

A COMPARISON OF TWO DIABETIC EDUCATION PROGRAMS DESIGNED TO  
TREAT ADULT ONSET DIABETES MELLITUS

by

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## Abstract

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The purpose of this study was to compare the diabetic education programs of two certified diabetic dietitians, one with heavy focus on diet and the other with focus on exercise, over 6 months to determine which program was more successful in the treatment of type 2 diabetes. A total of 40 randomly selected subjects that met the criteria for having type 2 diabetes mellitus were separated into 2 groups (exercise and diet). Participants in each group had an initial evaluation of their body mass index, hemoglobin A1c, morning fasting blood sugar, waist circumference, weight, and blood pressure. These measures were repeated again after three and six months of treatment for analysis. A 2 x 3 repeated measures ANOVA with one between subjects factor group (diet & exercise) and one within subjects factor time (pre, 3 months, 6 months) was used to determine the effects of diabetic education program on the following dependent variables: BMI, hemoglobin A1c, morning fasting blood sugar, waist circumference, weight, diastolic blood pressure, and systolic blood pressure. After 6 months of either an intensive exercise regimen or diet regimen, there were significant decreases seen for all dependent variables (BMI, hemoglobin A1c, fasting blood sugar, waist circumference, weight, systolic blood pressure, and diastolic blood pressure). It was further indicated that the exercise group was associated with accelerated decreases in these variables as compared to the diet group by a significant margin. Individualized exercise programs appear to be the most effective at controlling type 2 diabetes as well as decreasing the risk of other comorbidities.

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## Chapter 1

### Introduction

Type 2 diabetes mellitus, or adult onset diabetes, is the most common form of diabetes. Millions of Americans are diagnosed with type 2 diabetes every year, and many more are unaware they are at high risk. On average, someone is diagnosed with diabetes every 17 seconds (American Diabetes Association, 2013).

Diabetes is caused by a problem in the way the body makes or uses insulin. Insulin is needed to move glucose into cells, where it is stored and later used for energy (American Diabetes Association, 2008). With type 2 diabetes, body fat, liver, and muscle cells do not respond correctly to insulin. This is called insulin resistance. As a result, blood sugar does not get into these cells to be stored for energy which is a vital component for neural and vascular tissue health. When sugar cannot enter cells, high levels of sugar build up in the blood causing hyperglycemia. Type 2 diabetes usually occurs slowly over time. Most people with the disease are overweight when they are diagnosed. Low activity level, poor diet, and excess body weight around the waist increase the risk of developing type 2 diabetes (Abbatini et al., 2012). Being overweight puts added pressure on the body's ability to properly control blood sugar using insulin and therefore makes it much more likely for one to develop diabetes. Chronic hyperglycemia of diabetes is associated with long-term damage, dysfunction, and failure of various organs, especially the eyes, kidneys, nerves, heart, and blood vessels (Bowman et al., 2003).

The goal of treatment at first is to lower high blood glucose levels. It is no surprise that the initial treatment for type 2 diabetes is diet modification and increased physical activity. Working closely with an endocrinologist or dietitian specifically specializing in diabetes education is usually the first step. This will cover issues dealing with portion control, exact measurements of protein, carbohydrates, and fat needed in a diet, as well as education on blood sugar monitoring and recognizing low sugar symptoms (Bennett et al., 1997). Regular exercise is important to everyone and has been proven to be beneficial to those with type 2 diabetes. Exercise in which heart rate and respiration rate is increased helps lower blood sugar level without medication. It also burns extra calories and fat which is important in weight management. Exercise can improve health by improving blood flow and blood pressure.



Prior researchers have focused more on the combination of diet and exercise for treating type 2 diabetes mellitus. There is very limited information available on diet versus exercise groups and the physiology behind those programs. Peter Bennett and colleagues (1997) performed a six year study looking at diet only, exercise only, or diet plus exercise groups for the treatment of type 2 diabetes. They concluded that, over six years, there was a significant difference across all groups for reduction in body mass index and fasting blood sugar. It was noted that the exercise and exercise plus diet groups yielded results of greater significance than the diet only group which suggests that there should be more studies that focus on the differences between diet and exercise programs rather than a combination of the two as well as etiologies behind outcomes.

### 1.1 Purpose

The purpose of this study was to compare the diabetic education programs of two certified diabetic dietitians, one with heavy focus on diet and the other with focus on exercise, over 6 months to determine which program was more successful in the treatment of type 2 diabetes.

### 1.2 Hypothesis

The program that focuses more on consistent physical activity will ultimately provide better blood sugar control as well as facilitate the most weight loss.

### 1.3 Definition of Terms

Fasting blood sugar: A blood sample was taken after an overnight fast of 10-12 hours. A reading greater than 125 mg/dL indicates diabetes.

Gastroparesis: A medical condition consisting of a paresis (partial paralysis) of the stomach, resulting in food remaining in the stomach for an abnormally long time.

Glucose: A simple monosaccharide found in plants. It is one of the three dietary monosaccharides, along with fructose and galactose, that are absorbed directly into the bloodstream during digestion.

Hemoglobin (A1c) test: Indicates average blood sugar level for the past two to three months. It measures the percentage of blood sugar attached to hemoglobin, the oxygen-carrying protein in red blood cells. An A1C level of 6.5 percent or higher on two separate tests indicates diabetes.

Hyperglycemia: A condition in which an excessive amount of glucose circulates in the blood plasma. A blood sugar reading greater than 100 mg/dL indicates glucose intolerance.

Hypoglycemia: An abnormally diminished content of glucose in the blood. It can produce a variety of symptoms and effects but the principal problems arise from an inadequate supply of glucose to the brain, resulting in impairment of function. Initial effects can manifest with a blood sugar reading of less than 80 mg/dL.

Insulin: A peptide hormone produced by beta cells of the pancreas that is central to regulating carbohydrate and fat metabolism in the body. Insulin causes cells in the liver, skeletal muscles, and fat tissue to absorb glucose from the blood.

Oral glucose tolerance test: Fasting blood sugar level is measured after an overnight fast then a sugary liquid is consumed. Blood sugar levels are tested periodically for a two hour period. A blood sugar level less than 140 mg/dL is normal. A reading of more than 200 mg/dL after two hours indicates diabetes.

Peripheral neuropathy: Damage to nerves of the peripheral nervous system, which may be caused either by diseases of or trauma to the nerve or the side effects of systemic illness (Type 2 diabetes).

Peripheral vascular disease: refers to the obstruction of large arteries *not* within the coronary, aortic arch vasculature, or brain. This is most common in the lower extremities.

Polydipsia: A non-medical symptom in which the patient displays excessive thirst.

Polyuria: A condition usually defined as excessive or abnormally large production or passage of urine.

Random blood sugar: A blood sample will be taken at a random time. A reading greater than 200 mg/dL is indicative of diabetes.

#### 1.4 Assumptions

It was assumed that men and women would have similar physiologic responses to diet and exercise. It is also assumed that the subjects followed all guidelines of their respected program.

#### 1.5 Limitations

The subject pool was not large enough to use similar demographics and be gender/age specific.

## Chapter 2

### Review of Literature

#### 2.1 Diabetes

The vast majority of cases of diabetes fall into two broad etiopathogenetic categories. In one category, type 1 diabetes, the cause is an absolute deficiency of insulin secretion. Individuals at increased risk of developing this type of diabetes can often be identified by serological evidence of an autoimmune pathologic process occurring in the pancreatic islets and by genetic markers. In the other, much more prevalent category, type 2 diabetes, the cause is a combination of resistance to insulin action and an inadequate compensatory insulin secretory response.

