MODERATE INTENSITY EXERCISE AND POSTPRANDIAL GLUCOSE EXCURSIONS IN DIABETIC INDIVIDUALS

by

Anna L. Schwartz

An Abstract
of a thesis submitted in partial fulfillment of the requirements for the degree of Master of Science
in the Department of Nutrition and Kinesiology
University of Central Missouri

December, 2012
ABSTRACT

by

Anna L. Schwartz

Introduction: Physical activity improves insulin sensitivity but the extent to which postprandial glucose is improved is not fully understood. Purpose: To examine the effects of moderate-intensity aerobic exercise in sedentary prediabetic or type II diabetic individuals compared to sedentary healthy individuals on postprandial glucose excursions. Methods: An exercise intervention group (EIG) and a control group (CG) completed pre- and posttests consisting of a 3-day analysis of postprandial glucose using a continuous glucose monitor. Subjects of the EIG (n = 6) were sedentary, diagnosed with either prediabetes or type II diabetes, and completed 8 weeks of moderate-intensity aerobic exercise for 30-45 min on 3-5 days/week. Subjects of the CG (n = 7) were sedentary healthy individuals which completed 8 weeks of nonintervention. Results: An independent samples t-test indicated no significant differences between groups from pre- to posttest in peak postprandial glucose excursions. Conclusion: Results of this study indicate moderate-intensity aerobic exercise performed for 30-45 min on 3-5 days/week is not effective in eliciting an overall change in postprandial glucose in sedentary prediabetic or type II diabetic individuals compared to sedentary healthy individuals.
MODERATE INTENSITY EXERCISE AND POSTPRANDIAL GLUCOSE EXCURSIONS IN DIABETIC INDIVIDUALS

by

Anna L. Schwartz

A Thesis presented in partial fulfillment of the requirements for the degree of Master of Science in the Department of Nutrition and Kinesiology University of Central Missouri

December, 2012
MODERATE INTENSITY EXERCISE AND POSTPRANDIAL GLUCOSE EXCURSIONS IN DIABETIC INDIVIDUALS

by

Anna L. Schwartz

December, 2012

APPROVED:

Thesis Chair: Dr. Steve Burns
Thesis Committee Member: Dr. Janice Putnam
Thesis Committee Member: Dr. Susan Stockton

ACCEPTED:

Chair, Department of Nutrition & Kinesiology: Dr. Mike Godard

UNIVERSITY OF CENTRAL MISSOURI
WARRENSBURG, MISSOURI
ACKNOWLEDGEMENTS

This research was supported by a Willard North Research Award. I would like to thank Dr. Steve Burns for the abundant amount of time he has spent on this entire process helping me complete this thesis and for his generous attitude towards me in this accomplishment. I would like to thank my thesis committee members, Dr. Janice Putnam and Dr. Susan Stockton, both of which supported me during this entire endeavor, gave me sound critique, and contributed excellent problem solving ideas for this study. I would like to thank my husband, Michael Schwartz for his endless patience and encouragement toward me during this entire process. I would like to thank my family for their encouragement and support in furthering my education towards this endeavor. I would like to thank Cassandra Davis and Aryn Lessmeier for their wonderful assistance with data collection and exercise sessions. I would also like to thank Mary Brinkley for providing me with the equipment in sufficient time to complete data collection. I would like to thank Andrew Gai for his aid in statistical analysis. I would like to express my thanks to all the participants of this study; I have greatly enjoyed meeting and working with each one of you. Lastly, I would like to thank the human subjects committee of the University of Central Missouri for granting ethical approval to this study.
# Table of Contents

LIST OF TABLES .................................................................................................................. ix

CHAPTER 1: NATURE AND SCOPE OF THE STUDY .......................................................... 1

  Purpose of the Study ......................................................................................................... 3
  Need for the Study ............................................................................................................. 4
  Research Questions ........................................................................................................... 5
  Delimitations ....................................................................................................................... 6
  Limitations .......................................................................................................................... 6
  Assumptions ......................................................................................................................... 7
  Hypotheses ........................................................................................................................... 7
  Definition of Terms ............................................................................................................. 8

CHAPTER 2: REVIEW OF LITERATURE ............................................................................. 11

  Development of Diabetes .................................................................................................. 11
  Blood Glucose Measurement Techniques ....................................................................... 13
  Controlling Blood Glucose Excursions .......................................................................... 16
  Benefits of Exercise in Diabetes ....................................................................................... 18
  Exercise Intervention Strategies in Diabetes .................................................................... 20
  Summary ............................................................................................................................. 27

CHAPTER 3: METHODOLOGY ......................................................................................... 29

  Selection of Participants ................................................................................................... 29
  Research Groups .............................................................................................................. 30
  Instrumentation ................................................................................................................. 31
  Study Design ...................................................................................................................... 32
Data Analysis ..........................................................................................................................34

CHAPTER 4: RESULTS ...........................................................................................................35

Group Descriptives ...............................................................................................................35
Within Group Differences in Postprandial Blood Glucose ....................................................36
Between Group Differences in Postprandial Blood Glucose ..................................................36
Within Group Differences in Percent Body Fat ......................................................................37
Between Group Differences in Percent Body Fat ...................................................................37

CHAPTER 5: DISCUSSION ....................................................................................................39
Postprandial Blood Glucose Excursions ..................................................................................39
Percent Body Fat ....................................................................................................................40
Conclusion ..............................................................................................................................41
Limitations and Future Research ............................................................................................42

REFERENCES .......................................................................................................................45

APPENDICES .........................................................................................................................49

A. Human Subjects Review Board Approval ...........................................................................49
B. Flyer .....................................................................................................................................50
C. Informed Consent Form .......................................................................................................51
D. Physician Consent Form ......................................................................................................53
E. Food & Glucose Level Diary Form .......................................................................................54
F. Participant Information Sheet ...............................................................................................55
G. Exercise Intervention Form ..................................................................................................56
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Tables</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mean Group Descriptives</td>
<td>36</td>
</tr>
<tr>
<td>2. Mean Highest Postprandial Blood Glucose (HPBG)</td>
<td>37</td>
</tr>
<tr>
<td>3. Mean Percent Body Fat (%BF)</td>
<td>38</td>
</tr>
</tbody>
</table>
CHAPTER 1
NATURE AND SCOPE OF
THE STUDY

Diabetes mellitus is becoming increasingly prevalent in our society and worldwide. In 2011, the International Diabetes Federation (IDF) estimated that more than 366 million people in the world have diabetes and that by the year 2030, this number will nearly double to 552 million (IDF, 2011a). There are two main forms of diabetes mellitus, type I and type II diabetes. According to the American College of Sports Medicine (ACSM), type I diabetes (insulin-dependent) usually occurs during early years of life and may be genetically inherited; this is a state of insulin deficiency due to the destruction of pancreas beta cells and an inability to produce adequate levels of insulin (Ehrman et al., 2010). Decreased insulin release and an increase in counter-regulatory hormones in these individuals may lead to ketoacidosis as a result of fatty acid oxidation, thus plasma pH levels decrease to a more acidic level. In order to maintain normal blood glucose levels, patients require exogenous insulin injection as an intervention (Ehrman et al., 2010).

Prediabetes is usually a precursor condition to type II diabetes, which is characterized by hyperglycemia, a problem in which fasting glucose levels are impaired (IFG) at 100-125 mg/dL or the individual suffers from impaired glucose tolerance (IGT) as measured by a 2-hr plasma glucose level of 140-199 mg/dL following an oral glucose tolerance test (OGTT), or a glycosylated hemoglobin (HbA1c) value between 5.7-6.4% (American Association of Diabetes Educators, 2012c). Sadly, many individuals do not even know they have prediabetes before complications arise and the problems develop into type II diabetes. In fact, the American Association of Diabetes Educators (AADE) estimates more than 79 million adults in the United States have been diagnosed with prediabetes and this number does not even take into
consideration the number of children suffering from this condition; additionally, individuals suffering from this condition may eventually contribute to the diabetic population (AADE, 2012c). Accordingly, the IDF estimates 183 million individuals in the world with diabetes are actually undiagnosed (IDF, 2011a).

Type II diabetes (non-insulin-dependent) is characterized by fasting hyperglycemic values ≥126 mg/dL confirmed on two occasions; these values are due to insulin resistance in combination with insulin deficiency in which insulin secretion by the pancreas is defective (Ehrman et al., 2010). It is thought to be in part, a result of obesity and a sedentary lifestyle. Patients usually require oral medication or in some cases, insulin prescription as an aid to maintaining normal blood glucose levels (Ehrman et al., 2010). The main risk factors that have been identified in the pathophysiology of type II diabetes include age ≥45 years, central obesity (waist circumferences in males ≥40 in. and in females ≥35 in.), a BMI ≥25 kg/m², a sedentary lifestyle, having a diabetic first degree relative, hypertension (≥140/90 mmHg), a low level of high-density lipoprotein (HDL) cholesterol (<35 mg/dL), a high triglyceride level (>250 mg/dL), IGT or IFG diagnosis or clinical insulin resistance conditions, or a history of vascular disease (Ehrman et al., 2010).

Research has indicated that risk for cardiovascular disease (CVD) increases with the duration of diagnosis as a type II diabetic (Shen, 2010). According to Shen (2010), type II diabetics have a two- to four-fold higher risk of developing CVD than the normal population due to the problems developed in diabetes. In addition, approximately 75% of diabetes deaths are due to CVD, such as macrovascular and microvascular diseases and even cardiomyopathy (Shen, 2010). Macrovascular diseases include coronary artery disease (CAD), stroke, and peripheral vascular disease; whereas microvascular diseases include retinopathy, nephropathy, and
neuropathy (Shen, 2010). Diabetic patients obviously have many complications affecting the vasculature and according to Magalhães, Appell, and Duarte (2008), and Sonne et al. (2007), one such complication is atherosclerosis, a type of CVD which is considered a main contributor to morbidity and mortality of type II diabetic patients.

