The effect of yoga practice on glucose control, physiological stress, and well-being in type 2 diabetes: exploring a mechanism of action

Maricarmen Vizcaino

University of Texas at El Paso, vizcainoyoga@gmail.com

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THE EFFECT OF YOGA PRACTICE ON GLUCOSE CONTROL, PHYSIOLOGICAL STRESS, AND WELL-BEING IN TYPE 2 DIABETES: EXPLORING A MECHANISM OF ACTION

MARICARMEN VIZCAINO
Doctoral Program in Interdisciplinary Health Sciences

APPROVED:

Kathleen O’Connor, Ph.D., Chair
Kristin Gosselink, Ph.D.
Jules Simon, Ph.D.
Kathryn Schmidt, Ph.D.
Jeannie Concha, Ph.D.

Charles Ambler, Ph.D.
Dean of the Graduate School
Dedication

For Pedro and Isabel
You were my strength and inspiration for every step I took throughout this journey
THE EFFECT OF YOGA PRACTICE ON GLUCOSE CONTROL,
PHYSIOLOGICAL STRESS, AND WELL-BEING IN TYPE 2 DIABETES:
EXPLORING A MECHANISM OF ACTION

by

MARICARMEN VIZCAINO, MS

DISSERTATION

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ABSTRACT

Multiple studies have found yoga practice to be effective in improving glucose control and other health markers of adults with type 2 diabetes mellitus (T2DM). However, current findings cannot reach a consensus given multiple methodological inconsistencies. The primary purpose of this dissertation work was to investigate the impact of yoga practice on the glucose control of participants with T2DM through two different approaches and hence two separate exploratory studies. The first study, a quasi-experimental design, examined the effect of eight weeks of yoga practice on glucose control taking into account previous limitations in the literature. The second study, a single-subject design, examined the acute effect of yoga practice on momentary glucose control. The secondary purpose was to explore a mechanism of change that may explain possible improvements in glucose control of T2DM patients by investigating diurnal variations of hormones associated with the stress response and examining concurrent variations in measures of psychological and emotional health. In the quasi-experimental study, yoga participants showed a decrease in hemoglobin A\textsubscript{1c} at the end of the intervention compared to the control group, but change was not statistically significant. Diurnal curves of both cortisol and dehydroepiandrosterone (DHEA) showed an overall trend towards improvement, and perceived stress was found significantly lower at the end of the intervention in yoga participants. Changes in morning cortisol and DHEA were found significantly correlated to perceived stress, positive and negative emotions. In the single-subject design, some participants showed the greatest decrease in glucose levels after 60 min. of yoga practice compared to a control condition, and these decreases appeared to be related to decreases in cortisol and changes in positive and negative emotions, but results were inconsistent. In addition, the magnitude of the effect of yoga on glucose seems to vary between individuals and depend on current level of health status. Findings from this study guarantee further investigation in the future. In addition, this dissertation provides important lessons learned for future researchers focusing on this topic and this priority population.
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CHAPTER 1: INTRODUCTION, STATEMENT OF PURPOSE, AND SPECIFIC AIMS

1.1 INTRODUCTION

1.1.1 Introduction and Relevance of the Study

Numerous studies have investigated the effect of yoga practice on the glucose control of type 2 diabetes mellitus (T2DM) patients. The majority of the studies have found significant decreases in glucose levels and improvements in other health markers; however, due to multiple methodological flaws it is not currently possible to conclude with confidence that yoga is beneficial for the health of the T2DM patient. Moreover, the majority of the current studies in the literature lack an adequate description of participants’ characteristics and of the yoga intervention. Consequently, it is difficult to determine if yoga practice is safe for all T2DM patients including those suffering from diabetes-related complications and comorbidities. Similarly, it is difficult to determine what type of yoga and which yoga components are safe and effective in improving the health of people living with this chronic disease.

The present dissertation work continues to investigate the effect of yoga practice on the glucose control of T2DM patients and attempted to address some of the limitations in the current literature. In addition, it uses two different approaches to examine the effect of yoga on glucose control in diabetes: one quasi-experimental design that explores the effect of six weeks of yoga practice and a single-subject design that explores the effect of a 60-min yoga practice session. Consequently, the present dissertation work investigates both the chronic and the acute effects of yoga practice on the glucose control of T2DM. The findings of both study designs are presented here and provide important aggregated information into the beneficial effects of yoga on the glucose control in T2DM.
Additionally, this dissertation explores a possible mechanism that may explain potential benefits of yoga practice on the glucose control of T2DM patients and therefore represents a continuation of the previous research by the present author. Previous studies have found concurrent reductions in glucose control and psychological stress. However, except for the present author, no other study has attempted to investigate a mechanism that links the physical and mental health of the patient with T2DM that can explain observed improvements in glucose control following a yoga-based intervention.

The present dissertation improves upon previous work by investigating diurnal variations of the stress hormone cortisol across four different time points during the day. Cortisol has a direct influence on glucose metabolism and may be detrimental in the health of the T2DM patient during chronic stress. The diurnal variations of dehydroepiandrosterone (DHEA) are also examined, which is an important anti-inflammatory and anti-oxidant in the body that counteracts the effects of cortisol. Lastly, psychological measures are expanded to include positive dimensions of psychological and emotional health.

1.1.2 Background

1.1.2.1 What is Diabetes?

Diabetes mellitus is a broad term to describe a group of disorders characterized by chronically elevated blood glucose levels and other disturbances of metabolism that are the result of irregular oxidation and utilization of glucose. Incidence of all types of diabetes is increasing, but particularly type 2 diabetes mellitus (T2DM). In adults, T2DM represents approximately 90-95% of all diagnosed cases of diabetes, whereas type 1 comprises 5% of cases and currently has no known cause or prevention strategy (CDC, 2014; WHO, 2015). T2DM is characterized primarily by two conditions: a reduced sensitivity to insulin in liver, muscle, and adipose tissue,
a condition defined as insulin resistance; and an impairment of β-cell secretory function that leads to inadequate insulin output (Leu & Zonszein, 2009).

Diabetes is an independent predictor for cardiovascular disease (CVD) mortality even after adjusting for age, sex, and other CVD risk factors (Devereux, 2009). Other serious diabetes-related complications include damage the nervous system and the eyes, high blood pressure, and high low-density lipoprotein cholesterol (ADA, 2015; CDC, 2014).

1.1.2.2 Diabetes Statistics

According to the Centers for Disease Control and Prevention (CDC, 2014), 29.1 million Americans have diabetes, representing 9.3% of the population. During the period of 2003 to 2006, rates of death from all causes were approximately 1.5 times higher in individuals 18 years or older previously diagnosed with diabetes compared to adults without diabetes in the United States (US). In 2010, diabetes represented the seventh leading cause of death in the country.

Similarly, the World Health Organization (WHO) estimated that in 2014 the prevalence of diabetes worldwide was 9% among adults older than 18 years (WHO, 2015), while the International Diabetes Federation (IDF) estimated this figure in 8.3%, or approximately 382 million people, from which 46% of cases are currently undiagnosed (IDF, 2013). The IDF projects that in the next decades there will be a 55% increase of diabetes cases representing 592 people in the world living with this chronic disease in the year 2035 (IDF, 2013).

1.1.2.3 Cost of Diabetes to the Society and the Individual

Diabetes represents a large economic burden to both the society and the individual. The CDC estimates that approximately $176 billion were spent in 2012 in direct medical costs in the treatment of diabetes, while $69 billion were spent in indirect costs related to disability, work loss, and premature death in the US (CDC, 2014). The IDF, on the other hand, reported that most
countries around the world dedicate between 5% and 18% of their total health expenditure exclusively to diabetes, averaging 10.8% of total health expenditure worldwide (IDF, 2013).

It is also estimated that average medical expenditures for diabetes patients is 2.3 times higher compared to those without diabetes (CDC, 2014). Moreover, 80% of people diagnosed with diabetes live in low- and middle-income countries (IDF, 2013), which makes diabetes management more difficult because of the economic burden, especially for those without medical insurance. In Latin America, it is estimated that between 40% and 60% of medical expenses come from patients and their families’ income (IDF, 2013).

Previous research has found that low-income patients are at a greater risk for acute illness complications, and are more likely to experience hospitalizations or emergency department visits for hyperglycemia or hypoglycemia compared to those with higher incomes (Dungan et al., 2008). Hence, it is of crucial importance that people suffering from this chronic disease find affordable options that aid in diabetes management so that complications are avoided. The IDF stated that the implementation of inexpensive and easy-to-use interventions can also decrease the large economic burden of diabetes, particularly in developing countries (IDF, 2013).

1.1.2.4 Relevance of Diabetes for the U.S.-Mexico Border

In North America, the US has the highest number of people diagnosed with diabetes, while Mexico has the second largest (IDF, 2013). Both countries possess a large prevalence of overweight, obesity, and physical inactivity among their populations (WHO, 2011); all risk factors for developing diabetes. The diabetes epidemic, therefore, is expected to continue in these regions of the continent in the following years. Moreover, this chronic disease seems to be a particular problem in the border region between these two countries.
The US-Mexico Border Diabetes Prevention and Control Project by the Pan American Health Organization (PAHO) estimated that more than 1.11 million people in the bi-national border region have been diagnosed with diabetes representing a prevalence of 14.9%, which is significantly higher compared to the rest of the U.S. In addition, 40.2% of adults in the Mexico Border States and 11.6% of adults in the US Border States were undiagnosed in 2002, whereas 12.5% of adults were categorized are pre-diabetics in the US-Mexico border region (PAHO, 2010).

Of equal concern was the high prevalence of factors that predispose individuals to develop type 2 diabetes over time within the border region. The reported overweight and obesity prevalence rates among those without diabetes were estimated as 41.2% and 30.6%, respectively (PAHO, 2010). Also observed was a more sedentary lifestyle among individuals between the ages of 44 to 64; as little as 12.8% of US participants and 14.7% Mexican participants reported job-related physical activity (PAHO, 2010). These figures indicate that in the border region diabetes is expected to continue its growing trend in the following years.

Moreover, the reported overweight and obesity prevalence rates among those already diagnosed with diabetes were estimated as 29.7% and 49%, respectively. In addition, 35.2% of participants with diabetes also suffered from hypertension, whereas an estimated 27.3% of diabetics also reported smoking. Hence, people with diabetes in the border region are also at a risk for developing diabetes-related complications and cardiovascular disease (PAHO, 2010).

In Texas, it has been reported that the prevalence of diabetes is higher close to the Mexico border, and diabetes-related lower extremity amputations are almost twice as high along the US-Mexico border compared to non-border counties (Huang, 2006). Specifically in El Paso, a city located in West Texas along the US-Mexico border and in close proximity to Juarez,
Mexico, the diabetes rate was estimated as 15.3% in 2013 (Saldivar, 2014), a prevalence also much higher than the rest of the country. El Paso Diabetes Association has estimated that in 2012, diabetes emergencies cost local hospitals an excess of 100 million dollars (EPDA, n.d.).

1.1.3 The Role of Stress in Type 2 Diabetes Mellitus

1.1.3.1 The Physiological Response to Stress

Optimal physiological functions and the sustenance of life in general are the result of the body maintaining a stable internal environment in spite of the demands from the external environment. In order to deal with these demands, the body is capable of eliciting a series of physiological changes that allows it to respond to the potential threat to the organism’s integrity and ultimately return to a state of homeostasis (Lovallo, 2005). This is what is defined as the physiological response to stress.

There are two different types of systems that maintain optimal functioning in the body: homeostatic systems and allostatic systems. The first one must be maintained within narrow limits, such as blood oxygen, pH, or body temperature. The second one possesses broader ranges and is the one that allows the body to respond to challenges (McEwen, 1998). Hence, allostatic systems allow the body to remain stable by being able to change themselves in order to meet external demands (McEwen & Lasley, 2002).

Allostasis is produced by a complex organized system of communication between several physiological systems in the body including the sympathetic nervous system, the endocrine system, and the immune system. The allostatic response has two purposes. The first one is to initiate a complex adaptive pathway, which is initiated at the brain where the hypothalamus secretes a hormone called corticotropin-releasing factor (CRF). The CRF targets the pituitary, which in turn secretes another hormone called the adrenocorticotropic (ACTH). The ACT
stimulates the adrenal glands to secrete the major stress hormones epinephrine and cortisol. The connection between the brain and the adrenal glands is known as the hypothalamic-pituitary-adrenal (HPA) axis and it represents the cornerstone of allostasis (McEwen, 1998).

The stress response originates from the integration of a variety of cognitive, emotional, neurosensory, and peripheral somatic signals arriving from different pathways (Charmandari, Tsigos, & Chrousos, 2005). Therefore, it is not only actual threats recognized by the brain but also perceived threats that stimulate a physiological response that leads to behavioral and physiological adaptations. Behavioral changes, such as enhanced arousal and focused attention, improve the capacity of the individual to be alert to the impending challenge and react if necessary. On the other hand, the main objective of physiological changes is to increase energy available for mobilization. For this purpose, oxygen and nutrients are redirected to the central nervous system (CNS) and exercising muscle; meanwhile, other functions are inhibited such as digestion, growth, and reproduction (Charmandari et al., 2005).

Adaptations in metabolism are initiated with the actions of the catecholamines, epinephrine and norepinephrine, and glucagon. In order to enhance availability of vital substrates as part of the immediate stress response these hormones elevate blood glucose levels rapidly by mobilizing glucose from existing storage sites through glycogenolysis and lipolysis. This process is known as the fight-or-flight response, first recognized by Walter Cannon in the first half of the 20th century, and describes the role of the sympathetic-adrenal medullary system in allowing an animal or human to deal with immediate threats to the organism. These threats may be the encounter with a predator or simply perceived danger which lead to fast physiological adaptations that include an increased heart rate and respiratory rate, an increased conversion of glycogen to glucose, among others. These in turn increase blood flow and availability of oxygen
in the blood, as well as availability of glucose in the skeletal muscle and brain cells. Once the threat is removed, the body re-establishes homeostasis and returns to normal physiological function (McCarty, 2016).

During the second phase of the stress response glucocorticoids, such as cortisol, sustain and prolong the availability of glucose previously initiated in the first phase. This is achieved through enhanced gluconeogenesis and increased provision of substrates from peripheral tissues that include primarily amino acids from muscle and glycerol from adipose tissue. In addition, glucocorticoids maintain glucose levels elevated through inhibition of further substrate storage by decreasing glucose uptake in peripheral tissues like muscle and fat, a condition known as insulin resistance (Sapolsky, Romero, & Munck, 2000).

The second purpose of the allostatic response is to shut down the physiological changes induced by stress once the challenge or the threat has passed. This shutting down of central and peripheral responses is essential for successful adaptation. If the inactivation of the stress response is inadequate there will be an overexposure to stress hormones, which over long periods of time can lead to allostatic load and consequently pathophysiological consequences (Charmandari et al., 2005; McEwen, 1998).

Research indicates that chronic stress significantly impact glucose homeostasis and is associated with the dysregulation of metabolism over time including visceral accumulation of adipose tissue and insulin resistance (Kyrou, Randeva, & Tsigos, 2017). Overexposure to stress hormones would be especially detrimental for those already diagnosed with T2DM since it can further augment the inability of the body to oxidize glucose effectively leading to poor glycemic control. Therefore, interventions that help to manage psychological stress and in turn decrease the magnitude and the frequency of the physiological response to stress would be especially
relevant for T2DM patients as part of a holistic health management program that aims to improve glycemic control and overall health.

1.1.3.2 Psychological Distress and Self-Care

One of the main sources of stress for individuals living with diabetes is the burden of caring for this chronic disease. The need for self-care may generate high levels of stress above and beyond the everyday stress that we all experience as part of our everyday lives. Self-care not only includes attending doctor’s appointments and rigorous medication regimes, but also constant glucose monitoring, adjustments to diet and physical activity, and continual checking for symptoms that may indicate any of the diabetes-related complications.

According to the American Diabetes Association (ADA) diabetes-related distress is the psychological stress related to the burden of self-care that may disrupt the life of the diabetes patient, and is characterized by emotions of worry, frustration, concern, and burnout (Gebel, 2013). It is estimated that between a third and a half of people with diabetes will experience diabetes distress in an 18-month period (ADA, 2013).

Previous studies have found an association between diabetes-related distress and poor health outcomes in patients with T2DM. Karlsen, Oftedal, & Bru (2011) found a statistically significant association between diabetes distress and the presence of diabetes-related complications in 425 Norwegian adults, aged 30-70 years, with T2DM. Another cross-sectional study by Ting et al. (2011) found significant associations between diabetes distress and high glucose levels, and between diabetes distress and obesity, in 189 Chinese adults, aged 18-65 years, with T2DM. In addition, Ting et al. (2011) observed a significant negative association between diabetes distress and quality of life; indicating that the more distress the lower the quality of life in patients with T2DM.
Similarly, Tsujii et al. (2012) found a significant association between diabetes distress and poor long-term glucose control in 3305 Japanese adults with T2DM and a mean age of 64.9 years. Interestingly, Tsujii et al. (2012) found no association between depression and glucose control. Moreover, the relative risk for poor glycemic control significantly increased as diabetes distress increased even after adjusting for age, sex, body mass index, type of diabetes therapy, and diabetes duration. On the other hand, depressive symptoms showed no significance for relative risk. The results from this study may indicate that diabetes distress, instead of depression, is linked to health deterioration in patients with T2DM.

Fisher et al. (2010) examined the previous hypothesis in an 18-month observational study that included 506 patients with T2DM. The sample was comprised of males and females, multiple ethnicities, mean age of 57.8 years, and a mean duration of disease 8.1 years. The authors found that only diabetes distress but not depression was significantly associated with poor glucose control in both, the cross-sectional model and the time-covarying model. That is, only diabetes distress was related to poor glucose control at baseline and across time when controlling for variables such as age and sex.

Recent studies support the previous findings. A longitudinal study by Aikens (2012) examined if depressive symptoms and diabetes-related distress could predict glycemic control in 253 adults, aged 27-88 years, previously diagnosed with T2DM. The author found that diabetes distress scores, but not depression scores, were statistically and positively associated with high glucose levels at baseline. Also, diabetes-related distress was a significant predictor for high glucose levels at six months even after adjusting for age, sex, insulin use, and depression scores; whereas depression scores were not a significant predictor for glucose control.
Based on the previous evidence, reducing psychological stress, in particular diabetes-related distress, is of utmost importance given the connection between poor mental health and physical health outcomes in adults with T2DM and should be the focus of further scientific inquiry. A few studies have already investigated the impact of behavioral interventions aimed at reducing the stress associated with diabetes care on the health status of patients with T2DM, and have found positive results. For example, Zagarins, Allen, Garb, & Welch (2012) implemented a six-month diabetes self-management education intervention to 234 adults with T2DM, aged 30-80 years, and found significant reductions in diabetes distress at the end of the study, which were related to significant improvements glucose control.

Future studies should continue to investigate therapies that may reduce psychological stress and consequently improve the health status of patients with T2DM. Psychological stress that derives from the burden of self-care not only affects self-care itself (ADA, 2015), but also may continue to activate the physiological stress response previously described overexposing patients with T2DM to stress hormones. Chronic elevations of cortisol are particularly detrimental since cortisol, by increasing insulin resistance and gluconeogenesis, maintains glucose levels elevated (Lovallo, 2005) which are already abnormally high in individuals with T2DM.

1.2 STATEMENT OF PURPOSE

The purpose of this dissertation work was to investigate the effect of yoga practice on the glucose control of T2DM patients and contribute to the current literature by addressing several methodological limitations in previous studies. It explored the chronic and acute effects of yoga practice on the glucose control of this specific population through two different methodological approaches: the chronic effect of yoga was examined through the implementation of an 8-week
yoga intervention and assessment of changes in hemoglobin A1c, whereas the acute effect of yoga was examined through the implementation of a 60-min yoga session and assessment of changes in capillary glucose. In addition, this dissertation explored a possible mechanism that may explain potential benefits of yoga practice on the glucose control of T2DM patients by examining changes in measures of psychological health and well-being along with biomarkers of the stress response.

1.3 SPECIFIC AIMS AND HYPOTHESES

The specific aims of this dissertation work were:

**Aim 1:** To investigate the impact of yoga practice on the glucose control of participants with T2DM through two different approaches and hence two separate exploratory studies. The first study examined the chronic effect of yoga practice on glucose control taking into account previous limitations in the literature. The second study examined the acute effect of yoga practice on momentary glucose control.

The hypotheses of the first study were the following:

H1: Hemoglobin A1c will significantly decrease following eight weeks of practice in the yoga group and compared to a control group following standard care alone

H2: Perceived stress and diabetes-related distress will significantly decrease following eight weeks of practice in the yoga group and compared to a control group following standard care alone

H3: Positive emotions, balance emotions, and psychological well-being will increase, whereas negative emotions will decrease following eight weeks of practice in the yoga group and compared to a control group following standard care alone
H₄: Diurnal variations of salivary cortisol and salivary DHEA will significantly improve following eight weeks of practice in the yoga group

The hypotheses of the second study were the following:

H₁: Glucose levels will decrease following a 60-min yoga session compared to a 60-min control condition
H₂: Positive affect will increase following a 60-min yoga session compared to a 60-min control condition
H₃: Negative affect will decrease following a 60-min yoga session compared to a 60-min control condition
H₄: Salivary cortisol levels will decrease following a 60-min yoga session compared to a 60-min control condition

Aim 2: To explore a mechanism of change that may explain possible improvements in glucose control by investigating if decreases in psychological stress, along with increases in emotional and psychological well-being, take place concurrently with improvements in the stress hormone profile and glucose control. The overarching hypothesis was that improvements in psychological and emotional health will reduce physiological stress, which in turn will improve glucose control of T2DM patients (Figure 1).

The hypotheses for the first study were the following:

H₁: Changes in measures of psychological and mental health will be significantly associated to changes in the stress hormone profile
H₂: Changes in the stress hormone profile will be significantly associated to changes in glucose control
The hypothesis for the second study was the following:

H₁: Improvements in emotional health will match decreases in salivary cortisol and glucose levels
Figure 1.
The hypothesized effect of yoga practice on the glucose control of individuals with type 2 diabetes mellitus. Dark grey box represents the independent variable. Light grey boxes represent different dimensions of the independent variable. Blue boxes represent the dependent variables. Orange boxes represent psychological and biological measures that are used to quantify concepts under study.
CHAPTER 2: LITERATURE REVIEW

2.1 YOGA AS A COMPLEMENTARY THERAPY IN TYPE 2 DIABETES MELLITUS

Yoga may be an adequate complementary therapy in the management of T2DM. Research has previously shown the effectiveness of yoga in improving physical health, including muscular strength and flexibility, in healthy adults of varied ages (Halder, Chatterjee, Pal, Tomer, & Saha, 2015); and in decreasing pain and enhancing functional ability in individuals with musculoskeletal conditions like rheumatoid arthritis and low back pain (Ward, Stebbings, Cherkin, & Baxter, 2013). Studies have also found yoga effective in reducing cardiovascular risk factors such as systolic and diastolic blood pressure, heart rate, and respiratory rate in a variety of populations including those at risk for diabetes and those already diagnosed with diabetes (Cramer et al., 2014).

Moreover, research supports the beneficial impact of yoga practice on mental health. Previous studies have found significant decreases in psychological and physiological outcomes associated to stress in a varied of participants including children aged 10-17 years and healthy adults aged 20-67 years (Chong, Tsunaka, Tsang, Chan, & Cheung, 2011; Sharma, 2014). Yoga practice has been shown to decrease symptoms of anxiety and depression, perceived stress, and negative affect; whereas it increases positive psychological attitudes, mindfulness, and well-being. Yoga also has been shown to inhibit rises in serum cortisol levels during a stress challenge, to decrease salivary cortisol levels over time, and to improve heart rate variability (Chong et al., 2011; Sharma, 2014).

Studies have also found yoga practice more effective than traditional exercise in improving multiple health-related outcomes, except physical fitness, in both healthy individuals and populations with chronic diseases. For instance, yoga has been found to be more beneficial
than exercise for reducing pain and fatigue; improving anti-oxidant status, heart rate variability, sleep, and quality of life; and decreasing perceived stress and salivary cortisol; whereas exercise is more effective than yoga for improving maximal oxygen consumption, energy expenditure, and maximal heart rate (Ross & Thomas, 2010).