Diabetes mellitus is a group of metabolic diseases characterized by hyperglycemia resulting from defects in insulin secretion, insulin action, or both. Several pathogenic processes are involved in the development of diabetes. These range from autoimmune destruction of the  $\beta$ -cells of the pancreas with consequent insulin deficiency to abnormalities that result in resistance to insulin action. The basis of the abnormalities in carbohydrate, fat, and protein metabolism in diabetes is deficient action of insulin on target tissues. It is often unclear which abnormality, if either alone, is the primary cause of the hyperglycemia (Bonner-Weir et al., 2003). A diagnosis of type 2 diabetes can be made from simple blood tests including a hemoglobin A1c test of 6.5 or greater, random sugar test of 200 mg/dl or greater, fasting blood sugar of over 125 mg/dl, an oral glucose tolerance test of 200 mg/dl or greater, or any combination of the above (Bergenstal et al., 2012).

In Type 2 diabetes, hyperglycemia may be present for a long period of time without causing clinical symptoms and as a result it can go undiagnosed until significant organ damage is detected. Symptoms of marked hyperglycemia include polyuria, polydipsia, weight loss, and blurred vision (American Diabetes Association, 2008). Long-term complications of diabetes are plentiful and dangerous. Many years of uncontrolled diabetes can lead to serious problems. The eyes can become infected causing macular degeneration and vitreous detachment causing blindness. Feet and skin can develop sores and ulcers which may ultimately require amputation. Diabetes makes blood pressure and cholesterol control more difficult leading to cardiovascular complications including heart attack, stroke, and peripheral vascular disease. Nerves can easily be damaged causing pain, tingling, and a loss of

sensation. Peripheral neuropathy is a common complication associated with type 2 diabetes and can cause fecal/urinary incontinence, gastroparesis, burns secondary to lack of sensation, and leads to catastrophic falls/fractures. Lastly, high blood sugar can lead to kidney damage and eventually organ failure requiring dialysis (Ahima et al., 2001).

In some individuals with diabetes, adequate glycemic control can be achieved with weight reduction, exercise, and/or oral glucose-lowering agents. These individuals therefore do not require insulin. Other individuals who have some residual insulin secretion but require exogenous insulin for adequate glycemic control can survive without it. Individuals with extensive  $\beta$ -cell destruction and therefore no residual insulin secretion require insulin for survival. The severity of the metabolic abnormality can progress, regress, or stay the same (American Diabetes Association, 2013).

Type 2 diabetes poses a direct threat to the future of healthcare. The total estimated cost of diagnosed diabetes in 2012 was \$245 billion, including \$176 billion in direct medical costs and \$69 billion in reduced productivity (American Diabetes Association, 2012). People with diagnosed diabetes incur average medical expenditures of about \$13,700 per year, of which about \$7,900 is attributed to diabetes. People with diagnosed diabetes, on average, have medical expenditures approximately 2.3 times higher than what expenditures would be in the absence of diabetes (American Diabetes Association, 2013).

## 2.2 Obesity

Obesity and diabetes are a major cause of morbidity and mortality in the United States. An increasing prevalence of type 2 diabetes cannot be divorced from the rising prevalence of obesity and physical inactivity in our society with an estimated 97 million adults in the United States being overweight or obese (Bowman et al., 2003). Each year, an estimated 300,000 United States adults die of causes related to obesity, and diabetes is the seventh leading cause of death (Leong & Wilding, 1999). Increases in obesity and diabetes among US adults continue in both genders, all ages, all races, all educational levels, and all smoking levels.

The mechanism by which obesity, now the most common American disease, leads to non-insulin-dependent diabetes mellitus is largely unknown, however, various studies have identified possible explanations for this link. It is generally agreed that insulin resistance is an invariable accompaniment of obesity but that normoglycemia is maintained by compensatory hyper-insulinemia until the pancreatic  $\beta$

cells become unable to meet the increased demand for insulin, at which point type 2 diabetes begins.

The mechanism by which  $\beta$  cells become unable to meet rising insulin demand has never been uncovered, primarily because of the unavailability of human pancreatic islets for appropriate study. Post-mortem studies in patients with type 2 diabetes indicate that the  $\beta$  cell mass is reduced (Bonner-Weir et al., 2003).

Camasta et al. (2004) conducted a study on beta cell function, obesity, and the benefits of weight loss. In nondiabetic subjects, obesity is associated with a modest expansion of  $\beta$ -cell mass. Both fasting insulin secretion and the total insulin response to oral glucose have the following characteristics: 1) they increase with BMI in an approximately linear fashion, 2) both fat-free and fat mass are significant positive correlates, and 3) BMI exerts a positive effect separate from that of insulin resistance (i.e., obesity may be a state of primary insulin hyper-secretion). In contrast, dynamic properties of  $\beta$ -cell function, such as glucose sensitivity (i.e., dose-response function), rate sensitivity, and potentiation, do not appear to be substantially altered by the presence of obesity, body fat distribution, or insulin resistance as long as glucose tolerance is maintained. Weight loss, by diet or restrictive bariatric surgery, was associated with consensual decrements in insulin resistance and insulin hyper-secretion.

It has been shown that diabetic glycemic control and insulin resistance improve with reductions in obesity, but the treatment of obesity is difficult, and sustained weight reduction rarely occurs with dietary management alone. Hypo-caloric diets should be combined with education and low-impact exercise, as well as behavioral techniques used to encourage long-term changes (Leong & Wilding, 1999). Physical activity and low body mass index have been associated with lower diabetes risk however several prospective studies among women found that activity only slightly attenuated the diabetes risk associated with high body mass index. In a study conducted by Bowman et al. (2009), it was concluded that active men with normal and overweight BMIs had lower diabetes hazards than their inactive counterparts, but no difference by weekly activity was seen in obese men. Elevated BMI is felt to be the key driver of diabetes risk, with relatively modest attenuation by activity.

### 2.3 Cardiovascular disease

Patients with diabetes have an increased incidence of atherosclerotic cardiovascular, peripheral arterial, and cerebrovascular disease. Cardiovascular disease (CVD) is the most frequent and costly complication of type 2 diabetes. When patients with diabetes develop clinical CVD, they sustain a worse prognosis for survival than do CVD patients without diabetes (Benjamin et al., 2000). Howard & Resnick (2002) looked at all epidemiologic studies which focused on Native Americans, who collectively experienced little or no diabetes or CVD in the past, but experience both conditions in epidemic proportions today. Almost half of the Native Americans studied had diabetes at baseline. When CVD events were stratified by diabetic status, the relative CVD risk among diabetic men was twice that of non-diabetic men, and the risk among diabetic women was threefold that of non-diabetic women. Among all CVD events, diabetes accounted for 56% in men and 78% in women. Most CVD deaths occurred in those with diabetes. Recent attention has focused on defining the relative strength of CVD risk factors in diabetic populations (American Heart Association, 2013).