Clearly, diabetes is increasingly becoming an issue worldwide. Currently, Ehrman et al. (2010), and Mooradian and Thurman (1999) indicate ideal prevention and maintenance for type II diabetes includes lifestyle intervention which adjusts diet, physical activity, and medication. Accordingly, the current intervention recommendations for CVD include lifestyle changes increasing physical activity, consuming a low saturated fat and low sodium diet, blood-pressure and low-density lipoprotein-lowering medication, and smoking cessation (Ehrman et al., 2010). Several risk factors for both diseases are common and the interventions for both diseases target the same changes. Ehrman et al. (2010), and Nygaard, Tomten, and Høstmark (2009) concluded that studies reviewed have shown a dose-response relationship, in which risk for diabetes decreases in individuals who increase physical activity. Studies have also indicated that any energy decrement as a result of diet or increased physical activity or exercise has a positive effect on blood glucose maintenance (Ehrman et al., 2010; Nygaard et al., 2009).

Ideally, a lifestyle change increasing physical activity may be the most ideal intervention for type II diabetics and to help these individuals decrease their risk for development of CVD. Even a small change in physical activity may make a difference in the quality of life these individuals will have.

**Purpose of the Study**

The purpose of this study was to examine the effects of aerobic exercise at a moderate-intensity in sedentary prediabetic or type II diabetic individuals, and a lack of moderate-intensity
aerobic exercise in sedentary healthy individuals on postprandial blood glucose excursions and percentage of body fat. If aerobic exercise at a moderate-intensity is a significant intervention strategy to help individuals with hyperglycemic postprandial glucose excursions to maintain or reduce postprandial glucose excursions, then physicians, exercise physiologists, and health care providers in general should consider the intervention of aerobic exercise at a moderate-intensity as a means of prevention and treatment of type II diabetes.

**Need for the Study**

According to the IDF (2011b) 4.6 million deaths a year worldwide are due to diabetes, and additionally, McArdle, Katch, and Katch (2010) indicated that an even greater number of diabetics die from CVD which is affected by diabetic complications, such as hypertension and lipid concentrations. The ACSM indicates physical activity or exercise is an essential component to diabetes and CVD management and therapy; however, much care must be taken in exercise prescription due to the complications which may be exacerbated by vigorous exercise (Ehrman et al., 2010). Currently, AADE, ACSM, and IDF recommend gradually progressing to 30 min of moderate-intensity physical activity most days of the week to assist in weight loss which has shown to improve glucose and lipid concentrations, insulin resistance, as well as blood pressure (AADE, 2012b; ACSM, 2010; IDF, 2011a). In particular, ACSM recommends physical activity in diabetic patients consisting of moderate-intensity (40-60% VO_{2}\text{max}) aerobic exercise, 3 days/week, for a total of at least 150 min/week, with no more than two consecutive days between bouts to allow for exercise-induced improvements in insulin action (ACSM, 2010). Activity mode should use large muscle groups and keep the heart rate up for an extended period of time. This includes activities like brisk walking which is easily attainable by most diabetic patients. However, for individuals already participating in moderate- or vigorous-intensity (>60%
VO\textsubscript{2max} aerobic exercise, ACSM recommends 30 min for 5 days/week or 20 min for 3 days/week to provide additional blood glucose or cardiovascular benefits (ACSM, 2010).

According to Thompson, Gordon, and Pescatello (2010), individuals starting exercise should begin slow and gradually increase in duration and intensity. It is important for individuals to realize there is a dose-response relationship in physical activity and health, in which it is better for an individual to participate in some activity rather than none, whereas, more activity may be better than less activity (Thompson et al., 2010). Additionally, the studies reviewed by Healy et al. (2007) indicated the intensity of physical activity may not need to be quite so high for hyperglycemia to be easily modified by physical activity. Even light physical activity showed small shifts in 2-hr plasma glucose levels, which in sedentary diabetics may be effective (Healy et al., 2007). The conclusion was made that most individuals in our society and in the work environment may be more likely to participate and continue a physical activity intervention at a light- to moderate-intensity (Healy et al., 2007). Therefore, the concept of performing moderate physical activity consisting of even just a brisk walk may be the most effective intervention strategy for sedentary diabetic individuals to incorporate into their daily routine. In contrast, studies have shown a rebound effect on insulin improvement in which blood glucose maintenance decreases if an individual ceases exercise intervention after a few weeks of sedentary behavior (McArdle et al., 2010; Mikus et al., 2012). This indicates how important it is for an individual to make physical activity part of their lifestyle in order to establish and maintain normal postprandial blood glucose levels.

**Research Questions**

RQ1 What effect does 8 weeks of moderate-intensity aerobic exercise have on postprandial glucose excursions in a sedentary prediabetic or type II diabetic individual?
RQ2 What effect does 8 weeks of moderate-intensity aerobic exercise have on percent body fat in a sedentary prediabetic or type II diabetic individual?

**Delimitations**

The study was delimited to:

1. A total of thirteen ($N = 13$) sedentary healthy, prediabetic, and type II diabetic men and women within the age range of 18 to 65 years, who were not pregnant, or on an insulin pump;
2. Patients from the Diabetic Clinic of the Western Missouri Medical Center and individuals of the surrounding Central Missouri region;
3. All subjects complied with the informed consent form, and all prediabetic or type II diabetic subjects also complied with the physician consent form;
4. All subjects of the exercise intervention group participated in at least 3 days of moderate-intensity aerobic exercise for at least 30 min for eight consecutive weeks;
5. Postprandial glucose excursions were recorded using a continuous glucose monitor;
6. Determination of percent body fat for each subject was estimated by dual energy x-ray absorptiometry; and
7. An 8 week intervention.

**Limitations**

The investigation was limited by:

1. The sample size of the study ($N = 13$) was small, demanding caution in extrapolation of the data;
2. Accuracy of subject record keeping on the food and glucose level diary form during both the pre- and posttest, and during exercise intervention on the exercise intervention form;

3. Subject adherence to pre- or posttest and exercise guidelines;

4. Subject diet during pre- and posttest was not controlled;

5. Subject medication was not controlled;

6. Daily physical activities other than assigned exercise sessions were not controlled or recorded; and

7. Subjects in the control group were instructed not to participate in exercise but to remain sedentary.

Assumptions

It was assumed that:

1. All subjects were honest and accurate in responding to all data recording and collection;

2. All subjects understood the procedures of the study;

3. All research personnel were competent in all procedures of the study;

4. All subjects followed pre- and posttest instructions;

5. All subjects exercised within assigned age predicted heart rate range; and

6. The testing instruments were valid and reliable for the study.

Hypotheses

H1: Eight weeks of aerobic exercise at a moderate-intensity (55-65% HR_{max}) for 30-45 min, 3-5 days a week will be effective in reducing postprandial glucose excursions in sedentary prediabetic and type II diabetic individuals, compared to no exercise in sedentary healthy individuals.
H₂: Eight weeks of aerobic exercise at a moderate intensity (55-65% HR\textsubscript{max}) for 30-45 min, 3-5 days a week will be effective in decreasing percent body fat of sedentary prediabetic and type II diabetic individuals, compared to no exercise in sedentary healthy individuals.

**Definition of Terms**

For consistency of interpretation, the following terms were defined:

- **Aerobic exercise.** Physical activity which uses major muscle groups to perform repetitive movements such as walking, jogging, running, swimming, and biking. Aerobic exercise helps to increase an individual’s cardiorespiratory endurance through improvement in the metabolic processes using beta-oxidation (McArdle et al., 2010).

- **Age predicted maximum heart rate (HR\textsubscript{max}).** An estimate of the maximum heart rate attained at the highest workload performed by men or women. It may be calculated by taking 220 minus the age of the individual (HR\textsubscript{max} = 220 – age) with a standard deviation of approximately ±10 bpm (Ehrman et al., 2010).

- **Antioxidants.** Free radical scavengers consumed in the diet, such as vitamins C and E, which avert or decrease the degree of oxidative damage (McArdle et al., 2010).

- **Cardiovascular disease.** A classification of disease affecting the heart and circulatory system, eventually leading to life threatening problems (Ehrman et al., 2010).

- **Diabetes mellitus.** A metabolic disease in which the individual is deficient in insulin secretion and/or unable to effectively use insulin resulting in hyperglycemia (Thompson et al., 2010).

- **Endothelial dysfunction.** The inability of endothelial cells to help the affected smooth muscle (in blood vessels) to relax, thus decreasing vasodilation and increasing vasoconstriction (Sonne et al., 2007).
**Fasting plasma glucose (FPG).** A measurement of the composition of blood glucose level after at least an 8 hr period in which no caloric sustenance is consumed (Ehrman et al., 2010).

**Glycosylated hemoglobin (HbA1c).** A test that measures the amount of glycation (the addition of saccharides to proteins or lipids) in blood which may be used to monitor diabetes (Ehrman et al., 2010).

**Hyperglycemia.** Elevated blood glucose levels; elevated fasting level ≥130 mg/dL or a postprandial level ≥180 mg/dL (Ehrman et al., 2010).

**Insulin resistance/Insulin sensitivity.** A problem in which regular insulin production is not sufficient to cause a normal insulin response in muscle, adipose tissue, or hepatic tissue (Ehrman et al., 2010).

**Oral glucose tolerance test (OGTT).** A test used to screen or diagnose diabetes and to evaluate the body’s ability to normalize glucose levels within the blood. Blood samples are taken after an 8 hr overnight fast; beginning with a fasting glucose sample, the consumption of a 75 g glucose drink, and blood glucose samples every 15 min for a total duration of 2 hrs. Normal glucose responses to the 2 hr post-load are equal to ≤139 mg/dL, whereas prediabetes or IGT may be indicated by a value of 140-199 mg/dL, and a value of ≥200 mg/dL is indicative of type II diabetes. Test must be confirmed on two separate occasions for diagnosis (Ehrman et al., 2010).

**Oxidative stress.** The addition of oxygen to cellular components leading to accumulation of free radicals which increases the risk for cellular damage and deterioration (McArdle et al., 2010).
Physical activity. Any physical movement that is repetitive, involving major skeletal muscle groups and requires an increase in energy metabolism (Thompson et al., 2010).

Postprandial glucose excursions. Elevated blood glucose peak values after a meal, which is considered a risk factor for CVD and diabetes mellitus (Nygaard et al., 2009).

Prediabetes. A pre metabolic state characterized by hyperglycemia in which blood glucose levels are between normal and high, this condition includes either impaired fasting glucose (IFG) at 100-125 mg/dL, or impaired glucose tolerance (IGT) at 140-199 mg/dL following an OGTT, or both and may increase the risk for developing type II diabetes (Ehrman et al., 2010).

Sedentary. Individuals who do not accumulate more than 30 min of moderate-intensity physical activity 3 days a week for the past 6 months (Thompson et al., 2010).