2.1.1 Current Research on the Chronic Effect of Yoga on Type 2 Diabetes Mellitus

Multiple studies have investigated the chronic impact of yoga practice on several health markers of patients with T2DM. Glycemic control measures have included fasting blood glucose (FBG), post-prandial glucose (PPG), and glycated hemoglobin (HbA1c). The term FBG refers to blood glucose levels during the fasting state; PPG refers to blood glucose levels 2 hours after eating a meal, most commonly measured with a 75-g oral glucose tolerance test (OGTT) for research and diagnostic purposes (ADA, 2015). On the other hand, HbA1c is the non-enzymatic attachment of glucose molecules to the hemoglobin chain, and reflects glucose levels in the last 2-3 months; hence, it is used as a measure of long-term glycemic control (Vella, 2008).

According to the ADA (2015), all three tests can be used to diagnose and monitor the progression of diabetes. However, the International Diabetes Federation has suggested that HbA1c should be used to monitor blood glucose control using high-precision methods (IDF, 2012).

Additional outcomes investigated in the yoga and diabetes literature have included insulin binding receptor and internalization of the insulin receptor complex (Gordon et al., 2008), measures for lipid profile (Agrawal et al., 2003; Agte & Tarwadi, 2004; Balaji et al., 2011; Bindra et al., 2013; Gordon et al., 2008; Kumar & Kalidasan, 2014; Madanmohan et al., 2012; Nagarathna et al., 2012; Pardasany et al., 2010; Singh et al., 2008; Singh et al., 2015; Skoro-

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1 For the purposes of this dissertation the term “chronic” is defined as any period of yoga practice longer than four weeks and less than six months.
Kondza et al., 2009; Rajesh et al., 2013; Vaishali et al., 2012), oxidative stress (Agte & Tarwadi, 2004; Hedge et al., 2011; Gordon et al., 2008; Mahapure et al., 2008), autonomic function (Jyotsna et al., 2014; Rajesh et al., 2013), antioxidant status (Hedge et al., 2011), cognitive brain function (Kyizom et al., 2010), blood pressure (Agrawal et al., 2003; Gordon et al., 2008; Kumar & Kalidasan, 2014; Skoro-Kondza et al., 2009; Singh et al., 2015), renal function (Agrawal et al., 2003; Gordon et al., 2008), psychological stress (Singh et al., 2015; Vizcaino, 2013), and quality of life (Agrawal et al., 2003; Madanmohan et al., 2012; Singh et al., 2015; Skoro-Kondza et al., 2009; Jyotsna et al., 2014; Vizcaino, 2013).

Studies have used a variety of designs including matched-control, pre-post, cohort studies, and randomized controlled trials (Appendix A, Table 1). Length of interventions has ranged from 45 days to six months, and number of participants has ranged from ten to 277. All studies have included both sexes, except for Madanmohan (2012) that included only females and Rajesh et al. (2013) that included only males. All studies have included T2DM patients following standard care that included diabetes medication, except for Popli et al. (2014) who recruited only adults not taking oral hypoglycemic drugs or insulin. Most of the control groups, when used, followed standard care alone, but there were a few studies in which yoga was compared against a prescribed exercise program (Gordon et al., 2008; Nagarathna et al., 2012; Subramaniyan et al., 2012) or other practices such as tai-chi (Pardasany et al., 2010) and music (Singh et al., 2015).

The majority of the studies have found significant improvements in varied health outcomes of patients with T2DM following yoga practice. Pre-post test designs using a 6-week yoga intervention observed improvements in glucose control, lipid profile, and mental health of participants previously diagnosed with T2DM. Females (N=15), aged 36-63 years, in the Madanmohan (2012) study showed significant decreases in FBG, PPG, cholesterol, triglycerides,
among others, after the yoga intervention. On the other hand, in preliminary data, this author found significant reductions in anxiety and perceived stress levels, and significant improvements in measures of self-care and quality of life after yoga practice in 10 adults of both sexes, aged 60-80 years (Vizcaino, 2013).

Another pre-post test design by Rajesh, Sastry, & Parvathi (2013) also found significant improvements in glucose control, including FBG and HbA₁c, and lipid profile of 98 male patients of ages 30-60 years that completed 100 days of yoga practice. In addition, significant reductions were found in systolic blood pressure, diastolic blood pressure, and resting heart rate at the end of their intervention.

Controlled trials have also found yoga effective in improving several health markers of adults with T2DM. Hedge (2011) divided 123 patients aged 40-75 years into a treatment group that underwent a three-month yoga intervention and a control that followed just standard care. At the end of the study he found significant decreases in body mass index, FBG, PPG, and HbA₁c; in addition to improvement in anti-oxidant status in the experimental group but not in the control group. Similarly, Popli (2014) observed significant reductions in FBG, PPG, and HbA₁c in the experimental group that completed a six-month yoga program, whereas the control group did not show any observable pattern of improvement in glucose control from a sample of 80 patients aged 30-60 years.

Controlled designs matching the groups for age and sex have encountered similar findings. Mahapure, Shete, & Bera (2008) allocated 30 patients aged 40-55 years into an experimental group that practiced six weeks of yoga and a control group following standard care, and found significant increases in the antioxidant enzyme superoxide dismutase in the experimental group, whereas the control group showed significant decreases in this marker of
antioxidant activity at the end of the study. In addition, the experimental group showed significantly greater decreases in HbA$_{1c}$ and FBG compared to the control group.

Similarly, Kyizom, Singh, Singh, Tandon, & Kumar (2010), observed significant decreases in FBG and PPG only in the experimental group that completed a 45-day yoga program, but not on the control group, in a sample of 60 patients aged 35-60 years; while Gordon et al. (2008) found significant improvements in the antioxidant enzyme superoxide dismutase, HbA$_{1c}$, and FBG in the experimental group that completed a six-month yoga program, but not on the control group, in a sample of 231 patients aged 40-70 years.

Another controlled design by Dash & Thakur (2014) investigated the impact of a 40-day yoga program and divided 60 patients aged 40-60 years into experimental and control groups that were matched for age, sex, body mass index, duration of diabetes, and glycemic baseline parameters. At the end of the intervention, significantly greater reductions in FBG, PPG, and HbA$_{1c}$ were found in the experimental group compared to the control group. Additionally, a significant improvement was found only in the lipid profile of patients that practiced yoga, including cholesterol, triglycerides, and high density lipoprotein.

A number of randomized controlled trials have also found yoga effective in improving several health markers of adults with T2DM. The first trial that appeared in the literature examined the impact of 12-weeks of yoga practice, twice per week, in 11 patients with T2DM and found significant improvements in FBG and HbA$_{1c}$ at the end of the study compared to 10 controls following diet alone. In addition, three patients from the yoga group reduced their glucose lowering medication at the end of the study. However, no information was provided on statistical significance of medication reduction or the age of the participants and hence it is
difficult to generalize findings from this study (Monroe, Power, Comer, Nagarathna, & Dona, 1992).

In more recent years, several randomized controlled trials have implemented three-month interventions of daily yoga practice to participants with T2DM between the ages of 35-69 years and all have found significant improvements in glucose control, including FBG, HbA₁c, and PPG, and several markers of lipid metabolism in the yoga group compared to the control group (Agrawal et al., 2003; Balaji, Varne, & Ali, 2011; Kumar & Kalidasan, 2014; Sharma et al., 2015; Vaishali, Kumar, Adhikari, & UnniKrishnan, 2012).

Amita, Prabhakar, Manoj, Harminder, & Pavan (2009) also found significant decreases in FBG and PPG, along with improvements in what they described as symptoms associated with diabetes such as headache, insomnia, anxiety, and distress in 20 adults with T2DM aged 35-65 years that engaged in three months of daily yoga practice. Unfortunately, no information was provided on the 21 patients that comprise the control group even when this study was reported to randomly divide participants into experimental and control groups. Similarly, Agte & Tarwadi (2004) found reductions in HbA₁c, FBG, PPG, total cholesterol, and triglycerides in 57 patients aged 45-65 years that completed a four-month yoga intervention; however, no statistical comparison with the 30 patients that comprised the control group was provided.

Other studies implementing three-month yoga interventions have also reported enhancements in glucose control and lipid metabolism in participants with T2DM. Bindra, Nair, & Darotiya (2013) found significant declines in HbA₁c, FBG, total cholesterol, low density lipoprotein, and triglycerides in an experimental group that practiced three months of yoga compared to a control group in a sample of 100 patients aged 35-65 years; whereas Pardasany, Shenoy, & Sandhu (2010) found significant decreases in HbA₁c, FBG, PPG, low density
lipoprotein, and total cholesterol in the yoga group compared to the control group in a sample of 45 patients aged 40-60 years.

In contrast, Skoro-Kondza, Tai, Gadelrab, Drincevic, & Greenhalgh (2009) found small decreases in HbA\textsubscript{1c} that were not statistically significant in 29 adults with T2DM with a mean age of 60 years that completed a three-month yoga intervention, compared to 30 adults with T2DM that served as controls. However, their intervention had a frequency of practice of twice per week instead of daily practice like the previous studies, and attendance was reported to be low, approximately 50%. Hence, it may be possible that continuous practice is crucial to observe significant improvements in glucose control.

Shorter yoga interventions have been found effective in improving health markers of patients with T2DM when practice is daily. Singh, Kyizom, Singh, Tandon, & Madhu (2008) implemented a 45-day yoga intervention to 30 patients between the ages of 35-60 and found significant reductions in FBG, HbA\textsubscript{1c}, and PPG levels and an improved lipid profile at the end of the study compared to 30 patients in the control group. On the other hand, Subramaniyan, Subramaniyan, & Chidambaran (2012) implemented 15 days of yoga practice to a group of 10 patients aged 31-40 years and found significant decreases in FBG, comparable to the decreases observed in 10 patients that engaged in brisk walking during the same period of time.

Longer interventions by Singh, Khandelwal, & Sherpa (2015) and Nagarathna et al. (2012) also used daily practice and found yoga effective in enhancing the overall health of adults previously diagnosed with T2DM, except for Jyotsna et al. (2013). Nagarathna et al. (2012) implemented a nine-month yoga program to 141 patients aged 30-78 years and observed significant decreases in all markers of glucose control and lipid profile at the end of the study. On the other hand, their exercise control of 136 patients aged 30-74 years following a
calisthenics program showed significant improvement in only some health markers including PPG, HbA1c, triglycerides, total cholesterol, and very low density lipoprotein at the end of the study.

Singh et al. (2015) investigated the impact of six-months of yoga and music therapy on glucose control, lipid profile, and mental health of participants with T2DM compared to standard care in a sample of 278 patients between the ages of 23-73 years. At the end of the study, the yoga group showed significantly greater improvements in FBG, PPG, HbA1c, high density lipoprotein, anxiety, and quality of life compared to the music and standard care group.

In contrast, Jyotsna et al. (2013) found no changes in FBG, PPG, HbA1c in 36 participants aged 35-72 years with T2DM that practiced yoga for a period of six months compared to 28 participants with T2DM and the same age range that followed just standard care. Nonetheless, the authors found significant improvements in sympathetic autonomic functions and quality of life in the yoga group compared to the control. The intervention implemented by Jyotsna et al. (2013) focused exclusively on the breathing element of yoga called pranayama; therefore, it is possible that a more holistic approach that incorporates all elements of yoga is necessary to observe improvements in glucose control in participants with T2DM.

2.1.2 Current Research on the Acute Effect of Yoga on Type 2 Diabetes Mellitus

Research on the acute effect of yoga practice on glucose control and other health markers in T2DM is very limited, with only one study reported by the current literature (Cokolic, Herodez, Sternad, & Krebs, 2013). In this study, changes in PPG in participants with T2DM that completed a single 30-min yoga session were investigated. The experimental group was composed of 110 patients, whereas the control group was composed of 101 patients; each group was further divided into those taking diabetes medication and those not taken medication. All
participants provided baseline blood samples followed by the consumption of a 250 kcal meal. After that, a 90-min lecture plus a 30-min session was completed by the experimental group and a 120-min lecture was completed by the control group. The authors found significant decreases in blood glucose levels after yoga practice in the experimental group, both in those taking medicine and those without medicine; whereas the control group still showed elevated glucose levels after the 120-min lecture. In addition, overall well-being substantially improved in participants that completed the yoga session. Therefore, it is possible that the effect of yoga on glucose metabolism starts immediately after the first session, but it is only sustainable with constant practice.

2.1.3 Limitations of Current Research on Yoga and Type 2 Diabetes Mellitus

The majority of the studies previously described showed the effectiveness of yoga practice in improving multiple health markers of patients with T2DM including those of glucose control, lipid metabolism, autonomic function, oxidative stress, mental health, and quality of life across a large range of ages and both sexes, compared to standard care alone and some forms of exercise. Nonetheless, the principal concern regarding the positive results reported in the literature is the multiple methodological limitations that decrease the confidence in the results and hence weaken the support of scientific evidence of yoga as a complementary therapy in T2DM.

2.1.3.1 Assessment of Glucose Control

Numerous studies did not report any information on blood collection, handling, and testing (Agrawal et al., 2003; Agte & Tarwadi, 2004; Amita et al., 2009; Bajali et al., 2011; Bindra et al., 2013; Hedge et al. 2011; Jyotsna et al., 2014; Kyizom et al., 2010; Monroe et al., 1992; Popli et al., 2014; Singh et al., 2008; Sharma et al., 2015; Skoro-Kondza et al., 2009;
Vaishali et al., 2012), some reported collection of venous blood without information on blood processing or analysis (Madanmohan et al. 2012, Pardasany et al., 2010), and others reported analysis method but no assay information (Kumar & Kalidasan et al., 2014; Gordon et al., 2008b; Nagarathna et al., 2012).

Moreover, two studies reported the use of glucometers instead of glucose analyzers for the measurement of FBG (Gordon et al., 2008b; Subramaniyan et al., 2012). Previous research has found that results obtained from glucose meters and laboratory glucose analyzers can differ significantly enough to influence clinical care in patients kept at similar glucose concentrations (Petersen et al., 2008).

Also, none of the studies that reported measurement of PPG provided a protocol for an oral glucose tolerance test to obtain this glucose assessment (Agte & Tarwadi et al., 2004; Amita et al., 2009; Balaji et al., 2011; Cokolic et al., 2013; Dash et al., 2014; Hedge et al., 2011; Jyotsna et al., 2014; Kumar & Kalidasan, 2014; Kyizom et al., 2010; Madanmohan et al., 2012; Nagarathna et al., 2012; Pardasany et al., 2010; Popli et al., 2014; Sharma et al., 2015; Singh et al., 2008; Singh et al., 2015). Variations in protocol can significantly affect the results. For example, you can obtain a different result depending on the type of specimen that you are collecting during the procedure; capillary whole blood tends to overestimate blood glucose concentration compared to venous whole blood across several time points during the test (Kuwa, Nakayama, Hoshino, & Tominaga, 2001).

Hence, because many yoga studies omit specific information on glucose analyses it is very difficult to determine if results were valid and reliable. It is possible that variations in glucose between pre- and post- assessments were partly due to variations in protocol or unreliable equipment. In addition, it is difficult to make comparisons between studies given
variations in methodology, and consequently difficult to generalize positive findings of yoga practice for T2DM.

Another concern is the lack of reporting of equipment used to assess glucose control. Certain health conditions, such as hemolytic anemias, renal disease, or liver disease, can affect the accuracy of HbA1c results (IDF, 2012; WHO, 2011). For instance, in individuals with hemoglobin variants, like sickle cell anemia, certain HbA1c tests provide falsely high or low readings that can result in over-treatment or under-treatment of diabetes. Therefore, researchers should either use a method that is not affected by hemoglobin variants or exclude participants with these conditions (NGSP, 2010). In the yoga and diabetes literature previously presented, only one of the studies that measured HbA1c reported exclusion of participants with health conditions that may affect the accuracy of the test (Vizcaino, 2013), and only two studies reported methods that are not affected by hemoglobin variants (Nagarathna, 2012; Vizcaino, 2013).

2.1.3.2 Control of Extraneous Variables

Another important limitation in the current literature of yoga and diabetes is the lack of control and/or monitoring of variables that may significantly impact glucose variations of participants with T2DM, and are not the main focus of the study. These variables include diet, exercise, and medication. Diet and exercise alone can significantly improve glucose control in T2DM patients as shown in several large randomized clinical trials (Diabetes Prevention Program Research Group, 2002; Lindstrom et al., 2006; Li et al., 2008). Likewise, medications significantly lower glucose levels through a variety of mechanisms including increased insulin secretion, improved insulin sensitivity, reduced glucose absorption in the gastrointestinal tract, and reduced glucose output from the liver, among others (Beaser, 2010). Therefore, it is of
crucial importance that any changes in diet, additional exercise other than yoga, and medication are monitored and kept constant during the duration of the intervention to ensure that observed improvements in glucose control are due solely to yoga practice and not due to extraneous variables not under investigation.

The majority of the studies in the yoga and diabetes literature failed to report any monitoring of changes in diet and exercise levels during the intervention, or failed to use a statistical model to control for these variables. Some studies reported that diet and medication were held constant during the intervention (Hegde et al., 2011; Rajesh et al., 2013; Singh et al., 2008; Balaji et al., 2011), whereas others reported that participants were instructed to record their diet, exercise and medication (Agte & Tarwadi, 2004; Gordon et al., 2008b; Jyotsna et al., 2014; Pardasany et al., 2010; Sharma et al., 2015; Singh et al., 2015; Vaishali et al., 2012) but no information on these records were provided in the results that allow the reader to determine if changes in extraneous variables took place during these studies or not.

Only one study conducted actual estimations on diet and exercise changes before and after the intervention through diet recalls that were analyzed with dietary software for caloric intake and macronutrient composition; and a physical activity questionnaire that estimated frequency, duration, and intensity of physical activity (Vizcaino, 2013). Also, only one study conducted statistical analysis on medication changes before and after the intervention through quantification of dosage per day; although no distinction was made between different classes of oral hypoglycemic agents (Nagarathna et al., 2012).

Hence, based on the current literature it is not possible to establish the degree of influence of extraneous variables on measures under investigation, and in turn, the independent role of
yoga in the observed improvements in glucose control and other health markers in these studies is still unknown.

2.1.3.3 Inadequate Description of Patients’ Characteristics

Few authors have provided a complete description of T2DM participants in their studies (Appendix A, Table 2). Only 13 studies showed the initial body mass index of the participants (Agrawal et al., 2003; Agte & Tarwadi, 2004; Amita et al., 2009; Balaji et al., 2011; Dash et al., 2014; Hedge et al., 2011; Gordon et al., 2008; Jyotsna et al., 2014; Rajesh et al., 2013; Singh et al. 2008; Singh et al., 2015; Vaishali et al., 2012; Vizcaíno, 2013). From those studies that reported body mass index, only one included participants with obesity (Vizcaíno, 2013); in fact, the majority of the studies included patients that were marginally overweight. It is well-known that obesity increases insulin resistance (Bonadonna et al., 1990; Ciaraldi, 2010), which will worsen glucose control in diabetes. Based on current findings, it appears that yoga is effective to improve glucose control in normal to marginally overweight adults with T2DM; the efficacy of yoga on the glucose control of patients with T2DM and concurrent obesity is still unknown.

Similarly, only 13 clearly specified presence/absence of diabetes-related complications (Agrawal et al., 2003; Amita et al., 2009; Balaji et al. 2011; Dash et al., 2014; Hedge et al., 2011; Kumar & Kalidasan, 2014; Kyizom et al., 2010; Gordon et al., 2008; Popli et al., 2014; Sharma et al., 2015; Singh et al. 2008; Vaishali et al., 2012; Vizcaíno, 2013), and for those that reported complications (Hedge et al., 2011; Vaishali et al., 2012) there was no further description on which specific complications participants were suffering from such as neuropathy, retinopathy, among others. Based on the current literature, it is still uncertain whether yoga practice is safe or not for patients that suffer diabetes-related complications or comorbidities that may require special precautions during exercise (ADA, 2015; Vizcaíno, 2014).
In addition, only three studies reported specific information on the type of diabetes medication used by patients (Agrawal et al., 2003; Singh et al., 2015; Vizcaino, 2013). Some studies mentioned that participants were taking oral hypoglycemic agents and/or insulin, or using diet and exercise control alone, whereas others only mentioned that participants were on medication. As a result, we are also still uncertain about the safety of yoga for patients taking medications such as sulfonylureas that increase the risk of hypoglycemia.

2.1.3.4 Limited Research on the Acute and Long-Term Effects of Yoga on T2DM

Current research is limited to the effects of yoga after several weeks of practice, specifically from 6 to 24 weeks. Only one study has investigated the acute effects of yoga on the glucose metabolism of T2DM patients (Cokolic et al., 2013), and no longitudinal study has been reported so far on yoga and T2DM. It is important that future research also focuses on the acute effects of yoga practice on glucose control and other health parameters in T2DM participants. Exploring both the acute and the chronic effects of yoga in diabetes can help us understand whether any potential benefits derive from transitory changes in metabolism or from long-term physiological adaptations that improve glucose kinetics and other functions in the body. In addition, longitudinal studies can inform us whether the body keeps adapting and evolving from constant practice, and any potential side effects from long-term practice.

2.1.4 Strategies to Address Current Limitations in the Literature

Given shortcomings in the current literature, future investigations must follow more rigorous scientific methodology in order to provide strong evidence of the beneficial use of yoga as a complementary therapy in the treatment of T2DM. Specifically, methods for the assessment of glucose control should be valid and reliable, comparable to large randomized controlled trials that have previously investigated the impact of exercise on diabetes. There should be close
monitoring of any changes in diet, physical activity, and medication during the duration of the yoga intervention so these can be taken into account when interpreting the results.

In addition, an adequate description of participants’ characteristics is of utmost importance to clarify the effects of yoga across different T2DM subgroups. This information is critical so that clinicians make informed decisions about the suitability of yoga as a complementary therapy for their patients with T2DM with specific diabetes-related complications and comorbidities.

2.1.5 The Relevance of Investigating Acute Effects of Yoga on Type 2 Diabetes Mellitus

For many decades the science of exercise physiology has extensively investigated physiological adaptations to exercise. Following exercise training, the amount of change in physiological responses such as breathing, circulation, and metabolism can be quantified, which is termed an “adaptation.” Moreover, the amount of adaptation of a physiological response at rest, during and after exercise, is often associated with an improvement in health. Hence, changes in blood pressure, lipid profile, insulin sensitivity, heart function, and body composition would be considered “health” adaptations (Buckley, Holmes, & Mapp, 1999).

There are numerous physiological adaptations as a result of exercise training. Cardiorespiratory changes following prolonged aerobic exercise include a lower resting heart rate which is associated with increased vagal tone and reduced sympathetic nervous activity, a decrease in total peripheral resistance which contributes to lower blood pressure, and an increased size of the cardiac muscle that allows the heart to pump more blood per beat with less effort (Guilder & Janot, 2015). There is also an increase number of mitochondria and improved capillary density following endurance training; hence there is better blood circulation to the exercising muscle and better oxygen transport (Powers & Howley, 2007).
Neuromuscular adaptations include gains in muscle strength as a result of synchronization of motor unit activation and muscle hypertrophy (Wright, 2015). In addition, the hormonal response to a given absolute exercise load decreases with continuous exercise, which may be the result of enhanced target tissue sensitivity or responsiveness. For instance, there is a reduced stimulation of the sympathetic nervous system at the same absolute workload after exercise training (Wright & Merrill, 2015). Because of these and other physiological adaptations, exercise decreases the risk of developing CVD, T2DM, and some forms of cancer; it also lowers all-cause mortality and morbidity (Garber et al., 2011).

Investigating the acute effects of exercise can help us understand how the above mentioned physiological changes begin to take place in the body as a result of exercise demands. In fact, acute physiological changes represent important immediate benefits to our health. For instance, glucose metabolism is enhanced temporarily after just a single exercise session. This is particularly helpful in T2DM patients who experience immediate reductions in glucose levels due to increased glucose utilization following exercise without the need of insulin. As a reminder, T2DM suffer from a condition known as insulin resistance in which the hormone insulin cannot work properly. As a result, during resting conditions and after a meal consumption peripheral tissues struggle to obtain glucose from the bloodstream and subsequently utilize it for metabolic functions; that is why glucose levels remain elevated. But since glucose is transported into the skeletal muscle cell through a different mechanism during exercise that does not require insulin (Ploug, Galbo, & Richter, 1984), a person with diabetes can obtain from exercise the same benefits that a person without diabetes would obtain (Goodyear & Kahn, 1998; Kennedy et al., 1999). We know about these immediate benefits because of prior studies examining acute effects.
Studies on the acute effects of exercise can also help us to determine the duration, intensity, and frequency that is required from a particular form of exercise to elicit beneficial physiological changes, which in turn guide exercise recommendations. For example, previous research has found that isocaloric exercise bouts (that is, exercise sessions that require the individual to spend the same amount of calories) of moderate and high intensity produce identical changes in glucose homeostasis and insulin secretion in T2DM, indicating that overall energy expenditure, and not maximum exercise intensity is responsible for the glucose metabolism changes observed following exercise in T2DM (Galbo, Tobin, & van Loon, 2007).

