Lowering Blood Glucose Levels: The Effect of active static flexibility on plasma blood glucose of those with type 2 diabetes, prediabetes, and those at risk for type 2 diabetes

by

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DEDICATION

I would like to dedicate my work to my grandfather, Vivan Lee.

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Table of Contents

List of Boxes and Tables

Abstract

The purpose of this experiment was to determine if static stretching could produce lower blood glucose levels in people diagnosed with type 2 diabetes, those classified as pre-diabetic, and those at risk for diabetes. Volunteers for this study were classified as part of the criteria stated above. Participants static stretched or sat. During both trials, participants drank fruit juice with a high sugar content and had their blood glucose tested before, during, and after. The experimental group completed the stretches; the control group sat for the duration of the time. There was a decrease in blood glucose values in the experimental group from thirty to fifty-two minutes in stretching compared to the control group. When comparing the half waypoint to the end of the stretching, there was a significant difference favoring the control group. The statistical analysis did not indicate that stretching was more beneficial than sitting

CHAPTER I

INTRODUCTION

Type 2 diabetes is a disease present in over twenty-nine million Americans (CDC 2014). Characterized by hormone inefficiency, type 2 diabetes is considered a metabolic disease that affects blood glucose. Specifically, diabetes deals with the peptide hormone insulin that is secreted by β cells in the pancreas. Insulin interacts with muscle and liver cells as well as fatty tissue by relaying a message to insulin-sensitive cells to increase uptake of glucose; when the body resists the effects of this hormone, one is diagnosed as a type 2 diabetic. Criteria for diabetes include a fasting plasma glucose of at least 126 mg/dl, symptoms consisting of polyuria, polydipsia, unexplained weight loss and a random blood glucose of at least 200 mg/dl or more, or an oral glucose tolerance test resulting in a plasma glucose of at least 200 mg/dl, or an HbA1C of greater than 6.5% (American Diabetes Association [ADA], 2013).

When insulin binds to its receptor cell membrane, a signal transduction pathway is triggered that causes a special glucose transporter (GLUT-4), which was originally inside a vesicle of the cytoplasm of the cell, to join the plasma membrane (Widdmaier et al., 2016). As the name implies, the glucose transporter allows glucose to enter the cell, lowering the blood glucose concentration. However, when insulin is not effective, some other source must cause GLUT-4 to move from the cytoplasm into the cell membrane. Exercise has been shown to do this. In 1993, Brozinick et al. saw a significant increase in the concentration of GLUT-4 in rats after muscle contraction. Because of this finding, along with many others, one of the key recommendations for type 2 diabetes involves exercise because of the muscle contraction associated with it. The ADA recommends aerobic exercise for 150 minutes a week and taking no more than a two-day break in between exercise (ADA 2015).

However, diabetes has the ability to cause neuropathy, nephropathy, high blood pressure, and ketoacidosis, which can make it difficult to achieve recommended dose of exercise (ADA, n.d.). Stretching offers a possible alternative to help lower blood glucose levels by offering a reasonable solution that can help bring the person closer to the necessary recommendations. Stretching has been shown to be effective in multiple studies starting in 1932 when Feng found that stretching could increase the metabolism of the muscle. Mitsumoto et al. (1992) demonstrated an increase of glucose transporters in the plasma membrane upon relaxation and stretch of muscle cells *in vitro*. Taking these findings outside the lab, Nelson et. al. performed a study in 2011 showing that blood glucose levels decreased in patients who completed a physically assisted passive stretching session. This study showed one way stretching could be performed, but required a person to implement the stretches passively. However, not everyone always has a person to stretch them. Static stretching has the potential to show results in a more practical manner by allowing the person to perform the stretch him or herself. The purpose of this experiment was to determine if static stretching could produce statistically significant lower blood glucose levels in a person with type 2 diabetes or those at risk for diabetes.

Hypothesis

Blood glucose levels will lower significantly following a forty-minute static stretching regimen in individuals at risk or diagnosed with type 2 diabetes.

CHAPTER II

LITERATURE REVIEW

Type 2 Diabetes:

The term *diabetes mellitus* was coined in two different times. The first time was in the first century by the Greek as simply *diabetes*, meaning to "siphon". Then, in the 1600s mellitus was added, which is a Latin word meaning "honey sweet." However, symptoms of *diabetes mellitus* were documented in ancient Egyptian times when a polyuria-like description was written (Ahmed 2002). Today, diabetes has multiple forms: type 1, type 2, and gestational diabetes; ancient India first noted congenital and late onset types, but the official distinction was made by Sir Harold Percival Himsworth in 1936 (Mandal, 2012).

