT is mediated by increased plasma insulin levels. This response is only present in patients with type II diabetes, as insulin production is absent in type I diabetes (Centers for Disease Control and Prevention, 2011b).

**High intensity interval training and glycemic control in healthy non-diabetic adults.**

Research on the effect of HIIT on glycemic control is more prevalent in healthy non-diabetic patients. This could be because the musculoskeletal and cardiometabolic risks are lower for non-diabetic participants. Healthy subjects naturally may also be more physically fit than diabetic subjects. For the following studies, the cycle ergometer was considered superior to running interval training. Even though the intensity during running was lower than the cycle ergometer, obese individuals developed shin splints and dropped out (Nybo et al., 2010).

Four of the following studies used maximal effort during cycle ergometer training and two of them used submaximal training. Richards et al. (2010) studied young and healthy sedentary or recreationally active subjects. Subjects were randomly assigned to one of three groups: 1) 6 sessions of HIIT, 2) 1 session of HIIT, or 3) sedentary control. Insulin sensitivity was recorded before and 72 hours after treatments. Insulin sensitivity was evaluated by the euglycemic clamp method (golden standard). Results showed that 2-3 days after a 2-week exercise program of 6 HIIT sessions, fasting blood glucose was not improved. However, insulin sensitivity was improved compared to baseline measurements. Insulin sensitivity did not improve after one session of HIIT or in the sedentary control group.

In contrast to the study of healthy subjects by Richards et al. (2010), Whyte et al. (2010) studied overweight and obese sedentary men using a HIIT program similar to that used by
Richards et al. and Whyte et al. found no improvement in fasting blood glucose, but insulin sensitivity was improved at both 24 hours and 72 hours post-intervention compared with baseline measurements. These results supported the findings of Richards et al.

Babraj et al. (2009) evaluated insulin sensitivity before and 48-72 hours after HIIT interventions using the oral glucose tolerance test (OGTT) and Cederhold index. In contrast to the results found by Richards et al. (2010) and Whyte et al. (2010), fasting blood glucose (FBG) and fasting insulin levels were unchanged. However, both glucose area under the curve (AUC) (-12%) and insulin AUC (-37%) were significantly reduced during OGTT. HIIT may have improved insulin action by using up muscle glycogen stores.

Burgomaster et al. (2007) looked at muscle GLUT4 content in response to HIIT. Results showed that HIIT elevated muscle GLUT4 content by 20% after 1 week of training compared with baseline. The levels remained increased for the rest of the 5 week training program. Furthermore, levels remained elevated after 6 weeks of detraining. Burgomaster et al. also evaluated cytochrome c oxidase subunit 4 (COX4) protein content, an indicator of muscle oxidative capacity. COX4 protein content increased by 35% after 1 week of HIIT and remained significantly higher compared with baseline levels after 6 weeks of detraining.

These findings suggest that some physiological benefits of HIIT may remain even if training is discontinued. This is important for participants who have difficulty adhering to an exercise program. People who are not willing or able to continually participate in HIIT may still benefit from physiologically adaptations obtained during training. Future research should examine how long these physiological benefits last.
Sub maximal models have also been examined and compared with maximal interval training models in regards to glycemic control. Nybo et al. (2010) found that 20 minutes of near maximal running (40 minutes of total exercise including rest) per week for 12 weeks was equally effective as 150 minutes of running at 65% VO$_2$max per week over 12 weeks. Both exercise programs both improved fasting blood glucose and blood glucose two hours after oral ingestion of 75 grams of glucose. Sandvei et al. (2012) had similar results to Nybo et al., finding that 7.5-15 minutes of near maximal running each week was sufficient to improve glucose regulation.

These studies suggest that a submaximal interval training program may produce similar results to maximal interval training. This is important to consider when working with diabetic patients as they may not be willing to complete maximal interval training.

**High intensity interval training and glycemic control in adults with type II diabetes.**

There are few studies on HIIT in people with diabetes. Many studies use a less intense form of interval training that does not require maximal effort since the diabetic population is largely sedentary and less willing to complete maximal exercise training.

Little et al. (2011) examined the effects of six HIIT sessions spread over two weeks on glucose regulation 48-72 hours after the final training day in subjects with type II diabetes. The majority of subjects completed 60 minutes or less of exercise each week before the study. The interval training included 30 minutes of high intensity exercise each week with a total of 75 minutes per week including warm up, cool down, and rest periods. Little et al. used a submaximal training program. Glucose regulation was evaluated using 24 hour continuous glucose monitoring with standardized dietary regulation. Blood glucose levels were reduced by 13% 24 hours after the last exercise training session. Standard 3 hour postprandial glucose AUC
for breakfast, lunch, and dinner was reduced by 30%. These results may be important to clinicians as postprandial hyperglycemic control is a goal for type II diabetes management.

Little et al. (2011) also found that GLUT4 protein content was increased by 369% after two weeks of training. This increase in GLUT4 would greatly increase skeletal muscle glucose uptake. Glucose uptake by GLUT4 is not insulin-dependent and increased GLUT4 protein content is highly beneficial to participants with type II diabetes (Colberg et al., 2010).