Hence, a greater emphasis should be placed on the energy expended during an exercise session, rather than on the intensity used which can be just a matter of personal preference. A person with T2DM can choose to exercise at a moderate intensity for 60 minutes or at a high intensity for 30 minutes, as long as both equal the same amount of calories expended, in order to positively impact glucose metabolism. The American Diabetes Association (2015) actually recommends that adults with diabetes, just as the general population, should engage in at least 150 min/week of moderate-intensity exercise or 75 min/week of vigorous-intensity exercise, which is an equivalent of 30 min/day/5xweek and 25 min/week/3xweek respectively. For diabetes patients, the only caveat is the presence of diabetes-related complications; for instance, vigorous exercise is not recommended for those with proliferative diabetic retinopathy.

Investigating the acute effects of yoga on health adaptations can help us understand the initial physiological changes that occur in the body following this practice and that represent immediate benefits to our health. In people with T2DM, it is of particular importance to examine the acute effects of yoga on factors that represent the greatest impact on physical and mental health such as glucose control, lipid profile, depression, and diabetes-related distress.
Research on the acute effects of yoga may also help us elucidate the intensity, frequency, and duration of the practice that is necessary to obtain health-related benefits that ultimately lead to overall health improvements, especially relevant for a population like individuals with T2DM that may consider yoga as a complementary therapy. Lastly, investigating the acute effects of yoga using different styles and components of yoga can continue to open up the field of inquiry into which form of yoga and which aspect of yoga are the most beneficial for health adaptations.

2.1.6 The Importance of Accurate Description of Yoga Intervention

Yoga is a rich and complex practice, with deep philosophical roots that are thousands of years old. The practice can be divided into different yoga schools or branches based on the philosophical perspective of the path of choice. Even when the goal of all yoga practices is the same and some principles between them may overlap, the specific focus of each school is different, e.g. devotion to a Supreme Being, selfless action for the benefit of others, study of ancient scriptures, moral discipline, meditation on sound, among others (Hewitt, 2001; Feuerstein, 2001).

One of these branches or yoga schools is hatha yoga. This practice emphasizes the strengthening and purification of the body through physical poses and cleansing procedures. In addition, the practitioner learns to have control over the senses through breathing techniques and meditation (Feuerstein, 2001). In common and simple terms, hatha yoga can be defined as a discipline that enhances physical health through exercise and hygiene, heightens awareness and control over respiration, and improves mental health by teaching the individual to control fluctuations of the mind that may derive in strong negative emotions.

Hatha yoga appears to be the most common form practiced in the U.S. (Ross, Friedmann, Bevans, & Thomas, 2013; Singleton, 2010). The practice has evolved so much over the last
century that modern yoga has little resemblance to the original spiritual path described by ancient Hindu philosophical texts; as a result, some authors describe contemporary practice as postural yoga (Singleton, 2010). Hatha is also used to describe a general term for yoga (Woodhall & Sattin, 2013). From hatha yoga a multitude of yoga styles have emerged such as Bikram yoga, practiced in a 100 degree temperature room; Iyengar yoga, practiced with a variety of props that aid in proper posture alignment; restorative yoga, a gentle variation that uses multiple props for deep relaxation; Asthanga yoga, a series of poses practiced in rapid transitions that require high levels of strength, flexibility, and balance; among others.

A shortcoming of current yoga research in general is the inadequate description of the yoga intervention in a large proportion of yoga studies (Elwy et al., 2014). In the same way, the majority of the studies investigating the impact of yoga in T2DM did not provide a detailed description of the yoga intervention implemented. As table 1 shows only a few studies specified yoga school or style used (Agte & Tarwadi, 2004; Amita et al., 2009; Cokolic et al., 2013; Gordon et al., 2008; Jyotsna et al., 2013; Pardasany et al., 2010; Vizcaino, 2013), and some authors did not even describe the frequency of yoga practice (Agte & Tarwadi, 2004; Bindra et al., 2013; Pardasany et al., 2010). Since most of the reports did not explicitly state the yoga school followed in the study, it can only be assumed that hatha yoga was implemented based on the incorporation of hatha yoga elements like asanas, pranayama, and meditation. However, it is difficult to determine the specific hatha yoga style used by researchers based on the information provided.

Furthermore, as can be observed in Table 1, yoga components included in the interventions varied greatly between studies. As a result, we are still uncertain about which components may be exerting the influence on the observed reductions in glucose control and
other health parameters reported in the literature. Or, it can be the case that yoga as a holistic intervention that integrates physical movement with breath control, meditation, and relaxation, provides the health benefits reported by the previously described studies.

Given multiple modes of current yoga practice it is of special importance that researchers describe in detail the specific yoga intervention implemented during a study. Different styles of practice may produce different effects. Asthanga yoga may induce greater exercise-derived benefits, such as improved insulin sensitivity; whereas restorative yoga may induce greater relaxation and subsequent decrease in stress hormones.

Furthermore, some styles may be inadequate for T2DM. Hot yoga may be harmful for patients with autonomic neuropathy that are unable of proper thermoregulation. Similarly, styles like Asthanga and Vinyasa flow may be extremely difficult for patients that are deconditioned and have limited range of motion, strength, and balance (ADA, 2015; Vizcaino, 2014). A previous study that investigated the feasibility of community-based yoga classes for adults with T2DM reported that in the yoga teachers’ perspective few participants were suited to a general yoga class due to their frailty, low fitness levels, and present comorbidities; therefore, participants with T2DM should have personalized yoga plans (Skoro-Kondza et al., 2009). A previous report also recommended the careful design and implementation of yoga programs that take into consideration the initial fitness level of the patient and current diabetes-related complications (Vizcaino, 2014).

Lastly, if positive results are found in a study, the careful description of the yoga intervention can be used as a template for future yoga programs implemented across community centers and the clinical setting. By incorporating emerging knowledge on beneficial impact and
safety of yoga for different populations, such as for T2DM patients, the validity of yoga as a complementary therapy in a variety of chronic diseases and health conditions can be supported.

2.2 POSSIBLE MECHANISMS OF CHANGE FOLLOWING YOGA PRACTICE IN TYPE 2 DIABETES MELLITUS

In spite of the putative beneficial effects of yoga practice on the health of adults with T2DM, it is still unknown how yoga may produce changes in glucose control. Recognizing how yoga improves glucose control can further support the use of this practice as part of an integrative health care plan for the diabetes patient.

Several yoga studies have suggested mechanisms of change that might explain the improvements in glucose control after yoga practice. Some authors have proposed that twisting and compression during asanas may stimulate intra-abdominal organs (Madanmohan et al., 2012), which ultimately leads to the rejuvenation of pancreatic beta cells and in turn increases utilization of glucose in peripheral tissues and the liver (Balaji et al., 2011; Kumar & Kalidasan, 2014; Kyizom et al., 2010; Sharma et al., 2015; Singh et al. 2008; Subramaniyan et al., 2012).

However, none of the studies actually investigated these proposed mechanisms and therefore there is no empirical evidence substantiating these hypotheses that may explain how the beneficial outcomes previously presented take place.

For instance, C-peptide concentrations are used to assess endogenous insulin production and are usually lower in later stages of T2DM when the pancreas has lost a significant capacity to secrete insulin (Bell, 2003). Significant increases in C-peptide levels have been observed following pharmacological therapies, such as thiazolidinedines treatment (Ovalle & Bell, 2002), but there are no yoga studies in the literature that have investigated changes in C-peptide
concentrations in diabetes patients. Thus, there is no direct evidence of the regeneration of pancreatic beta cells following a yoga intervention.

Authors have also suggested that insulin sensitivity is enhanced following yoga practice. Several studies have found increases in insulin sensitivity following endurance exercise in T2DM patients, which can be the result of enhanced glucose transport to the cell surface and improvements in lipid metabolism (Colberg, 2013). Numerous yoga studies have found significant improvements in PPG after yoga practice, which may indicate that yoga as an alternative form of exercise improves glucose tolerance. Nonetheless, insulin sensitivity has not been measured directly.

None of the studies previously described, including those that suggested enhanced insulin sensitivity as a potential mechanism of change, has described the implementation of clamp techniques, or estimations such as the homeostasis model assessment (HOMA) or quantitative insulin sensitivity check index (QUICKI) for the assessment of insulin sensitivity (Trout, Homko, & Tkacs, 2007). Only Gordon et al. (2008) and this author reported measurement of insulin levels in T2DM patients undergoing a yoga intervention and found no significant changes in this parameter (Gordon et al., 2008; Vizcaino, 2013).

Moreover, the insulin sensitivity theory represents an additional problem. The majority of the studies that have examined effects of exercise on insulin sensitivity in T2DM patients have used exercise interventions that range from moderate to vigorous in intensity. Similarly, large prospective clinical trials that have found improvements in glucose control after a behavioral intervention have used moderate intensity physical activity. Prior research has classified yoga as a “low intensity” form of physical exercise that does not meet current recommendations for levels of physical activity that are required to improve and sustain health (Hagins, Moore, &
Rundle, 2007). Given the “low intensity” level of yoga practice, improvements in insulin sensitivity similar to those observed during endurance exercise would not be expected, except perhaps in yoga styles that are considerably physically demanding like modern vinyasa.

Other mechanisms suggested to explain improved glucose status following yoga practice are regulation of psychoneuroendocrine function (Madanmohan et al., 2012), normalization of autonomic balance through the decrease of sympathetic nervous system and the increase of vagal tone (Amita et al., 2009; Madanmohan et al., 2012; Mahapure et al., 2008; Nagarathna et al., 2012; Rajesh et al., 2013), reduction of psychological stress (Amita et al., 2009; Mahapure et al., 2008; Monroe et al., 1992; Singh et al. 2008), and decreased stress hormones (Subramaniyan et al., 2012). Nonetheless, none of these previous authors presented empirical evidence to support these suggested mechanisms and did not even present a description of their postulations.

Detailed hypotheses have been presented recently. In a previous publication, this author suggested that yoga may work through two different pathways. In the first one, yoga may lower psychological stress and anxiety that may be accompanied by decreases in the hormone cortisol. This is turn, may reduce the chronic activation of gluconeogenesis at the liver and may enhance the insulin response from the pancreas, which translates into lower circulating glucose levels and better glycemic control. In the second one, by reducing psychological stress and anxiety yoga may improve overall well-being which in turn may enhance diabetes self-care which include following dietary and physical activity guidelines, among others (Vizcaino, 2013). Better self-care subsequently improves glucose control as supported by the literature (ADA, 2015).

On the other hand, Hansen & Innes (2013) stated that mechanistic pathways underlying the presumed beneficial impact of yoga on cardiovascular and diabetes risk profiles are likely complex and interacting, and suggested four different pathways. In the first one, the decreased
activation of the sympathoadrenal system and hypothalamic pituitary adrenal (HPA) axis, or decreased levels of stress, will lead to improved sleep and mood which in turn improve metabolic profile including reduced insulin resistance, dyslipidemia, and obesity and increased glucose tolerance. In the second one, vagal stimulation and improved parasympathetic function will lead to lower levels of perceived stress and subsequent improved sleep, mood, and metabolic profile. In the third one, yoga practice may lead to selective activation of specific brain structures and neurochemical systems related to positive mood and attention, which will in turn produce beneficial changes in neurological structure and function, affect and memory, and sympathetic/parasympathetic balance. These changes will then improve metabolic profile, cardiovascular function and inflammatory responses. On the last pathway, improved fitness, strength, and physical function may lead to improved metabolic and psychological risk profiles, neuroendocrine function, potential weight loss and improved body composition. Hansen & Innes (2013) clarified that these mechanisms are still speculative; however, they provide a conceptual framework that incorporates possible pathways through which yoga can enhance health and that can inform future research and clinical interventions.

2.3 THE CONTRIBUTION OF A REDUCED PHYSIOLOGICAL STRESS RESPONSE TO GLUCOSE CONTROL IN TYPE 2 DIABETES MELLITUS

The overall theory that yoga may improve glucose control through stress reduction is supported in light of previous findings. Amita et al. (2009) found decreases in a variety of symptoms including insomnia, anxiety, and distress, along with significant improvements in FBG in T2DM patients undergoing a 3-month yoga intervention. This author found significant improvements in perceived stress, anxiety, and measures of quality of life in combination with trends towards improvement in cortisol levels, FBG, and HbA1c in T2DM patients after a 6-week
yoga intervention (Vizcaino, 2013). Similarly, Madanmohan et al (2012) and Agrawal et al. (2003) found significant improvements in quality of life along with better glucose control in participants with T2DM following yoga practice of six weeks and three months respectively.

Singh et al. (2015) also found significant improvements in glucose control and psychological health in T2DM patients after a 6-month yoga program. In this particular study there were three different groups, all receiving standard care that consisted of 150 minutes of moderate-intensity physical activity per week, which is similar to previous lifestyle interventions for this population like the Diabetes Prevention Program. The control group followed standard care only, another group listened to classical instrumental music for 30 minutes twice a day in addition to the exercise, and the yoga group engaged in the practice of asanas and pranayama in addition to the exercise.

The three groups improved in all measures of glucose control at the end of six months, as would be expected due to the endurance exercise. However, there was a larger effect size in all measures of glucose control in the yoga group compared to the other groups. In addition, the yoga group also showed substantially greater decreases in anxiety and depression, and greater increases in quality of life compared to the other two groups. The results from this study may indicate that yoga produces a positive effect on the health of the diabetes patient that is above and beyond the effect produced by exercise alone and simple relaxation. Hence, it is the theory of stress reduction induced by yoga practice that is being investigated in depth in this dissertation work (Figure 1).
2.4 THE MIND-BODY CONNECTION: A SUGGESTED MECHANISM OF CHANGE

Previous research has shown that improvements in mental health take place concurrently with improvements in glucose control in participants with T2DM. Nonetheless, other than the present author (Vizcaino, 2013), no study has investigated the link between improved mental health and improved glucose control in this population. It is likely that this link is a decreased activation of the physiological stress response as a result of reduced psychological stress. That is, it is possible that decreases in perceived stress, anxiety, and depression in conjunction with increases in well-being may reduce the chronic exposure to stress hormones and allow for an optimal functioning of physiological systems in the body, which in individuals with T2DM translates into an improved glucose control.

In previous research, this author observed decreases in salivary cortisol in 10 adults with T2DM following six weeks of yoga practice along with decreases in perceived stress and state anxiety; however, changes in cortisol were not statistically significant (Vizcaino, 2013). This discrepancy may be due to very low statistical power, calculated post-hoc as 0.28. It may be possible that with a larger sample size changes in cortisol may achieve statistical significance and the association between improved mental health and reduced physiological stress in T2DM can be supported. Research investigating the role of yoga and meditation practice in mental and physiological stress in other populations reinforce this hypothesis.

2.4.1 Yoga, Mental Health, and Stress Hormones

A pilot study that implemented a two-month yoga intervention to 12 individuals living with HIV found significant improvements in perceived stress and distress levels associated with specific traumatic events compared to 12 controls (Agrawal, Kumar, & Lewis, 2015). There was also a trend towards improvement in cortisol and dehydroepiandrosterone (DHEA) levels in the
yoga group only; however, changes were not statistically significant perhaps also due to low statistical power.

On the contrary, a previous study investigating the efficacy of six-week yoga practice on stress levels and hypothalamic pituitary adrenal axis (HPA) dysregulation in 44 breast cancer patients found significant reductions in anxiety, depression, perceived stress, and salivary cortisol, compared to 44 controls. Moreover, authors found a significant positive correlation between morning salivary cortisol and anxiety and depression (Vadiraja et al., 2009). In the same line, another study examining the impact of yoga therapy in 54 adults with diagnosed depression found significant decreases in serum cortisol levels at the end of the three-month intervention compared to a control condition; in addition, reductions in cortisol levels were significantly associated to reductions in depression scores (Thirthalli et al., 2013).

Yoga has also been observed to decrease physiological stress after a single session in healthy college students. In a study by West, Otte, Geher, Johnson, & Mohr (2004), 21 students were assigned to an African dance class, 18 were assigned to a yoga class, and 30 were assigned to a biology lecture that served as the control. Before and after their assigned condition all participants completed scales on perceived stress and affect, and provided a saliva sample for cortisol analysis. At the end of the 90-min sessions, there was a significant decrease in perceived stress and negative affect in both the African dance and yoga groups but not in the control group; however, salivary cortisol significantly decreased only in the yoga group. Moreover, changes in positive affect and cortisol showed a significant negative correlation only in the yoga group, that is, as positive affect increased cortisol levels decreased in those that practiced yoga.
2.4.2 Mindfulness Programs, Mental Health, and Cortisol Rhythm

The cortisol awakening response (CAR) refers specifically to the dynamic cortisol secretion following awakening that is part of the normal circadian physiology of the human body. Alterations in the CAR response have been observed in physical and psychological disorders such as patients with chronic pain, gastrointestinal disorders, post-traumatic stress disorder, and chronic fatigue syndrome (Fries, Dettenborn, & Kirschbaum, 2009). Therapies that incorporate yoga elements and meditation, such as mindfulness programs, have been found useful in modifying the CAR towards a normal pattern.

For example, Carlson, Speca, Patel, & Goodey (2004) investigated the impact of an eight-week mindfulness-based stress reduction (MBSR) program on 59 patients with breast cancer and 10 patients with prostate cancer. At the end of the study, patients showed significant improvements in quality of life, stress symptoms, and sleep quality, which were accompanied by a shift from “abnormal” towards a “normal” pattern of cortisol secretion.

Similarly, Matousek, Pruessner, & Dobkin (2011) implemented an eight-week MBSR program in 33 women that completed treatment for breast cancer and found significant reductions in depressive symptomatology, perceived stress, and medical symptoms at the end of the study. In addition, a significant increase was observed in the CAR response following the intervention, indicating that cortisol secretion improved towards a normal pattern since these participants showed abnormal lower values of cortisol at the beginning of the study.

In the same line, a study examining the effects of an eight-week MBSR program on 71 patients with varying cancer diagnoses found significant improvements in perceived stress, post-traumatic stress symptoms, and emotional health in the experimental group as compared to the controls at three months follow-up. Researchers also observed a significant increase in salivary
cortisol levels at the end of the study in those participants with initial low levels of this hormone, whereas those participants with initial high levels showed significant decreases in cortisol (Branstrom, Kvıllemo, & Akerstedt, 2013). Interestingly, among patients with initial low cortisol levels, change in cortisol from baseline to three-month follow-up was negatively correlated with change in perceived stress with marginal significance, whereas among patients with initial high cortisol levels change in cortisol from baseline to three-month follow-up was positively correlated with change in post-traumatic stress symptoms with marginal significance (Branstrom et al., 2013). That is, participants with initial abnormal levels of cortisol moved towards a more normal profile three months following the intervention which was associated to improvements in mental health.

These results support the effectiveness of interventions that include components of yoga and meditation in re-establishing normal secretion patterns in the stress hormone cortisol, which are in turn associated with improvements in psychological and emotional health. Therefore, it may be possible that yoga practice, through improvements in mental health, also reduce the activation of the physiological stress response and normalizes stress hormone profile in patients with T2DM. This is especially important given that previous studies have reported the CAR to be blunted in adults with T2DM (Bruehl, Wolf, & Convit, 2009).

2.4.3 The Impact of Well-Being and Positive Emotions on the Stress Response

The investigation of the missing link between mental health and glucose control in T2DM will not be complete without the exploration of the contribution of yoga practice to the positive dimensions of mental health. As mentioned previously, yoga practice has been found effective in improving different aspects of mental health in healthy populations of varied ages, and some studies have also found concurrent improvements in cortisol secretion, which may
imply a possible relationship between mental health and physiological systems, especially those related to the stress response.

Previous cross-sectional studies support the connection between well-being and biological markers linked to the stress response. Niekerk, Huppert, & Herbert (2001) examined the association of salivary cortisol and DHEA with measures of well-being in 46 healthy men between the ages of 62-76 years. They found a significant association between higher morning DHEA and lower confusion, higher evening DHEA and lower anxiety and lower negative mood in the following morning. Conversely, higher morning cortisol and morning cortisol/DHEA ratio were significantly related to higher anxiety, general Mood disturbance, and higher negative mood in the evening. In the same line, an interesting study by Ryff, Singer, and Love (2004) explored the relation between different dimensions of well-being and a variety of neuroendocrine, immune, and cardiovascular markers in a sample of 135 healthy women between the ages of 61 and 91 years. They found that women with higher levels of personal growth and purpose in life had in average lower levels of salivary cortisol throughout the day compared with those showing lower levels of these dimensions of well-being.

The biological marker DHEA has also been investigated in resilience and the ability to recover from trauma. Petros, Opacka-Juffry, & Huber (2013) found resilience and DHEA levels significantly associated in a non-clinical sample of 32 adults with a mean age of 29 ± 5.7 years, even after controlling for age and gender. On the other hand, Yehuda, Brand, Golier, & Yang (2006) observed significantly higher DHEA levels in 40 male veterans with post-traumatic stress disorder (PTSD) compared with a group without PTSD, and these high DHEA levels could in turn be predicted by symptom improvement and coping. The authors suggested that DHEA
appeared to be linked to recovery from the impact of trauma supporting the role of DHEA in moderating recovery in this particular population.

Findings from these cross-sectional studies support the connection between mental and physical health. However, they do not explain whether changes in measures of well-being cause changes in physiological measures or vice versa. It is possible that enhancement of mental health produced the changes observed in physiological function based on the results from some experimental studies.

For instance, an investigation of the effects of an emotional self-management program on stress and emotions of 45 healthy adults found significant decreases in salivary cortisol along with significant increases in salivary DHEA in those that completed the four-week program compared to the controls. Moreover, DHEA was found significantly and positively related to positive affective states such as warmheartedness, represented by emotions like kindness, love, care, forgiveness, and compassion. On the other hand, cortisol was found significantly and positively associated to anxiety, burnout, hostility, and depression, whereas it was significantly and negatively associated to contentment and warmheartedness (McCraty, Barrios-Choplin, Rozman, Atkinson, & Watkins, 1998).

Another study examined the effects of an eight-week MBSR program on physiological and psychological outcomes in 36 early stage breast cancer survivors aged 55-62 years. At the end of intervention the experimental group showed significant increases in mindfulness scores compared to the control group. In addition, within-group analyses revealed significant decreases in morning cortisol in those completing the program, but not within controls. Additionally, the intervention group showed significant reductions in blood pressure, heart rate and respiratory rate compared to the control group (Matchim, Armer, & Stewart, 2011).
These behavioral interventions taught participants in the experimental group to approach everyday life with a different perspective such as an increased awareness of the present moment, substitution of negative emotions with positive emotions, and the conscious generation of inner peace and calm. That is, participants in the previous studies were taught to actively change their approach to potential stressful situations and ordinary life events, and in turn showed improvements in stress hormones compared to a control condition.

Therefore, it is possible that participants with T2DM may also learn to approach potential stressful situations and everyday life with a different mindset following a yoga intervention, which in turn can translate into decreases in the activation of the physiological response to stress. This would be particularly relevant for T2DM because, as mentioned previously, elevations in cortisol increase insulin resistance which is already elevated in diabetes. That is, constant activation of the stress response may lead to chronic elevations of the hormone cortisol which in turn worsen the ability of the body to metabolize glucose circulating in the bloodstream.

On the other hand, when an individual fosters a life with peace in spite of actual stressful events, activation of the stress response is less frequent and subsequently the damaging effects of chronic physiological stress decrease. This can translate into the proper functioning of cortisol, which is supposed to be deactivated after allowing the body to adapt to demanding conditions. In addition, other hormones such as DHEA may also exert its beneficial effect on the body by properly regulating immune and metabolic functions. This can eventually translate into an improved glucose control for the individual living with T2DM (Figure 1).

### 2.4.4 How Can Yoga Increase Well-Being?

Some authors suggest that the beneficial impact of yoga on mental health may come from its effects on mindfulness. Salmon, Lush, Jablonski, & Sephton (2009) described yoga as
mindfulness in motion since it provides the opportunity to maintain attention to body and breath as the practitioner progresses through a sequence of postural configurations. According to Salmon et al. (2009) attention can also be directed towards thoughts and emotions that unfold during the practice. Other authors in the field of emotion research have suggested that the capacity to regulate breathing and to witness one’s emotions as they come and go, as it occurs in yoga practice, are important processes for the regulation of emotional distress (Greenberg, 2008). Different components of yoga including postures, breathing, and meditation may train the individual to cognitively assess the nature of emotions, and in turn regulate the emotional experience not only during practice but in other situations as well.