Currently, the American Heart Association (ADA) diagnoses type 2 diabetes when an individual has the ability to produce insulin, but the body resists the insulin produced (ADA). Because one of the roles of insulin is to tell the cell to increase glucose uptake; when the cell does not listen, glucose cannot be used effectively and floats around in the blood causing dangerous side effects (Widmaier et. al.). In the past, diabetes was the diagnosis if ants were attracted to one's urine, but can now be determined by taking one of four blood tests (Mandal 2012). The National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK), American Diabetes Association (ADA), and Centers for Disease Control share a common diagnosis of diabetes if fasting plasma glucose is above

126mg/dL or above, oral glucose tolerance or random plasma glucose is above 200 mg/dL, or if HbA1c percentage is above 6.5% (NIDDK 2016).

The onset of type 2 diabetes can be recognized before an official diagnosis. The ADA identifies pre-diabetes using three of the same tests for full onset of type 2 diabetes. A pre-diabetic has a HbA1c percentage between 5.7 and 6.5%, a fasting plasma glucose between 100 and 126 mg/dL, and/or an oral glucose tolerance test between 140 and 200 mg/dL (ADA).

Although pre-diabetes has official diagnosis criteria, many individuals in the world today are at risk for diabetes without falling into either of the previous categories. Basic quizzes can be taken at leisure to determine if an individual is at risk for diabetes. These quizzes can be found at the ADA, NIDDK, and Harvard Disease Risk index (9,10,11). All of these quizzes quantify disease risk using a combination of the following criteria: older than 45 years old, an immediate family member with diabetes, a history of gestational diabetes, a physically inactive lifestyle, overweight, and/or a family background of African American, American Indian, Asian American Pacific Islander, or Hispanic descent. While the diagnosis of diabetes is important, the treatment is what allows the patient to have an unaltered lifespan.

Treatment:

The American Association of Clinical Endocrinologists and American College of Endocrinology published a joint executive summary in February 2017 with fourteen founding principles when it comes to treating diabetic patients. The first treatment principles include patient specificity, obesity control, and lifestyle optimization (Garber et. al. 2017). This executive summary defines lifestyle optimization as medical nutrition therapy, regular physical activity, sufficient amounts of sleep, behavioral support, and smoking cessation and avoidance of all tobacco products. (Garber et. al., 2017). Both the executive summary and ADA support personalized treatment, but as far as medical treatment, the ADA proposes glucose lowering medications and physical activity as a priority for diabetes treatment (Mosenzon et. al., 2016).

Ultimately, a major component of type 2 diabetes treatments involve physical activity. The ADA recommends 150 minutes a week of moderate activity with no more than two days of recovery (ADA, 2017). In 1999, a study completed by Kennedy et. al. found that an acute bout of exercise could increase translocation of GLUT-4 to the membrane. GLUT-4 is a protein that can be sent to the membrane of cells to allow glucose to enter even if the cell is not affected by insulin. Therefore, Kennedy et al. showed that exercise affects blood glucose levels by increasing the number of glucose transporters in the cell.

Even though exercise has been shown to be effective in treating diabetes, the mode of exercise that produces the most benefit has been highly studied. In a meta-analysis conducted by Snowling and Hopkins (2006), it was determined that aerobic and resistance training both shows positive and similar benefits (Snowling & Hopkins 2006). These results were replicated by Farias et. al. (2015) who found similar results in glycemic control with those who completed resistance training and cardiovascular training (Farias et. al. 2015). Although studies have shown the positive blood glucose changes with resistance training and aerobic fitness training, few studies have assessed flexibilities role in diabetes treatment.

Flexibility:

Flexibility is defined by the American College of Sport's Medicine (ACSM) as the ability to move a joint through a full range of motion (ACSM 2014). Common ways flexibility is utilized is in the practice of yoga, gymnastics, and dance. As a component of the five health-related physical fitness measures, flexibility is important in everyday activities. ACSM recommends that the average person stretch at least two to three times a week but can be most beneficial if done daily (*ACSM's Guidelines for Exercise Testing and Prescription,* 2014). In 2012, Lock et. al. completed a study assessing flexibility in older adults. He and his team showed that static stretching can decrease blood pressure as well as improve completion of a stand up, sit down test (Locks et. al., 2012). Other benefits in stretching include prevention of injury, decreasing balance issues and even back pain (Harvard Health Publications).

There are many ways to increase flexibility such as static and dynamic stretching. Static stretching is defined as holding a stretch without movement as opposed to dynamic stretching, which involves moving the joint while receiving the same stretching feeling. The many benefits of flexibility for the average population have been studied, Lock et. al. (2012) and ACSM, but not many studies have shown the benefits of flexibility and stretching in the non-insulin-dependent diabetic population.