Lipoprotein abnormalities have been identified among the several risk factors that could account for an increase in atherosclerosis (Steiner, 2005). Patients with diabetes often have unhealthy cholesterol levels including high low density lipoprotein (LDL) cholesterol, low high density lipoprotein cholesterol, and high triglycerides. This triad of poor lipid counts often occurs in patients with premature coronary heart disease. It is also characteristic of a lipid disorder associated with insulin resistance called diabetic dyslipidemia in those patients with diabetes (Gladstone & McLaughlin, 1998). When too much LDL (bad) cholesterol is in the blood, it may be deposited in the inner walls of the arteries. Together with other substances, it can form plaque and cause the risk of heart disease to increase. People with diabetes have the same risk for heart disease and stroke as those who already have cardiovascular disease, so therefore should strive for even lower levels of LDL cholesterol. If a person with diabetes lowers their LDL cholesterol, this can reduce cardiovascular complications by 20 percent to 50 percent (Ginsberg & Tuck, 2001). HDL (good) cholesterol is present in lower levels in people with diabetes and cardiovascular disease. It works in the body by removing cholesterol from the blood. Triglycerides are the main form in which fats exist in the body. They come from fats eaten in foods, and they are also made in the body by the liver. A high triglyceride level contributes to atherosclerosis, a build-up of plaque

on the inner lining of the arteries that can cause them to harden and reduce blood flow (Buse et al., 2007). Current guidelines on preventing cardiovascular disease recognize the need not only to reduce LDL levels, but also to increase HDL and decrease triglyceride levels in diabetic patients.

The DAIS (Diabetes Atherosclerosis Intervention Study), which was conducted exclusively in patients with type 2 diabetes, found that fenofibrates reduce the progression of angiographic coronary artery disease (Gladstone & McLaughlin, 1998). In a large clinical event study, FIELD (Fenofibrate Intervention and Event Lowering in Diabetes), patients with type 2 diabetes who took Fenofibrate for 5 years had significant reductions in total cardiovascular disease events, particularly nonfatal myocardial infarction (MI) and coronary revascularization (Barter et al, 2005).

## 2.4 Kidney disease

Diabetes is the leading cause of kidney failure. One of the main complications is nephropathy, which manifests initially by microalbuminuria, then by clinical proteinuria, leading to a progressive chronic renal failure and end-stage renal disease. Microalbuminuria is considered today as an indicator of renal endothelial dysfunction as well as an independent predictor of the cardiovascular risk (Best et al., 2006). The kidneys normally do not filter large molecules into the urine, so albuminuria can be an indicator of damage to the kidneys and long-standing diabetes.

When diabetes is present, CVD is the leading cause of death among patients with end stage renal disease (Benjamin et al., 2000). The mechanism by which kidney function is compromised can be distinguished by looking at the physiology of the renin-angiotensin-aldosterone system (RAAS) (Lim & Lip, 2003). The RAAS possesses various autocrine and paracrine effects which drive most of the pathophysiological mechanisms in diabetes-related heart and kidney disease. It is intimately involved in sodium, potassium, and blood volume homeostasis. Hypofunction of this system results in potassium retention, sodium loss, and volume depletion. In uncontrolled diabetes, electrolyte disturbances are frequently observed and often attributed to the osmotic diuresis accompanying glycosuria and albuminuria (Assal et al., 1975).

The RAAS system appears to function normally in uncomplicated diabetes mellitus. Alterations in this system, however, have been observed in several of the microvascular and electrolyte complications associated with diabetic kidney disease. In a study conducted by Lim & Lip (2003), it was found that

plasma renin activity (PRA) and aldosterone were decreased in diabetics with nephropathy and hypertension. In uncontrolled diabetes, PRA and aldosterone are stimulated secondary to the associated dehydration with hypovolemia. The report concluded that the altered status of the function of the renin-angiotensin-aldosterone system in diabetes mellitus was the cause of several diabetic complications (Lim, Lip, & MacFadyen, 2004). Several animal studies using 24-hour blood pressure monitoring clearly indicate that at similar levels of blood pressure both ACE inhibitors and nondihydropyridine calcium antagonists (nonDHPAs) significantly decrease proteinuria. Moreover, animal studies that combined a nonDHPA with an ACE inhibitor demonstrated further attenuation in the rise of proteinuria as well as prevention of mesangial matrix expansion and glomerulosclerosis when compared to either agent alone (Bakris, DeQuattro, McMahon, & Weir, 1998). The renin-angiotensin system blockade is thus the standard in the management of the patient with type 2 diabetes mellitus.

There is recent evidence indicating that blockade of the renin-angiotensin system with angiotensin II antagonists has marked nephroprotective effects in patients with hypertension and type 2 diabetes, both at early and late stages of renal disease. Interruption of the renin-angiotensin system (RAS) with drugs such as ACE inhibitors (ACEIs) has proven beneficial in diabetic renal disease. Brammer et al. (2002) investigated the effects of blockade of the RAS by Ramipril, an ACEI, and its relationship to advanced glycation in experimental diabetic nephropathy. Diabetics treated for 12 weeks showed a reduction in renal advanced glycation end products (AGEs). This attenuation of renal AGEs occurred in the context of reductions in both glomerular and tubular nitrotyrosine, a marker of protein oxidation. It is conceivable that blockade of the RAAS alone may have effects on the formation of advanced glycation end products by either improving renal function or reducing oxidative stress (Brammar et al., 2002). This is very beneficial considering those with macroalbuminuria, or large amounts of protein excreted in the urine, have a CVD risk that is four to five times that of diabetic individuals without albuminuria, and thirty to forty percent of all diabetics, whether insulin-dependent or not, develop persistent proteinuria (Gall et al., 1992).

The hormone vasopressin acts on the kidneys and blood vessels to help prevent loss of water from the body by reducing urine output and helping the kidneys reabsorb water into the body. An elevation in plasma vasopressin has been well documented in patients with adult onset diabetes mellitus.



This elevation normally contributes to limit the rise in urine output accompanying the markedly increased solute excretion resulting from glycosuria, increased food intake, and protein catabolism (Cass et al., 2009). Bankir et al. (2003) performed a study using Brattleboro rats genetically devoid of vasopressin. Their results suggested that, besides this beneficial effect, the rise in vasopressin could also represent a risk factor for diabetic nephropathy: hyperfiltration, microalbuminuria and renal hypertrophy. This study concluded that the actions of vasopressin play a critical role in the albuminuria of diabetes. Robertson, Vinicor, & Zerbe (1979) observed plasma vasopressin levels in uncontrolled diabetes. Concentrations of the antidiuretic hormone, vasopressin, were measured in 28 patients with severe hyperglycemia to determine if abnormalities in hormonal regulation of water excretion could contribute to the extreme dehydration of uncontrolled diabetes mellitus. Vasopressin levels were markedly elevated in both nonketotic and ketotic patients indicating that vasopressin deficiency plays no role in the polyuria that accompanies hyperglycemia, however, the increases in vasopressin represent an ineffective effort to conserve water in the face of an overwhelming solute diuresis caused by the glucosuria. The reasons for such marked elevations in plasma vasopressin in these diabetic patients were multifactorial. The diabetic patients had evidence of hypovolemia, which was sufficient in magnitude to stimulate vasopressin release (Robertson, Vinicor, & Zerbe, 1979).

## 2.5 Hypertension

Hypertension is a well established major risk factor for CVD. Insulin resistance and hypertension are the components of metabolic syndrome and often coexist which doubles the risk for developing CVD. Clinical studies have shown that about 50% of hypertensive individuals have glucose intolerance, whereas up to 80% of patients with type 2 diabetes have hypertension (Feihl, Ruilope, & Waeber, 2001).