Levine (2009), a researcher in the field of cognitive experimental psychology, provided a detailed and simple illustration of the concept of emotional regulation following yoga practice based on the philosophy of Patanjali and the Bhagavad Gita, another ancient Hindu text. He explained that in the ordinary mind information coming from the senses or from memory gives rise to fear, agitation, anger, attachment, aversions, and ego needs. These in turn will influence how an individual interprets and emotionally reacts to the incoming information. In addition, the restless, distracting activities of the mind, inner dialogues, and the succession of memories contribute to the mind’s turbulence and ultimately impair clear thinking due to confusion and misinterpretations. Hence, the individual acts from impulse and desire without regard for long-term consequences. Moreover, the fluctuations of the mind block out potential processes for self-transformation such as careful observation, reflection, and re-directing of the mind’s processes.

On the contrary, in the enlightened mind, the moral foundation of yoga serves as a filter through which the incoming information is analyzed, interpreted, and reflected upon. Postures, pranayama, and meditation, further prepare the practitioner for deeper levels of immersion so
that reflection is possible. Hence, emotions like anger, fear, aversion, and attachment are dramatically diminished and no longer determine the mind’s interpretation and action. The turbulence of the mind has ceased; the individual no longer reacts automatically but is capable of inspecting habits of thought, beliefs, and becomes aware of unconscious prejudices (Levine, 2009).

Hence, yoga is different than other mind-body techniques, like massage or biofeedback, because it provides a philosophical framework from which benefits can be extended from the actual practice into everyday life. Yoga is not just a program of physical poses and relaxation exercises, as it is commonly known in most fitness classes, but an ancient spiritual practice that is thousands of years old. Nonetheless, aside from its spiritual connotation this ancient discipline represents a profound system of philosophy through which an individual may improve his emotional, psychological, and social well-being. In other words, yoga may help practitioners to achieve ‘flourishing,’ which is an important concept in the field of positive psychology defined by Keyes (2002) as a state of complete mental health characterized by positive emotions and optimal psychological and social functioning.

Of particular relevance are the yoga sutras of Patanjali, an ancient treatise composed by the sage Patanjali around 200 A.C. that later came to be regarded as one of the six classical schools of Indian philosophy, (Bahadur, 1977). The Patanjali’s sutras or the eight-limbed path of Patanjali are a systematic method that allows the practitioner to train the mind in order to transcend his current psychological state. The first two steps of the eight-limbed path composed the moral foundation of yoga, also known as yamas and niyamas. This moral foundation is especially relevant for the translation of yoga practiced in the mat, to everyday situations and life events.
Across four different chapters composed of several *sutras*, or statements, Patanjali provides an explanation of the different steps that must be followed to change the nature of the wandering mind. For example, in *sutra* II.33, it is instructed that when you are overwhelmed by negative thoughts, you should cultivate counteracting thoughts or positive emotions (Bryant, 2009). This particular *sutra* is important first, because it recognizes that these states will arise even in the advanced practitioner, and second, because it indicates that there is a solution to these unpleasant mental states. Bryant (2009) further explained that the more one practices thoughts that are similar to the *yamas* and *niyamas* principles, such as truthfulness and contentment, the more the quality of the mind will be transformed and eventually negative thoughts will appear less often.

The principles presented by this last *sutra* are similar to recent theories in the field of positive psychology. Recent research has found that resilient individuals have the capacity to engage positive emotions in order to regulate unpleasant emotional experiences, such as a person experiencing happiness and interest along with anxiety (Fredrickson, 2001). Also, positive emotions, like joy and contentment, are associated with faster cardiovascular recovery from negative emotions compared to neutral emotions after exposure to an anxiety-inducing laboratory test (Fredrickson, Mancuso, Branigan, & Tugade, 2000).

As a result of her extensive research, Fredrickson has proposed a theoretical perspective called ‘The broaden-and-build theory.’ In her theory, the author states that positive emotions have the capacity to expand an individual’s personal physical, intellectual, social, and psychological resources which can be helpful to manage future challenges (Fredrickson, 2001). In other words, Fredrickson suggests that the cultivation of positive emotions eventually makes it easier to deal with future unpleasant emotions and uncontrollable circumstances.
It could be said that positive emotions change the nature of the mind, as presented by Patanjali in his *sutras* II. 35 - II.45. In these series of statements, the sage describes the multiple benefits derived from all the *yamas* and *niyamas*, including focus, happiness and wisdom. Then, it may be possible that the practice of the moral foundation of yoga can increase an individual’s intellectual and psychological resources as proposed by Fredrickson.

Although research is limited on the relevance of yogic philosophy on physical and mental health, there have been previous reports of the usefulness of Patanjali’s work for psychiatric disorders and addictions. In one report, an improvement rate of 84% was found among patients suffering from anxiety, depression, and neurosis that completed 30 sessions of a modified version of the eight-limbed path implemented by a therapist (Vahia et al., 1972). In another report, an overall recovery rate of approximately 60% over five years was found among alcohol and drug users that completed a program modeling the yoga sutras of Patanjali (Terhune, 1997).

Preliminary work on a healthy population also supports the potential of yogic philosophy for the enhancement of mental health. A recent study by the present author (Vizcaino, 2015) used a mixed-design methodology to investigate the impact of yoga practice that emphasized an explanation and discussion on the sutras of Patanjali on the mental health of college students free from physical and psychiatric disease. Significant decreases were found in perceived stress in conjunction with significant increases in mindfulness following four months of practice. Most importantly, in their written reflections participants described improvements across different dimensions of well-being such as positive affect, environmental mastery, and social acceptance.

### 2.5 Overview

Numerous studies have examined the effect of yoga practice for six weeks to six months on the physical health of T2DM patients and have found significant improvements in a variety of
glucose control parameters including hemoglobin A\textsubscript{1c}. Nonetheless, these studies present multiple methodological limitations including inadequate description of methodology, participants’ characteristics, and yoga intervention implemented. Hence, the current published literature does not yet provide strong support for the use of yoga as a complementary therapy for the treatment of diabetes.

Also, the current published literature does not yet provide an insight into the acute effects of yoga on the physical health of T2DM patients which would inform on the initial physiological changes that take place following practice, especially as it relates to glucose metabolism. Lastly, no previous study has empirically examined a potential mechanism that may explain the potential benefits of yoga practice for the physical health of T2DM patients.

The present dissertation work attempts to address previous limitations in the literature in order to provide further support for the use of yoga as a complementary therapy for people diagnosed with T2DM. In addition, it explores a mechanism of change and suggests that yoga practice, by reducing psychological stress, decreases the impact of the physiological response to stress which in turn allow the body to improve metabolism and ultimately enhance glucose control.
CHAPTER 3: QUASI-EXPERIMENTAL DESIGN STUDY

3.1 METHODS

3.1.1 Participants

Participants were recruited from the university through email campus announcements and flyers posted around campus. Flyers were also posted around the community including coffee shops, tea houses, restaurants, and commercial businesses. An announcement was also broadcasted in several occasions in channel 44, which is a Spanish channel that is focused mainly on the Hispanic border community.

An attempt was made to involve the medical community by reaching out to multiple physicians. More than 40 letters were sent to specialists in the areas of endocrinology, internal medicine, and family medicine that currently work at private clinics around El Paso west side area and at the University Medical Center (UMC). The letters announced the study that was being currently conducted by the Interdisciplinary Health Sciences department of the university and asked permission to post flyers in the offices and/or to refer the study to current patients. Unfortunately, no medical doctor responded. Emails were also sent to several physicians and “promotoras de salud” announcing the study and asking for help with recruitment. No one responded to these emails.

Official permission to recruit and post flyers was sought at several health clinics in the area. La Fe and Salud y Vida, P.A. never responded to emails or phone calls, whereas in Centro San Vicente permission was granted but no interested individuals from this clinic ever contacted the principal investigator. An official permission to recruit at the UMC premises was also underway, but permission was never granted and communication ceased completely with the individual that was in charge to establish a possible collaboration.
Lastly, the El Paso Diabetes Association (EPDA) kindly cooperated by announcing the study in their social network webpage and by posting flyers in their headquarters. The study was also announced in person at nutrition sessions and free yoga classes were offered at this location.

Interested individuals were pre-screened with a health questionnaire to determine qualification to participate in the study. The following inclusion criteria were addressed in the questionnaire: (1) previously diagnosed with Type 2 diabetes mellitus by personal physician, (2) females between 50 and 65 years of age, (3) no previous experience with yoga and/or meditation practice, and (4) post-menopausal. Exclusion criteria included: (1) musculoskeletal injuries, (2) liver disease, (3) current smokers, (4) current frequent drinkers, and (5) currently taking hormone replacement therapy.

The previous inclusion and exclusion criteria was established to decrease the possibility that factors unrelated to the main questions under investigation confound the results. Some studies have suggested that traits like age, sex, habitual smoking, heavy drinking, and oral contraceptive use influence the circadian rhythm of cortisol, a variable under investigation. Although some authors have suggested that impact of some of these traits is minimal (Fries, et al. 2008), expert consensus suggest that these traits should be controlled for by statistical adjustment or exclusion strategies (Stalder et al., 2015). Therefore, only post-menopausal women were recruited within a specific age range to deal with the confounders of age, sex, and menstrual cycle; it also excluded smokers, heavy drinkers, and those taking hormone replacement therapy.

3.1.2 Design

Given that participants were recruited as a convenience sample the study used a quasi-experimental design. Upon determining eligibility, participants that were willing to commit to eight weeks of yoga practice, twice per week, were placed in the yoga group. On the other hand,
those willing to come to the laboratory twice during a period of eight weeks in between visits with no yoga commitment were placed in the control group.

Hence, the study follows a pretest-posttest nonequivalent control group design. Both groups completed the same measures prior to the intervention, the intervention was administered to only one group, and after the intervention both groups completed the same measures again. In this type of design, time-related threats to internal validity are minimized since both groups are observed during the same period of time and consequently should experience the same time-related factors. However, in this design assignment bias may cause the groups to be different (Gravetter & Forzano, 2006).

Therefore, demographic characteristics and medical history were collected and carefully analyzed to determine possible intrinsic differences between participants and reduce a potential threat to internal validity. Other threats, such as differential instrumentation, testing effects, and maturation were reduced by following the same strict protocol and using the same equipment for both groups when collecting all data pre- and post-intervention.

3.1.3 Protocol

The study was approved by the Institutional Review Board (IRB) of the University of Texas at El Paso. Participants were asked to report to the exercise science laboratory at the College of Health Sciences of the university a week before starting the yoga classes at a convenient time and day for them. Once in the laboratory, participants were provided with the IRB informed consent form, which was explained in detailed by the principal investigator (PI). After the informed consent form was signed, blood pressure and heart rate were assessed followed by anthropometric characteristics including height, body mass, waist circumference, and body composition. Then, a small blood sample was taken for the measurement of glucose
control. Next, participants completed all self-report psychological questionnaires that assessed levels of stress and well-being in the past month, as well as current lifestyle including diabetes self-care, physical activity, and diet. Detailed instructions were provided on what each scale was intended to measure and how each scale was completed.

Before participants left the laboratory, they were trained to collect the saliva samples at home. They were provided with a kit containing detailed written instructions and collection material. Instructions included avoidance of alcohol and food 60 minutes before sampling, avoidance of dental procedures 48 hours prior to collection, among others. A medication log was also provided so that participants could take it home and complete it having their own medication available for reference. Participants were asked to return to the laboratory to deliver the saliva samples and the medication log at a convenient time and day during the following week.

Each participant spent approximately 80-90 minutes in the laboratory during each visit. The IRB form and all surveys were provided in both English and Spanish depending on participants’ preference. All anthropometric data, surveys, and biological parameters were measured before the beginning of the intervention and at the end of the intervention by all participants, except for the saliva samples which were only collected by the yoga group.

3.1.4. Measures

3.1.4.1 Physical measures

*Height.* Height was measured to the nearest 0.1 cm without shoes with a stadiometer

*Body mass.* Body mass was measured to the nearest 0.1 kg with a scale.

*Body mass index (BMI).* Body mass index was calculated by dividing mass in kilograms by height in meters squared.
**Waist circumference.** The waist circumference was measured to the nearest 0.1 cm at the narrowest part of the torso, above the umbilicus and below the xiphoid process, while the participant was standing with the arms at the side, feet together, and abdomen relaxed. A cloth tape measure with a spring-loaded handle (Gulick tape, model 67021, Country Technology, Inc., Gays Mills, WI) was placed around the skin surface without compressing the subcutaneous adipose tissue by pulling on the end of the tensioning mechanism until the calibration point was seen; the measurement next to the tape’s zero line was recorded. Duplicate measurements were taken and the procedure was repeated if measures were not within 5 mm of each other. The average of the two measurements was recorded as the waist circumference in centimeters for each individual (ACSM, 2014).

**Blood pressure and heart rate.** Blood pressure and heart rate were measured with an automatic digital blood pressure monitor (Model HEM-907XL, Omron Healthcare Inc., Vernon Hills, IL). Participants were asked to sit quietly on a chair for at least five minutes prior to their blood pressure/heart rate measurement with their arm at heart level. An appropriate sized cuff was wrapped firmly around the upper arm and aligned with the brachial artery. Systolic pressure, diastolic pressure, and heart rate were displayed on the LCD screen. Measurements were taken in duplicate within five minutes apart from each other. The average of the two measurements was recorded as the blood pressure in mmHg and heart rate in beats per minute for each participant (ACSM, 2014).

**Body composition.** Body composition was estimated through plethysmography with the BOD POD® body composition system (Life Measurement Inc., Concord, CA). This machine calculates body volume by air displacement inside a closed chamber. Using the calculated body volume along with body mass, the individual’s percent fat mass, fat mass, and lean mass is
estimated. The machine was properly warmed up at the beginning of each data collection day and was properly calibrated before each measurement as indicated in the operator’s manual (version 1.69).

For the measurement protocol participants were asked to wear either a bathing suit or tight-fitting clothing, a cap that covered their hair completely, and no jewelry. Each participant was asked to step on a scale and keep still for a few seconds while body mass was recorded by the machine’s scale. Then, participants were asked to enter the chamber and remain still, quiet and relaxed while body composition assessment was taking place. The machine asked for 2-3 tests, each lasting approximately one minute, with a brief pause between tests that allowed for the opening of the chamber. In total, participants were inside the chamber no more than five minutes during each visit.

Detailed instructions of the procedure were provided before the tests to inform participants about what will happen during the tests and decrease any possible anxiety associated with these tests. Participants were also informed that they could ask to have the tests terminated at any point or they could decline the body composition assessment completely if they wish. After the tests were completed, participants were asked to step out of the chamber carefully and were allowed to put on their clothes again. Percent fat mass was recorded, as well as fat mass and lean mass in kilograms for each participant.

3.1.4.2 Biological measures to assess glucose control and the stress hormone profile

*Hemoglobin A₁c.* Glucose control was assessed through hemoglobin A₁c or glycated hemoglobin (HbA₁c) with the DCA 2000+ analyzer (Bayer HealthCare LLC., Elkhart, IN), which utilizes an immunochemical technique with monoclonal antibody. The procedure measures specifically the concentration of hemoglobin A₁c and the concentration of total
hemoglobin; the ratio is reported as percent hemoglobin A\textsubscript{1c}. Before data collection pre- and post-intervention, the machine was tested for accuracy with the DCA hemoglobin A\textsubscript{1c} control kit (Siemens Healthcare Diagnostics Inc., Tarrytown, NY). The kit allows the calculation of both normal and abnormal hemoglobin A\textsubscript{1c} values within set ranges. The machine’s proper operation was also tested pre- and post-intervention through multiple optical tests, as described by the operator’s manual.

During data collection, the PI collected a small blood sample from each participant through fingerstick after following a proper hand hygiene protocol and putting on gloves. Each participant was sitting down and was asked to hold a hand in a downward position, so that gravity aided to augment blood supply. The puncture site was disinfected with an alcohol swab and allowed to air dry. Then, a lancet device was placed against the puncture site and was pressed down firmly. The used lancet was discarded into a sharps container. The glass capillary of the DCA capillary holder was filled with approximately 1 \(\mu\)L of whole blood and was then inserted into the DCA reagent cartridge (Siemens Healthcare Diagnostics Inc., Tarrytown, NY). Analysis started within five minutes after blood collection. The cartridge was scanned and inserted into the machine for analysis. After approximately 6-7 minutes, results were displayed in the screen and provided percent hemoglobin A\textsubscript{1c} which was recorded for each participant.

**Cortisol and dehydroepiandrosterone (DHEA).** Cortisol and dehydroepiandrosterone (DHEA) levels were assessed through saliva. Participants who completed the yoga intervention were asked to collect four saliva samples at home (immediately after awakening, 30 minutes after waking, noon, and bedtime) prior to the intervention and another four samples post-intervention. Participants were provided detailed instructions verbally at the lab and in writing for future reference. They were also provided with a form and asked to record collection time on
every sample. Every single salivary sample was used for the measurement of both cortisol and DHEA.

For the saliva collection, participants were asked to tilt the head forward and gently force saliva through the saliva collection aid and into the vial (Salimetrics LLC, State College, PA). The vial was filled to at least 1 mL. Participants were then instructed to place the samples in their home refrigerator freezer and return the samples to the laboratory at a convenient day and time for them within the next week. Participants were provided with an insulated bag and dry ice to transport samples. Once samples were returned, they were stored in a -20° C freezer until analysis.

On the day of the analysis all samples were thawed completely, centrifuged at 1500 x g for 15 minutes, and analyzed for cortisol/DHEA content using enzyme competitive immunoassay kits specifically designed and validated for the quantitative measurement of these biological markers (Salimetrics LLC, State College, PA). In these kits, cortisol/DHEA in standards and samples compete with cortisol/DHEA enzyme conjugate for the antibody bindings sites on a microtitre plate. Following an incubation period unbound components are washed away. Bound cortisol/DHEA enzyme conjugate produces a reaction, which when it is stopped produces a yellow color that can be read through optical density on a standard plate reader. The amount of cortisol/DHEA enzyme conjugate detected is inversely proportional to the amount of cortisol/DHEA that is present in the sample. Each sample was analyzed in duplicate and the average of the two results for each biological marker was recorded as the cortisol value (µg/dL) or DHEA value (pg/mL).

**DHEA/Cortisol ratio.** Several studies have found that the assessment of stress hormones in isolation sometimes cannot provide useful information on the health status of an individual.
suffering from a chronic condition and/or high levels of stress. For instance, Cruess et al. (1999) found no changes in cortisol as disease progressed in HIV-seropositive men, but observed significant increases in the cortisol/DHEA-S ratio. Similarly, Ozasa, Kita, Inoue, & Mori (1990) found no changes in individual levels of cortisol and DHEA, but significant reductions in the DHEA/cortisol ratio after gynecological surgery in otherwise healthy women. As a result, it has been suggested that DHEA-to-cortisol ratios are a clinically important marker of anabolic balance and may indicate susceptibility to diseases associated to stress and aging (Maninger et al., 2009). Therefore, the DHEA/cortisol ratio was also examined in the present investigation.

3.1.4.3 Questionnaires to assess psychological stress, emotional and psychological well-being

Perceived Stress Scale (PSS). General perceived stress was assessed with the Perceived stress scale (PSS) by Cohen, Kamarck, & Mermelstein (1983). The scale measures the degree to which individuals find their lives unpredictable, uncontrollable, and overloaded. It is composed of ten items, each answered in a 5-point Likert scale ranging from ‘never’ to ‘very often.’ The scale has demonstrated adequate psychometric properties in previous investigations (Cohen & Williamson, 1988).

Problem Areas in Diabetes Questionnaire (PAID). Stress associated specifically with diabetes, that is diabetes-related distress, was assessed with the problem areas in diabetes questionnaire (PAID) by Polonski et al. (1995). The PAID is a self-report questionnaire that consists of 20 items that describe negative emotions associated to diabetes. Items are answered in 5-point Likert scale ranging from ‘not a problem’ to ‘serious problem,’ and cover areas related to diabetes care, diabetes complications, and living with diabetes. Research has shown that the
PAID has high reliability ($\alpha = 0.95$), and adequate discriminant and convergent validity (Polonski et al., 1995).

**Scale of Positive and Negative Experience (SPANE).** The scale of positive and negative experience (SPANE) by Diener et al. (2009) measures frequency of subjective feelings of well-being and ill-being in the last month. It is composed of 12 items; six items assess positive feelings whereas six items assess negative feelings. Each item is answered in a 5-point Likert scale ranging from ‘very rarely or never’ and ‘very often or always.’ The scale has demonstrated good psychometric characteristics including reliability ($\alpha = 0.89$) and convergent validity with other scales of feelings and other relevant scales (Diener et al. 2010).

**Flourishing scale.** The flourishing scale by Diener et al. (2009) measures social-psychological prosperity. It is composed of eight items that describe different dimensions of human functioning including positive relationships, feelings of competence, and purpose in life. Each item is answered in a 7-point Likert scale ranging from ‘strong disagreement’ to ‘strong agreement.’ The scale has shown adequate psychometric characteristics such as reliability ($\alpha = 0.87$) and convergent validity with other measures of psychological well-being and other relevant scales (Diener et al. 2010).

### 3.1.4.4 Extraneous variables

In order to reduce the possibility that external factors not of interest in this study threatens internal validity, all participants were asked to maintain current levels of physical activity, diet, and medication, and were asked to report any changes in their lifestyle during the duration of the study. These variables were also assessed and monitored through self-report scales and analyzed for significant changes pre- and post- intervention. In addition, participants provided a medication log before and at the end of the intervention.
**Self-care inventory revised (SCI-R).** The revised version of the self-care inventory (SCI-R) was used to measure diabetes self-care. The SCI-R is a 10-item self-report measure that has previously shown adequate psychometric properties including reliability, convergent and discriminate validity (Weinger, Butler, Welch, & La Greca, 2005). It uses a 5-point Likert scale ranging from ‘never’ to ‘always’ to assess how well a patient has followed recommendations for self-care in the past month. The scale covers areas related to glucose monitoring, medication compliance, diet, and exercise, among others.

**Physical activity.** Physical activity was estimated through the International Physical Activity Questionnaire (IPAQ) short version targeted to adults 18-65 years of age and previously assessed for adequate validity and reliability (Craig et al., 2003). The IPAQ short version asks specific questions about the frequency and duration of different modes of physical activity including those of vigorous intensity, moderate intensity, and walking. Overall physical activity per week is estimated in METs (metabolic equivalents). In addition, the IPAQ asks about the time that an individual spends sitting on a given day.

**Diet.** Diet was documented through a brief questionnaire that focused on the incorporation of healthy foods into the diet as outlined by the American Diabetes Association (2011). Participants answered in a simple yes and no dichotomy to nine questions that asked whether certain foods were consumed on a regular basis such as healthy fats, low-fat protein, fruit, and vegetables.

**Medication.** A medication log was completed by all participants which described all prescribed and over-the-counter medication currently taken. The log included name of medication, dosage, number of pills per day and number of days per week.
3.1.5 Intervention

The yoga group underwent an 8-week systematic holistic yoga program that included poses (asanas), breathing exercises (pranayama), meditation, and philosophical principles based on the Eight-Limb Path of Patanjali. Classes lasted between 50-60 minutes and had a frequency of twice per week. Participants were provided with all yoga equipment they needed including mats, straps, blocks, and blankets. Classes took place at a gymnasium at the university campus Mondays and Wednesdays from 5 pm to 6 pm. Classes were taught in Spanish since all participants were fluent in Spanish, but not in English.

A simple, straightforward explanation of philosophical principles was provided at the beginning of the first session of every week. Participants’ were provided with 5-10 minutes lectures on a specific topic, followed by the opportunity to ask any questions or clarify any doubts. Then, on the second session of every week participants were provided with handouts that reviewed the topic of the week.

For the physical aspect of the program, asana instruction started every day with a gentle warm-up that included neck and shoulder rolls, hip circles, torso lateral flexions, and gentle forward flexions. Then, actual asanas were performed and modified to accommodate varied levels of flexibility, balance, and strength. Each asana was held for at least three long and deep breaths. Participants were encouraged to adjust their body only up to a comfortable position that allow them to obtain the maximum benefit of the pose without pain.