Little et al. (2011) asked subjects to rate how enjoyable they would consider participating in HIIT three times a week for a month and found that the mean response was 7.9 on a scale from 1 (not enjoyable at all) to 9 (very enjoyable). They also evaluated rate of perceived exhaustion and found a range of 4-8 on a 10 point scale during training. These results suggest that on average, participants considered HIIT somewhat enjoyable and perceived exhaustion was variable. This is important when considering the barrier of discomfort for physical activity in diabetes (Houmard et al., 1991).

Gillen et al. (2012) used the same exercise program as Little et al. (2011). Their results showed that a single exercise session was sufficient to reduce 3 hour postprandial glucose AUC. Additionally, they found that the amount of time that glucose was above 10 mmol/L during 24 hours post-exercise period compared to the sedentary control was significantly decreased. However, after 24 hours, blood glucose reduction was no longer significant (p=0.16). The results seem to suggest that HIIT improves glycemic control, however Gillen et al. used the same subjects from the study by Little et al. It is possible that the participants were still exhibiting benefits from the study by Little et al. and that the benefits found by Gillen et al. were not due to the exercise treatment in the study. However, the sedentary control did not show significant increases in glycemic control, suggesting that the interval training may have been effective.
Kjaer et al. (1990) examined the effect of 5 minutes of high intensity interval exercise in relation to blood glucose control during and up until 3 hours postexercise in type II diabetic subjects. They found that the rise in glucose levels in type II diabetics compared to controls was greater and lasted longer. Peak blood glucose levels were seen in type II diabetic subjects at 30 minutes post-exercise, with baseline levels at 147 mg/dL and 30 minutes post-exercise levels at 169 mg/dL. Blood glucose levels began to decrease at one hour post-exercise. For non-diabetic controls, blood glucose increased from baseline level of 90 mg/dL to a peak of 100 mg/dL at 10 minutes post-exercise. At one hour post-exercise, blood glucose did not differ from baseline levels in non-diabetic controls. Plasma insulin levels were increased in both groups after exercise and returned to baseline at 120 minutes post-exercise.

Plasma epinephrine and glucagon were also measured. The increase in these hormones following exercise was higher in type II diabetic patients compared with non-diabetic controls. Type II diabetic subjects showed increased insulin effect on glucose uptake by insulin clamp technique 24 hours after exercise. Other studies have supported this finding that insulin helps to dispose of glucose after short term HIIT programs (Devlin, Hirshman, Horton, & Horton, 1987; Devlin & Horton, 1985). Kjaer et al. (1990) attributed post-exercise hyperglycemia and hyperinsulinemia in type II diabetes to hormonal responses.

These studies demonstrate that HIIT may provide multiple benefits that increase glycemic control in people with type II diabetes. They also show that the response to HIIT is highly variable. Blood glucose tests may be affected by factors such as the time of testing, the last meal, stress levels, hormone responses, and insulin activity (Gillen et al., 2012; Kjaer et al., 1990; Little et al., 2011). Future considerations for the method of testing glycemic control are important, especially when working with diabetic patients.
**Glycosylated hemoglobin A\textsubscript{1c} as a measurement of glycemic control in type II diabetics.** Glycosylated hemoglobin A\textsubscript{1c}, HbA\textsubscript{1c}, is formed by a reaction of glucose with the $\alpha$ amino group of the valine residue at the N-terminus of $\beta$ globin chains. Internal rearrangement of the resulting aldimine produces a stable ketoamine derivative (Peacock, 1984). HbA\textsubscript{1c} blood concentration is a sensitive measure used in the evaluation of glycol-metabolic control in diabetes and in the diagnosis of diabetes mellitus (Standards of Medical Care in Diabetes, 2012). HbA\textsubscript{1c} is considered the golden standard for measuring glucose control (Cox & Edelman, 2009) and was endorsed by the American Diabetes Association (ADA) as a first-line screening and diagnostic test in 2009 (Gillett, 2009).

Despite the accuracy of this test, very few studies examining the effect of HIIT on glycemic control have used HbA\textsubscript{1c}. HbA\textsubscript{1c} is an excellent test for research, especially for long term experiments. HbA\textsubscript{1c} blood levels represent the average glucose control over the last three months. For this reason, it is more accurate than a blood glucose test at a single time point (Cox & Edelman, 2009).

In addition to the accuracy of the HbA\textsubscript{1c} test, it is easy to obtain and does not require fasting. HbA\textsubscript{1c} levels are often monitored by physicians and may be accessed by researchers with permission from participants. This method of assessment is also more convenient to the researcher because it only requires one test before and one test after the treatment. Researchers do not need to control for factors that affect blood glucose variation during a given day. HbA\textsubscript{1c} is also a valuable tool because it measures insulin function (Cox & Edelman, 2009). The studies in this review show that HIIT has a significant impact on insulin (Gillen et al., 2012; Kjaer et al., 1990; Little et al., 2011), further justifying the use of HbA\textsubscript{1c} as a measurement of glycemic control.
Summary

Type II diabetes is a serious condition characterized by impaired glycemic regulation (Centers for Disease Control and Prevention, 2011b). Aerobic and resistance training provide improved glycemic control to diabetic patients (Boulé et al., 2001; Snowling & Hopkins, 2006; Umpierre et al., 2011), but the clinical exercise guidelines for type II diabetic patients may not be followed due to time constraints and discomfort during exercise (Egan et al., 2013).