Insulin induces vasorelaxation by stimulating the production of nitric oxide (NO) in endothelium and regulates sodium homeostasis by enhancing sodium reabsorption in the kidney, thereby, contributing to the regulation of blood pressure (Reaven, 1991). Studies have demonstrated that insulin resistance can develop not only in the classic insulin-responsive tissues, but also in cardiovascular tissues where insulin participates in the development of cardiovascular diseases and hypertension (Barnett, 1994).

With mismanaged diabetes, hypertension is associated with increased systemic and vascular inflammatory responses and oxidative stress, which may also contribute to vascular dysfunction. During

recent years a number of studies have shown that tight blood pressure control is essential in diabetic patients in order to provide maximal protection against cardiovascular events and the deterioration of renal function (Barnett, 1994). Evidence from clinical trials shows that reducing systolic blood pressure to <140 mm Hg results in 30%-60% reductions in CVD events, however, epidemiologic evidence suggests that lowering to optimal systolic blood pressure levels of <120 mm Hg may be additionally beneficial (Beckman, Creager, & Libby, 2002). All the major classes of antihypertensives can be used in diabetics however the calcium antagonists and ACE inhibitors have better metabolic profiles and can reduce insulin resistance.

The blood pressure lowering arm of the ADVANCE study (Action in Diabetes and Vascular disease: Controlled Evaluation) reported that the routine administration of a fixed combination of an angiotensin-converting enzyme inhibitor and diuretic to a broad cross-section of patients with type 2 diabetes reduced the risk for cardiovascular and kidney outcomes, regardless of initial blood pressure level (Chalmers, Patel, & Poulter, 2005).

## 2.6 Stroke

Diabetes is a major risk factor for development of ischemic cerebrovascular disease. Patients with diabetes are at least two times more likely to have a stroke than non-diabetics. Approximately 13% of patients with diabetes over 65 years old have had a stroke (Biller & Love, 1993). In addition, they are more likely to suffer increased morbidity and mortality after stroke.

The mechanism of production of a stroke secondary to diabetes may be due to cerebrovascular atherosclerosis, cardiac embolism, or rheologic abnormalities (Biller & Love, 1993). Clinical manifestations of atherosclerosis occur primarily in 3 vascular beds: coronary arteries, lower extremities, and extracranial carotid arteries. Diabetes increases the incidence and accelerates the clinical course of each (Beckman, Creager, & Libby, 2002). Jorgensen, Nakayama, Olsen, & Raaschou (1994) conducted the Copenhagen stroke study. This was a community-based study included 1135 acute stroke patients in which 20% had diabetes. All patients were evaluated until the end of rehabilitation by weekly assessment of neurological deficits (Scandinavian Stroke Scale) and functional disabilities (Barthel Index). The diabetic stroke patient was 3.2 years younger than the non-diabetic stroke patient and had hypertension more frequently. Intracerebral hemorrhages were six times more frequent in diabetic patients. Initial

stroke severity, lesion size, and site were comparable between the two groups, however, mortality was higher in diabetic patients. Diabetes independently increased the relative death risk by 1.8%. Outcome was comparable in surviving patients with and without diabetes, but patients with diabetes recovered more slowly. Mortality increased with increasing glucose levels on admission in non-diabetic patients independent of stroke severity. It was concluded that diabetes influences stroke in several aspects including age, subtype, speed of recovery, and mortality.

Diabetes also increases the likelihood of severe carotid atherosclerosis. Patients with insulin resistance frequently manifest several alterations in coagulation mechanisms that predispose them to arterial thrombosis. These alterations include increased fibrinogen levels, increased plasminogen activator inhibitor-1, and various platelet abnormalities (Abbott, Donahue, MacMahon, Reed, & Yano, 1987). Numerous studies have shown that coagulation abnormalities occur in the course of diabetes mellitus, resulting in a state of thrombophilia. These observations are supported by epidemiological studies which demonstrate that thromboembolic events are more likely to occur in diabetic patients. This statement is supported by in vitro studies which demonstrate how glucose can directly determine alterations in the coagulation system. The abnormalities observed involve all stages of coagulation affecting both thrombus formation and its inhibition, fibrinolysis, and platelet/endothelial function. The final result is an imbalance between thrombus formation and dissolution, favoring the former. Hyperglycemia most likely determines the onset of these abnormalities through three mechanisms which are, respectively, non-enzymatic glycation, the development of increased oxidative stress, and a decrease in the levels of Heparin Sulphate. The first seems to affect the functionality of key molecules of coagulation in a negative sense. Oxidative stress constitutes an important pro-thrombotic stimulus, while the decrease in Heparin Sulphate determines a reduction in antithrombotic defenses (Ceriello, 1993).

## 2.7 Aging

Because of the aging of the population and an increasing prevalence of obesity and sedentary life habits in the United States, the prevalence of diabetes is increasing. Insulin secretion declines with advancing age, and this decline may be accelerated by genetic factors. Diabetes mellitus has long been recognized as a cause of accelerated aging. Advanced glycosylation end products (AGEs) are a potentially useful marker for monitoring glycemic control, predicting the risk of diabetes and aging

associated clinical complications, and monitoring the treatment of patients with micro and macrovascular diseases (Wu, 1993). AGEs or AGE proteins are derived from nonenzymatically glycated proteins after further cross-linking with other proteins and additional rearrangement. AGE-proteins can be assayed by either radioreceptor or immunoassays in blood and tissues (Wu, 1993). Products of advanced protein glycosylation accumulate in tissues as a function of time and sugar concentration. AGEs induce permanent abnormalities in extracellular matrix component function, stimulate cytokine and reactive oxygen species production through AGE-specific receptors, and modify intracellular proteins (Brownlee, 1995). Advanced glycation end products alter the structure and function of molecules and increase oxidative stress in biological systems. These consequences promote the pathogenesis of diabetic complications and changes associated with aging including atherosclerosis, as well as renal, eye, and neurological disease. Both specific and nonspecific receptor mechanisms mediate these detrimental effects but also participate in the removal and degradation of AGEs (Palace & Vlassara, 2003).

## 2.8 Risk factor modification

The root causes of type 2 diabetes are insulin resistance and low insulin production that are greatly associated with obesity. Due to obesity being the number one risk factor for developing type 2 diabetes, it is no surprise that the first line of treatment is diet and exercise. If treated early, the complications associated with adult onset diabetes and the risk of developing further comorbidities significantly decline (American Diabetes Association, 2008). A randomized trial conducted by Barrett-Connor and colleagues (2002) found that lifestyle interventions including ~150 min/week of physical activity and diet-induced weight loss of 5–7% reduced the risk of progression from impaired glucose tolerance (IGT) to type 2 diabetes by 58%. Diet alone, exercise alone, and combined diet and exercise were equally effective in reducing the progression from impaired glucose tolerance (IGT) to diabetes. Therefore, there is firm and consistent evidence that programs of increased physical activity and modest weight loss reduce the incidence of type 2 diabetes in individuals with IGT.

Large cohort studies have found that higher levels of habitual aerobic fitness and/or physical activity are associated with significantly lower subsequent cardiovascular and overall mortality (Castaneda-Sceppa et al., 2006) to a much greater extent than could be explained by glucose lowering

alone. Essentially all of the association between higher BMI and higher mortality was explained by confounding with cardiorespiratory fitness.