Because all participants had been sedentary for a long time their range of motion was limited and therefore most asanas had a very low level of difficulty. Over time, participants were encouraged to adjust their body into higher levels of difficulty that allowed them to feel deeper stretches and generate greater muscular force. More challenging poses were also introduced over
time; however, participants never reached a difficulty level seen in styles of yoga such as power or vyniasa flow during the 8-week period and hence the entire program can be considered for beginners. The physical practice comprised approximately 20-30 minutes of each class.

For the mental aspect of the program, short periods of mindfulness meditation were introduced at the first day of classes. Participants were instructed to first become aware of their bodily posture and release muscular tension consciously with every exhalation by focusing on one part of their body at a time beginning with the feet and legs and ending at their face. Then, they were instructed to shift their attention to the natural rhythm of their breath.

As the intervention progressed, participants were guided to explore non-judgmentally and with curiosity any mental distractions and emotions that may be present at that particular moment. Then, they were invited to release those distractions and emotions with patience during every exhalation until they could center their entire attention on their breath. Meditations at the beginning of every class were short expanding from 5-10 minutes.

Meditation/relaxation exercises at the end of classes were between 10-15 minutes. These were conducted while participants were laying prone on the ground in the “savasana” or “corpse” pose. Similar to initial meditations, participants were instructed to relax their bodies consciously one part of the body at a time, then to shift their attention to their breath and clear their minds.

A more detailed description of the yoga intervention is presented in Appendix C, including sample classes and sample handouts provided to participants. Handouts were provided in both English and Spanish, based on participants’ preference.

3.1.6 Statistical analysis

Data was analyzed with the Statistical Package for the Social Sciences (SPSS) version 20. Data is presented as means and standard deviations. Statistical assumptions were examined prior
to analysis. All data was found to be normally distributed for both the yoga and the control group, as assessed by skewness and kurtosis values and by visual inspection of normal Q-Q plots, except for hemoglobin A\textsubscript{1c} scores.

Paired t-tests were conducted separately by group to assess differences between pre- and post-intervention scores in body composition, stress hormones, and questionnaires for stress and well-being. On the other hand, because hemoglobin A\textsubscript{1c} data showed positive skewness a log transformation was attempted; however, even after the transformation data remained not normal. Hence, the Wilcoxon signed-rank test was chosen to assess differences between pre- and post-intervention scores for this variable.

In addition, Pearson correlation analyses were conducted to assess association among the variables under investigation, that is, between glucose control and stress hormones, and between these biological parameters and measures of psychological stress and well-being. Significance was set at alpha 0.05.

Because of low recruitment difficulties and the resulting small sample, this study may be considered of exploratory nature. A statistical power analyses was performed \textit{post hoc} using the statistical software G*Power version 3.1.9.2 (Faul, Erdfelder, Lang, & Buchner, 2007). Using an alpha = 0.05 and a medium effect size of 0.5, the power for a t-test examining a difference between two dependent means (matched pairs) was 0.32 for a sample size of 7 and 0.24 for a sample size of 5, which are the number of participants in the yoga group and the control group respectively.

\textbf{3.2 RESULTS}

Participant recruitment for this study lasted approximately six months, from May 2016 to October 2016. A total of 37 potential participants were screened, qualified, and placed in a
waiting list until the recruitment period ended. Given that potential participants lived in different areas across El Paso, different locations for the yoga classes were offered including the offices of the EPDA, public library branches on the central and east side regions, and the university campus. Because many participants spoke Spanish only, they were offered the option to have yoga classes and all paperwork in Spanish. Free transportation was also offered to and from the laboratory to those potential participants who lived far from the university.

The majority of potential participants declined to participate a few weeks before the study started. Reasons included no longer interested, unwillingness to attend yoga classes in locations offered, unwillingness to attend the laboratory, and schedule conflicts. Several potential participants scheduled laboratory appointments but never showed up or cancelled last minute. Three potential participants completed laboratory assessments but never showed up to the yoga classes.

Because of these challenges the few participants who were available to start the study were placed in the yoga group. Meanwhile, two of the participants who completed laboratory assessments and never attended classes were invited to return for a second laboratory assessment in the month of December and be part of the control group, and an additional three participants were recruited last minute for a total of five women for the comparison group.

A total of eleven women started the yoga intervention. Four participants withdrew within the first two weeks of classes because of varied reasons including family emergencies, schedule conflicts, flu, and sciatic pain. Hence, only seven participants completed the yoga program, whereas five participants were part of the control group. Characteristics of participants are shown in Tables 3-6.
Demographic characteristics and health history of participants from both groups were similar. Both groups were comprised of women from Hispanic origin previously diagnosed with T2DM that followed similar lifestyles such as no exercise, not following any specific diet, no smoking, and no drinking. Both groups also had similar diabetes duration and comorbidities, had no other serious medical conditions, and were taking similar types of diabetes medication.

Nonetheless, the yoga group were comprised of participants with higher educational degrees, higher income, and better access to health insurance. In addition, the yoga group had a slightly higher initial hemoglobin $A_1c$ and a better body composition profile compared to the control group.

Table 3
*Baseline Health Characteristics of Participants from the Quasi-experimental Study*

<table>
<thead>
<tr>
<th></th>
<th>Yoga (n=7)</th>
<th>Control (n=5)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>54.57</td>
<td>4.96</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>161.26</td>
<td>3.91</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>72.86</td>
<td>13.91</td>
</tr>
<tr>
<td>BMI (kg/m$^2$)</td>
<td>27.95</td>
<td>4.98</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>107.29</td>
<td>11.70</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>63.86</td>
<td>3.53</td>
</tr>
<tr>
<td>HR (beats/min)</td>
<td>78.86</td>
<td>2.67</td>
</tr>
<tr>
<td>$A_1c$ (%)</td>
<td>8.60</td>
<td>2.70</td>
</tr>
</tbody>
</table>

*Note.* BMI= Body mass index, SBP= systolic blood pressure, DBP= diastolic blood pressure, HR= heart rate, $A_1c$= hemoglobin $A_1c$
Table 4  
*Demographic Characteristics of Participants from the Quasi-experimental Study*

<table>
<thead>
<tr>
<th>Ethnicity</th>
<th>Yoga (n=7)</th>
<th>Control (n=5)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>Frequency</td>
</tr>
<tr>
<td>Hispanic</td>
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<td>4</td>
</tr>
<tr>
<td>White</td>
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<td>0</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elementary school</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Some high school</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>High school degree/GED</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Some college</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>College degree</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Graduate studies</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Income</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Less than 20,000</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>36,000 - 49,000</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Above 50,000</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Health insurance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>5</td>
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</tr>
<tr>
<td>No</td>
<td>2</td>
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</tr>
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</table>

*Note.* Data from one participant missing.
Table 5  
*Health History of Participants from the Quasi-experimental Study*

<table>
<thead>
<tr>
<th></th>
<th>Yoga (n=7)</th>
<th>Control (n=5)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>Frequency</td>
</tr>
<tr>
<td><strong>Diabetes duration</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 10 yrs</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>10 – 19 yrs</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>20 yrs or more</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Comorbidities</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
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<td>1</td>
</tr>
<tr>
<td>Neuropathy</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>High blood pressure</td>
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<td>3</td>
</tr>
<tr>
<td>High cholesterol</td>
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<td>3</td>
</tr>
<tr>
<td>Depression</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>Other medical conditions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>No</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td><strong>Currently exercising</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>No</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td><strong>Currently on a diet</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>No</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td><strong>Currently smoking</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td><strong>Currently regular drinker</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No</td>
<td>7</td>
<td>4</td>
</tr>
</tbody>
</table>

*Note.* Data from one participant missing.
Table 6  
*Medication used by participants from the Quasi-experimental Study*

<table>
<thead>
<tr>
<th>Type of medication</th>
<th>Yoga (n=7) Frequency</th>
<th>Control (n=5) Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Diabetes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfonylureas</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Biguanides</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>TZDs</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Combination</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Incretin</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Insulin</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood pressure</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Pain</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Depression</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Allergy</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Glucocorticoid</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Osteoporosis</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Thyroid</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Multivitamin/supplements</td>
<td>6</td>
<td>5</td>
</tr>
</tbody>
</table>
Attendance for this study was high with a mean of 15.29 (2.29) out of 16 sessions, representing 95.6%. Reasons for missed sessions as reported by participants included holidays (Halloween and Thanksgiving), family emergencies, heavy traffic, illness unrelated to the intervention, among others.

No adverse events were reported during the yoga intervention, such as hypoglycemic episodes or musculoskeletal injuries associated with the practice. Some participants did report feeling slightly uncomfortable during certain movements that required deep torso forward flexions and rotations due to previous back surgeries or lack of flexibility at the spine. However, as participants were taught to enhance their body awareness they were able to modify their own body posture to a comfortable position and they welcomed any modifications suggested by the instructor.

During informal conversations with participants, the majority of them expressed that some of the poses were challenging but feasible. They also reported that the program helped them to ease muscular tension and allowed them to become aware of the capacities of their own bodies to move in varied planes and degrees of motion. The majority expressed that the most helpful and transferable component of yoga practice was the breathing (pranayama), which allowed them to reach calmness in periods of conflict and high stress during their everyday lives. They also reported that they particularly enjoyed the holistic quality of the program that combined mental (meditation) with physical practice (asanas), in addition to presenting brief yogic philosophical principles.

3.2.1 Changes in Body Composition

Data was missing for one participant from the control group because she was claustrophobic and opted out of the body composition assessment. Hence, seven people were
included in the yoga group and only four people were included in the control group for statistical analysis.

The yoga group showed a trend towards improvement in the body composition profile (Table 7). Percent fat decreased, pre = 40.23 vs. post = 38.69; fat mass decreased, pre = 30.04 vs. post = 28.89; and lean mass increased, pre = 42.77 vs. post = 43.61. In contrast, the control group showed no improvement in body composition profile (Table 7). Percent fat increased, pre = 44.88 vs. post = 45.68; fat mass increased, pre = 32.83 vs. post = 33.53; and lean mass slightly decreased, pre = 39.48 vs. post = 39.10.

Table 7
Changes in Anthropometric and Body Composition Variables in Yoga and Control Groups Following the Yoga Intervention

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yoga (n=7)</td>
<td>Pre-</td>
<td>Post-</td>
<td>Pre-</td>
<td>Post-</td>
<td>Pre-</td>
<td>Post-</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>72.86</td>
<td>13.91</td>
<td>72.49</td>
<td>13.78</td>
<td>73.24</td>
<td>6.35</td>
<td>73.50</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>27.95</td>
<td>4.98</td>
<td>27.81</td>
<td>4.86</td>
<td>29.69</td>
<td>3.14</td>
<td>29.80</td>
</tr>
<tr>
<td>Percent fat (%)</td>
<td>40.23</td>
<td>9.01</td>
<td>38.69</td>
<td>9.85</td>
<td>44.88</td>
<td>3.47</td>
<td>45.68</td>
</tr>
<tr>
<td>Fat mass (kg)</td>
<td>30.04</td>
<td>11.72</td>
<td>28.89</td>
<td>12.06</td>
<td>32.83</td>
<td>3.97</td>
<td>33.53</td>
</tr>
<tr>
<td>Lean mass (kg)</td>
<td>42.77</td>
<td>6.23</td>
<td>43.61</td>
<td>6.14</td>
<td>39.48</td>
<td>1.02</td>
<td>39.10</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>92.17</td>
<td>10.70</td>
<td>90.64</td>
<td>9.82</td>
<td>98.30</td>
<td>4.21</td>
<td>97.50</td>
</tr>
</tbody>
</table>

Note. No statistical differences were found in paired-t-tests between pre- and post- scores at alpha level 0.05.

3.2.2 Changes in Glucose Control

One participant from the control group was excluded from the glucose analyses because she reported to have suffered from anemia during the duration of the intervention, which is
known to affect accurate hemoglobin A\(_1c\) measurement. Hence, seven people were included in the yoga group and only four people were included in the control group for the non-parametric test. The yoga group showed a small decrease in hemoglobin A\(_1c\) following the intervention, pre = 8.60 vs. post = 8.49, \(Z = -0.17, p = .87\); however, change was not statistically significant.

On the other hand, the control group showed almost equal pre- and post- intervention values; pre = 8.00 vs. post = 8.01, \(Z = -0.37, p = .71\).

### 3.2.3 Changes in Stress Hormones

Participants showed substantial variation in cortisol rhythm as can be observed in Figures 2-8 (Appendix B) and the large standard deviations shown in Table 8. Cortisol awakening responses, defined as the period immediately upon awakening and 30 minutes after, ranged from -0.01 to 0.72 at pre-intervention and from -0.09 to 0.54 at post-intervention. Noon values ranged from 0.06 to 0.28 at pre-intervention and from 0.05 to 0.22 at post-intervention, whereas bedtime values ranged from 0.01 to 0.29 at pre-intervention and from 0.03 to 0.13 at post-intervention.

Nonetheless, in average participants showed lower than normal values as compared to healthy controls in previous studies (Bruehl et al., 2009; Wust et al., 2000) immediately upon awakening, 30 minutes after awakening, and at noon, which indicates that this group of women with T2DM showed a blunted cortisol curve in the morning. On the other hand, participants showed higher than normal bedtime cortisol values as compared to participants without diabetes in other studies (Bruehl et al., 2009; Shin et al., 2011). See Figure 9 below.

Similarly, participants showed considerable variation in DHEA rhythm as reflected in Figures 10-15 (Appendix B) and substantial standard deviations observed in Table 8. But in contrast to cortisol, in average participants showed higher than normal values as compared to healthy individuals of varied ages previously reported by the literature (Ahn, Lee, Choi, Kwon,
& Chun, 2007; Hucklebridge et al. 2005) immediately upon awakening, 30 minutes after awakening, and at noon; whereas bedtime values were approximately normal. See Figure 16 below.

Close inspection of Figure 9 reveals that the average cortisol curve for the participants of this study was similar pre- and post- intervention, except for cortisol immediately upon awakening which showed a trend towards a higher value. On the other hand, visual analysis of Figure 16 reveals that all DHEA values showed a trend towards a lower value at the end of the intervention, except DHEA at bedtime. In addition, the DHEA/cortisol ratio at bedtime showed a trend towards improvement following the yoga intervention.

Table 8
*Changes in salivary cortisol and salivary DHEA before and after the intervention in the yoga participants*

<table>
<thead>
<tr>
<th></th>
<th>Pre (n=7)</th>
<th></th>
<th>Post (n=7)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Wake-up cortisol</td>
<td>0.24</td>
<td>0.22</td>
<td>0.41</td>
<td>0.36</td>
</tr>
<tr>
<td>(µg/dL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 min. cortisol</td>
<td>0.29</td>
<td>0.30</td>
<td>0.31</td>
<td>0.26</td>
</tr>
<tr>
<td>(µg/dL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noon cortisol</td>
<td>0.17</td>
<td>0.09</td>
<td>0.14</td>
<td>0.06</td>
</tr>
<tr>
<td>(µg/dL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bedtime cortisol</td>
<td>0.09</td>
<td>0.11</td>
<td>0.07</td>
<td>0.04</td>
</tr>
<tr>
<td>(µg/dL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wake-up DHEA†</td>
<td>619.19</td>
<td>628.74</td>
<td>423.85</td>
<td>217.14</td>
</tr>
<tr>
<td>(pg/mL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 min. DHEA†</td>
<td>466.06</td>
<td>571.35</td>
<td>310.81</td>
<td>225.98</td>
</tr>
<tr>
<td>(pg/mL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noon DHEA†</td>
<td>235.05</td>
<td>167.54</td>
<td>163.98</td>
<td>95.01</td>
</tr>
<tr>
<td>(pg/mL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bedtime DHEA†</td>
<td>114.66</td>
<td>83.27</td>
<td>101.64</td>
<td>33.04</td>
</tr>
</tbody>
</table>

*No statistical difference was found in paired-t-tests between pre- and post- values.
†One participant was excluded from the DHEA analyses.
Figure 9. Comparison of pre- and post-intervention cortisol curves of T2DM participants with normal values from prior literature

Figure 16. Comparison of pre- and post-intervention DHEA curves of T2DM participants with normal values from prior literature
3.2.4 Changes in Psychological Stress and Well-Being

Overall negative mental health showed a trend towards improvement in the yoga group following the intervention. Perceived stress decreased, pre = 19.00 vs. post = 13.14; diabetes distress slightly decreased, pre = 24.64 vs. post = 23.57; and negative emotions decreased, pre = 14.00 vs. post = 11.57. However, only perceived stress showed substantial change. On the contrary, overall negative mental health worsened over time in the control group. Perceived stress increased, pre = 9.60 vs. post = 12.00; diabetes distress increased, pre = 22.50 vs. post = 32.75, $t(4) = -1.13, p = 0.32$; and negative emotions remained similar, pre = 12.60 vs. post = 12.40, $t(4) = 0.13, p = 0.90$.

Similarly, positive mental health showed a trend towards improvement in the yoga group following the intervention. Positive emotions increased, pre = 24.00 vs. post = 26.00; balance between positive and negative emotions improved, pre = 10.00 vs. post = 14.43; and flourishing increased, pre = 46.57 vs. post = 49.57. On the other hand, positive mental health also worsened over time in the control group. Positive emotions decreased, pre = 27.20 vs. post = 23.80; balance between positive and negative emotions decreased, pre = 14.60 vs. post = 11.40; and flourishing decreased, pre = 49.20 vs. post = 45.60.
Table 9

*Changes in Psychological Stress Measures in Yoga and Control Groups Following the Yoga Intervention*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Yoga (n=7)</th>
<th>Control (n=5)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-</td>
<td>Post-</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>PSS</td>
<td>19.00</td>
<td>8.51</td>
</tr>
<tr>
<td>PAID</td>
<td>24.64</td>
<td>17.06</td>
</tr>
</tbody>
</table>

*Note.* PSS= Perceived stress scale, higher scores represent higher perceived stress. PAID= Problem areas in diabetes scale, higher scores represent higher diabetes-related emotional distress. *Paired t-tests indicated that post-intervention scores were statistical significantly lower than pre-intervention scores in the yoga group at alpha level 0.022. No other statistically significant differences were found at alpha level 0.05.

Table 10

*Changes in Emotional and Psychological Well-being Measures in Yoga and Control Groups Following the Yoga Intervention*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Yoga (n=7)</th>
<th>Control (n=5)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-</td>
<td>Post-</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Positive emotions</td>
<td>24.00</td>
<td>5.63</td>
</tr>
<tr>
<td>Negative emotions</td>
<td>14.00</td>
<td>5.80</td>
</tr>
<tr>
<td>Balance emotions</td>
<td>10.00</td>
<td>10.94</td>
</tr>
<tr>
<td>Flourishing</td>
<td>46.57</td>
<td>9.74</td>
</tr>
</tbody>
</table>

*Note:* No statistical differences were found after paired t-tests between pre- and post- scores at alpha level 0.05. Positive, negative, and balance emotions from the scale of positive and negative experience (SPANe); higher scores in balance represent that the respondent rarely or never experiences any of the negative feelings and very often or always has all of the positive feelings. Higher scores in flourishing represent a respondent with higher levels of psychological and social well-being.
3.2.5 Correlations Between Variables Under Investigation

Correlation analysis revealed no discernible trends of association between glucose control and changes in stress hormones or measures of psychological stress and well-being. On the other hand, there was a trend towards a negative association between perceived stress and cortisol immediately upon awakening, $r (7) = -0.77, p = 0.03$; that is, the greater the psychological stress, the less cortisol at wake-up time. There was also a trend towards positive association between positive and balance emotions and cortisol immediately upon awakening, $r (7) = 0.80, p = 0.02$ and $r (7) = 0.78, p = 0.03$ respectively; which indicates that the more positive emotions and balance affect, the more cortisol at wake-up time. Similarly, there was a trend towards negative association between positive emotions and DHEA 30 min following awakening, $r (6) = -0.81, p = 0.04$; indicating that as positive emotions increase, DHEA decreases. There were also trends towards positive associations between perceived stress and DHEA at noon, $r (6) = 0.87, p = 0.02$, and between negative emotions and DHEA at noon, $r (6) = 0.90, p = 0.01$; that is, as psychological stress and well-being worsen, DHEA at noon increased. In addition, there were trends towards a negative association between positive emotions and DHEA at noon, $r (6) = -0.94, p = 0.005$, and between balance emotions and DHEA at noon, $r (6) = -0.95, p = 0.004$; that is, as positive emotions and balance affect increased, DHEA at noon decreased. No other statistical trends were found between the different time points measured for stress hormones and scores from psychological stress and well-being.

Correlation analyses also indicated trends of associations among the different measures of psychological stress and well-being. Perceived stress showed a trend towards a negative association to positive emotions and balance affect, $r (12) = -0.78, p = 0.003$ and $r (12) = -0.90, p$
< 0.001 respectively; and a trend towards a positive association to negative emotions, $r (12) = 0.89$, $p < 0.001$. Positive emotions showed a trend towards a negative association to negative emotions, $r (12) = -0.72$, $p = 0.008$, and a trend towards a positive association to balance affect, $r (12) = 0.93$, $p < 0.001$. No trends of associations were found between diabetes-related distress and psychological stress or well-being, or between flourishing and psychological stress or well-being.

### 3.2.6 Changes in Extraneous Variables

Self-care showed a trend towards improvement in the yoga group following the intervention, pre = 33.81 vs. post = 40.48; whereas it decreased slightly for the control group, pre = 40.00 vs. post = 38.33. Physical activity levels remained the same for both groups pre- and post-intervention; for the yoga group, pre = 76.07 vs. post = 71.14; and for the control group, pre = 373.20 vs. post = 373.20. Diet patterns also remained the same for both groups pre- and post-intervention; for the yoga group, pre = 6.29 vs. post = 6.14; and for the control group, pre = 6.80 vs. post = 6.80. Lastly, medication logs, as reported by participants, did not change pre- and post-intervention.

It was interesting to find that self-care increased; however, physical activity, diet, and medication remained the same. This indicates that there is some aspect of self-care that improved in yoga participants after the intervention beyond the dimensions measured by the physical activity and diet scales and the medication log. In order to analyze this possibility, a secondary analysis was performed in which every single item of the self-care scale was assessed for pre- and post-intervention score differences for the yoga group. Results revealed that almost all items reflected higher scores, which indicate better self-care; however, only item #7 “Eat meals/snacks
on time” and item #2 “Record blood glucose levels” showed strong trends towards improvement.

See Table 11 below.

<table>
<thead>
<tr>
<th>Item</th>
<th>Pre</th>
<th>Post</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Check blood glucose with monitor”</td>
<td>3.29</td>
<td>3.43</td>
<td>0.36</td>
</tr>
<tr>
<td>“Record blood glucose results”</td>
<td>2.86</td>
<td>4.43</td>
<td>0.08</td>
</tr>
<tr>
<td>“Take the correct dose of diabetes pills or insulin”</td>
<td>4.29</td>
<td>4.29</td>
<td>1.00</td>
</tr>
<tr>
<td>“Take diabetes pills or insulin at the right time”</td>
<td>4.14</td>
<td>4.29</td>
<td>0.36</td>
</tr>
<tr>
<td>“Eat the correct food portions”</td>
<td>2.71</td>
<td>3.00</td>
<td>0.46</td>
</tr>
<tr>
<td>“Eat meals/snacks on time”*</td>
<td>3.14</td>
<td>3.86</td>
<td>0.04</td>
</tr>
<tr>
<td>“Keep food records”</td>
<td>1.00</td>
<td>1.14</td>
<td>0.36</td>
</tr>
<tr>
<td>“Read food labels”</td>
<td>2.71</td>
<td>3.00</td>
<td>0.46</td>
</tr>
<tr>
<td>“Treat low blood glucose with just the recommended amount of carbohydrate”</td>
<td>1.86</td>
<td>2.14</td>
<td>0.46</td>
</tr>
<tr>
<td>“Carry quick acting sugar to treat low blood glucose”</td>
<td>1.86</td>
<td>2.14</td>
<td>0.52</td>
</tr>
<tr>
<td>“Come in for clinic appointments”</td>
<td>4.43</td>
<td>5.00</td>
<td>0.23</td>
</tr>
<tr>
<td>“Wear a Medic Alert ID”</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>“Exercise”</td>
<td>2.00</td>
<td>1.43</td>
<td>0.17</td>
</tr>
</tbody>
</table>

*Statistically significant at alpha 0.05 as indicated by a paired-t test.