Type II Diabetes. A type of metabolic disorder in which the body is unable to react effectively to insulin and eventually leads to pancreas beta cell deficiency to produce insulin (Ehrman et al., 2010).
CHAPTER 2
REVIEW OF LITERATURE

The literature reviewed will report the effects of exercise intervention programs on hyperglycemia and glucose excursions most often experienced in prediabetes or type II diabetes. The main health problems these individuals face and mechanisms of controlling these issues will be identified. The benefits of exercise in decreasing the risk for diseases and complications that ensue from diabetes mellitus will also be described in detail. Finally, this review will discuss the ideal exercise duration, intensity, and mode for decreasing postprandial glucose excursions in prediabetes and type II diabetes. The literature reviewed is presented under the following sections: (1) development of diabetes, (2) blood glucose measurement techniques, (3) controlling blood glucose excursions, (4) benefits of exercise in diabetes, (5) exercise intervention strategies in diabetes, and (6) a summary.

Development of Diabetes

Diabetes mellitus is highly prevalent in our society. It is estimated that currently 2% of the world population is affected by this disease (Magalhães et al., 2007). There are two main forms of diabetes mellitus; type I and type II diabetes. However, according to the World Health Organization (WHO), prediabetes is a problem characterized by hyperglycemia which usually occurs prior to the onset of type II diabetes (WHO, 2011). Type I diabetes is mainly a result of genetics, in which insulin producing-pancreas beta cells are destroyed by an autoimmune response (Ehrman et al., 2010). Whereas, Type II diabetes is thought to be mainly a result of excess body fat, a high carbohydrate (CHO) diet, and a sedentary lifestyle resulting in insulin resistance and defective insulin secretion (WHO, 2011). According to ACSM, type II diabetes is
the most prevalent form accounting for approximately 90-95% of all individuals with diabetes mellitus (Ehrman et al., 2010).

The IDF (2011a) stated that diabetes mellitus is an additional economic burden to the United States population and global populations; consequently, $465 billion was estimated to have been spent globally in 2011 on diabetes healthcare. In addition, WHO estimates China will spend approximately $558 billion on diabetes, CVD, and stroke through the years 2006-2015 (WHO, 2011). These estimates may not even include those individuals who are considered prediabetic. A great amount of money is spent just trying to manage and control glucose levels within these individuals. As a result of disturbances in glucose homeostasis, many problems ensue which require more effort and money to stabilize. Such problems may include macrovascular, microvascular, and neural disease complications leading to organ and tissue damage, and possibly morbidity and mortality consequences (Ehrman et al., 2010). The mechanisms by which these complications develop are accumulation of advanced glycation end product, oxidative stress, increased endothelial growth factors, and decreased nitric oxide availability resulting in impaired vasodilatory response, smooth muscle cell dysfunction, and impaired blood composition (Cade, 2008; Heine & Dekker, 2002).

According to Heine and Dekker (2002), hyperglycemia stimulates the production of reactive oxygen species by non-enzymatic glycation, auto-oxidation of glucose, and polyol stimulation. In addition, postprandial hyperglycemia may cause a decrease in antioxidant capacity and increase low-density lipoprotein (LDL) oxidation. The tissues most likely to be affected by this problem have a high energy need or may have a low free radical scavenging ability, such as pancreas beta cells. Atherosclerosis is a common problem correlating to postprandial hyperglycemia due to the increased oxidative stress imposed on blood vessels and
the increased LDL levels. In addition, increased triglyceride plasma concentrations after a high-fat meal may decrease insulin sensitivity, and thus increase the development of atherogenesis. Increased adipose tissue and triglyceride lipoprotein concentrations cause an increased concentration of acyl CoA which may inhibit the mitochondrial adenine nucleotide translocater; causing an increase in the ATP:ADP ratio. Free radical production is stimulated with the decreased level of ADP stores by accumulation of electrons in the electron transport chain. Chronic adenosine accumulation may also cause stimulation of renal vasoconstriction through the sympathetic nervous system, thus contributing to insulin resistance in the alteration of hemodynamic concentrations. Heine and Dekker (2002) concluded that oxidative stress caused by increased intracellular triglyceride levels may contribute to beta cell dysfunction over time. Overall, extreme variations in blood glucose levels leading to hyperglycemia is a main contributor to chronic beta cell dysfunction, and ultimately decreased insulin sensitivity and the onset of type II diabetes.

**Blood Glucose Measurement Techniques**

Blood glucose levels are a good predictor of homeostasis within the body. The incline or decline of blood glucose levels causes problems leading to acidic or alkaline reactions that contribute to the damaging hemodynamic changes of blood. Determination of glucose levels is a beneficial technique for diabetics to help maintain glucose excursions within normal limits of homeostasis. Accordingly, based on the association of risk for having or developing retinopathy, blood glucose levels are used as an indicator for diagnosis of prediabetes and diabetes (Ehrman et al., 2010). ACSM recognizes three forms of criteria which may be used in the diagnosis of diabetes; fasting plasma glucose (FPG), the 75 g oral glucose tolerance test (OGTT), or the glycosylated hemoglobin (HbA\textsubscript{1c}) value (Ehrman et al., 2010). However, any one of these
criteria must be confirmed on preceding days unless hyperglycemia is obviously present in the individual. Barrot-Connor and Ferrara (1998) believe the OGTT is more effective than FPG in diagnosing diabetes through the detection of isolated post-challenge hyperglycemia (IPH) or postprandial hyperglycemia. However, the Expert Committee on the Diagnosis and Classification of Diabetes Mellitus (ECDCDM) considers the FPG to be the best standard for diagnosis of type II diabetes (ECDCDM, 2003).

Post-challenge hyperglycemia is a condition measured by the OGTT, in which an individual has a normal FPG but has hyperglycemic values two hours after glucose consumption (Barrot-Connor & Ferrara, 1998). This condition may explain why many individuals suffer from diabetic consequences and eventually develop diabetes but are not classified as prediabetic or diabetic when only the FPG test is administered (Barrot-Connor & Ferrara, 1998). However, the ECDCDM recommends the OGTT not be used as a diagnostic technique in clinical practices due to inconvenience, cost, and less chance of reproducibility, but concluded both the FPG and OGTT tests are the most ideal methods for diagnosing diabetes and the choice for which test to use should be based on sensitivity, convenience, cost, and reproducibility (ECDCDM, 2003).

Glycosylated hemoglobin (HbA1c) test is considered by ECDCDM not an effective test for determination of diabetes based upon lack of standardized methodology in laboratory reference ranges (ECDCDM, 2003). However, HbA1c value may be beneficial as an indicator for glycemic intervention effectiveness and therapy modification purposes. When standardized methodology is used in the HbA1c test then measurements may be beneficial in the detection of diabetes. The HbA1c test measures A1c values throughout the course of weeks on any given day and time; rather than the FPG and OGTT, which only sample blood once or within a 2-hr time frame after an 8 hr fast. HbA1c is a measurement of glucose attached to dead red blood cell
molecules over a 3 month period. The use of this test is beneficial because it gives a greater picture of what is really happening in the blood over a longer period of time; thus, it may be more indicative of the effectiveness of blood glucose control within an intervention. Elevation of $A_1c$ above normal value means an individual may be suffering from chronic hyperglycemia. As classified by the American Diabetes Association (ADA, 2011), AADE (2012c), and ECDCDM (2003), normal ranges of HbA$_{1c}$ are approximately 4-5.9%, prediabetic values range from 5.7-6.4%, and diabetic values are approximately $\geq 8.0\%$, but in well controlled diabetic patients the value should be maintained to $\leq 7.0\%$.

Blood glucose values measured throughout a time frame of days are a better predictor of risk for developing CVD and mortality than fasting blood glucose values because the harmful peaks experienced in glucose excursions contribute to the development of CVD and may be detected by continuous blood glucose monitoring (Nygaard et al., 2009). Blood glucose may continually be monitored through the use of sensor equipment, called continuous glucose monitors (CGM). According to Danne, Lange, and Kordonouri (2008), CGM equipment has proven useful to help decrease both glucose excursions and HbA$_{1c}$ values. An established parameter for variations in glycemic values is the mean amplitude of glycemic excursions (MAGE); this value may be detected by CGM equipment and may be more reliable as a control for glucose excursions than HbA$_{1c}$ value.

The Continuous Glucose Monitoring System by Medtronic Minimed is approved by FDA and is a popular sensor used by many diabetic patients for the maintenance of glucose excursions (Danne et al., 2008). This CGM is minimally invasive and measures blood glucose levels by sampling interstitial fluid of subcutaneous tissue. A small monitor unit is connected to a sensor with a dialysis catheter. The catheter is inserted subcutaneously and records blood glucose values
every 10 s; the values are averaged every 5 min and then stored. However, since the glucose sample is taken from subcutaneous interstitial fluid, there is a 5-10 min time lag between blood and interstitial fluid glucose levels which must be considered by patients relying on this method. After the period of collection (usually three days), data is analyzed on a computer system and graphed as a continuous blood glucose line graph, however finger pricks should be taken in conjunction at least three times a day to compare the values recorded on the CGM. Results of studies reviewed by Danne et al. (2008) have shown CGM use is not a sufficient means of significantly decreasing glucose excursions or HbA₁c values, but may be used to help patients decrease the level of MAGEs or glucose excursion peaks, and to detect both hyper- and hypoglycemic events.

Because the CGM continually measures blood glucose levels throughout the day, use of the CGM is beneficial in detecting blood glucose trends which may be missed by self-monitored finger pricks and may be a means of improving glucose instability; even without a significant decrease in HbA₁c values, diabetic patients may notice an improvement (Danne et al., 2008). Overall, CGM method is the most appropriate approach in determining an individual’s blood glucose level throughout the day and to observe effects made by intervention strategies to help normalize blood glucose excursions.

**Controlling Blood Glucose Excursions**

Controlling blood glucose excursions is a very challenging goal of prediabetic and diabetic patients; postprandial glucose excursions may be even harder to control than fasting glucose levels among these individuals (Mooradian & Thurman, 1999). Elevated postprandial glucose values or hyperinsulinemia are considered independent risk factors for the development of macrovascular problems and thus increase the risk for coronary heart disease (CHD),
indicating the importance for control in prediabetic and diabetic patients (Mooradian & Thurman, 1999). Methods for controlling glucose may include medicinal or hormonal intervention, use of equipment (such as the CGM), diet intervention, and exercise intervention (Irvine & Taylor, 2009). In essence, any intervention intended to normalize blood glucose levels in diabetic patients is beneficial in altering the effects of postprandial glucose excursions (Mooradian & Thurman, 1999).