In people with IGT, a program of weight control is recommended, including at least 150 min/week of moderate to vigorous physical activity and a healthful diet with modest energy restriction (An et al, 1997.) Unfortunately, too often physical activity is an underutilized therapy for treatment of obesity and type 2 diabetes. Favorable changes in glucose tolerance and insulin sensitivity usually deteriorate within 72 hours of the last exercise session: consequently, regular physical activity is imperative to sustain glucose-lowering effects and improved insulin sensitivity. In a position paper for the American College of Sports Medicine, Albright et al. (2000) conducted a study focused on obesity and specific exercise modalities for the treatment of type 2 diabetes. Outcomes contributed significantly to motivation to begin and maintain an exercise or diet program. It was suggested that interventions designed to encourage adoption of an intervention regimen must be responsive to the individual's current stage of readiness and focus efforts on moving the individual through the various "stages of change."

## Chapter 3

### Methods

#### 3.1 Subjects

A total of 40 randomly selected subjects that met the criteria for having type 2 diabetes mellitus were separated into 2 groups (exercise and diet). The duration of disease was not a factor in the selection process. Subjects were not excluded on the basis of having other comorbidities. The subject pool was limited only to those who were maintained on oral diabetic medications for treatment. Those that received either basal insulin or mealtime insulin were excluded. Subjects were not excluded based on racial composition.

Participants in each group had an initial evaluation of their body mass index, hemoglobin A1c, morning fasting blood sugar, waist circumference, weight, and blood pressure. These measures were repeated again after three and six months of treatment for analysis.

#### 3.2 Exercise group

The exercise group included 10 males and 10 females. Subjects had an average age of  $62.35 \pm 8.63$  with a range of 48-76 years. Participants first received medical clearance or referral from their health care provider prior to starting the program. Participants were counseled on the importance of incorporating regular exercise into their daily routine. They were educated on safety measures and proper exercise form when utilizing machines or free weights to avoid injury. Subjects were required to meet with their trainers five times every week. The sessions were directed by each individual trainer in order to hold participants accountable. The exercise protocol consisted of 10 minutes of dynamic warm-up, 25 minutes of high intensity interval training (HIIT), 20 minutes of resistance training alternating arms and legs, then a 10 minute cool-down/stretch.

The HIIT was broken down into cycles of four exercises lasting one minute each followed by a thirty second break before starting the next cycle. Cycles were repeated three times then another set of four exercises was introduced. Each exercise focused on different muscle groups to avoid muscle fatigue and engage the entire body. Subjects were all required to wear Polar heart rate monitors and exercise within the range of 60-75% maximum heart rate.

An optimal daily caloric intake value was calculated for each subject using the Harris-Benedict equation based on their intensity of exercise, age, height, and weight. Subjects were required to log their daily caloric intake. They were required to meet their individual optimal daily caloric demands to avoid hypoglycemia while training. Participants were not given strict dietary modifications. They were encouraged to limit their carbohydrate intake and focus on whole grain substitutes.

### 3.3 Diet group

The diet group included 10 males and 10 females. Subjects had an average age of  $65.05 \pm 9.75$  with a range of 46-82 years. Participants first received medical clearance or referral from their health care provider prior to starting the program. They were counseled on the need for and importance of diabetic education. They were provided a copy of the glycemic index table and food pyramid which outlined basic food groups and their contribution to blood sugar. Subjects were also provided an example of how to read food labels. Participants were then educated on portion sizes and how to approximate portion size by using their hand for comparison (thumb= 1oz, palm=3 oz, and fist=1 cup). The focus of the diet forward program was to provide the body consistent but limited carbohydrate intake throughout the day. Emphasis was placed on whole grain carbohydrates however this was not a requirement. Subjects were instructed to eat 2-3 full meals daily consisting of only 2-3 carbohydrate choices of 15 grams each (totaling about 30-45 grams) and 3 ounces any protein source. No limitations were placed on non-starchy vegetables which could be eaten at any point throughout the day. Only one 5 gram serving of unsaturated fats was permitted daily. Subjects were instructed to eat a snack consisting of 15 g carbohydrate if they missed any major meal throughout the day as well as 2-3 hours after all meals. Subjects were instructed to check their fasting blood sugar before meals and again two hours post-meal following the rule that the post-meal reading should not exceed 50 mg/dl from the pre-meal reading. All beverages were required to be sugar free. Subjects were also required to use liquid cooking oils as opposed to solid fats.

Participants were not given a strict exercise regimen to follow, but they were encouraged to increase their movement throughout the day by using the stairs, parking further from a building, etc. They were also encouraged to get at least thirty minutes of moderate intensity exercise 3-5 days per week.

Participants were not required to log their physical activity or caloric intake as the risk for hypoglycemia was low in this group.

### 3.4 Statistical analysis

Data was analyzed using SPSS version 19.0 for Windows. Values were expressed as means  $\pm$  SD. The distribution of each dependent variable was examined for normality, equality of variance and equality of covariance. A 2 x 3 repeated measures ANOVA with one between subjects factor group (diet & exercise) and one within subjects factor time (pre, 3 months, 6 months) was used to determine the effects of diabetic education program on the following dependent variables: BMI, hemoglobin A1c, morning fasting blood sugar, waist circumference, weight, diastolic blood pressure, and systolic blood pressure. Follow-up tests of significant ANOVA effects were compared using the Tukey post hoc test. The level of significance was set at  $P < 0.05$ .



## Chapter 4

### Results

All participants from each group completed their respected programs (N = 40). There were no medication changes made by the subject's primary care providers during the course of the study therefore all data was included in the analysis.

#### 4.1 Body mass index

Body mass indices for both the exercise and diet groups were measured at zero, three, and six months. Descriptive statistics are shown in Table 4.1. A 2 x 3 analysis of variance (ANOVA) was conducted. There was a significant difference between group and time,  $F(2, 76) = 29.94$ ,  $p = 0.000$ . A Tukey post hoc test revealed that the exercise group participants had a lower BMI than those in the diet group at six months,  $\bar{x} 2.40 \pm 1.38$ ,  $p < 0.05$ . This confirms that subjects consistently lost a percentage of body fat throughout both programs however the decrease in BMI was accelerated in the exercise group when compared to the diet group. These values are shown graphically in Figure 4.1. For descriptive statistics see Appendix 1.

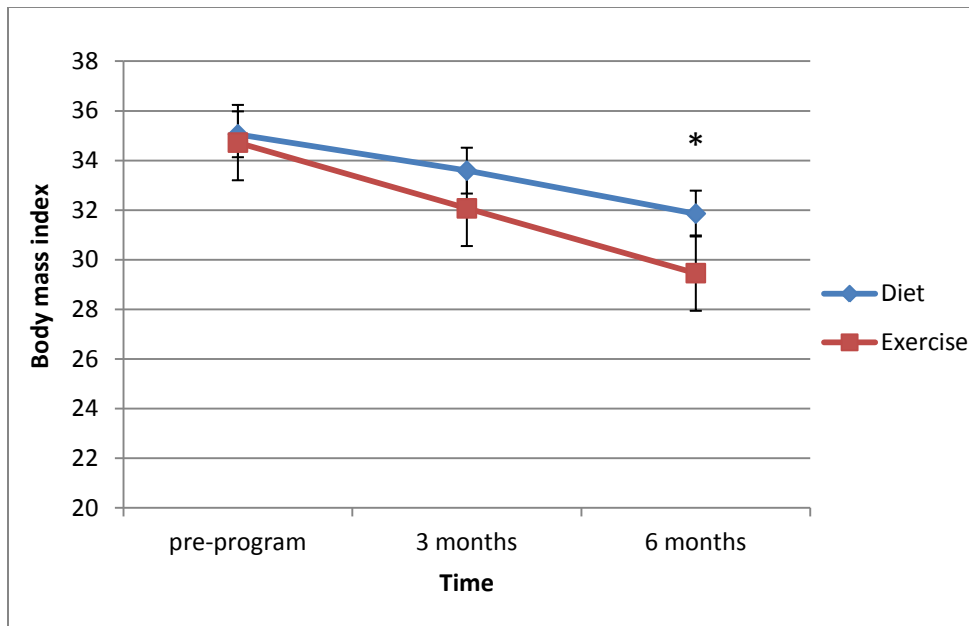


Figure 4.1 Average decreases in BMI over time for both exercise and diet groups.