Note. Items from the Self Care Inventory-revised version (SCI-R). Higher scores indicate that the respondent has more frequently followed a recommended diabetes treatment plan; scores range from 1=never to 5=always.
3.3 DISCUSSION

The primary goal of the present quasi-experimental design study was to investigate the effect of eight weeks of yoga practice on the glucose control of individuals previously diagnosed with T2DM while addressing previous limitations in the current literature. A careful description of the yoga intervention was presented including description of components incorporated into the program, examples of suggested home practice, and an operational definition as suggested by (Schmalzl et al., 2015). This information is particularly relevant to determine what aspects of yoga practice are effective and safe. In addition, it serves as a comprehensive guide for future studies that seek to replicate or expand on the findings presented in this dissertation, and for yoga professionals that work with this particular population.

A detailed description of participants’ characteristics was also presented such as initial level of glucose control and body composition, presence or absence of diabetes-related complications and comorbidities, and medication taken. All of the previous characteristics are of special relevance because they may determine what is safe and effective from an exercise/movement therapy intervention that seeks to improve glucose control and other health parameters in people with diabetes. For example, an individual with T2DM that presents poor glucose control and several diabetes-related complications may be considered of fragile health and very different compared to an individual with well-controlled glucose levels and no complications; consequently it is unlikely that these two individuals are capable of engaging in the same type of yoga intervention in terms of length, frequency, and intensity.

The present quasi-experimental design study also addressed previous limitations in the literature by providing a detailed description of methods used to assess glucose control and other variables under investigation. It also took into account conditions that may affect the accuracy of
measurement of dependent variables. For example, one participant from the control group was excluded from glucose analysis because she reported to have suffered from anemia during the duration of the intervention, and anemia is known to impact accurate assessment of hemoglobin A₁c. The study also focused just on women of a certain age range to control for the possible impact of sex and age on variations in stress hormones. Additionally, the study monitored and recorded extraneous variables that may directly impact glucose control beyond the yoga intervention such as diet, medication, and additional physical activity.

3.3.1 Safety of Yoga Practice for Type 2 Diabetes Mellitus Patients

During and after the intervention none of the participants reported any adverse event related to yoga practice, except for mild discomfort during spinal forward flexions and rotation which was decreased with appropriate pose modifications and props. Several participants expressed that the physical aspect of the yoga program was challenging but feasible and helpful to ease muscular tension. Furthermore, participants reported that the program was helpful to reduce mental stress and foster positive emotions such as calmness and patience during periods of conflict and high stress.

Therefore, based on the results from this study it can be concluded that eight weeks of yoga practice, twice a week, that incorporates a variety of yoga elements such as breathing work, physical poses, meditation and basic philosophy, is safe for women previously diagnosed with T2DM who are between the ages of 50 and 65, overweight, with moderately controlled glucose levels, sedentary, with comorbidities of high blood pressure and high cholesterol, free from diabetes-related complications, and of varied diabetes duration.

Nonetheless, it is important to highlight that the yoga program presented to the participants of this study was especially tailored to their needs and the progress they showed
week by week. As mentioned previously, if participants expressed any discomfort during a particular pose, appropriate modifications were presented that usually included the use of props like straps or blankets; hence, during a given class diverse configurations of a single yoga pose could have been observed. In the same line, progress to more challenging poses was only attempted if participants previously showed adequate technique and strength on simple poses.

Therefore, yoga professionals that either implement a yoga-based intervention in a research study or yoga classes in a community setting should closely monitor participants for cues that offer an insight into what is comfortable and feasible during a session, and determine progress based on these observations and participants’ feedback.

3.3.2 Glucose Control Following Yoga Practice

Participants who completed the yoga program in the present quasi-experimental design study showed a trend towards improved glucose control after eight weeks of practice, whereas participants in the control group showed no difference in glucose levels in that same 8-week period. However, change in the yoga group was not statistically significant, which may be due to low statistical power estimated as 0.32 for a t-test examining a difference between two dependent means for a sample size of 7, which was the size of the yoga group. Previous quasi-experimental investigations that have found significant reductions in glucose levels have used total participant samples that have ranged from 40 to 231.

Another possible explanation for the lack of statistical significance may be the large variation in glucose changes among participants in the yoga group. For example, one participant’s hemoglobin A1c decreased from 12.1% to 10.8%, representing a 1.3% change which has important clinical significance since a 1% change has been previously associated with reductions in microvascular complications in diabetes patients (Stratton et al. 2000). On the other
hand, another participant’s hemoglobin A\textsubscript{1c} decreased from 7.1% to 6.6%, representing a 0.5% change. Moreover, others experienced only a 0.1% change which could be due to measurement error. In contrast, the control group showed more stable hemoglobin A\textsubscript{1c} levels, their changes ranged from -0.3 to 0.2% between the beginning and end of the study, which explains their minimal average change.

The trend toward improved glucose control observed in the participants that completed the yoga program of this study is unlikely due to confounding variables since patterns of physical activity, medication, and broad composition of diets remained the same during the duration of the intervention. However, it is possible that decreases in glucose levels were due to an improved diabetes management as indicated by an increasing trend in self-care scores. Thus, even when the incorporation of certain foods, such as healthy fats, low-fat protein, fruit, and vegetables, did not change, it appears that yoga participants started to take care of timing of meals and became more aware of their daily glucose levels. Timing of meals is especially important for T2DM as it allows for more stable glucose levels throughout the day, whereas glucose monitoring brings awareness of the type of food and activities that may drop or elevate glucose levels, which in turn may translate into a better glucose control.

Nonetheless, an alternative explanation for the observed trend in improved glucose control may be the mechanism under exploration in the present investigation. It may be possible that glucose levels decreased due to a trend towards normalization of the stress hormone profile following yoga practice as shown by changes in salivary cortisol and DHEA.
3.3.3 The Stress Hormone Profile after Yoga Practice

3.3.3.1 Salivary cortisol

The group of women with T2DM in this study showed lower than normal cortisol values in the morning and higher than normal cortisol values at bedtime. This is in line with previous studies that have found a trend towards a lower wake-up cortisol levels and significantly higher bedtime cortisol in participants with diabetes compared to participants without diabetes (Lederbogen et al. 2011). Similarly, Hackett, Steptoe, & Kumari (2014) found a significantly flatter cortisol slope across the day and significantly higher bedtime cortisol levels in T2DM patients compared to people without diabetes, which was independent of covariates such as age, sex, waking time, and BMI.

Substantial variations in cortisol rhythm among yoga participants in this study, and their average abnormal values, can make the results difficult to interpret. However, it may be possible that in order to appropriately understand variations between pre- and post-intervention cortisol curves, initial values and their implications need to be taken into account.

Interpretation of cortisol dynamics is complex. Elevated cortisol values have been previously associated to an increased risk of cardiovascular disease, lower immune function, and cognitive impairment (Lundberg, 2005); as well as allostatic load (McEwen, 2006), metabolic disturbances such as obesity and Cushing’s syndrome (Restituto et al., 2008), and environmental and emotional stressors (Korenblum et al., 2005). On the other hand, reduced cortisol values have been associated with disease states. Previous studies have found lower morning cortisol profiles in women suffering from chronic fatigue syndrome compared to healthy controls (Nater et al., 2008), lower basal cortisol levels in women with post-traumatic stress disorder compared to controls (Meewisse, Reitsma, Vries, Gersons, & Olff, 2007), a lower cortisol awakening
response (CAR) in depressed women compared to non-depressed women (Stetler & Miller, 2005), and a lower CAR in women with T2DM compared to women without diabetes (Bruehl et al., 2009). Therefore, optimal physical and psychological health seem to be associated with a cortisol pattern that reflects a balance, and in contrast too high or too low values reflect disturbances in homeostasis.

Interventions that seek to improve both physical and mental health in populations that suffer from a chronic condition may help to reverse cortisol levels to “normal” values. This can be observed in previous investigations that have aimed to improve quality of life in cancer patients. For instance, in the study by Matousek et al. (2011) women with breast cancer that showed initial morning cortisol curves lower than normal experienced significant elevations in morning cortisol values in conjunction with significant improvements in depressive, perceived stress, and medical symptoms following an 8-week mindfulness intervention.

Similarly, in the study by Carlson et al. (2004) cancer patients that completed an 8-week mindfulness program showed significant improvements in quality of life and symptoms of stress, but no significant average mean changes of the three cortisol values under investigation (08:00, 14:00, and 20:00 hrs) and no apparent change in the overall slope from pre- to post-intervention. However, when examining individual cortisol slopes different patterns emerged and some of those participants that had initially higher than normal cortisol elevations in the afternoon no longer showed afternoon cortisol elevations at post-intervention.

In the present study there was no significant change between average bedtime cortisol levels pre- and post- intervention. Nevertheless, when examining individual values those participants that showed higher than normal nighttime cortisol values at pre-intervention, as compared to healthy samples from previous studies (Bruehl et al., 2009; Shin et al., 2011),
showed decreases in nighttime cortisol values at post-intervention, whereas those participants that showed lower than normal nighttime cortisol values at pre-intervention showed increases in nighttime cortisol values at post-intervention. For example, nighttime cortisol levels for subject Y4 decreased from 0.2089 to 0.0790 µg/dL, whereas nighttime cortisol levels for subject Y8 increased from 0.0171 to 0.0930 µg/dL.

In addition, the group as a whole showed an increase in cortisol values immediately upon awakening following the intervention, from 0.2378 to 0.4102 µg/dL, which brings the average a little closer to normal values shown in healthy participants from previous investigations; 0.5438 µg/dL and 0.5481 µg/dL for the Bruehl et al. (2009) study and the Wust et al. (2000) study respectively. Authors have suggested that a higher wake-up cortisol that contributes to a higher total cortisol curve reflects normal hypothalamic-pituitary-adrenal (HPA) axis plasticity in individuals with a normal glucose profile and without central adiposity (Joseph & Golden, 2017).

In prior studies, a higher mean cortisol throughout the day, especially within an hour post awakening, was significantly correlated with a lower waist-to-hip ratio and better sleep quality in a sample of middle-aged adults without diabetes (Lasikiewicz, Hendrickx, Talbot, Dye, 2008). Similarly, a higher cortisol post awakening was found to be associated with normal weight and waist circumference in older adults with normal fasting glucose (Champaneri et al., 2013). Therefore, it can be inferred from the previous studies that adequate cortisol elevations in the morning are an indication of optimal metabolic functioning. Consequently, in people with metabolic disturbances, such as T2DM patients that show a blunted cortisol curve following awakening, higher cortisol levels in the morning would be beneficial.

In the present study, the trend towards a higher wake-up cortisol observed in the participants that completed the yoga intervention was associated with changes in psychological
stress and well-being. As perceived stress decreased and positive emotions and balance affect increased, cortisol immediately upon awakening moved closer to normal values.

The lack of statistical significant in wake-up cortisol changes in the present investigation may be due to lack of power. In a study examining the effect of yoga on the neuroendocrine and physical function in women with rheumatoid arthritis, the cortisol curve following awakening appeared to be also blunted at the beginning of the intervention; at the end of the 10-week program the morning cortisol curve also showed elevations toward normal values but changes were not statistically significant, perhaps because the yoga group was also small at n=9 (Bosh, Traustadottir, Howard, & Matt, 2009).

3.3.3.2 Salivary DHEA

Women with T2DM in this study showed higher than normal DHEA levels immediately upon awakening, 30 min after awakening, and at noon, whereas bedtime DHEA appeared to be normal as compared to a healthy population as described by the literature (Ahn et al. 2007). This is in line with previous studies that have found statistically significantly higher plasma morning DHEA levels in women with diabetes as compared to non-diabetic controls of the same age (Szpunar, Blair, & McCann, 1977).

Similar to cortisol, the DHEA profile seems to be altered in individuals suffering from chronic conditions. Heuser et al. (1998) found that participants clinically diagnosed with major depression of varied ages exhibited higher plasma DHEA levels throughout the day compared to non-depressed participants. Higher salivary morning DHEA levels have also been found in individuals with PTSD as compared to controls, but no differences in nighttime levels have been observed (Gill, Vythilingam, & Page, 2008), which is comparable to the findings in the present investigation.
Furthermore, like cortisol, the trend towards reductions in the DHEA curve of the participants that completed the yoga program was associated with changes in psychological stress and well-being. As positive emotions and balance affect improved, and perceived stress decreased, DHEA 30 min after awakening and DHEA at noon moved closer to normal values.

These findings are similar to previous observations in which DHEA has been found associated with positive affective states (McCraty et al., 1998); nevertheless, in the study by McCraty et al. (1998) participants were healthy and presented DHEA values within normal ranges at the beginning of the intervention; in turn the association was reverse, the higher the positive affective states, the higher the DHEA.

Finally, although decreases in DHEA were not statistically significant, this appears to be the first study that reports higher than normal salivary DHEA levels from time of awakening to noon in women with T2DM, and a reverse trend towards normal values following a behavioral intervention, which guarantees further investigation in the future not only for yoga research but for all interventions aiming to improve the overall health of the patient with T2DM.

3.3.3.3 DHEA/Cortisol Ratio

Previous authors have previously highlighted the significance of examining the anabolic balance represented by the DHEA-to-cortisol ratio which will determine the net impact on tissues and subsequent susceptibility to diseases of stress and aging (Maninger, Wolkowitz, Reus, Epel, & Mellon, 2009). Hormones do not act in isolation, they modulate each other and interact in complex and varied ways. Hence, it is reasonable to place particular attention to these hormones in conjunction following a particular intervention or treatment rather than focusing on either hormone independently. For this study, the DHEA/cortisol ratio at bedtime was assessed given that nighttime values of these hormones have been found useful in previous investigations
to predict the presence of chronic conditions such as depression (Goodyear et al., 1997; Young, Gallagher, & Porter, 2002). Results from the present study suggest a trend towards hormonal balance following yoga practice. Additional examination into this phenomenon is crucial to understand the impact of the synergistic activity of stress hormones on the glucose metabolism and other health parameters of T2DM patients.

3.3.4 Limitations

The major limitation of this study was its small sample size, and consequently its low statistical power to detect a possible effect of the yoga intervention on the variables under study. Even when the results in glucose, physiological stress, and well-being showed trends in the directions that were hypothesized, the majority of the changes were not statistically significant. Therefore, it is difficult to make strong conclusions about the findings from this study and additional research with adequate power is needed to support conclusions.

In addition, the small sample size reduces the external validity of the study. Participants from this study had characteristics that resemble the general T2DM population such as overweight, sedentary, high blood pressure, and high cholesterol. Nonetheless, other individual differences, such as specific medications, could still have had an impact on measures under investigation which could had been minimized with a sufficiently large sample.

Another limitation was the usefulness of the chosen measures to capture concepts under study. Salivary cortisol could had been influenced by temporary conditions such as unreported sickness or a particularly stressful event the day before, and hence they would not reflect the effect of the yoga intervention but instead reflect these transitory states. An additional problem with sampling could had been participants’ non-adherence to the protocol. This potential problem was minimized by providing detailed verbal and written instructions, and by asking
participants to maintain a log that described the day and time of saliva collection. However, it may still be possible that participants’ actions differed from what they reported on paper, which could have had an impact on the accurate measurement of the hormonal curves under investigation.

Moreover, scales on psychological stress and well-being may be insufficient to provide an understanding on the complexity of stressful events experienced by participants on their everyday lives during the duration of the intervention and the impact of yoga on emotional regulation. For instance, a couple of participants reported going through difficult life transitions during the study such as work demands and family conflicts including a divorce, and their scores on some of the scales did not show considerable changes at the end of the study. However, it is possible that yoga acted as a buffer and prevented stress levels and negative emotions to rise through difficult life events. This possible explanation is supported by participants’ own accounts when, during casual conversations with the PI of this study, they described how yoga has been helpful for maintaining calm and a sense of peace during periods of stress. Therefore, future investigations should not limit the exploration of the impact of yoga on psychological stress and well-being to quantitative scales, but instead include a mixed approach methodology that includes in-depth face-to-face interviews along with investigator’s detailed observations in conjunction with quantitative measures.
CHAPTER 4: SINGLE-SUBJECT DESIGN STUDY

4.1 METHODS

4.1.1 Participants

Participants were recruited through campus announcements and television announcements on channel 44, which were the most helpful strategies from the previous study. To ensure participant commitment, interested individuals that contacted the PI were reminded of the importance of attending laboratory sessions and completing the entire intervention before signing up for the study. In addition, participants were offered a $50 dollar gift card and reminded that they will be dropped from the study if they missed more than one session.

Interested individuals were pre-screened with a brief health questionnaire to determine qualification to participate in the study. Inclusion criteria included: (1) previously diagnosed with T2DM or at risk for developing T2DM; (2) older than 18 years of age; and (3) no previous experience in yoga and/or meditation. Exclusion criteria included: (1) medical conditions that prevented individual from participation in the yoga classes (e.g. current musculoskeletal injuries, chronic and severe pain, among others); (2) current cold/flu or infections of any kind; (3) women undergoing menstruation or menopause; and (4) inability to attend all sessions during the duration of the study.

Because the focus was on the individual responses of each participant and not the group as a whole, variability between subjects was no longer relevant and hence people of both sexes and varied ages were recruited. Instead, the focus was placed on potential variability within subjects and this is what guided inclusion and exclusion criteria. For example, conditions that may place the body under physical stress such as an acute infectious disease may significantly impact variation in stress hormones like cortisol from one week to the next (Stalder et al., 2015).
Therefore, potential participants that were suffering from any cold/flu or infections of any kind at the moment of recruiting were excluded. In addition, information on diet, physical activity, and medication was no longer used to assess and control extraneous variables, but to provide a rich description of each participant’s lifestyle and medical history.

Participant recruitment for this study lasted only two weeks, from November 23rd to December 9th. A total of five participants enrolled for this study, three were previously diagnosed with T2DM by their personal physician and two were at risk for developing T2DM (family history of T2DM, sedentary, and overweight). However, due to budget limitations the biological data from pre-diabetic individuals could not be assessed, and hence they were excluded from final analysis.

Participants with diabetes were given the option to attend the sessions either in the morning or in the late afternoon at the UTEP campus based on their schedule and/or personal preference. Sessions were offered to be conducted either in English or Spanish, also depending on participants’ personal preference. Therefore, participants themselves determined that sessions took place Monday through Thursday from 6 to 7:30pm, and in the Spanish language.

The three participants had similar characteristics. They were all Hispanic of similar ages, post-menopausal, sedentary, overweight but not obese, with high levels of percent body fat, and had moderate-to-poorly controlled glucose levels. Tables 12-14 summarize health and demographic characteristics of participants. Additional background, reasons to start yoga practice, and concerns about yoga practice are presented in Table 15.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Participant A</th>
<th>Participant M</th>
<th>Participant C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemoglobin A(_1)c (%)</td>
<td>11.6</td>
<td>10.4</td>
<td>11.5</td>
</tr>
<tr>
<td>Length of disease (yrs)</td>
<td>10</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Blood pressure (mmHg)</td>
<td>106/67</td>
<td>139/76</td>
<td>131/82</td>
</tr>
<tr>
<td>Diabetes-related complications</td>
<td>No</td>
<td>Possible neuropathy</td>
<td>No</td>
</tr>
<tr>
<td>Comorbidities</td>
<td>High cholesterol</td>
<td>High blood pressure and high cholesterol</td>
<td>No</td>
</tr>
<tr>
<td>Other medical conditions</td>
<td>No</td>
<td>Fatty liver disease</td>
<td>Arthritis</td>
</tr>
<tr>
<td>Family history of diabetes</td>
<td>Mother</td>
<td>No</td>
<td>Both parents, all brothers and sisters</td>
</tr>
<tr>
<td>Post-menopausal</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Prescribed medication</td>
<td>Metformin, victoza, cholesterol</td>
<td>Metformin, insulin, blood pressure, cholesterol</td>
<td>None</td>
</tr>
<tr>
<td>Over-the-counter medication</td>
<td>None</td>
<td>None</td>
<td>Multivitamin</td>
</tr>
<tr>
<td>Level of physical activity</td>
<td>Sedentary</td>
<td>Sedentary</td>
<td>Sedentary</td>
</tr>
<tr>
<td>Regular drinker</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Smoker</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
Table 13
*Anthropometric and Body Composition Characteristics of Participants with T2DM in the Single-Subject Design Study*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Participant A</th>
<th>Participant M</th>
<th>Participant C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (cm)</td>
<td>157</td>
<td>153</td>
<td>162.5</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>71.93</td>
<td>64.87</td>
<td>65.91</td>
</tr>
<tr>
<td>BMI (kg/m$^2$)</td>
<td>28.8</td>
<td>27.7</td>
<td>24.8</td>
</tr>
<tr>
<td>Percent fat (%)</td>
<td>49.5</td>
<td>39.6</td>
<td>44.6</td>
</tr>
<tr>
<td>Fat mass (kg)</td>
<td>35.6</td>
<td>25.7</td>
<td>29.4</td>
</tr>
<tr>
<td>Lean mass (kg)</td>
<td>36.3</td>
<td>39.2</td>
<td>36.5</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>95.3</td>
<td>91</td>
<td>91</td>
</tr>
</tbody>
</table>

*Note. BMI= Body mass index*

Table 14
*Demographic Characteristics of Participants with T2DM in the Single-Subject Design Study*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Participant A</th>
<th>Participant M</th>
<th>Participant C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>59</td>
<td>51</td>
<td>62</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>Hispanic</td>
<td>Hispanic</td>
<td>Hispanic</td>
</tr>
<tr>
<td>Highest degree of education completed</td>
<td>Bachelor’s degree</td>
<td>Elementary</td>
<td>Some community college</td>
</tr>
<tr>
<td>Income per year</td>
<td>20,000 – 35,000</td>
<td>36,000 – 49,000</td>
<td>36,000 – 49,000</td>
</tr>
<tr>
<td>Health insurance</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Medication/health services</td>
<td>Insurance</td>
<td>Out-of-pocket</td>
<td>Out-of-pocket</td>
</tr>
</tbody>
</table>

96
<table>
<thead>
<tr>
<th>Participant</th>
<th>Background</th>
<th>Reasons to start yoga practice</th>
<th>Concerns about yoga practice</th>
<th>Performance during yoga practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Sedentary, long periods of sitting Used to exercise, but family responsibilities made it difficult Multiple medication-hyperglycemia, high cholesterol Smoker</td>
<td>Always have been interested in yoga “I’ve heard yoga is better as you get older” Feel it may help with leg cramps</td>
<td>None. Excited about starting classes</td>
<td>Expressed to be slightly uncomfortable during the first week of yoga Looked more comfortable and relaxed during second week of yoga</td>
</tr>
<tr>
<td>M</td>
<td>Sedentary Never tried to manage emotions before Multiple medication-hyperglycemia, high cholesterol, insomnia</td>
<td>Wanted to relax and relieve stress</td>
<td>Afraid not to be able to practice yoga</td>
<td>Looked very distressed during the first yoga class Looked a lot more confident and comfortable during the second week of yoga</td>
</tr>
<tr>
<td>C</td>
<td>Sedentary, long periods of sitting Not currently taking any medication, but trying to manage diabetes through diet and exercise</td>
<td>Interested in starting some form of exercise Believes meditation may offer calmness</td>
<td>None… “I accept my limits”</td>
<td>Looked interested during lectures and explanation of yogic philosophy, but did not engage sufficiently during yoga asanas or exercises presented in final lecture</td>
</tr>
</tbody>
</table>
4.1.2 Design

The study follows a single subject research design, which allows to explore a cause and effect relationship between variables using one or a few subjects, and hence it is considered a true experimental design (Gravetter & Forzano, 2006). The single subject design is particularly suited for the topic of yoga and diabetes given the heterogeneity of T2DM patients and of yoga interventions. Scholars have previously pointed out that variability and heterogeneity across individuals is an issue for group research designs, and that clinicians are not interested in whether a particular treatment/therapy works on average but whether it works for the individual; hence, single subject designs are ideal to inform decisions about individual patients (Guyatt et al., 2000), and are considered a method that provides evidence-based practice in general which may lead to greater acceptance by the public (Satake, Jagaroo, & Maxwell, 2008). Single subject designs are used commonly in medical research as they provide the opportunity to answer important biomedical research questions and improve direct patient care. They are also particularly suited for primary care practice-based research in which treatments can be individualized to improve outcomes (Janosky et al., 2009). Finally, this research design has the advantage of allowing the study of the effect of an intervention within the limitations of a research situation where funds are scarce (Janosky, 2005), such as a doctoral dissertation.