Blood glucose and Flexibility:

A systematic review and meta-analysis study states that yoga could be a complementary treatment for individuals with type 2 diabetes in terms of acute glycemic control (Vizcaino et. al., 2016). In 2009, there was a study published by Skoro-Kondza et al. highlighting an attempted trial assessing the benefits of long-term yoga on the diabetic population. In conclusion, Skoro-Kondza et al. found that the population at hand was not flexible enough to participate in everyday yoga, and that it was difficult for the participants even to come to the yoga sessions and participate (Skoro-Kondza et. al., 2009). Yoga can be a great way to implement flexibility, but in order to target the diabetic population, a simpler method, such as static stretching, may need to be used. The difference is a more beginner friendly atmosphere in stretching as compared to the multitasking of breathing, strength and balance that yoga incorporates. In 2014, Kanaya et. al. completed an experiment comparing yoga and static stretching benefits for people who had pre-diabetes over the course of a year. The overall study outcome showed relatively little differences in blood glucose, blood pressure, and BMI changes between yoga and static stretching groups.

Furthermore, there are two studies that correlate static stretching to changes in blood glucose levels. The first was completed in 2011 by Nelson et. al. In that study, participants completed a forty-minute static stretching session following intake of a sugary drink and a two-hour fast. During those forty minutes, the researchers physically placed the participants in the stretching position placing enough stress on the joint until the participant expressed verbal discomfort. Blood glucose was measured before, during, and after the stretching session. Using the same people for the control trial and experimental trial, this study found significant blood glucose changes between the trials with a 25mg/dL difference between the trials (Nelson et. al., 2011).

The second study took fifteen hospital patients with type 2 diabetes and had them complete an eight-week physically assisted static stretching regimen (Park, 2015). Following the same protocol as the Nelson et al. study, however, the participants only completed one trial and HbA1c percentage levels were measured. This was because for Park's study, the participants completed several sessions over an 8-week period. Park found no change in percentage levels for the control group, who did not participate in any type of stretching, and a 0.6% change in the experimental group, who completed the physically assisted static stretching program.

These two studies differed in time only, but both used physically assisted static stretching. However, when it comes to the large population of diabetics who may not have an exercise partner, there is a need for a study that relates non-physically assisted static stretching to blood glucose.

CHAPTER III

METHODS

Participants:

Using physician recommendations, adults from a southern college area were recruited. In order to participate, males and females either were diagnosed with non-insulin dependent type 2 diabetes or had an increased risk of type 2 diabetes as defined by the ADA diabetes risk test (ADA, 2015). The participants signed an informed consent in an individual meeting after physician approval.

Procedure:

After signing informed consent, participants came in following a two-hour fast and randomly completed one of two testing trials: static stretching or a control. During both trials, participants drank a 355 ml can of fruit juice with forty-three grams of sugar.

After thirty minutes, blood glucose was measured using a glucometer (OneTouch Ultra, Lifescan, Chesterbrook). After the blood glucose assessment, the experimental group completed nine stretches, five lower body and four upper body. These stretches (explained in box 1) were adapted from stretches used in the Nelson et. al. (2011) study. Each stretch was held for thirty seconds and repeated four times with a fifteen-second break between stretches. For the stretches that required an individual limb to be stretched, the one stretch was repeated all four times on the right side before moving to the left side. Separating each new stretch was a thirty-second break. After twenty-two minutes of stretching, blood glucose was checked. Stretching then resumed, and blood glucose was checked again at the conclusion of forty-five minutes. The control group drank the fruit juice, sat for seventy-five minutes, and complete blood glucose assessments at the same time periods as the intervention trial. The testing trials occured in a counterbalanced order separated by at least three days.

Data Analysis:

The blood glucose changes were analyzed using a paired samples t-test. Two change scores were calculated. The first change score is from baseline blood glucose to the 20 minutes blood glucose. The second change score is from 20 minute blood glucose to 40 minute blood glucose. A p-value of 0.05 will determine if significant blood glucose changes occur at 0, 22, and 45 minutes between the control and intervention trials. The statistical package for the social sciences (IBM, Armonk, New York) will be used for all calculations.

Box 1. Stretches used for testing.