Jung and Jung (2005) indicated that medicinal intervention of exogenous insulin injection, multiple times throughout the day is the most effective means of controlling blood glucose levels. However, this mechanism may not be the most ideal intervention strategy due to cost and inconvenience; an ideal intervention strategy would be something a diabetic individual may do in conjunction or in replacement of insulin injection, such as exercise. Blood glucose may be lowered after a small bout of exercise for 24 to 72 hrs, thus regular exercise may allow glucose modifications even without the use of medication (Ehrman et al., 2010; Jung & Jung, 2005). ACSM recommends a physical activity intervention in combination with a healthy diet to help diabetic patients maintain optimal HbA1c values of approximately 7.0% (Ehrman et al., 2010). As glycemic control deteriorates with time, oral agents and insulin therapy may eventually need to be implemented (Ehrman et al., 2010).

Performing regular exercise causes an improved insulin response in skeletal muscle and adipose tissue, ultimately leading to physiological and cellular adaptations which improve insulin action. Such adaptations may include but are not limited to increased muscle blood flow, increased muscle glucose delivery, increased muscle glucose extraction, increased insulin receptor density, increased glucose transporter type 4 (GLUT-4), increased glucose uptake, increased free fatty acid (FFA) clearance, increased insulin sensitivity, and decreased
hyperinsulinemia, decreased abdominal adiposity, decreased FFA release, decreased plasma FFA, and decreased gluconeogenesis (Ehrman et al., 2010). Overall, exercise allows improvement in insulin sensitivity, glucose tolerance, and decreased risk for CVD complications.

In contrast, exercise does not affect glucose control in type I diabetes the same as in type II, rather the benefit of exercise comes from improvements in lipid and lipoprotein profiles, decreasing the risk for CVD (Ehrman et al., 2010). Recommended exercise intervention strategies are ultimately not the same for type I and II diabetes, nor are the responses to exercise. As indicated by Galbo, Tobin, and van Loon (2007), and Raczyńska, Zubik, and Jeliński (2011), type I diabetes does not show the same hormonal response to exercise, nor is glucose homeostasis maintained due to insulin deficiency in skeletal muscle. Therefore, only prediabetes, type II diabetes, and nondiabetes will be considered in the results of this study intervention.

**Benefits of Exercise in Diabetes**

Exercise brings a variety of benefits to any individual regularly participating. With just a moderate level of activity, health benefits and physical fitness adaptations can be noticeable. Such adaptations may include but are not limited to decreases in hypertension, resting heart rate, lipid profile, triglyceride storage, and stress; and increases in strength, cardiovascular endurance, immune function, and psychological aspects. In addition, a decreased risk of multiple complications and diseases associated with diabetes occurs with regular moderate-intensity exercise. Such reductions include but are not limited to hyperglycemia, HbA$_{1c}$ value, obesity, CVD, macrovascular diseases, and microvascular diseases. ACSM has indicated the importance of exercise on normal individuals as well as disease populations to help improve daily life and cognitive function (Ehrman et al., 2010). When safely administered, exercise is just as beneficial in diabetic populations as it is in the normal population. Stress and depression are very common
in diabetic individuals due to the daily complications encountered by their health problems; this affects their overall quality of life. ACSM recognizes that regular physical activity or exercise may help diabetic patients improve quality of life by decreasing stress and ultimately depression (Ehrman et al., 2010).

Certain influences must be identified in order to understand how exercise affects blood glucose concentration. Exercise causes blood glucose values to increase because counter-regulatory hormones, such as catecholamines and glucagon are released by the liver to increase hepatic glucose production to aid in energy production, but diabetics may be unable to increase glucose uptake in skeletal muscle due to insulin insufficiency, a condition known as hyperglycemia (Ehrman et al., 2010). Hypoglycemia results when a diabetic patient does not have enough blood glucose available due to increased levels of exogenous insulin or oral sulfonylureas (Ehrman et al., 2010).

In order for exercise to be beneficial, the benefits of exercise must outweigh the risks of exercise in diabetic patients. The two main risks diabetic patients face are hyper- and hypoglycemia. Therefore, it is important for diabetic individuals to monitor their blood glucose values before, during, and after an exercise session, and to take the appropriate actions in the maintenance of glucose values. ADA recommends taking blood glucose samples before and after each exercise session, and during if symptoms suggest; actions to be taken to maintain euglycemia include adjustments in medication and CHO intake (ADA, 2004). In order to safely participate in exercise, an individual must have a blood glucose range of 100-250 mg/dL; if blood glucose range is >250-300 mg/dL (hyperglycemia), then the patient may need to postpone exercise until levels fall to an ideal value; if blood glucose range is <100 mg/dL (hypoglycemia), then the patient should consume 20-30 g of CHO before exercising (ADA, 2004). Hypoglycemia
occurring during or post-exercise may also warrant consumption of 20-30 g of CHO; glucose monitoring should be continued several hours post-exercise due to acute post-exercise influence of diabetes (ADA, 2004; Ehrman et al., 2010). In view of all things discussed, exercise implementation for diabetes prevention and maintenance is a challenging mechanism but beneficial for most patients. Exercise intervention allows for adaptations to occur, which increase an individual’s health and fitness and ultimately decreases their risk for the progression of complications or development of more problems.

**Exercise Intervention Strategies in Diabetes**

Most exercise interventions for the diabetic population center around low- to moderate-intensity aerobic exercise. Aerobic activities may include walking, cycling, water aerobics, and much more. To improve cardiac or skeletal muscle function, physiologic capabilities, and glucose and fat mobilization or utilization in diabetes, both ACSM and AADE recommend a combination of both aerobic and resistance exercise (AADE, 2012b; ACSM, 2010; Ehrman et al., 2010). ACSM recommends 3-7 days/week of 50-80% heart rate reserve (HRR) or 55-65% \( HR_{\text{max}} \) aerobic exercise, with an equivalency of 12-16 rate of perceived exertion (RPE) level on the Borg Scale, for 20-60 min per bout in type II diabetes; for a total of at least 150 min/week of moderate-intensity aerobic exercise or for 90 min/week of vigorous-intensity aerobic exercise (Ehrman et al., 2010; Raczyńska et al., 2011). However, an increase in duration to one hour and a gradual decrease in intensity are recommended for patients with a goal to decrease fat mass (Raczyńska et al., 2011).

Thompson et al. (2010) indicated there is a dose response relationship with exercise and health, in which it is better to participate in some exercise, rather than none. Individuals with extreme glucose levels may have serious complications which may become exacerbated with
exercise (Ehrman et al., 2010). With all of this in mind, sedentary type II diabetic individuals should start an exercise program slowly, and gradually increase in duration and intensity just as any sedentary individual in order to decrease risk for injury and to increase exercise compliance (Thompson et al., 2010).

The importance of aerobic activity is to decrease the amount of fat mass and successfully maintain the loss. According to Campbell and Rössner (2001), approximately 80-90% of all type II diabetic individuals are classified as overweight with most fat stored abdominally; this problem is a common obstacle for successful diabetes management. Studies have shown that as little as a 5-10% sustained weight reduction in obese type II diabetic individuals may warrant significant health benefits (AADE, 2012a). Environmental factors leading to central abdominal obesity contribute greatly to the development of type II diabetes. Lifestyle changes consisting of realistic goals should be incorporated into an intervention strategy for these individuals. Ideally prevention of obesity and metabolic problems would be the best approach to fixing this problem in our society, but in most cases, weight reductions are easily reversed following cessation of preventative measures. Most studies reviewed by Campbell and Rössner (2001) indicated the majority of individuals participating in an exercise intervention for weight reduction relapsed within four years. This may be due to the idea that some individuals may believe the exercise intervention and goals are unattainable for them. In addition, the majority of obese type II diabetic individuals have a much lower aerobic capacity, in which a value of 56% of VO$_2$max may be used just to walk; whereas in healthy individuals, walking only amounts to a value of 35% of their VO$_2$max (Campbell & Rössner, 2001). According to Galbo et al. (2007), mitochondrial and endothelial dysfunction in these individuals usually contributes to a decreased
VO$_2$\textsubscript{max} due to decreased capacity to remove oxygen from the blood and an impaired increase in surface area of capillaries in working muscles.

Therefore, small lifestyle modifications increasing physical activity and adjusting dietary intake may be more beneficial for the prevention and treatment of type II diabetes, CVD, and obesity because individuals are more likely to continue to participate in this form of intervention (Campbell & Rössner, 2001). In addition, Raczyńska et al. (2011) indicated that performing physical activity or exercise regularly as part of a daily routine is the most beneficial strategy to aid in glucose tolerance, homeostasis, and decreasing fat mass, which is associated with increased insulin sensitivity and normalization of blood glucose and serum lipids. Whereas, according to Healy et al. (2007), even decreasing the percentage of time spent sedentary throughout the day by increasing the percentage of time spent accumulating light-intensity physical activity may help individuals normalize blood glucose levels; where light-intensity physical activity was defined to be normal household tasks, such as washing the dishes or ironing. Overall, this may suggest even small changes in lifestyle leading to increased physical activity accumulation throughout the day can be easily accomplished by most individuals.

Healy et al. (2007) also indicated that physical activity and sedentary behavior have both been shown to be independently correlated with blood glucose levels. The purpose of the experiment by Healy et al. (2007) was to determine differences in 2-hr post-challenge plasma glucose levels in individuals without diabetes using Uniaxial Actigraph Accelerometers to measure sedentary time, light-intensity activity, and moderate- to vigorous-intensity activity for at least 10 hrs of recorded activity. Accelerometers were worn for 7 days continuously during waking hours; subjects were instructed to record duration, intensity, and type of activity completed when it was not worn. Results of their study showed that individuals who spent more
time sedentary had higher 2-hr plasma glucose levels, however, individuals who spent more time in light- and moderate- to vigorous-intensity physical activity had lower 2-hr plasma glucose levels. Significant dose-response associations were found in the 2-hr plasma glucose test between sedentary time and light-intensity and moderate- to vigorous-intensity physical activity time. However, this association was not seen in the FPG test. Individuals spent the majority of waking hours in light-intensity physical activity compared to time spent in the moderate- to vigorous-intensity physical activity; therefore, even an intervention changing sedentary behavior to light-intensity physical activity behavior may be more successful than moderate- to vigorous-intensity physical activity behavior change. Reducing sedentary time by incorporating more light-intensity physical activity might be a more successful and practical intervention strategy for our society in a variety of settings, at the home and in the work environment (Healy et al., 2007).