Single subject designs have been used previously in the exploration of the feasibility and usefulness of yoga practice for chronic health conditions. For instance, Flink, Nicholas, Boersma, & Linton (2009) evaluated two different techniques aimed to manage chronic back pain and used a single subject cross-over design with multiple baselines and measures with six subjects; all participants started the baseline at the same time, were randomly assigned to either of the two comparison techniques and then switched (cross-over design), and completed the
follow-up together. On the other hand, Hall, Verheyden, & Ashburn (2011) used a single subject ABA design to investigate the impact of eight weekly yoga sessions on the balance, mobility, and quality of life of a 69-year old female with an 8-year history of Parkinson’s disease; a one week baseline was followed by eight weeks of once a week 60-min yoga classes and five weeks of treatment withdrawal. Similarly, Bastille & Gill-Body (2004) used a single subject AB design to investigate the impact of a yoga-based exercise program on four individuals with chronic post-stroke hemiparesis; each participant completed a baseline phase lasting between four to seven weeks followed by an 8-week intervention phase.

The present study followed a single subject research ABAB design which seeks to establish a baseline followed by an intervention, then a withdrawal phase, and finally a second intervention. If outcomes under investigation are improved during the intervention, but return to baseline during the withdrawal period, changes are attributed to the intervention. If outcomes are once again improved during the second intervention, the efficacy of the intervention is further supported (Tripodi, 1994). Effects under investigation can be analyzed between both B to A, and then A to B, which further strengthens conclusions between the intervention and outcomes (Janosky et al., 2009).

4.1.3 Protocol

The study was approved by the Institutional Review Board (IRB) of the university. Participants were asked to report to the exercise science laboratory at the College of Health Sciences of the university at a convenient time for them on the weekend before starting the study. The same procedure to collect baseline physical health characteristics of participants in the quasi-experimental study was followed in this study. For a detailed description of the procedure refer to the previous section. Before leaving the laboratory, participants completed a series of
questions that asked about their lifestyle before and after diagnosis, and their expectations for the yoga classes.

For the intervention, participants were asked to attend all sessions with at least two hours of fasting, that is, two hours after their last meal to avoid variations in glucose due to diet. Once participants were in the classroom they were asked to sit for at least five minutes prior to starting any measurements, which allowed for blood pressure and heart rate to be reduced close to resting values.

Blood pressure and heart rate were measured first, followed by the collection of a small blood sample for glucose measurement. Then, participants completed a brief survey on positive/negative affect while they placed a swab inside their mouths for the collection of salivary cortisol. Saliva collection took approximately 2-3 minutes. After collection, saliva samples were immediately placed in ice so they will freeze before transportation and final storage at -20° C until analysis. The same procedure was repeated 5-10 minutes after the lectures/yoga classes ended. All sessions lasted approximately 90 minutes including pre- and post- measurements and the lectures/yoga classes.

4.1.4 Measures

All baseline measures were the same as in the quasi-experimental study which included height, body mass, body mass index, waist circumference, blood pressure, heart rate, body composition, and hemoglobin A1c. Their detailed description can be found in the previous section. For the intervention of the present study measures included the following:

4.1.4.1 Blood pressure and heart rate

Blood pressure and heart rate were measured with an automatic digital blood pressure monitor (Model BP710N, Omron Healthcare Inc., Lake Forest, IL). Participants were asked to sit
quietly on a chair for at least five minutes prior to their blood pressure/heart rate measurement with their arm at heart level. The cuff was wrapped firmly around the upper arm and aligned with the brachial artery. Systolic pressure, diastolic pressure, and heart rate were displayed on the LCD screen. Blood pressure was recorded in mmHg and heart rate in beats per minute for each participant.

4.1.4.2 Blood glucose

Blood glucose was measured with a blood glucose monitoring system (Contour® Next, Ascensia Diabetes Care US Inc., Parsippany, NJ). Prior to collection the PI followed proper hand hygiene protocol. Then, every participant was asked to hold a hand in a downward position so that gravity aided to augment blood supply. The puncture site was disinfected with an alcohol swab and allowed to air dry. A lancet device was placed against the puncture site and was pressed down firmly. The used lancet was discarded into a sharps container. Whole blood was collected with a test strip, which was then inserted into the glucose monitoring system. Results appeared within 5 seconds on the screen and were recorded in mg/dL for each participant. The test strip was discarded. The lancet device was disinfected after it was used with every participant and the glucose monitoring system was disinfected at the end of every session.

4.1.4.3 Salivary cortisol

Cortisol was assessed through saliva. Saliva was collected with an oral swab (Salimetrics LLC, State College, PA) that was placed under the tongue for approximately 2-3 minutes. Once the swab was removed from the mouth it was immediately inserted into the tube insert of the swab storage tube (Salimetrics LLC, State College, PA). Samples were stored at -20 °C until analysis. Detailed description of analysis is presented in the previous section. Salivary DHEA
was excluded because this hormone can only be collected through the passive drool method, and this study collected saliva with a swab due to ease of collection for a 90-minute session.

4.1.4.4 Positive and Negative Affect Schedule (PANAS)

The positive and negative affect schedule questionnaire was used to assess changes in feelings and emotions between the different phases of the study. The scale asks the respondent to indicate to what extent he/she feels that particular feeling or emotion right now, and therefore measures momentary and transient mental states. It is composed of 20 words, each classified in a 5-point Likert scale ranging from ‘very slightly or not at all’ to ‘extremely.’ The scale has previously demonstrated adequate psychometric properties (Watson, Clark, & Tellegen, 1988).

4.1.4.5 Additional information

In order to obtain a more complete background of participants’ history, the same questionnaires on physical activity, self-care, and medication used in the quasi-experimental study were administered prior to the beginning of the intervention, as well as open-ended questions that aimed to discover motivations to start yoga practice and concerns about yoga practice. Detailed field notes were collected on participants’ responses. Field notes were also recorded about participants’ performance during yoga sessions. Any possible identifiers were excluded from the notes.

4.1.5 Interventions

During the first phase of this study (A1), participants listened to lectures on nutrition for 60 minutes. During the second phase (B1), participants engaged in yoga practice for 60 minutes. On the third phase (A2), or the withdrawal phase, participants listened to lectures on exercise for 60 minutes. On the final phase (B2), participants engaged in yoga practice once again. All sessions were provided in Spanish given that all participants were fluent in this language.
Handouts from lectures and yoga sessions were provided in the language chosen by each participant (see Appendix D and E). In addition, mats were provided to all participants during yoga practice.

**Lectures.** Information provided during the lectures was derived from the guidelines offered by the American Diabetes Association (ADA, 2009), and from the diabetes (Mirsky & Rattner, 2006) and exercise science literature (Powers & Howley, 2007). The PI designed and implemented these sessions. She has educational degrees in Kinesiology, a certification as a personal trainer by the National Strength and Conditioning Association (NSCA), and previous experience designing and implementing exercise programs. During the last exercise session, the PI was assisted by a track and field coach who also has previous experience designing and implementing exercise programs.

The first week lectures (sessions 1-2) focused on nutritional advice whereas the second week lectures (sessions 5-6) focused on exercise guidelines. Session 1 provided basic information on macronutrients such as carbohydrates, proteins, and fats; and explained the carbohydrate counting diet as it is described and recommended by the ADA. Session 2 provided tips on nutrition, as recommended also by the ADA, and included how to read labels, how to snack, and how to choose wisely at a restaurant/fast food chain. Session 5 described briefly what are the different modes of exercises and their benefits, tips to prepare for exercise, tips to get started and keep exercising, and special precautions for those with diabetes. Lastly, session 6 provided general exercise recommendations, explained how to work with different exercise intensities, presented examples on aerobic and resistance exercise, and engaged participants in simple exercises in order to teach them appropriate technique.
**Yoga practice.** Yoga classes (sessions 3-4 and sessions 7-8) consisted of basic yoga poses, such as those that relieve tightness across neck and shoulders and relieve lower back pain, and simple sitting and standing poses; breathing exercises, relaxation techniques, meditation, and philosophical principles. The PI also designed and implemented these sessions. She has a certification as an Experienced Registered Yoga Teacher (E-RYT) by Yoga Alliance, and more than 10 years of experience with a variety of populations including young and older adults, and diabetes patients.

Session 3 introduced the broad concept of yoga and its different philosophical branches and styles. Yoga was practiced sitting on a chair; exercises included gentle neck and shoulder stretches, hip openers, and modified yoga poses. Session 4 introduced the moral foundation of yoga and provided examples on the different yamas and niyamas. Yoga was practiced on the floor and included basic sitting asanas, gentle spinal twists, and gentle hip openers. Session 7 described the concept of pranayama and introduced basic breathing exercises such as diaphragmatic breathing and alternate nostril breathing. Yoga was practiced standing and included modified versions of the warriors and some balancing poses. Session 8 concluded the intervention by explaining the concepts of concentration, meditation, and samadhi. The meditation period lasted slightly longer in this session; for the physical practice participants were allowed to perform the same poses that were presented the previous day without any modifications if they chose to.

Explanation of philosophical principles was provided in simple everyday language and lasted no more than 10 minutes. This was followed by a short meditation of about 5-10 minutes that centered on conscious relaxation of the body and awareness of the natural rhythm of the
breath. Physical practice lasted approximately 30 minutes. All sessions ended with a 10-min relaxation period in the pose known as ‘savasana’ or ‘corpse pose.’

4.1.6 Analysis

Raw data from biological measures and questionnaires obtained during the intervention was displayed in graphs to allow for visual inspection. The effect of the intervention was assessed through examination of changes in patterns before and after every session (pre, post) between the different phases of the study (e.g. A₁ vs. B₁ and B₂ vs. A₂), and between participants. Data was further assessed by plotting differences in outcome scores to allow an easier comparison between phases and detect any association between biological measures and questionnaires.

4.2 RESULTS

Attendance was very good for this study. Only one participant missed one session because of a family emergency; the other two participants completed all eight sessions. None of the participants reported an adverse event during the yoga sessions, such as an hypoglycemic episode or musculoskeletal injuries derived from the practice.

All participants seemed interested and engaged during the nutrition sessions (phase A₁). The first day, in which the carbohydrate counting diet was presented, they looked a little concerned as they expressed that their current diets differ from current recommendations for diabetes patients. On the second day, in which practical tips were presented for reading labels, choosing healthy snacks, among others, they looked a little more relaxed.

For the first week of yoga classes (phase B₁) all participants looked interested and curious as the practice of yoga was defined and the moral foundation was presented. They also paid close attention to the instructions provided during the physical practice. However, they looked a little
uncertain when trying to accommodate their bodies to basic yoga poses. During these first two sessions, all participants appeared tense and a little frustrated for being unable to emulate the instructor’s movements.

Participant A expressed to have felt uncomfortable during the final relaxation which is conducted lying supine on the floor (savasana or corpse pose) because of lower back pain. Participant C did not report any pain, but did not express any relief or benefit from the practice either. On the contrary, participant M looked very distressed and in pain during practice and when asked about the reasons she reported to suffer from pain all over body, especially muscles and joints; she further described that her pain was sometimes so severe that she even had trouble putting on clothes, and when performing the stretches and movements during yoga classes she felt that her pain intensified.

For the exercise sessions (phase A₂) participants looked interested in the information presented. Nonetheless, there was a large difference in attention, engagement, and mood between sessions. On the first day, only information was provided and participants remained seated the entire session; questions and discussion was limited. On the second day, examples were provided on aerobic and resistance exercise and participants were prompted to stand from their seats to conduct simple body weight exercises in order to learn correct technique. All participants looked surprised as they realized they were able to perform these exercises safely and without major effort; subsequently, they all appear motivated and excited at the end of the session.

For the second week of yoga classes (phase B₂) all participants looked more comfortable and confident during the physical practice. They no longer appeared tense or frustrated, and they seemed to be able to focus on their own breathing and body movements instead of trying to emulate others and the instructor. In the last day, all participants looked genuinely interested as
the last phases of the Eight-limb Path of Patanjali were presented and seemed quite engaged during the meditation. During the physical portion of the class, participants were given the option to perform the yoga poses with or without modifications and all decided to execute the poses without any adaptations or props, which reflected their new level of confidence during yoga practice. During this last week participant A expressed to have felt truly relaxed, whereas participant M expressed to have experienced such relief in her muscles and joints that she was able to sleep better the night following the first class. Participant C did not express discomfort nor relief. They all felt content and looked accomplished as the study was concluded.

4.2.1 Changes in Blood Pressure and Heart Rate

Participant A

Blood pressure was normal throughout the study sessions for participant A; systolic blood pressure (SBP) < 129 mmHg and diastolic blood pressure (DBP) < 86 mmHg. During the baseline (A₁) SBP remained the same, whereas DBP decreased slightly. On the other hand, during the intervention (B₁) both SBP and DBP decreased. During the withdrawal phase (A₂) overall blood pressure increased. In contrast, SBP decreased during the re-introduction of the intervention (B₂) and DBP increased slightly. Heart rate was normal throughout the study sessions, 68-93 beats per minute. During the baseline (A₁) heart rate decreased slightly more compared to the intervention (B₁). During the withdrawal phase (A₂) heart rate decreased only in lecture 3 but increased in lecture 4. Similarly, during the second intervention (B₂) heart rate decreased only in yoga session 3 but increased in yoga session 4. See Figure 17 and 20.

Participant M

During the study sessions blood pressure varied for participant M from borderline systolic hypertensive (141-153 mmHg) to systolic hypertensive (162-177 mmHg), and from
normal DBP (82-84 mmHg) to mild hypertensive DBP (90-97 mmHg). During the baseline (A₁), blood pressure varied too; both SBP and DBP increased a few points during lecture 1, whereas both SBP and DBP decreased during lecture 2. During the intervention (B₁), both SBP and DBP increased, especially during yoga session 1. In contrast, during the withdrawal phase (A₂), overall blood pressure increased, and decreased during the second intervention (B₂). Heart rate was normal throughout the study sessions, 69-82 beats per minute. During both the baseline (A₁) and the intervention (B₁) heart rate decreased. Similarly, heart rate decreased during both the withdrawal phase (A₂) and the second intervention (B₂). See Figures 18 and 21.

Participant C

Blood pressure also varied for participant C during the study sessions from borderline systolic hypertensive (144-149 mmHg) to normal (117-139 mmHg), and from normal DBP (75-84 mmHg) to high normal (86-90 mmHg). Overall blood pressure increased during the baseline (A₁), whereas it decreased during the intervention (B₁). On the second week blood pressure varied between sessions within the same phase; decreased during lecture 3 but increased during lecture 4 (withdrawal phase or A₂), SBP increased and DBP decreased during yoga session 3, and both SBP and DBP decreased during yoga session 4 (intervention or B₂). Heart rate was normal throughout the study sessions, 75-90 beats per minute. During both the baseline (A₁) and the intervention (B₁) heart rate decreased; however, it decreased more during yoga sessions compared to the lectures. On the contrary, heart rate decreased more during the withdrawal (A₂) phase compared to the second intervention (B₂). See Figure 19 and 22.
Figure 17. Blood pressure difference (mmHg) before and after sessions in participant A. Participant missed lecture 2 because of a family emergency.

Figure 18. Blood pressure difference (mmHg) before and after sessions in participant M. Data was lost for yoga session 3.
Figure 19. Blood pressure difference (mmHg) before and after sessions in participant C.

Figure 20. Heart rate difference (beats per minute) before and after sessions in participant A. Participant missed lecture 2 because of a family emergency.
Figure 21. Heart rate difference (beats per minute) before and after sessions in participant M. Data was lost for session 7.

Figure 22. Heart rate difference (beats per minute) before and after sessions in participant C.
4.2.2 Changes in Blood Glucose

All participants presented elevated blood glucose levels at the beginning of the sessions throughout the intervention; values were higher than what is currently recommended by the American Diabetes Association (80-130 mg/dL).

Participant A

During the sessions participant A showed initial glucose levels between 250 and 393 mg/dL. For participant A, larger decreases in glucose were observed during the intervention (B₁) phase compared to the baseline (A₁). Similarly, larger decreases in glucose were observed during the second intervention (B₂) compared to the withdrawal phase (A₂), except for lecture 4. See Figure 23.

Participant M

During the sessions participant M showed initial glucose levels between 129 and 325 mg/dL. During the baseline (A₁) participant M showed greater decreases in glucose compared to the intervention (B₁). On the contrary, she showed greater decreases in glucose during the second intervention (B₂) compared to the withdrawal phase (A₂). See Figure 24.

Participant C

During the sessions participant C showed initial glucose levels between 138 and 306 mg/dL. For participant C, a greater decrease in glucose was observed during yoga session 2, which was part of the first intervention (B₁) compared to the baseline (A₁). However, there was minimal change in glucose levels during yoga session 1. On the contrary, she showed greater decreases in glucose during the withdrawal phase (A₂) compared to the second intervention (B₂). See Figure 25.
Figure 23. Glucose difference (mg/dL) before and after sessions in participant A. Participant missed lecture 2 because of a family emergency.

Figure 24. Glucose difference (mg/dL) before and after sessions in participant M.
4.2.3 Changes in Salivary Cortisol

According to the literature, salivary cortisol values in the evening should range between 0.022 to 0.254 µg/dL for adult females ages 51-70 years.

**Participant A**

Throughout the intervention participant A showed normal initial salivary cortisol values, from 0.031 to 0.181 µg/dL. During the baseline (A₁) she showed small decreases in cortisol, whereas in the intervention (B₁) she showed slight increases. On the contrary, there was considerably variability on the second week. During the withdrawal phase (A₂), cortisol decreased on lecture 3 but increased on lecture 4; on the other hand, during the second intervention (B₂) cortisol decreased on both yoga sessions. See Figure 26.

**Participant M**

Participants M showed higher than normal initial cortisol values in two sessions; 0.906 µg/dL and 0.696 µg/dL for lecture 3 and yoga session 3, respectively. She showed similar decreases in cortisol in both the baseline (A₁) and the intervention (B₁). During the withdrawal...
phase ($A_2$) there was a substantial decrease in cortisol on lecture 3, but a slight increase on lecture 4. During the second intervention ($B_2$) there was also a substantial decrease in cortisol on yoga session 3 and a small decrease in cortisol on yoga session 4, although not as large as lecture 3. See Figure 27.

**Participant C**

Participant C showed higher than normal initial cortisol values in several sessions; 0.335 µg/dL, 5.863 µg/dL, 0.376 µg/dL, and 0.305 µg/dL, for lecture 1, lecture 2, lecture 4, and yoga session 4, respectively. She showed considerably variability within sessions of the same phase. During the baseline ($A_1$) cortisol increased on lecture 1 but decrease substantially on lecture 2. On the other hand, during the intervention ($B_1$) cortisol increased slightly on yoga session 1 and decreased on yoga session 2. On the second week, there was less variation; during the withdrawal phase ($A_2$) cortisol decreased on both days, and during the final intervention ($B_2$) cortisol increased slightly on yoga session 3 and decreased on yoga session 4. See Figure 28.

*Figure 26. Changes in salivary cortisol before and after sessions in participant A. Participant missed lecture 2 because of a family emergency.*
4.2.4 Changes in Momentary Emotions

**Participant A**

Participant A showed greater improvements in emotional well-being during the intervention (B₁) compared to the baseline (A₁). She showed increases in positive emotions during the yoga sessions, whereas positive emotions remained fairly the same during lecture 1. Also, negative emotions decreased during yoga, while it increased slightly during lecture 1.
Similarly, she showed greater improvements during the second intervention (B\textsubscript{2}) compared to the withdrawal phase (A\textsubscript{2}) with greater increases in positive emotions during yoga sessions compared to the lectures. However, there was a small decrease in negative emotions during the withdrawal phase (A\textsubscript{2}), and a small increase in negative emotions during the second intervention (B\textsubscript{2}). See Figure 29.

**Participant M**

Participant M showed variability between sessions within the same phases. During the baseline (A\textsubscript{1}), she showed increases in both positive and negative emotions on lecture 1, but decreases in both positive and negative emotions on lecture 2. Likewise, she showed no changes in positive emotions during the intervention (B\textsubscript{1}), but an increase in negative emotions during yoga session 1 and a decrease in yoga session 2. During the withdrawal phase (A\textsubscript{2}) there was small variability in emotions, whereas during the second intervention (B\textsubscript{2}) she showed a large decrease in negative emotions in yoga session 3 and small variability in yoga session 4. See Figure 30.

**Participant C**

Participant C showed an overall greater decrease in negative emotions during the baseline (A\textsubscript{1}) compared to the intervention (B\textsubscript{1}); however, there was a greater increase in positive emotions during the intervention (A\textsubscript{1}) compared to the baseline (B\textsubscript{1}). On the other hand, she showed greater decreases in negative emotions during the second intervention (B\textsubscript{2}) compared to the withdrawal (A\textsubscript{2}) phase. Positive emotions decreased during the withdrawal phase (A\textsubscript{2}), whereas they remained fairly the same during the second intervention (B\textsubscript{2}). See Figure 31.
Figure 29. Changes in momentary emotions before and after sessions in participant A. Participant missed lecture 2 because of a family emergency.

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<td>YOGA 4</td>
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</table>

Figure 30. Changes in momentary emotions before and after sessions in participant M.

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</tr>
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<tr>
<td>YOGA 4</td>
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<td>-2</td>
</tr>
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</table>
4.2.5 Association Between Variables

Participant A

Participant A showed small variability during the baseline (A₁) across all measures under study. On the other hand, during the intervention (B₁) she showed greater improvements in emotional well-being which was concurrent with decreases in blood pressure and glucose. The largest decrease in negative emotions was observed after yoga session 1 which was accompanied by decreases in both SBP and DBP, and a large decline in glucose levels. Nonetheless, cortisol increased slightly after yoga sessions.

During the withdrawal (A₂) phase there appears to be no association between variables under investigation. Following lecture 3, SBP and DBP increased, but heart rate, cortisol and glucose decreased. On the contrary, after lecture 4, SBP and glucose decreased while heart rate, DBP, and cortisol increased. On the other hand, positive emotions improved overall during the second intervention (B₂), which is concurrent with decreases in SBP, glucose, and cortisol.

Figure 31. Changes in momentary emotions before and after sessions in participant C.
Moreover, the greater increase in positive emotions is observed during yoga session 3 which is accompanied by the largest decrease in glucose and heart rate.

*Participant M*

Participant M showed no apparent association between variables under study during the baseline (A₁). During lecture 1, both positive and negative emotions increased along with blood pressure, whereas cortisol, glucose, and heart rate decreased. On the contrary, during lecture 2 both positive and negative emotions decreased and once again cortisol, glucose and heart rate decreased. However, she showed an association between variables during the intervention (B₂). During yoga session 1, there was an increase in negative emotions which was concurrent with increases in glucose and blood pressure; cortisol and heart rate showed minimal changes. During yoga session 2, there was a decrease in negative emotions which was concurrent with decreases in glucose, heart rate, and cortisol.

Similarly, there seems to be no association between variables under study during the withdrawal phase (A₂). There were minimal changes in emotions, but increases in blood pressure along with decreases in glucose and a substantial decline in cortisol on lecture 3. On the other hand, there appears to be an association between well-being and biological measures during the second intervention (B₂). The largest decrease in negative emotions is observed after yoga session 3, which is accompanied by the largest decreased in glucose and a large decrease in cortisol.

*Participant C*

Overall, participant C showed no apparent association between variables under investigation across the different phases of the study. During the baseline (A₁) and the intervention (B₁) she showed decreases in negative emotions along with decreases in glucose, but
there was considerable variability in cortisol changes. Moreover, blood pressure increases during the lectures, whereas it decreases during yoga; heart rate remains fairly constant during the lectures, whereas it decreases during yoga.

During the second intervention (B2) she showed a greater improvement in emotional well-being compared to the withdrawal phase (A2); however, this was not accompanied by a large decrease in glucose or cortisol. In fact, the largest decrease in glucose is observed after lecture 3 and the largest decrease in cortisol is observed after lecture 4.

Table 16. Hypothesized effect of yoga practice on variables under study and results from the single-subject design

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<td>decrease</td>
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</table>

Note. Cells highlighted support the hypothesized effect of yoga practice on glucose control, well-being, and the physiological response to stress. *Decrease was greater in yoga sessions (interventions) compared to the lectures (baseline and withdrawal).

4.3 DISCUSSION

The purpose of the present single-subject design was to examine the acute effect of yoga practice on momentary glucose control of participants with T2DM. Hence, the study examined
changes in capillary glucose with a portable monitoring system before and after 60 minutes of yoga practice. It was hypothesized that glucose levels will decrease after 60 minutes of yoga practice as compared to a control condition (lectures). Participant A showed greater glucose reductions during the yoga sessions compared to the lectures, except lecture 4, which supports the proposed hypothesis. On the other hand, participant M experienced greater glucose reductions during the lectures compared to the yoga sessions on week 1, and greater glucose reductions during the yoga sessions compared to the lectures on week 2, partially supporting the hypothesis. In contrast, participant C showed overall greater reductions in glucose during the lectures compared to the yoga sessions, which did not support the hypothesis. (Table 16).