Stretch	Description
Seated Knee Flexor	Participants will sit on the floor with their legs extended and arms stretched above their head. They will then lower their head toward their knees, stretch out their arms, and pull their chest to the ground, closer to their legs.
Seated Knee Flexor – hip adductor (bilateral)	The participants will sit on the floor in lotus position. They will lower their head toward to the floor, and pull their chest to the ground closer toward their legs.
Supine knee flexor-plantar flexor (Unilateral)	Participants will lie on their back with legs extended on the floor. The volunteers will then raise one straight leg, flex the hip, and flex the ankle by holding their leg. (Resistance bands will be used for those who cannot hold their leg)
Seated hip external rotators, extensors (unilateral)	Participants will sit on the floor with one leg extended. The opposite leg flexes at the knee, placing the foot against the extended leg's thigh. They then lower their head toward the extended knee and reach for their foot.
Prone Hip Flexor (unilateral)	Volunteers will lie on their stomach and flex one knee to about 60°. While the knee remains in the flexed position, the participant lifts the foot, which will lift the thigh to extend the hip. (Resistance bands will be used to reach the foot).
Seated shoulder lateral flexor (bilateral)	The person will sit in a chair with fingers locked together and placed behind the head. The person will then pull the elbows back toward the body's midline.
Seated shoulder extensors, adductors, retractors (unilateral)	While seated in a chair, participants extend one arm and place it horizontally across the chest. The opposite arm will then bisect the extended arm perpendicularly. They pull their arm against the chest as much as possible while keeping the other arm parallel to the floor.
Seated shoulder flexors, depressors (bilateral)	Participants sit on the floor with legs extended. Participants then leaned on their wrists and walked their fingers out posteriorly as far as possible away from their trunk.

Seated shoulder and elbow flexors (unilateral)	Participants sit on the floor with extended legs; one elbow flexes and were brought up next to the ear. From this position the shoulder will be flexed by taking the other hand and pulling the flexed elbow posteriorly.

CHAPTER IV

Results

Twelve individuals participated in the study; one participant exceeded the maximum blood glucose allowed, which excluded them from the study. Of the 11 participants who completed the trials (4 males and 7 females), 5 were diagnosed as type 2 diabetic (2 females and 3 males) (table 1). The other six participants were either at risk (1 male and 4 females) or diagnosed as pre-diabetic (1 female).

After fasting for at least two hours, the participants drank a high-sugar fruit juice and either stretched for 45 minutes or sat still for that duration while having blood glucose taken in the beginning, middle, and end. The individuals then repeated the same fast and fruit juice intake at least three days later but completed the other option. Although insignificant, there was a decrease in blood glucose values in the experimental group from the beginning of the stretching trial to the half way point compared to the control group; for the first twenty minutes, the blood glucose in the experimental group dropped an average of 30 mg/dL where the control group dropped only 15 mg/dL (table 2). When comparing the half waypoint to the end of the stretching, there was a significant difference favoring the control group; the experimental trial increased one mg/dL, and the control group decreased 20 mg/dL. Overall, the control trial decreased the most, however, this difference was insignificant. The experimental trial decreased 19 mg/dL whereas the control decreased about 35 mg/dL. When testing for any variation between the start times, no significance between the days the participants completed the trials was shown.

Table 1. Particpant Characteristics (Mean ±SD)

Characteristic	All (n=11)	Male (n=4)	Female (n=7)
Age (yr)	56 ±12	57 ±17	56 ±14
Height (in.)	67 ±3	70 ±3	65 ±2
Weight (kg)	86 ±12	91 ±16	84 ±9
Length of Diagnosis(yr.)	4 ±6	10 ± 8	1 ±2

Table 2. Blood Glucose Results between Control and Experimental Trials (Mean ± SD)

	Trials (n=11)					
	Minute 0		22 minutes		44 minutes	
	Exp.	Control	Exp.	Control	Exp.	Control

Glucose: (mg/dL)	159.8 ±34	174.9 ±28	129.4 ±44	159.6 ±40	130 ±46	139.2 ±40

Exp. = Experimental Trial

Table 3. Difference of Blood Glucose within the Trials (Mean ±SD)

	Trials (n=11)					
	0 - 22 Minutes		22 - 44 minutes		0 - 44 minutes	
	Exp.	Control	Exp.	Control	Exp.	Control
Glucose (mg/dL)	-30.36 ±31	-15.4 ±20	0.55 ±22	-20 ±16*	-29.8 ±30	-35.7±25

Exp. = Experimental Trial

* Significance with p value of 0.05

CHAPTER V

DISCUSSION

The study analyzed blood glucose levels in a static stretching regimen compared to blood glucose levels when not stretching at all. The purpose of this experiment was to determine if an active static stretching protocol could produce statistically significant lower blood glucose levels in people with type 2 diabetes and those who are pre-diabetic, or at risk population for diabetes in comparison to doing nothing. From the eleven participants that completed the study, the blood glucose levels were not significant different between the stretching and non-stretching trials most of the three time points (i.e. beginning, middle, and end of each session). There was a significant difference in blood glucose levels favoring the control group from the half way point to the end. On the other hand, when comparing the first twenty-two minutes of stretching to the control group, the difference in blood glucose seemed to be trending towards significance. Notably so, the first twenty-two minutes of stretching were stretches of the lower body, and the second twenty two minutes were of the upper body.