\*Indicates that the exercise group participants had a significantly lower BMI than those in the diet group at 6 months.

#### 4.2 Hemoglobin A1c

Hemoglobin A1c values for both the exercise and diet groups were measured at zero, three, and six months. Descriptive statistics are shown in Appendix 1. There was significant interaction between group and time,  $F(2, 76) = 18.33$ ,  $p = 0.000$ . A Tukey post hoc test revealed that the exercise group participants had a lower hemoglobin A1c than those in the diet group at six months,  $\bar{x} 0.830 \pm 0.29$ ,  $p < 0.05$ . This indicates that both programs were effective at lowering hemoglobin A1c however the decrease was accelerated in the exercise group as compared to the diet group. These values are shown graphically in Figure 4.2.

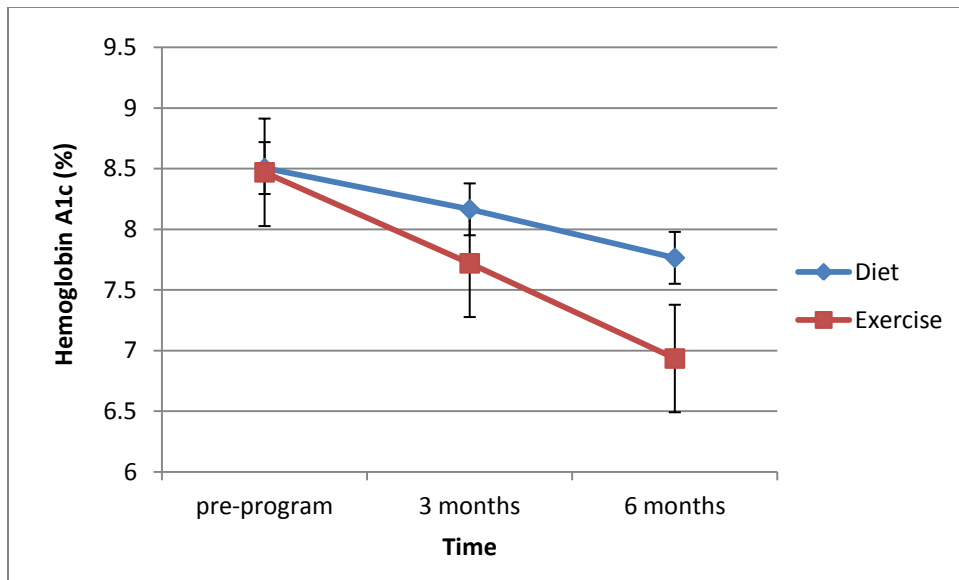


Figure 4.2 Average decreases in hemoglobin A1c over time for both exercise and diet groups.

\*Indicates that the exercise group participants had a significantly lower hemoglobin A1c than those in the diet group at 6 months.

#### 4.3 Fasting blood sugar

Morning fasting blood sugars for both the exercise and diet groups were measured at zero, three, and six months. Descriptive statistics are shown in Appendix 1. There was significant variation between group and time,  $F(2, 76) = 4.62$ ,  $p = 0.013$ . A Tukey post hoc showed that the exercise group participants had a lower fasting blood sugar than those in the diet group at both three and six months,  $\bar{x}_{\text{three}} 13.35 \pm 5.90$ ,  $p = <0.05$  and  $\bar{x}_{\text{six}} 15.2 \pm 4.66$ ,  $p < 0.05$ . This indicates that both programs were effective at lowering morning fasting blood sugars however the decrease was accelerated in the exercise group as compared to the diet group. These values are shown graphically in Figure 4.3.

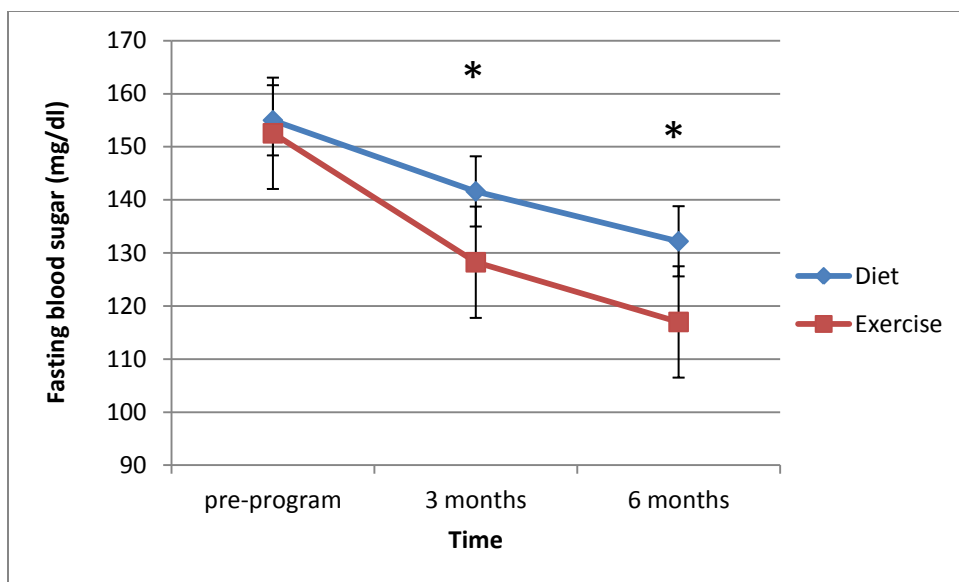


Figure 4.3 Average decreases in fasting blood sugars over time for both exercise and diet groups.

\*Indicates that the exercise group participants had a significantly lower fasting blood sugar than those in the diet group at 3 and 6 months.

#### 4.4 Waist circumference

Waist circumference (in inches) values for both the exercise and diet groups were measured at zero, three, and six months. Descriptive statistics are shown in Appendix 1. There was a significant difference between group and time,  $F(2, 76) = 46.36$ ,  $p = 0.000$ . A Tukey post hoc test showed that the exercise group participants had a higher decline in waist circumference than those in the diet group at six months,  $\bar{x} 4.83 \pm 1.77$ ,  $p < 0.05$ . This indicates that both programs were effective at decreasing waist circumference however the decrease was accelerated in the exercise group as compared to the diet group. These values are shown graphically in Figure 4.4.