HIIT is an alternate form of exercise that may provide equally beneficial improvements in glucose regulation, insulin sensitivity, GLUT4 content, COX4 content, and VO2max when compared with aerobic and resistance training (Gillen et al., 2012; Kjaer et al., 1990; Little et al., 2011). HIIT is less of a time commitment and the perceived exhaustion is less than aerobic or resistance training (Little et al., 2011). This is important when considering that the major barriers to physical fitness in diabetics are lack of time and discomfort during exercise (Egan et al., 2013).

There are few studies that have examined the effect of HIIT in type II diabetic patients. Specifically, there is very little published research on long term effects of a HIIT program on glycemic control in patients with type II diabetes. Very few studies have used HbA1c as a measure of glycemic control (Cox & Edelman, 2009). Future research should utilize this highly accurate measure to examine the long term effects of HIIT on glycemic control. Future research is needed to determine these effects and provide information about HIIT as a prevention or treatment of diabetes.
Chapter III

Methods and Procedures

Introduction

This study was designed to examine the effect of a twelve week high intensity interval training (HIIT) program on glycosylated hemoglobin A1c (HbA1c) levels in type II diabetic patients.

Description of Study Population

Twenty male and twenty female participants with type II diabetes [as defined by the American Diabetes Association (2013)] were recruited from the PeaceHealth St. Joseph Medical Center Nutrition and Diabetes Clinic in Bellingham, WA, following approval of the study from the University Human Subjects’ Committee. Participants (mean age 52 ± 3 years, body mass index 30.5 ± 1.9 kg/m²) exhibited baseline HbA1c values of >6.0% (Rosenzweig, Weinger, Poirier-Solomon, & Rushton, 2002), and had no exercise training within the past six months. Exclusion criteria included severe cardiovascular and cerebrovascular disease, diabetic nephropathy, diabetic retinopathy, and severe diabetic neuropathy. All participants were on antihyperglycemic medications and did not change the dosage of medication during the study. Likewise, participants were asked not to alter their diet during the course of the study. Participants performed an exercise stress test and were not allowed to participate in the study if abnormalities were seen in the electrocardiogram (ECG) recordings.
Design of the Study

This study utilized a pretest-posttest randomized groups experimental design in which participants were randomly assigned to either the control or treatment group.

Data Collection Procedures

**Instrumentation.** High intensity interval training (HIIT) was completed in the Exercise Physiology Laboratory at Western Washington University on a Monarck bicycle ergometer (Sweden). Maximal oxygen uptake (VO\(_2\) max) was obtained using the Parvo Medics metabolic cart (Sandy, UT). Glycosylated hemoglobin A\(_1c\) (HbA\(_1c\)) blood levels were taken before and after treatment and measured at the PeaceHealth laboratory (Bellingham, WA).

**Measurement techniques and procedures.** VO\(_2\) max was obtained prior to training using the Bruce Treadmill Test (Bruce, 1972). VO\(_2\) max was used to calculate the individual work rate for each participant to maintain 80% VO\(_2\) max during HIIT. The work rate was calculated using the VO\(_2\) max metabolic equation (Armstrong, Brubaker, Whaley, & Otto, 2005). The Monarck bicycle ergometer (Sweden) was set to the calculated work rate in order to maintain 80% VO\(_2\) max during HIIT.

**Training procedures.** Participants were randomly assigned to either the sedentary control group or the HIIT group. Sedentary control subjects were instructed not to alter their diet or physical activity during the 12 week study. HIIT subjects participated in a HIIT program five days a week for 12 weeks. Blood HbA\(_1c\) levels were measured both sedentary controls and HIIT subjects prior to treatment. HIIT subjects completed the Bruce Treadmill Test (Bruce, 1972) to find their VO\(_2\) max. Individual work rate needed to sustain 80% VO\(_2\) max during HIIT was calculated (Armstrong et al., 2005) and the bicycle ergometer was set at this work rate. During
training, HIIT participants were instructed to wear comfortable, loose fitting clothes, and athletic shoes. On training days, subjects completed a 10 minute warm up on the bicycle at 20% of the determined workload. During HIIT, subjects completed four to six 30 second “all-out” cycling bouts separated by 4 minute recovery periods. Participants were verbally encouraged during the “all-out” cycling bouts. Participants completed a 10 minute cool down on the bicycle at 20% of the determined workload. HIIT participants were instructed not to change their diet during the 12 week training program. At the conclusion of the 12 week experiment, HbA$_{1c}$ levels were measured.

**Data Analysis**

Statistical analysis was performed using a mixed factorial ANOVA to determine the difference in HbA$_{1c}$ levels due to high intensity interval training in type II diabetics.
References


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