Determining optimal exercise intensity and duration in type II diabetic individuals has given mixed results. According to one study by Galbo et al. (2007), after a mixed meal, repeated high-intensity exercise resulted in decreased glucose concentration and insulin secretion. It was suggested that type II diabetic individuals would benefit more greatly in the maintenance of glucose homeostasis from repeated high-intensity exercise that is intermittent and activities which attain VO$_2$max rather than continuous exercise. However, when different intensity exercise interventions are isocaloric, study results have shown identical responses. This finding indicates that overall energy expenditure and not intensity or duration of exercise intervention is the major determinant of glucose homeostasis and insulin secretion in type II diabetes. In contrast, an energy decrement consisting of caloric intake yields ideally the same reduction in postprandial glucose levels and insulin secretion as an isocaloric exercise energy decrement. In addition, prolonged moderate-intensity exercise decreases triglyceride plasma concentrations
after a high fat meal, in both chylomicrons and very low-density lipoproteins (VLDL); likely a result of increased fat oxidation during and a few hours after exercise. During the recovery period after both, moderate-intensity and intermittent vigorous-intensity exercise performed postprandial, Galbo et al. (2007) indicated a decrease in muscle glycogen concentrations and an increase in insulin sensitivity. However, neither type of exercise intensity influenced glucose and insulin responses to subsequent meals. In contrast, type II diabetic individuals taking exogenous insulin have observed decreases in hyperglycemia after an exercise session and within the following twenty-four hours when their diet was consistent (Galbo et al., 2007).

In the study by Nygaard et al. (2009), postmeal slow walking (rated as very light or level 9 on Borg’s Scale) was examined in thirteen healthy women ≥50 years to determine if the intervention helped to blunt the increase in blood glucose concentrations after consumption of CHO. The women completed three experimental interventions in a random crossover design, each after consumption of a CHO rich meal; a control intervention in which subjects remained seated, a slow 15 min walk (W15), or a slow 40 min walk (W40). Interventions were separated by a range of 4 to 30 days between each session; subjects were instructed not to participate in any physical activity two days prior to each exercise intervention and to consume approximately the same caloric intake during this period as recommended by the research personnel. Blood glucose concentration was determined in each session by finger-stick method: once before the meal in fasting state, and eleven other times throughout the exercise intervention (Nygaard et al., 2009).

Results of the study showed that even slow walking helped to decrease postprandial glucose values and the glucose peak value in both W15 and W40 experimental sessions, however, W40 observed a blunted postprandial blood glucose increase during exercise and a
delayed peak glucose value (Nygaard et al., 2009). The conclusion was made that slow walking after a CHO rich meal helps to decrease postprandial blood glucose response, but the effect is greater with duration spent walking. This may suggest a dose response between duration of light exercise and a reduction in postprandial glucose excursions. When compared to other studies, the magnitude of blood glucose reduction experienced in slow walking for a duration of 40 min was approximately the same as during exercise at 70% HR$_{max}$ for 30 min or at 57% VO$_2$max for 45 min; thus exercise at a lower heart rate value for a longer duration may be just as important in lowering postprandial glucose excursions as a higher intensity of exercise for a shorter duration (Nygaard et al., 2009). Again, this may indicate there is a greater blood glucose response following a meal when a greater caloric deficit is experienced by exercise intervention; either by greater duration or intensity of exercise.

In conclusion, depending on the overall energy expenditure, very low- to moderate-intensity exercise can be just as beneficial as high-intensity exercise in decreasing postprandial glucose excursions. In conjunction, slow to moderate walking after a meal to lower postprandial glucose excursions, may be safely recommended and administered by most individuals, including those with prediabetes or type II diabetes (Nygaard et al., 2009)

According to Irvine and Taylor (2009), peripheral neuropathy and decreased vascular supply caused by impaired glucose control in type II diabetes may contribute to muscle weakness, a decrease in muscle mass, and a change in muscle fiber structure. Resistance exercise may help to decrease blood glucose values by increasing glucose disposal rate (Irvine & Taylor, 2009). Some studies have compared both aerobic and resistance training within the diabetic population. ACSM recommends type II diabetic individuals perform resistance training 2-3 days/week on nonconsecutive days, at a moderate- or vigorous-intensity (50% or 75-80% of 1-
GLUCOSE EXCURSIONS

RM), at 10-15 repetitions (nearly to fatigue), 3-4 sets, and including 5-10 exercises using major muscle groups of upper-body, lower-body, and core (ACSM, 2010). Progression may occur when the individual may complete two more repetitions in addition to the 10-15 repetitions recommended on two consecutive training days; starting with an increase in weight, then an increase in sets, lastly an increase in frequency of training days (ACSM, 2010). A 6-month progression goal would be to perform 8-10 major muscle group exercises, 8-10 repetitions at vigorous-intensity (75-80% 1-RM), at least 3 days/week (ACSM, 2010).

Irvine and Taylor (2009) observed progressive resistance exercise studies in type II diabetic individuals to determine if this form of exercise intervention would help to decrease HbA$_1$c values, decrease fat mass, increase muscle mass, and increase strength compared to control and aerobic intervention studies. Only studies with ≥8 week durations were included because changes in HbA$_1$c value are more significant. A total of 372 type II diabetic subjects in nine randomized studies were analyzed. When compared to the control group, progressive resistance exercise resulted in a small but significant reduced HbA$_1$c value of 0.3%, but was not significant when compared to aerobic exercise intervention. Body composition resulted in no significant changes in lean or fat mass among any groups. However, strength measured by the percent change in one maximal repetition, dynamometry, and the change in maximum weight lifted, was significantly improved by approximately 35% in the progressive resistance exercise group but was not in either the aerobic exercise or control group. Researchers concluded that progressive resistance exercise may increase strength and decrease HbA$_1$c values, and thus be a clinically significant and feasible form of intervention to manage glucose levels in type II diabetes (Irvine & Taylor, 2009).
GLUCOSE EXCURSIONS

Reductions consisting of as little as 1% in HbA1c values have been shown to decrease risk for microvascular complications in diabetes by 37%, and decrease risk for death in diabetes by 21% (Irvine & Taylor, 2009). A glucose management intervention consisting of progressive resistance exercise performed in combination with medication, diet, and perhaps aerobic exercise could yield better results by significantly decreasing HbA1c values and ultimately complications in type II diabetic individuals (Irvine & Taylor, 2009). This article showed that aerobic exercise intervention must be performed most days of the week in order to be effective, whereas progressive resistance exercise may be performed only 3 days a week to be effective (Irvine & Taylor, 2009). However, both ACSM and AADE recommend a combination of both aerobic and resistance training because a longer duration and a greater caloric expenditure may occur, thus increasing blood glucose control (AADE, 2012b; ACSM, 2010; Ehrman et al., 2010).

Summary

A large amount of research has been conducted relating to the composition of exercise and blood glucose control. Some research has been conducted analyzing the optimal intensity and duration of aerobic exercise in reducing blood glucose levels in prediabetes and type II diabetes. The development of prediabetes and type II diabetes is very common, especially among sedentary, overweight, and middle aged adults. As a result of an unhealthy lifestyle, chronic problems develop and lead to pancreas beta cell dysfunction and ultimately insulin insufficiency. According to the review of literature, exercise is very beneficial in the maintenance of blood glucose levels.

Among all studies reviewed, reduction of postprandial blood glucose is the most predominant concern for exercise intervention due to the interest in decreasing the damaging effects of high blood glucose peaks after CHO consumption. Reducing postprandial glucose
excursions is of utmost importance in these individuals. A lifestyle increasing either physical activity or exercise has been shown to be an effective form of intervention for the maintenance of blood glucose values and to help increase insulin sensitivity. The primary mechanism behind all this seems to be increased energy expenditure; where the greater the energy expenditure, the greater the intervention. Duration and intensity of physical activity or exercise are the determining contributors. Thus, it seems both physical activity and exercise consisting of low- to moderate-intensity for a long duration or high-intensity for a short duration can both be effective intervention strategies. Most individuals within the prediabetic and type II diabetic population are sedentary and/or overweight, thus even a low- to moderate-intensity and shorter duration may be effective by allowing them to participate at a low exertion rate for a shorter period of time; gradually, increases may be made in duration or intensity.

Individuals of the diabetic population need an exercise intervention that is attainable and easily done in any environment; this may help increase exercise adherence. Moderate-intensity aerobic activity consisting of either walking or cycling is easily accomplished and considered attainable by most individuals. Walking or cycling at approximately 55-65% of age predicted maximum heart rate is rated moderate-intensity exercise. The goal of the present study is to determine if walking or cycling at a moderate-intensity for 30-45 min, 3-5 days a week elicits a normalizing effect on postprandial blood glucose excursions in prediabetic and type II diabetic individuals, as compared to healthy sedentary individuals.
CHAPTER 3
METHODOLOGY

The purpose of this study is to determine if an exercise intervention program consisting of walking or cycling at a moderate-intensity has an effect on postprandial glucose excursions and percent body fat in prediabetic and type II diabetic individuals when compared non-exercising healthy sedentary individuals. The research study included the following procedural topics: (1) selection of participants, (2) research groups, (3) instrumentation, (4) study design, and (5) data analysis.

Selection of Participants

This study was approved (see Appendix A) by the University of Central Missouri Human Subjects Review Board in Warrensburg, Missouri. Prediabetic and type II diabetic patients from the Warrensburg Western Missouri Medical Center: Diabetic Clinic and the surrounding areas were asked to participate in this study. In addition, healthy subjects (with no known disease which would affect blood glucose levels) of the community and surrounding areas were also asked to participate. A university-approved flyer (see Appendix B) of the study with contact information was distributed at the college, as well as throughout the Warrensburg and surrounding communities; individuals who were interested in the study contacted the author of the study for information, in which those who met inclusion criteria were allowed to volunteer for this study. Subject inclusion criteria were an age range of 18 to 65 years, not pregnant, not on an insulin pump, and classified as sedentary according to ACSM’s classification for sedentary individuals. ACSM’s classification for sedentary individuals includes those who do not accumulate more than 30 min of moderate-intensity physical activity 3 days a week for the past 6 months (Thompson et al., 2010). All subjects signed a university-approved informed consent
form (see Appendix C) and those who were prediabetic or type II diabetic additionally signed a university-approved physician consent form (see Appendix D) before participation in the study. These consent forms ensured subjects were able and willing to participate and when warranted, had obtained physician clearance.