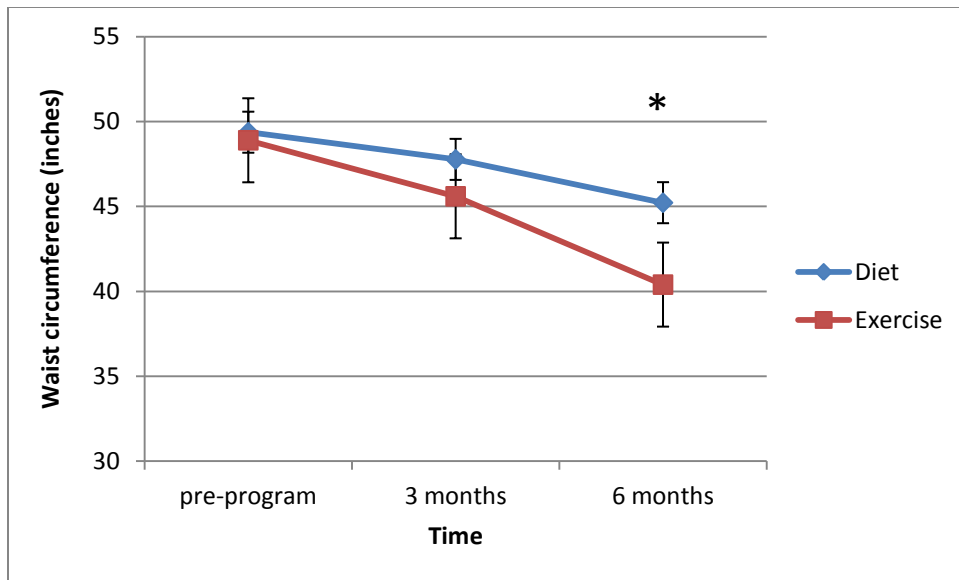


Figure 4.4 Average decreases in waist circumferences over time for both exercise and diet groups.

\*Indicates that the exercise group participants had a significantly lower waist circumference than those in the diet group at 6 months.

#### 4.5 Weight

Weight in pounds for both the exercise and diet groups was measured at zero, three, and six months. Descriptive statistics are shown in Appendix 1. There were significant differences seen between group and time,  $F(2, 76) = 36.97$ ,  $p = 0.000$ . A Tukey post hoc analysis showed that the exercise group participants had a higher decline in weight than those in the diet group at six months,  $\bar{x} 14.15 \pm 13.75$ ,  $p < 0.05$ . This indicates that both programs were effective at decreasing weight however the decrease was accelerated in the exercise group as compared to the diet group. These values are shown graphically in Figure 4.5.

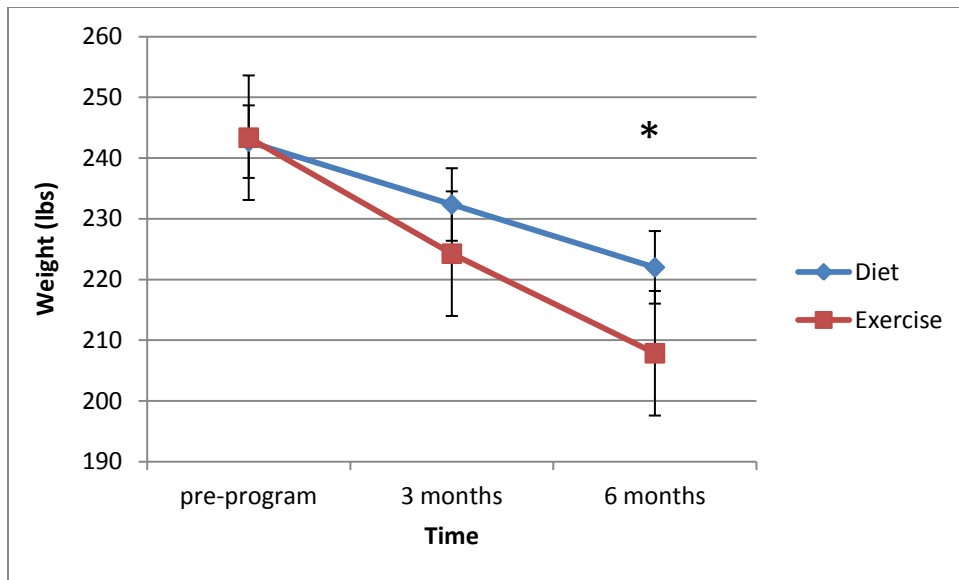


Figure 4.5 Average decreases in weight over time for both exercise and diet groups.

\*Indicates that the exercise group participants had a significantly lower weight than those in the diet group at 6 months.

#### 4.6 Diastolic blood pressure

Diastolic blood pressures for both the exercise and diet groups were measured at zero, three, and six months. Descriptive statistics are shown in Appendix 1. There were significant differences seen between group and time,  $F(2, 76) = 813.75$ ,  $p = 0.000$ . A Tukey post hoc test showed that the exercise group participants had a significantly lower diastolic blood pressure than those in the diet group at three months,  $\bar{x} 3.40 \pm 2.22$ ,  $p < 0.05$ . Both programs were effective at lowering diastolic blood pressures over time however this was accelerated by exercise as seen in Figure 4.6.

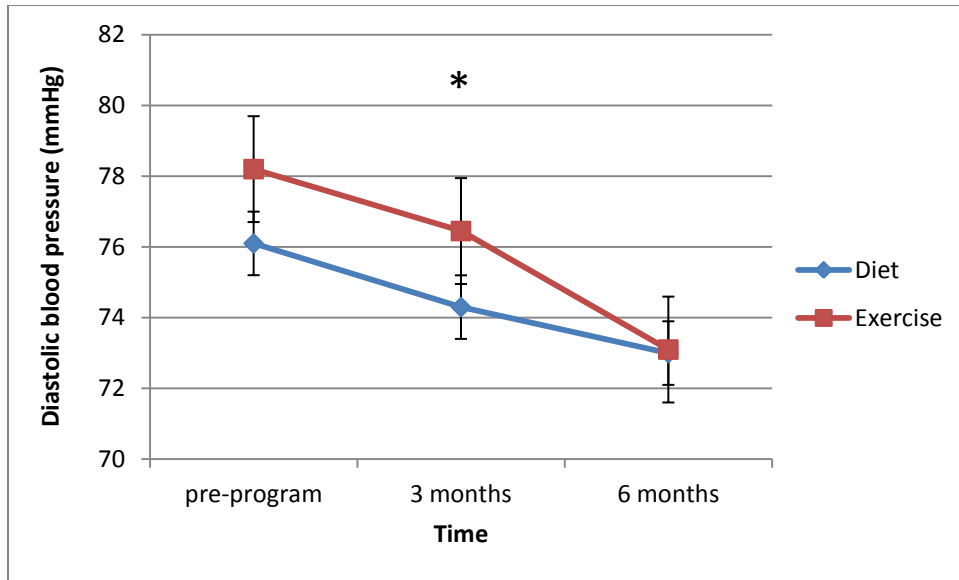


Figure 4.6 Average diastolic blood pressure readings over time for both exercise and diet groups.

\*Indicates that the exercise group participants had a significantly lower diastolic blood pressure than those in the diet group at 3 months.

#### 4.7 Systolic blood pressure

Systolic blood pressures for both the exercise and diet groups were measured at zero, three, and six months. Descriptive statistics are shown in Appendix 1. There was a significant difference between group and time,  $F(2, 76) = 192.41$ ,  $p = 0.000$ . A Tukey post hoc analysis revealed that the exercise group participants had a significantly lower systolic blood pressure than those in the diet group at three and six months,  $\bar{x}_{\text{three}} 1.2 \pm 2.17$ ,  $p < 0.05$  and  $\bar{x}_{\text{six}} 6.0 \pm 3.69$ ,  $p < 0.05$ . Both programs were effective at lowering systolic blood pressures over time however this was accelerated by exercise as seen in Figure 4.7.