In a study completed by Nelson et. al. (2011), participants completed a similar forty-minute static stretching session following intake of a sugary drink and a two-hour fast. During those forty minutes, the researchers physically placed the participants in the stretching positions and put stress on the joint until the participant expressed verbal discomfort – passive static stretching. While the active static stretching that occurred in the current study did not show significant results favoring the stretching protocol, the Nelson et. al. study did find significant blood glucose changes between the trials with a 25mg/dL difference between the trials in the first twenty minutes (Nelson et. al., 2011). In the current study, there was only a 15mg/dL difference between the trials in the first twenty minutes.

Another study took fifteen hospital patients with type 2 diabetes and had them complete an eight-week physically assisted static stretching regimen (Park, 2015). Following a similar protocol as the Nelson et al. study, the participants completed one stretching trial. HbA1c levels were measured and compared to a different group who did not complete the stretching protocol. Park found no change in percentage levels for the control group, who did not participate in any type of stretching, and a 0.6% change in the experimental group, who completed the physically assisted static stretching program, and this resulted in significant results in comparison to the control group. This study shows that passive static stretching may lower HbA1c levels over a longer period of time, which differs in the current study due to time.

In the current study, active static stretching did not demonstrate an ability to reduce blood glucose levels in those with diabetes or at risk for diabetes. Static stretching in these individuals should produce another route for glucose entry into the cell, lowering the blood glucose levels. This mechanism being through the GLUT-4 transporters in the cell membrane that allows glucose into the cytoplasm without the help of insulin; however, active static stretching may not produce enough of a stimulus to facilitate this adaptation. Active stretching may not reach the range of motion or level of discomfort that causes the physiological response of the blood glucose transporter. This reasoning stems from the idea that trained personnel can stretch a participant more than the participant can on their own.

An acknowledgement of the limitations in the study is pertinent. First, the experiment only looked at the immediate effect of glucose levels instead of the long-term possibilities of benefits. Another limitation includes the type of stretches done. There were no stretches that included the torso region – only lower and upper extremity stretches were completed.

In conclusion, active static stretching in people with type 2 diabetes, pre-diabetes, or those at risk for diabetes does not significantly lower blood glucose levels in comparison to doing nothing. The idea that a diabetic patient could stay at home and stretch himself or herself in order to reduce blood sugar levels after a high sugar meal may not be applicable. Further studies should be done to modify the stretches completed, and there should be consideration to try dynamic active stretching instead of static stretching.

CHAPTER VI

SUMMARY

The purpose of this experiment was to determine if static stretching could produce statistically significant lower blood glucose levels in persons with type 2 diabetes, those with pre-diabetes, and at risk populations for diabetes. Due to the possibility of peripheral neuropathy, diabetics may have a harder time completing their suggested daily activity levels; by studying the effect of static stretching on blood glucose, a possible alternative pathway could be found for diabetic exercise health prescription.

For the purpose of this study, males and females were diagnosed as type 2 diabetic, pre-diabetic, or had an increased risk of type 2 diabetes as defined by the ADA diabetes risk test (ADA, 2015). Participants came in following a two-hour fast and randomly completed one of two testing trials, static stretching or no activity at all. During both trials, participants drank 355 ml can of fruit juice with forty-three grams of sugar, and had their blood glucose tested after thirty, fifty-two, and seventy-five minutes. The experimental group completed nine stretches, five lower body and four upper body; the control group just sat for the duration of the time.

Although insignificant, there was a decrease in blood glucose values in the experimental group from the start time to the half way point in stretching compared to the control group that was trending towards significance; for the first twenty minutes, the blood glucose in the experimental trial dropped an average of thirty mg/dL where the control group dropped only fifteen mg/dL. When comparing the half way point to the end of the stretching session, there was a significant difference favoring the control group; the experimental trial increased one mg/dL, and the control group decreased twenty mg/dL. Overall, the control trial decreased the most, however, this difference was not significant. The experimental trial decreased nineteen mg/dL whereas the control decreased about thirty-five mg/dL. Therefore, static stretching the lower extremities for twenty minutes may not be a way to lower blood glucose in the diabetic population following a high-sugar intake meal.

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