**Research Groups**

A total of 19 subjects ($N = 19$, 5 males and 14 females) started this study. Subjects were divided into two groups; the experimental exercise intervention group (EIG, $n = 8$: 1 male and 7 female) and the control group (CG, $n = 11$: 4 male and 7 female). However, only 15 subjects completed the study (EIG, $n = 6$: 1 male and 5 female; CG, $n = 9$: 3 male and 6 female). Reasons why four subjects did not complete the study was two dropped out of the EIG during the intervention period due to time constraints, one from the CG never contacted the researcher back to meet for the posttest, another in the CG just did not want to do the posttest, and two from the CG were excluded from data analysis.

In whole, a total of 13 subjects ($N = 13$, 3 male and 10 female) were included in the data analysis of this study. The EIG consisted of six subjects ($n = 6$: 1 male and 5 female) and the CG consisted of seven subjects ($n = 7$: 2 male and 5 female). Subjects of the EIG were diagnosed with prediabetes or type II diabetes, and subjects of the CG were healthy nondiabetic individuals. Both groups completed pretest glucose monitoring for a minimum of three days each; after the pretest, subjects of EIG completed 8 weeks of an exercise intervention, whereas, subjects of the CG were instructed to remain sedentary for the 8 week period and to continue doing what they normally did. After the eight weeks were completed, all subjects received at least one day of rest and then met with researchers for the posttest.
Instrumentation

The pre- and posttest measurements included determination of percent body fat (%BF) using dual energy x-ray absorptiometry (DEXA) on a Lunar Prodigy Advance (GE Corporation, Fairfield, Connecticut, USA), software enCORE 2003 GE Medical Systems version 7.51. The DEXA scan is a quick and convenient method which scans the entire body or a portion of it by emission of photon beams (x-rays) at two different energy levels to estimate total or site specific fat mass (FM), lean tissue mass (LTM), and bone mineral content (BMC). It is based upon the restriction in fluctuation of x-rays across fat and fat-free masses, and is accurate in detecting very small changes, with a SEE of ±1.8% BF.

A Continuous Glucose Monitoring Sof-Sensor (CGMS iPro Continuous Glucose Recorder; Medtronic Diabetes, Northridge, CA) was used to assess each subject’s glucose levels throughout the course of at least three consecutive days during pre- and posttests. Trained and experienced research personnel fit each subject with a continuous glucose monitor (CGM) on the abdomen; the sensor (containing a catheter) was inserted on the left or right side, above or below the belt line, and approximately 1.5-2 cm away from the umbilical cord. Once the monitor had been placed on the subject and calibrated, then a bandage was used to cover and secure position of the CGM. University guidelines and precautions were used when dealing with blood or other bodily fluids. Subjects were instructed to take and record a blood glucose sample by finger-stick method at least four times a day (during the three day period), equally spaced; ideally before each meal and before bed. Blood glucose samples were taken for calibration against values recorded by the CGM. Each subject was provided with a blood glucose testing unit and strips if needed. Subjects were instructed to consume approximately the same caloric intake or similar foods (especially CHO content) and to refrain from exercise during the three day period of pre-
and posttests. All subjects were given a food and glucose level diary form (see Appendix E) and instructed to record time and date of blood glucose levels and everything consumed during the three day period. After the three day period, subjects returned to the Human Performance Lab where research personnel removed the CGM and downloaded and managed all data collected using the Solutions Software for CGMS iPro (Medtronic Diabetes). All data collected was kept secure and confidential, password protected in the locked lab.

**Study Design**

Subjects met with research personnel at the Human Performance Lab for pre- and posttests. The participant information sheet (see Appendix F) was used for data recording. Pre- and posttests began with measurement of %BF using a DEXA scan, followed by insertion and activation of the CGM. Insertion placement of CGM was based on subject preferences and needs; if subjects had a medication patch on the abdomen then that area was avoided. Subjects were instructed on the procedures for determining blood glucose levels using the finger-stick method, given a food and glucose level diary form and instructed on the procedures and guidelines for recording. Subjects were instructed to record date, time, and value of all blood glucose finger-sticks and all caloric consumption (instructed to consume ideally the same caloric intake with similar CHO content) during both the pre- and posttest periods. Subjects returned to the facility on the third day of pre- posttests for removal of the CGM and download of data collected using the Medtronic Minimed Solutions Software computer system.

Subjects in the experimental exercise intervention group (EIG) completed an 8 week intervention of moderate-intensity aerobic exercise consisting of walking (treadmill or track) or cycling at the University of Central Missouri’s Student Recreation and Wellness Center (SRWC), performed 3-5 days/week for 30-45 min. Maximum heart rate (HR_{max}) was determined
by the age-predicted heart rate equation (220 – age) and moderate-intensity exercise was determined to be within the range of 55-65% $HR_{\text{max}}$ (McArdle et al., 2010). If needed, each subject was given a heart rate monitor to wear during the exercise intervention to make sure they were within their target range. If a subject was on a heart rate lowering medication, the Borg Rate of Perceived Exertion Scale was used instead, at a moderate-intensity value of 12-16.

Additionally, subjects were instructed to record all exercise intervention criteria completed during each session on the exercise intervention form (see Appendix G) in a binder at the front desk of the SRWC; this included date, duration of exercise, average heart rate, caloric expenditure, and mode of exercise (treadmill, track, or cycle). Subjects were instructed to monitor blood glucose levels before, during, and after exercise and to perform preventative measures in case of a high or low blood glucose level; in case of emergency, CHO was provided by trained research personnel. After meeting multiple times with research personnel for exercise sessions, subjects were allowed to complete the exercise sessions on their own if the researcher considered them proficient in following the guidelines, safety precautions, and record keeping during exercise sessions. In addition to checking the exercise intervention form regularly, research personnel kept in contact with subjects via email and phone calls or texting in order to monitor and make sure the subjects were following the guidelines and continuing to exercise. After completion of the eight week intervention, subjects received at least one day of rest and the next day reported back to research personnel at the Human Performance Lab for the posttest.

The control group (CG) completed the pretest and then received eight weeks of nonintervention in which subjects were instructed to remain sedentary and to continue doing what they normally did until the posttest. Subjects of the CG reported back to research personnel
at the Human Performance Lab after the eight week duration. Both pre- and posttests were the same for both groups.

**Data Analysis**

Differences in postprandial glucose excursions in both pre- and posttests for both the EIG and the CG were measured by comparing the maximum glucose excursion recorded after a meal as indicated by the CGM data collection. Data for both groups was averaged and presented as means ± SD. In order to make sure subjects in both groups were similar, descriptive measurements from the pretest, including age, weight, height, and BMI were analyzed for differences between groups using an independent samples t-test. Differences in maximum postprandial blood glucose excursions and %BF pre- and posttest were analyzed within each group using a t-test: repeated measures design. Additionally, changes from pre- to posttests in both peak postprandial blood glucose level and %BF were compared between both groups using an independent samples t-test. Statistical significance was set at $\alpha < 0.05$.

$H_1$: Eight weeks of aerobic exercise at a moderate-intensity (55-65% HR$_{\text{max}}$) for 30-45 min, 3-5 days a week will be effective in reducing postprandial glucose excursions in sedentary prediabetic and type II diabetic individuals, compared to no exercise in sedentary healthy individuals.

$H_2$: Eight weeks of aerobic exercise at a moderate intensity (55-65% HR$_{\text{max}}$) for 30-45 min, 3-5 days a week will be effective in decreasing percent body fat of sedentary prediabetic and type II diabetic individuals, compared to no exercise in sedentary healthy individuals.
CHAPTER 4
RESULTS

Included in this section are the findings of the current study, beginning with the independent variable, exercise intervention group (EIG), and ending with the control group (CG). Specific attention is paid to the effects of the exercise intervention on reduction of postprandial glucose excursions as measured by the continuous glucose monitor (CGM) in pre- and posttest values. The purpose of this study was to examine the efficacy of moderate-intensity aerobic exercise to ameliorate postprandial blood glucose levels and percent body fat in sedentary prediabetic or type II diabetic individuals compared to sedentary healthy individuals.

Group Descriptives

Descriptive measurements were taken on all subjects during the pretest, this included age, weight, height, and BMI. Two subjects in the CG were excluded before data analysis because they were considered outliers; these individuals were of a much younger age, smaller weight, and smaller %BF than the other subjects of both the EIG and the CG. In whole, there were a total of thirteen subjects included in data analysis, six of which were in the EIG ($n = 6$) and seven were in the CG ($n = 7$). Data analysis was performed using Microsoft Excel. Means ± SD are presented for age, weight, height, and BMI in both groups (see table 1); an independent samples $t$-test indicated there were no significant differences between group means on any of these measurements. Therefore, subjects in both the EIG and the CG may be considered similar.
Table 1

*Mean Group Descriptives*

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (M ± SD)</th>
<th>Weight (kg) (M ± SD)</th>
<th>Height (cm) (M ± SD)</th>
<th>BMI (M ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EIG</td>
<td>49.33 ± 8.73</td>
<td>103.77 ± 18.82</td>
<td>167.25 ± 10.74</td>
<td>38.79 ± 8.12</td>
</tr>
<tr>
<td>CG</td>
<td>53.71 ± 9.45</td>
<td>113.79 ± 28.47</td>
<td>169.24 ± 7.08</td>
<td>39.44 ± 7.89</td>
</tr>
</tbody>
</table>

**Within Group Differences in Postprandial Blood Glucose**

The exercise intervention group participated in moderate-intensity aerobic exercise at least 3-5 days/week for 30-45 min, whereas the control group which remained sedentary did not participate in any exercise. It was hypothesized in the current study that the EIG would normalize or decrease postprandial blood glucose values more than the CG as measured by a three-day pre- and posttest continuous glucose monitor analysis. In order to determine if there were changes in maximum postprandial blood glucose excursions pre- to posttest in each group, a paired samples *t*-test was performed. There were no significant differences within the EIG, *t*(5) = 0.563, *p* > .05. Nor were there any significant differences within the CG, *t*(6) = 0.086, *p* > .05 (see table 2).