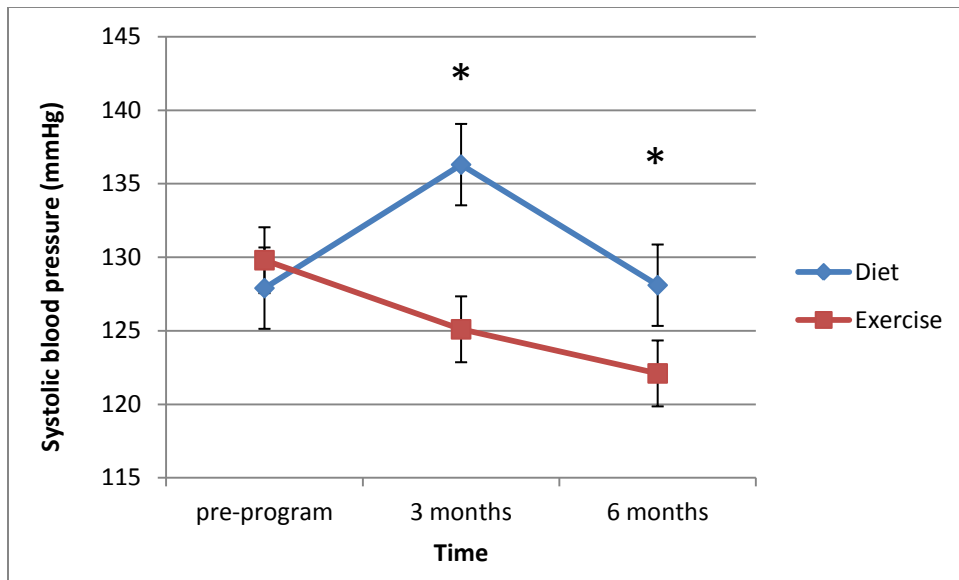


Figure 4.7 Average systolic blood pressure readings over time for both exercise and diet groups.

\*Indicates that the exercise group participants had a significantly lower systolic blood pressure than those in the diet group at 3 and 6 months.



## Chapter 5

### Discussion

#### 5.1 Conclusion

The purpose of this study was to compare two diabetic education programs, one with emphasis on diet, the other with emphasis on exercise to evaluate which program was superior at controlling type 2 diabetes. After 6 months of either an intensive exercise regimen or diet regimen, there were significant decreases seen for all dependent variables (BMI, hemoglobin A1c, fasting blood sugar, waist circumference, weight, systolic blood pressure, and diastolic blood pressure). It was further indicated that the exercise group was associated with accelerated decreases in these variables as compared to the diet group by a significant margin. Individualized exercise programs appear to be the most effective at controlling type 2 diabetes as well as decreasing the risk of other comorbidities.

The reduction in dependent variables observed in the intervention groups is consistent with the current understanding of the etiology of type 2 diabetes. In most instances this is associated with insulin resistance. The interventions of both diet and exercise used in this study are both known to influence insulin resistance. Results are consistent with previous studies in that improvements in diabetic control were seen with changes in both diet and exercise. It has been shown that lifestyle interventions including a modest amount of physical activity and diet-induced weight loss of 5–7% improved diabetic risk (Barrett-Connor et al., 2002). The results of our study extend previous data showing that lifestyle interventions can reduce the incidence of diabetes. Both groups were successful at improving diabetic metrics. The program design provided the element of accountability as both groups were required to meet with their dietitians five days a week. This likely contributed to individual success. Completion of intervention program is the hallmark of diabetic treatment. It has been shown in prior studies that outcomes contributed significantly to motivation to begin and maintain an exercise or diet program (Albright et al., 2000). The results of this study imply that diabetic individuals would benefit more from individualized intervention programs with frequent checkpoints designed to incorporate accountability.

In this study, there were decreases in all dependent variables in both exercise and diet groups. Although both groups yielded positive results for all dependent variables, results were accelerated by exercise. This may be related to how the body responds to the physiologic stress imparted by exercise.

Physical activity improves how the body uses insulin which better controls blood sugar over time, helps burn extra body fat, and improves blood circulation in order to facilitate glucose delivery to working muscles (Castaneda-Sceppa et al., 2006).

The results obtained from the exercise group were of clinical significance. The American Diabetes Association suggests an A1c of 7% is optimal. This is equivalent to a fasting blood sugar of about 154 mg/dl. Following the exercise intensive program the average A1c value at six months was 6.94%. This is a 20% decline from pre-program measures putting individuals in the optimal range. There was a 25% decline in fasting blood sugar over the six months to 117 mg/dl. This is well within normal limits recommended by the American Diabetes Association.

There are very limited protocols on strict diet control and extensive exercise regimens as separate entities. To confirm that the results of this study are sound, future research should be conducted that compares the two groups separately. After reviewing the conditions of the current study, it is recommended that future research is focused on insulin dependent type 2 diabetes or “brittle” diabetes in order to investigate whether or not this sensitivity can be corrected by variations in diet or exercise regimens.

## Appendix A

### Group means and standard deviations

Group means and standard deviations for BMI.

Group	Pre-program	3 months	6 months
Exercise	35.06 ± 4.91	33.60 ± 4.66	31.86 ± 4.50
Diet	34.72 ± 4.56	32.07 ± 4.33	29.46 ± 4.24

Group means and standard deviations for hemoglobin A1c.

Group	Pre-program	3 months	6 months
Exercise	8.5 ± 1.38	8.17 ± 1.26	7.77 ± 1.07
Diet	8.47 ± 1.21	7.72 ± 1.02	6.94 ± 0.73

Group means and standard deviations for fasting blood sugar (mg/dl).

Group	Pre-program	3 months	6 months
Exercise	155 ± 29.80	141.60 ± 19.61	132.20 ± 15.98
Diet	152.55 ± 22.59	128.25 ± 17.68	117 ± 13.35

Group means and standard deviations for waist circumference (inches).

Group	Pre-program	3 months	6 months
Exercise	49.38 ± 6.85	47.78 ± 6.36	45.23 ± 6.51
Diet	48.9 ± 5.23	45.6 ± 5.53	40.40 ± 4.52

Group means and standard deviations for weight (pounds).

Group	Pre-program	3 months	6 months
Exercise	242.70 ± 47.89	232.35 ± 44.49	222 ± 43.82
Diet	243.35 ± 45.16	224.25 ± 42.87	207.85 ± 43.14

Group means and standard deviations for diastolic blood pressure (mmHg).

<b>Group</b>	<b>Pre-program</b>	<b>3 months</b>	<b>6 months</b>
<b>Exercise</b>	76.10 ± 6.76	74.30 ± 6.69	73 ± 5.09
<b>Diet</b>	79.3 ± 7.28	76.45 ± 4.57	73.10 ± 4.33

Group means and standard deviations for systolic blood pressure (mmHg).

<b>Group</b>	<b>Pre-program</b>	<b>3 months</b>	<b>6 months</b>
<b>Exercise</b>	127.90 ± 7.44	126.30 ± 6.56	128.10 ± 15.36
<b>Diet</b>	128.20 ± 5.73	125.10 ± 7.12	122.10 ± 5.96

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### Biographical Information

The author received her Bachelor's degree in exercise physiology in 2010 from the University of Texas at Arlington. She began her graduate studies in exercise physiology in the spring of 2012. While pursuing her degree she was a medical scribe. Katelyn plans to pursue a career in nursing but also plans to return to the University of Texas at Arlington for a doctorate in exercise physiology. Her ultimate destination has yet to be declared. Katelyn's research interest is in adult onset diabetes and risk modification programs.