**Between Group Differences in Postprandial Blood Glucose**

To determine if the intervention had an effect on postprandial blood glucose levels, an independent samples *t*-test was conducted on the pre to post differences in peak postprandial glucose. Variances were assumed to be unequal according to an *F*-test. No significant differences between groups appeared pre to post with exercise intervention, *t*(11) = 0.572, *p* > .05. Means ±...
SD and mean differences are presented for highest postprandial blood glucose levels for pre- and posttests in both groups (see table 2).

Table 2

*Mean Highest Postprandial Blood Glucose (HPBG)*

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre (mg/dL) M ± SD</th>
<th>Post (mg/dL) M ± SD</th>
<th>Mean Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>EIG</td>
<td>192.50 ± 97.58</td>
<td>200.83 ± 75.09</td>
<td>8.33</td>
</tr>
<tr>
<td>CG</td>
<td>158.29 ± 32.33</td>
<td>176.00 ± 52.80</td>
<td>17.71</td>
</tr>
</tbody>
</table>

**Within Group Differences in Percent Body Fat**

It was hypothesized in the current study that the EIG would experience a greater decrease in percent body fat (%BF) than the CG as measured by a DEXA scan to determine body composition. To determine if there were changes in %BF pre- to posttest in each group, a paired samples t-test was performed. There were no significant differences within the EIG, \( t(5) = 0.516, p > .05 \). Nor were there any significant differences within the CG, \( t(6) = 0.925, p > .05 \) (see table 3).

**Between Group Differences in Percent Body Fat**

In order to determine if the intervention had a greater effect on %BF compared to the control group, an independent samples t-test was conducted. Variances were assumed to be unequal according to an F-test. No significant differences between groups appeared pre to post with exercise intervention, \( t(11) = 0.70, p > .05 \). Means ± SD of pre- and posttest %BF and mean differences are presented for both groups (see table 3).
Table 3

*Mean Percent Body Fat (%BF)*

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre %BF</th>
<th>Post %BF</th>
<th>Mean Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M ± SD</td>
<td>M ± SD</td>
<td></td>
</tr>
<tr>
<td>EIG</td>
<td>48.83 ± 5.51</td>
<td>48.58 ± 6.09</td>
<td>-0.25</td>
</tr>
<tr>
<td>CG</td>
<td>46.74 ± 8.05</td>
<td>46.81 ± 9.21</td>
<td>0.07</td>
</tr>
</tbody>
</table>
Postprandial Blood Glucose Excursions

It was hypothesized there would be a significant difference in peak postprandial blood glucose values between both groups, however the three-day pre- and posttest continuous blood glucose measurement for the exercise intervention group (EIG) was not significantly different from the control group (CG). This finding demonstrated that over an eight week period of moderate-intensity aerobic exercise intervention, postprandial blood glucose levels are not significantly changed in sedentary prediabetic and type II diabetic individuals when compared to sedentary healthy individuals. Rather, mean highest postprandial blood glucose (HPBG) slightly increased in both the EIG and the CG. However, the magnitude of the increase in the CG (17.71 mg/dL) was a little more than double that of the EIG (8.33 mg/dL). This could indicate that after eight weeks, sedentary healthy individuals progressively increase HPBG values two-times greater than prediabetic and type II diabetic individuals who participate in moderate-intensity aerobic exercise for 30-45 min, 3-5 days/week.

Previous research examining postprandial blood glucose with changes in physical activity status has shown that being physically active directly affects postprandial glycemic control, independent of increased fitness level or decreased adiposity (Ehrman et al., 2010; Mikus et al., 2012). Many prediabetic and type II diabetic individuals do not regularly accumulate enough physical activity to be considered physically active, additionally, these individuals are most often overweight or obese (Campbell & Rossner, 2001). Oftentimes, these individuals do not feel it is reasonable or attainable to participate in high-intensity physical activity or exercise consisting of
a well-rounded aerobic and resistance exercise program (Campbell & Rössner, 2001; Healy et al., 2007).

The least amount of exercise or physical activity at which postprandial blood glucose excursions may be effectively decreased or normalized overall, is not clearly understood at this time. The current study indicated even an eight week intervention of moderate-intensity aerobic exercise for 30-45 min on 3-5 days/week may not be significantly effective to reduce postprandial blood glucose excursions. However, more studies focusing on postprandial blood glucose excursions and exercise are needed, especially in those with prediabetes or type II diabetes.

**Percent Body Fat**

It was further hypothesized there would be a greater decrease in %BF in the EIG compared to the CG. However, %BF estimations as measured by the DEXA were not significantly different between or within the two groups. This observation indicated that over an eight week duration, %BF did not change. Any minor differences could have likely been a result of measurement errors associated with the DXA or possibly hydration and weight. Research has indicated even a weight reduction of only 5-10% from baseline has been effective in glycemic control in both prediabetic and type II diabetic individuals (AADE, 2012a; Ehrman et al., 2010). Further research indicates decreased central adiposity and maintenance of FFM would be the most beneficial result of weight reductions in these individuals (Heymsfield, Lohman, Wang, & Going, 2005; Roumen, Blaak, & Corpeleijn, 2009; Yavari, McEntee, McEntee, & Brines, 2011). Regularly participating in physical activity or exercise has shown to be very beneficial by augmenting decreases in FM, and therefore helping to increase insulin sensitivity and normalization of blood glucose (Raczyńska et al., 2011). More research is necessary to help
determine ideal reductions in %BF in those with prediabetes or type II diabetes, and also to examine which components of body composition are affected in weight reductions of exercise intervention strategies.

**Conclusion**

The purpose of this study was to examine the effects of aerobic exercise at a moderate-intensity in sedentary prediabetic or type II diabetic individuals, and a lack of moderate-intensity aerobic exercise in healthy nondiabetic individuals on postprandial blood glucose excursions and percentage of body fat. The current data suggests that eight weeks of moderate-intensity aerobic exercise 3-5 days/week for at least 30-45 min is not sufficient enough to significantly decrease postprandial blood glucose peaks or percent body fat in sedentary prediabetic or type II diabetic individuals, as compared to sedentary healthy individuals. The initial goal of the current study was to decrease postprandial blood glucose peaks to bring values closer to normal ranges and additionally decrease percent body fat. However, there were no significant differences observed even after exercise intervention. Interestingly, the HPBG values slightly increased in both groups, pre- to posttest. Although, when compared to the sedentary healthy CG, the increase in mean differences in HPBG values of the EIG was a little more than two-times less.

This observation could indicate that participation in moderate-intensity aerobic exercise may be useful by reducing the rate of progressive increases in postprandial blood glucose excursions in sedentary nondiabetic, prediabetic, and type II diabetic individuals. This concept is especially important for the development of effective prevention and maintenance strategies to decrease risk for type II diabetes or complications. Since many of those with prediabetes or type II diabetes are sedentary, even small increases in the amount of physical activity may lead to permanent lifestyle changes to aid in the maintenance of postprandial blood glucose excursions.
More studies are needed to determine the minimal amount of physical activity needed to effectively elicit improvements in postprandial glucose control and body composition within this population. In the current study, significant differences in highest postprandial blood glucose excursions and percent body fat were nonexistent between the two groups given the limitations.

**Limitations and Future Research**

This study was limited by multiple actions in response to encountered difficulties. First, an intervention group consisting of prediabetic and type II diabetic subjects was compared to a control group consisting of healthy nondiabetic subjects. The initial hypothesis only included prediabetic and type II diabetic individuals who were within the age range of 30-65 years. Due to difficulty gathering and retaining subjects which would meet these qualifications and who were willing to complete the exercise intervention (EIG) or remain sedentary (CG), the study was revised to include a wider age range of 18-65 years. However, despite this change, subjects were still unwilling to participate, especially in the CG because those who contacted the researcher were only willing to participate in the EIG. Therefore, the hypothesis and methods were revised to recruit a control group in which healthy individuals were allowed to volunteer for the study.

Consequently, the sample size for each group was very small thus further limiting the statistical power of the study; future research should include a greater sample size for both the EIG and the CG to increase the power of the study. Additionally, subjects in each group should consist of those who are diagnosed with prediabetes or type II diabetes.

Thirdly, caloric consumption was not controlled during either the pre- or posttest periods. Even though subjects were instructed to consume ideally the same type and amount of food and beverages during both the pre- and posttest periods, this was not tightly controlled. Further
research should provide subjects with identical meals of known caloric load and macronutrient mix during both the pre- and posttest periods.

Fourthly, subject medications were not controlled. Some subjects were on weight lowering and glucose lowering medications which would have most likely affected their results. In particular, subject 5 of the EIG experienced great changes in blood glucose values after his/her physician decreased medication dosage during the week before the posttest; however, this could possibly indicate that the intervention was working because the individual was able to decrease medication dosage. Further examination of this topic would be best in a clinical setting, where medications may be controlled.

Fifthly, duration of the intervention period was only eight weeks, this may not be long enough to notice a significant difference in peak postprandial blood glucose values and particularly body fat percentages with only a moderate level of aerobic exercise intervention. Perhaps, an intervention duration of twelve weeks would elicit greater differences between the EIG and the CG.

Another limitation to the current study was that body composition was measured by a DEXA scan which cannot distinguish between visceral and subcutaneous adipose tissue components. Differences in body composition as a result of intervention could be better analyzed with either a CT or MRI scan.

Lastly, further analysis of moderate exercise intervention in prediabetes and type II diabetes with respect to peak postprandial blood glucose excursions and %BF should examine responses to moderate-intensity aerobic exercise, resistance training, and a combination as compared to a control group. Both ACSM and AADE recommend a combination of aerobic and
resistance training to increase and maintain insulin sensitivity, glucose tolerance, FFM, and to decrease weight, adiposity, and HbA$_1c$ value (AADE, 2012b; ACSM, 2010; Ehrman et al., 2010).

Overall, further research on this topic would be more effective in a clinical setting where subject medication and meals may be controlled, subject participation would be greater, there would be greater access to CT or MRI equipment, and subject compliance may be closely monitored.
REFERENCES


GLUCOSE EXCURSIONS


APPENDIX A
HUMAN SUBJECTS REVIEW BOARD APPROVAL

9/26/2012

Anna L. McNew
29250 McCormick Rd.
mcnew@ucmo.edu
Sedalia, MO/65301

Dear Ms. Anna L. McNew,

Your amendment for your project titled, 'The Effects of Walking at a Moderate Intensity on Postprandial Glucose Excursions in Sedentary Diabetic Individuals', was approved by the Human Subjects Review Committee on 9/19/2012. This approval is valid through 9/14/2013. Your informed consent is also approved until 9/14/2013.

Please note that you are required to notify the committee in writing of any changes in your research project and that you may not implement changes without prior approval of the committee. You must also notify the committee in writing of any change in the nature or the status of the risks of participating in this research project.

Should any adverse events occur in the course of your research (such as harm to a research participant), you must notify the committee in writing immediately. In the case of any adverse event, you are required to stop the research immediately unless stopping the research would cause more harm to the participants than continuing with it.

At the conclusion of your project, you will need to submit a completed Project Status Form to this office. You must also submit the Project Status Form if you wish to continue your research project beyond its initial expiration date.

If you have any questions, please feel free to contact me at the number above.

Sincerely,

[Signature]

Janice Putnam, Ph.D., RN
Associate Dean of The Graduate School
putnam@ucmo.edu
ATTENTION: HEALTHY, PREDIABETIC, AND TYPE II DIABETIC SUBJECTS NEEDED!!!

...for a 2012 University of Central Missouri thesis experiment to examine blood glucose levels...Testing may be done for free to determine if individual is prediabetic.

**QUALIFICATIONS:**

Healthy or Prediabetic/Type 2 Diabetic

Sedentary

Age range of 18-65

Male or female (not pregnant)

Not on an Insulin Pump

**FREE BENEFITS:**

May participate in the Exercise Group or Non-Exercise Group

UCM Gym Access for Cardio Exercise (for duration of study: 8 wks)

Pre/Post Fitness Assessments and Consultation

DEXA Scan to determine Bone Mineral Density and Body Fat

**FOR QUESTIONS OR INTEREST PLEASE CONTACT**

ANNA SCHWARTZ, A GRADUATE STUDENT OF KINESIOLOGY, AT 660-287-1120 OR MCNEW@UCMO.EDU
Identification of Researchers: This research is being done by Anna Schwartz, a graduate student, and Steve Burns, a professor. We are with the Kinesiology Department at the University of Central Missouri.

Purpose of the Study: The purpose of this study is to determine if aerobic activity at a moderate intensity 3-5 days a week helps to normalize glucose excursions after meals in sedentary, prediabetic and Type II diabetic individuals.

Request for Participation: We are inviting you to participate in a study on exercise and postprandial glucose excursions. It is up to you whether you would like to participate. You may decide not to participate or to stop at any time without penalty. If you decide not to continue, your data will be removed from the collection.

Exclusions: You must be between the ages of 18-65 years, not pregnant, and not on an insulin pump to participate in this study. You may or may not be diagnosed with pre-diabetes or Type II diabetes. You must also be classified as sedentary, that is not performing more than 30 minutes of moderate physical activity, 3 days a week, over the past 6 months.

Description of Research Method: If you have prediabetes or Type II diabetes then you must first be cleared by your physician before participation in this study by completing the Physician Consent Form. You will then meet with researchers to complete pre testing, in which researchers will determine percent body fat, and fit you with a continuous glucose monitor and cover it with a bandage to secure position; monitors will be placed on abdomen or back, and you will wear it for a total of 3 days, in which it will record continuous blood glucose levels. You will be instructed to/how to keep a food diary and to record actual current blood sugar levels four times a day, equally spaced (ideally before each meal and before bed) for the three days wearing the monitor. You will be provided a blood sugar testing unit with strips to test 4 times/day for the three days. After the three days are completed, you will meet with researchers again to remove continuous glucose monitor and so researchers may record all data collected. If you are an experimental subject, you will then perform the exercise intervention at the University of Central Missouri Student Recreation and Wellness Center; walking (treadmill or track) or cycling at a moderate intensity (55-65% HRmax, or if on HR lowering medication then a moderate rate of perceived exertion on the Borg Scale) for 30-45 minutes, 3-5 days/wk for a total duration of 8 weeks. You will be given a heart rate monitor to wear during exercise sessions to help keep you within the target range. You will be monitored by trained and competent exercise science students/research assistants during exercise sessions. After duration of exercise intervention and a day of rest, you will meet with researchers to complete post testing (same as pre testing above). You will be instructed to follow similar eating patterns as during the pre testing period. However, if you are a control subject then you will only complete pre/post testing and have an 8 week (non intervention) period between testing.
Privacy: All of the information we collect will be kept secure and confidential, password protected in a locked lab. Your personal information will not be used when reporting findings from this study.

Explanation of Risks: There may be a risk of bruising, pain, or infection at the site of monitor insertion. The risks associated with participating in the exercise sessions are similar to the risks of everyday life with moderate physical activity. Risks may include an abnormal response in blood pressure, fainting, irregular, fast, or slow heart rhythm, and in rare instances, heart attack, stroke, or death. Any medical treatments provided if an injury occurs will be at the expense of the participant.

Explanation of Benefits: You will benefit from this study by participating in the exercise intervention; you will be given a privilege to use the University of Central Missouri Student Recreation and Wellness Center for the duration of the study. The exercise may help to stabilize your blood glucose levels and to encourage you to make exercise a lifestyle change by incorporating it into your everyday routine.

Questions: If you have any questions about this study, please contact Anna Schwartz. She can be reached at mcnw@ucmo.edu or at (660) 287-1120. If you have a medical concern, consult your personal physician. If you have any questions about your rights as a research participant, please contact the Human Subjects Protection Program at (660) 543-4621.

If you would like to participate, please sign a copy of this letter and return it to me. The other copy is for you to keep.

I have read this letter and agree to participate.

Signature: ____________________________
Date: ________________________________
APPENDIX D
PHYSICIAN CONSENT FORM

I (Physician), _______________________________ hereby consent to (Patient) _______________________________, participating in a moderate level of physical activity (walking either on a treadmill/track or cycling at 55-65% age predicted HR\text{max} for 30-45 min, 3-5 days/wk) for the duration of 8 weeks. If patient is on HR lowering medication then exercise intensity will be set according to a moderate rate of perceived exertion on the Borg Scale. Patient will wear a heart rate monitor which will be provided. Subjects will measure blood glucose levels before, during, and after exercise sessions and consume adequate carbohydrate if low, or if high, wait until blood glucose level is within an acceptable range for performing exercise. Subjects will be monitored by trained and competent exercise science students/research assistants at exercise sessions. Sessions will be conducted at the University of Central Missouri Student Recreation and Wellness Center.

I (Physician), _______________________________, also indicate with my initials that the patient is either prediabetic ______ or type II diabetic ______.

Please indicate if patient is on any HR lowering medication, and if so what kind? ________________

Signature of Physician: ___________________________ Date: ___________________________

Signature of Patient/Participant: ___________________________ Date: ___________________________

If you have any questions please contact Anna Schwartz at 660-287-1120 or mcnew@umo.edu
# Appendix E

## Food & Glucose Level Diary Form

**Name:**

**Date:**

CGMS® iPro® System Patient Log

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>BG Value*</th>
<th>Meal</th>
<th>Insulin / Medications</th>
<th>Exercise</th>
<th>Other/Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>B / L / D / S</td>
<td>Type of Food</td>
<td>Carbs</td>
<td>Type / Dose</td>
<td>L / M / I</td>
</tr>
</tbody>
</table>

Patient ID: __________________ iPro Serial #: __________________ Sensor Lot #: __________________ Meter Type/Brand: __________________

Meter SN #: __________________
APPENDIX F
PARTICIPANT INFORMATION SHEET

Name: __________________________ Healthy, Pre, or T2: ______ Gender (M/F): ___

Ht (in): ______ Age: ______ DOB: ______ 55-65%HR_{max}: _________________

EIG or CG: ______ Indicate if on any HR lowering medication: _________________

______________________________________________________________________________

Pre Test:

Date: ___________ Weight (lbs.): ________________

DEXA

%BF: _________

Post Test:

Date: ___________ Weight (lbs.): ________________

DEXA

%BF: __________
## APPENDIX G
### EXERCISE INTERVENTION FORM

<table>
<thead>
<tr>
<th>Name of Subject:</th>
<th>HR Range:</th>
</tr>
</thead>
</table>

### Weeks 1-2: 3 days/week for 30 min

<table>
<thead>
<tr>
<th>Day</th>
<th>M</th>
<th>T</th>
<th>W</th>
<th>R</th>
<th>F</th>
<th>Sa</th>
<th>Su</th>
<th>M</th>
<th>T</th>
<th>W</th>
<th>R</th>
<th>F</th>
<th>Sa</th>
<th>Su</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Exercise Duration (min) & kcals used**
- **Average HR (bpm)**
- **Mode of Exercise (TM, TK, or C)**

### Weeks 3-4: 3 days/week for 45 min

<table>
<thead>
<tr>
<th>Day</th>
<th>M</th>
<th>T</th>
<th>W</th>
<th>R</th>
<th>F</th>
<th>Sa</th>
<th>Su</th>
<th>M</th>
<th>T</th>
<th>W</th>
<th>R</th>
<th>F</th>
<th>Sa</th>
<th>Su</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Weeks 5-6: 4 days/week for 45 min

<table>
<thead>
<tr>
<th>Day</th>
<th>M</th>
<th>T</th>
<th>W</th>
<th>R</th>
<th>F</th>
<th>Sa</th>
<th>Su</th>
<th>M</th>
<th>T</th>
<th>W</th>
<th>R</th>
<th>F</th>
<th>Sa</th>
<th>Su</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Exercise Duration (min) & kcals used**
- **Average HR (bpm)**
- **Mode of Exercise (TM, TK, or C)**

### Weeks 7-8: 5 days/week for 45 min

<table>
<thead>
<tr>
<th>Day</th>
<th>M</th>
<th>T</th>
<th>W</th>
<th>R</th>
<th>F</th>
<th>Sa</th>
<th>Su</th>
<th>M</th>
<th>T</th>
<th>W</th>
<th>R</th>
<th>F</th>
<th>Sa</th>
<th>Su</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Exercise Duration (min) & kcals used**
- **Average HR (bpm)**
- **Mode of Exercise (TM, TK, or C)**

Note. M = Monday; T = Tuesday; W = Wednesday; R = Thursday; F = Friday; Sa = Saturday; Su = Sunday; HR = Heart Rate; TM = Treadmill; TK = Track; C = Cycling.