Discrepancy between patterns emerged in week 1 vs. week 2 in participant M may be explained by the intensity of the intervention sessions. As explained in the methods section, yoga sessions during the first week included gentle stretches and modified yoga poses sitting on a chair or on the floor. On the other hand, sessions during the second week included mostly standing and balancing poses, which represent a greater physical challenge compared to gentle poses on a chair or on the floor. Previous research has found that yoga standing postures elicit a greater physiological response compared to yoga sitting/lying poses including a higher heart rate, energy expenditure, and oxygen consumption (Hagins et al., 2007). Through a greater metabolic demand standing postures may in turn produce a larger utilization of glucose compared to sitting/gentle poses.

However, previous research has found that aerobic exercise of moderate intensity produces a decrease in glucose levels of approximately 20-40 mg/dL (Thompson et al., 2001), and glucose reductions in the yoga sessions of this study ranged between 17 and 116 mg/dL for participant M. Yoga practice represents physical activity of low intensity (Hagins et al., 2007)
and therefore it is unlikely more effective than aerobic exercise in improving glucose oxidation.

In addition, during the second week participant M showed larger decreases in glucose levels at the end of the yoga sessions compared to lecture 4, in which resistance exercises were performed. Consequently, the decreases in glucose observed in this single-subject study are unlikely the result of only the exercise effect and instead another mechanism may be contributing to the phenomenon observed. This mechanism may be a reduction in the magnitude of the stress response, which has a direct link to glucose metabolism, brought by improvements in emotional well-being as previously hypothesized and presented in Figure 1.

In order to explore the hypothesized mechanism momentary changes in positive and negative emotions, as well as changes in blood pressure, heart rate, and salivary cortisol were assessed before and after yoga practice, as representatives of emotional well-being and the stress response respectively. It was proposed that improvements in emotions will be concurrent with reductions in the previous biological variables in addition to reductions in glucose levels.

In participant M, changes in emotions were accompanied by changes in biological variables in the same direction; that is, as emotions worsen biological variables worsen and as emotions improved biological variables improved. On the first yoga session, she reported considerable discomfort during practice rather than physical relief due to her chronic muscle and joint pain. This is exemplified in Figure 30 where there are no changes in positive emotions and there is actually an increase in negative emotions after yoga session 1, which is concurrent with a substantial increase in blood pressure and a rise in blood glucose after yoga session 1 (Figures 18 and 24). On the other hand, she reported physical relief and relaxation during the second week of yoga practice, also exemplified in Figure 30 where small increases in positive emotions and
decreases in negative emotions are shown for yoga sessions 3 and 4, which are concurrent with decreases in blood pressure, heart rate, cortisol, and glucose (Figures 18, 21, 24, and 27).

The hypothesized mechanism is further supported by the trends observed in data from participant A. She showed greater improvements in emotional well-being after all yoga sessions compared to the lectures (Figure 29), which was concurrent with decreases in blood pressure and glucose (Figures 17 and 23). In fact, the greatest improvement in positive emotions is observed following yoga session 3, which is accompanied by decreases in blood pressure and heart rate, and the greatest glucose reduction observed across all sessions including the lectures.

On the other hand, trends observed in data from participant C do not support the hypothesis. She showed the greatest improvement in emotional well-being during the yoga sessions compared to the lectures, with the largest increases in positive emotions during the first intervention \(B_1\) and the largest decreases in negative emotions during the second intervention \(B_2\); see Figure 31. However, improvements in temporary emotions were not consistently concurrent with improvements in biological variables. For instance, the greatest decrease in negative emotions observed after yoga session 4 was accompanied by a small increase in glucose levels. In fact, overall participant C showed greater decreases in glucose following the lectures compared to the yoga sessions. Also, cortisol changes were similar between lectures and yoga practice, except for lecture 2 that showed the largest decrease across all sessions.

It is difficult to determine what made the lectures more effective than the interventions in reducing blood glucose for participant C. One possibility may be that participant C felt highly motivated to improve her diabetes self-care during the control conditions; lectures provided an easy-to-follow diet for diabetes patients and nutritional tips as well as accessible options to start and maintain an active lifestyle. As she experienced improvements in emotional well-being
during lectures, as shown in Figure 31, she also experienced reductions in the stress response which was in turn reflected in decreases in glucose. The greater decrease in glucose observed in lectures compared to yoga practice may be simply the result of different initial values and consequently greater room for change. For instance, at the beginning of lecture 3 glucose had a value of 306 mg/dL whereas at the beginning of yoga session 3 glucose had a value of 150 mg/dL; as a result, a greater decrease would be expected for lecture 3. Initial values may influence the degree of change observed after an intervention (Thompson et al., 2001), and hence is a factor that must be taken into consideration for future studies.

In conclusion, findings from this study partially support the proposed hypotheses. Larger decreases were observed in yoga sessions compared to the lectures on both weeks for participant A and on week 2 for Participant M. However, larger decreases in glucose were observed in the lectures compared to the yoga sessions in Participant C. Similarly, concurrent changes were observed between momentary emotions, cortisol, and glucose in participants A and M; however, the phenomenon was not observable in participant C (see Table 16). Hence, additional research is needed to elucidate the acute effect of yoga practice on the glucose control of T2DM patients.

4.3.1 Comparison with Previous Findings in the Literature

Even though research on the acute effect of yoga practice is limited, the results from this study are comparable to previous findings in the literature. Participants with diabetes in this study experienced small changes in heart rate and blood pressure after yoga sessions, except for a few sessions. Likewise, a previous exploratory study did not find significant changes in heart rate in healthy male and female volunteers following a 43-minutes yoga session (Resnik, McLean, & Smith, ) and a single-study design did not find significant changes in heart rate or blood pressure in healthy college athletes after 50-minutes yoga sessions (Fallon, 2008).
The small changes in blood pressure observed in this single-subject study may be the result of the physiological response to exercise previously found by the literature which is termed “post-exercise hypotension” or PEH; this phenomenon has been observed in exercise intensities as low at 40% of maximum oxygen consumption (Thompson et al., 2001), similar to the yoga sessions of this study. Previous research has found that PEH may last for up to 16 hours following the last exercise session, which confers special benefit to those individuals suffering from high normal to Stage I hypertension (Thompson et al., 2001), like participants M and C from this study.

Regarding glucose control, it is difficult to compare the results from the present investigation with those of the only published study available in the current literature on the acute effects of yoga practice on glucose metabolism of T2DM patients (Cokolic et al., 2013). First, Cokolic and colleagues followed a quasi-experimental study design and hence contained considerably different number of participants and different modes of data analyses. Second, they assessed different measures of glucose control; the present investigation examined momentary changes in capillary glucose, whereas the study by Cokolic et al. (2013) examined changes in postprandial glucose (PPG), that is, changes in glucose two hours after consuming a meal. Lastly, Cokolic et al. (2013) implemented an intervention called “laughter yoga” that included clapping, laughing, and walking in addition to the traditional yoga components, which is considerably different from the intervention implemented in this single subject study. Nonetheless, it may be possible that reductions in blood glucose observed in both studies are the result of similar mechanisms, that is, a combination between the exercise effect and a decrease in the stress response.
In regards to hormonal changes, participants A and M from this study showed decreases in salivary cortisol after the yoga sessions of the second intervention (B2), but increases in salivary cortisol after lecture 4 from the withdrawal phase (A2) in which resistance exercises were performed. Similarly, West et al. (2004) found significant decreases in salivary cortisol in healthy college students that completed a 90-minute yoga class, whereas salivary cortisol levels increased in students that completed a 90-minute African dance class. This phenomenon can be explained by the fact that moderate-to-high intensity exercise that lasts longer than 30 minutes has been found to increase cortisol levels, whereas low-intensity exercise has been found to decrease cortisol levels (Powers & Howley, 2007). As mentioned previously, yoga has been found to be a low-intensity form of exercise, and the African dance class may had been of at least moderate intensity. However, given the additional role of cortisol in the stress response, it cannot be discarded a possible influence of the relaxation response on the cortisol decreases observed in participants that engaged in yoga practice in these studies.

On the subject of mental health, overall T2DM participants in this study showed improvements in positive and negative emotions after 60 minutes of yoga practice. Fallon (2008) also found overall improvements in positive emotions following 50-minutes yoga sessions in healthy college students. Similarly, Berger & Owen (1992) found decreases in anger, confusion, tension, and depression scores after an 80-minute yoga session in a sample of college students, whereas West et al. (2004) found significant reductions in perceived stress and negative affect after a 90-minute yoga class also in college students.

Lastly, the results from this study that followed a single-subject ABAB design were not consistent across participants. Two out of three participants showed patterns in the variables under investigation that were in accordance with the hypotheses presented. In contrast, one
participant did not show a discernible pattern and hence, her results do not support the hypotheses under study. Similarly, Fallon (2008) found inconsistent results in her single-subject AB design study that examined the preventive impact of a yoga program on stress reduction and enhanced well-being in healthy African-American college athletes. In her study, three out of seven participants showed positive outcomes that included decreases in perceived stress, as well as increases in positive emotions and perceived well-being; another three showed inconclusive outcomes, and one showed negative outcomes.

Moreover, Fallon (2008) observed that the participant that showed negative outcomes in her study reported these at the beginning of the intervention, but as the intervention progressed participant’s scores improved. She explained that such inconsistency may be the result of an initial period of difficulty when one starts a new activity and that requires an adjustment period before the potential benefits of an intervention can be observed (Fallon, 2008). These observations are in line with the results from the present investigation that suggests that a period of adjustment to yoga and/or meditation practice may be necessary before the potential benefits of these practices can be detected.

4.3.2 Considerations for Future Studies

The different patterns observed between participants in single-subject designs may be the result of individual characteristics. In the case of people previously diagnosed with diabetes these can include history of chronic pain, diabetes-related complications, or comorbidities. For instance, a person suffering from chronic lower back pain, neuropathy, or arthritis may require additional time to adjust to yoga practice given that this discipline requires to move the body in diverse planes of motion which may at first aggravate physical discomfort and subsequently may affect the emotional and physiological response to an intervention. Therefore, individual
characteristics can augment differences in patterns that emerge from single subject designs and in turn obscure the true effect of yoga practice and its potential benefit to T2DM patients. Future studies should document extensively the health background of participants in order to take individual differences into consideration and clarify the magnitude and direction of the intervention effect on glucose control and other health markers of T2DM patients with specific characteristics.

Novice participants also seem to require a couple of sessions to understand the relaxing nature of yoga practice which may further increase variations between phases implemented. Participants’ inexperience in yoga and meditation practice may have an influence on what they experience at the mental level during the first few sessions of yoga practice, and subsequently on the physiological changes that take place. Previous research have found that meditation practitioners describe the practice as a skill difficult to learn and describe early attempts as personally challenging that induce self-doubt and sometimes physical discomfort (Lomas, Cartwright, Edginton, & Ridge, 2015). In the present study, participants looked a little anxious and restless during yoga practice, whereas in the second week they looked more comfortable and relaxed. It is possible that participants could have experienced anxiety as they attempted to focus their attention on their breathing and posture for the first time, and as they became more familiarized with the practice their anxiety diminished, which may explain greater improvements in emotional health in the yoga sessions of the second week compared to the sessions of the first week across all participants. However, these are only assumptions and future investigations should attempt to obtain a more throughout description of participants’ personal experience during practice in order to clarify the impact of yoga and meditation practice on temporary
emotions. Surveys may not be sufficient and instead participants’ own accounts, along with the investigator’s observations, may provide a richer description of the phenomenon under study.

Variations in the content of the interventions may also cause considerably different acute effects in both biological markers and mental health measures. Given the exploratory nature of the present study, the content of the yoga sessions varied as the physical practice was adjusted to the specific needs and limitations of participants. However, in order to clarify the acute effect of yoga practice on the physical and mental health of participants with T2DM future investigations must implement equal control conditions and very similar yoga sessions.

Subsequent single-subject designs that examine the acute effects of yoga may consider the possibility of establishing a ‘baseline’ yoga phase prior to the main intervention in which participants are allowed time to learn proper breathing, adequate technique, and the principles of non-self-judgement and non-competition that are inherent in this particular practice. Once the ‘baseline’ yoga phase ends, the main intervention that includes very similar yoga sessions can be implemented. Additionally, the ‘baseline’ yoga phase can elucidate the specific strengths and limitations of participants, and hence serve as a guide for the design of the main intervention that should always be tailored to the practitioner’s needs.

Lastly, another interesting strategy to assess the proposed mechanism of stress relief and subsequent reduction in stress hormones of T2DM patients would be to examine changes in catecholamines, specifically epinephrine and norepinephrine. Actions of these hormones take place within seconds (Sapolsky et al. 2000) and include increased rate of contraction of the heart muscle, constriction of blood vessels, and mobilization of glucose (McCarty, 2016). Hence, it would be expected to see decreases in heart rate, blood pressure, and glucose levels if catecholamines, as part of the stress response, are reduced following yoga practice and
meditation. The challenge would be to accurately assess catecholamines changes given the
difficulties of sample collection. For example, just the experience of venipuncture for blood
collection can be too stressful for a participant that can significantly elevate epinephrine and
norepinephrine levels which would not reflect the effect of a particular intervention but the effect
of the procedure (Mills & Ziegler, 2008). An alternative suggested by previous literature is the
use of a catheter that allows the subject to rest and bring catecholamines levels down to baseline
levels following the stress of the procedure before blood collection takes place (Mills & Ziegler,
2008); however, this strategy is time consuming, invasive, and requires adequately trained
personal.

Limitations

This study was exploratory in nature. Hence, it cannot provide strong conclusions for the
hypotheses presented. Instead, it can only provide suggestions and directions for future
investigations that continue to examine the acute effect of yoga practice on the physical and
mental health of T2DM patients.

Similar to the quasi-experimental design presented before in this dissertation work,
another limitation of this study may be the limited ability of the chosen measures to capture
concepts under study. Glucose variations could be easily influenced by other factors not under
investigation such as unreported changes in medication and diet. All participants reported the
kind of medication that were taken daily and they were asked to refrain from food consumption
two hours prior to classes; however, if a participant forgot to take her usual medication or
ingested a snack before assessments and did not report it, it could have had an impact on the
glucose variations detected before and after the intervention sessions.
Also, the survey used to assess changes in emotional well-being may not have been sufficient to capture participants’ experience during yoga practice. As mentioned previously, participants’ own accounts, along with the investigator’s observations, may be necessary to acquire a better understanding of what is difficult or challenging for a participant, or to what extent the different components of yoga practice are beneficial to participants’ perceived stress and well-being.
CHAPTER 5: CONCLUSIONS

5.1 LESSONS LEARNED

The present dissertation work provided ample opportunities for learning and for adjusting to unforeseen circumstances before and during the completion of the intervention and data collection. The greatest challenge was recruiting and securing sufficient number of participants for the originally planned randomized controlled design study and as indicated by an *a priori* power analysis. Recruiting strategies kept evolving as months passed and the number of potential participants remained low, in spite of the fact that the border area has a prevalence of T2DM higher than the rest of the country. Even when some strategies were more helpful than others, it was still not enough to obtain a sufficiently large sample to conduct sophisticated study designs such as a randomized experimental design. Consequently, a quasi-experimental design was conducted instead.

It is the opinion of this author that whenever time, resources, and financial support are limited, such as in theses and dissertations, investigators should look for alternative study designs especially when focusing on a difficult target population like diabetes patients. An alternative design that is conducted with rigorous methodology may be as valid and in some situations more appropriate than a randomized controlled trial. In a meta-analysis by Concato, Sha, & Horwitz (2000), results from well-designed observational studies, with either a cohort or a case-control design, were surprisingly similar to the results from randomized controlled trials in studies investigating the same topic. They concluded that alternative designs often considered ‘inferior’ do not systematically overestimate the magnitude of the effects of a particular treatment as compared to randomized controlled trials (Concato, Sha, & Horwitz, 2000).
Furthermore, previous authors have pointed out that the assumption that randomized controlled trials are always externally valid may be inappropriate in certain circumstances, such as evaluations of interventions that involve complex causal pathways that may be affected by multiple characteristics of the population or the environment (Victora, Habicht, & Bryce, 2004). That is, results that derive from an intervention that takes place under highly controlled conditions may not be observable in a real-life scenario when numerous factors come into play.

For the present dissertation work, a viable alternative could have been to plan a single-subject design from the beginning. As mentioned previously, single-subject designs have the advantage of informing decisions about patients with specific characteristics, which is particularly helpful whenever there is a large variability and heterogeneity across individuals in a given population (Guyatt et al., 2000), like that of T2DM patients. Single-subject designs are also particularly helpful for primary care practice-based research in which treatments can be individualized to improve outcomes (Janosky et al., 2009). This is especially relevant for the investigation of yoga as a complementary therapy in diabetes care. Given that yoga practice is composed of varied components such as physical poses, breath work, relaxation, and meditation, a single-subject cross-over design, for example, can inform about the specific components of yoga that are most effective and safe for a particular patient with specific characteristics.

Another strategy that can be followed in future investigations is to take into account the cultural characteristics of the population that is being recruited. Although it is difficult to determine the specific reasons that potential participants had to decline participation last minute, a possible explanation is the existence or non-existence of social support. Based on informal conversations with participants from the studies presented in this dissertation work, support from family was critical to start and continue yoga practice. For instance, one participant actually
enrolled in one of the studies because of her sons’ encouragement; moreover, her own sons would drive her to classes and wait for her in the parking lot to finish practice every single session. Another participant was driven to every class by her daughter and it was her daughter who encouraged her to continue attending classes even though other family members kept dissuading her and demanding for her attention. In fact, some participants reported that they had to negotiate with family members in order to have time available for their yoga practice. For example, one participant mentioned that she had to be determined and strong while establishing a limited number of hours that she could take care of her grandchildren for her adult children.

Previous research has found that Hispanic women who have high levels of social support are less likely to be sedentary than those with low support, and compared to other racial/ethnic groups (Eyler et al., 1999). Likewise, high levels of perceived family support have been associated to higher levels of diet and exercise self-care in Mexican-Americans with T2DM aged 55 years or older (Wen, Sheperd, & Parchman, 2004). Therefore, it appears that social support for a participant sample of Hispanic women is a critical factor that must be taken into account during exercise and movement therapy interventions.

Hence, a possible recruiting strategy when focusing on this particular population is to highlight potential health benefits of the practice and invite family members to be part of the intervention. This way, as family members get involved and experience benefits themselves, they may provide the social support that participants require to decide to enroll, continue attending classes and complete the intervention under study. Participation of family members would require additional permission from the institutional review boards of the academic institutions and a spacious location that allows a large group of individuals to practice together; but if the
academic support and the resources are available, this is definitely a strategy that must be considered.

Another challenge before and during the completion of this dissertation work was the limited budget available for the purchase of material and participant incentives. The challenge of a limited budget was further augmented by the current procedures of the university in the acquisition of goods through limited providers that in many occasions were significantly more expensive than providers available online. As a result, creative budget strategies were employed to overcome this financial barrier such as negotiating with approved providers for a student discount; borrowing of yoga mats and props from current fitness classes at the university and from family members instead of purchasing materials; and prioritizing how the money will be spent on biological markers and incentives. For example, instead of focusing assessments on nighttime salivary cortisol and DHEA for both yoga and control groups from the quasi-experimental design, which would provide limited data on hormonal function, the diurnal curves of both hormones were assessed only in the yoga group only; that is, all available funding for materials for hormone assessment was spent on the intervention group alone to explore the effect of the intervention in these biological markers. By the same token, participant incentives were only offered in the single-subject design study given the small sample.

Another difficulty presented before the beginning of the interventions of both studies presented in this dissertation work was securing a location for yoga practice. The university has evolved substantially in the last couple of years, and our own College of Health Sciences transitioned to a brand new building that contains modern technology in both classrooms and laboratories. However, there is no space for the implementation of interventions such as yoga or other movement therapies like tai-chi or qi-gong. As a result, this author had to reach to outside
departments to find a location for yoga practice, and these departments were not always willing
to assist given that their main focus was teaching the student population and serving the outside
community, and research was not among their priorities. In addition, even though a room was
reserved for the quasi-experimental study, on the first day of yoga classes it turned out that the
location was double-booked with a student fitness class. No support was offered from those in
charge of this building and preference was given to the student class, requiring negotiations with
the fitness instructor so that both classes could remain in the same location.

It is the present author’s belief that these issues have important implications for the future
of the university as a research institution. Open collaboration must exist between the departments
so that students can conduct research studies without unnecessary and unforeseen obstacles. In
addition, the College of Health Sciences must secure a space that can be used for a variety of
health interventions associated with the research of its faculty and graduate students. Similarly,
faculty members must be open for collaboration and facilitate the use of equipment and
laboratories to students that are not directly under the supervision so that students can be free to
pursue any line of research without being limited to the particular resources of their primary
advisors.

Lastly, another problem that presented during the implementation of the interventions
was the existence of unreported physical conditions in participants that caused pain or discomfort
during yoga classes. As described previously in the methods of both studies, the exclusion
criteria included medical conditions that may prevent participation in the yoga classes such as
chronic and severe pain, or musculoskeletal injuries. All participants claimed to be free of these
conditions at the moment of recruitment. However, during the classes of the quasi-experimental
design (8-week yoga intervention) one participant reported discomfort during forward torso
flexions and rotations due to a previous surgery, and another participant dropped from the study because of aggravated pain in her sciatic nerve. In addition, one participant from the single-subject design did not report her chronic muscle and joint pain at the moment of recruitment, but waited until the yoga practice was taking place.

Therefore, if future investigations plan to exclude participants with medical or physical conditions that may produce pain or discomfort during an exercise/movement therapy intervention, questionnaires may not be enough and instead a throughout face-to-face interview may be necessary during the initial evaluation. Researchers must be aware that they may need to probe potential participants with multiple open-ended questions as they try to determine prior medical history and even symptoms that may be indicative of complications or comorbidities. In the present dissertation work, several participants stated they were free from comorbidities such as high blood pressure and high cholesterol; nonetheless, an examination of their medication logs indicated that they were taking medication to lower blood pressure and cholesterol, which may indicate that they suffer from these comorbidities. Hence, it is of utmost importance that researchers expand their inquiries into the present health status of participants to ensure that they indeed comply with all inclusion/exclusion criteria and to take into account individual differences when interpreting the results.

5.2 IMPLICATIONS OF FINDINGS

Participants from this study did not report any adverse event during the yoga interventions. None of the participants experienced sudden drops in blood glucose or dangerous variations in blood pressure; and none of them reported injuries of any kind such sprains, strains, muscle tears, or lesions to the feet. Participants reported that classes were sometimes challenging but feasible and enjoyable. Participants that did not complete the 8-week yoga intervention or
that missed a session during the single-subject study did so because of reasons unrelated to yoga practice like family emergencies and work demands.

Hence, based on the results obtained from both studies presented in this dissertation work, it can be concluded that yoga practice is safe for women between the ages of 50 and 65 years who have been previously diagnosed with T2DM, who have been sedentary for many years, who are overweight, and who present comorbidities like high blood pressure and high cholesterol. The physical aspect of yoga practice must be of light intensity, at least in the first 8 weeks of practice, and must be tailored to the specific needs, limitations, and strengths of participants. Yoga researchers and teachers must be aware that participants may not always declare explicitly any pain or discomfort they may be experiencing during class, or previous medical conditions that might be exacerbated by yoga practice. Consequently, a thorough examination must be conducted at the beginning of a yoga program that not only includes a health questionnaire but also probing questions on previous injuries, current bodily pain, and medical history.

Results from the quasi-experimental study partially support findings from previous studies investigating the effectiveness of yoga for improving glucose control in T2DM patients. A trend towards improvement in hemoglobin A1c was found after eight weeks of yoga practice. Factors that may confound the results such as diet, medication, and additional physical activity did not change during the duration of the intervention, and therefore changes are assumed to be due to the intervention. Nonetheless, the low participant sample and large variation between participants’ results limit the ability of this study to provide strong conclusions. Additional research is still needed to confirm the effectiveness of yoga practice as a complementary therapy that aids glucose control in T2DM.
Similarly, glucose reductions observed during the single-subject design study showed considerable variation between participants. Consequently, at this point it is not possible to conclude that a single yoga session provides benefits in glucose control in T2DM. Nonetheless, larger decreases in glucose observed in yoga sessions compared to the lecture/exercise session guarantee further examination on the potential acute effect of yoga in reducing glucose levels beyond an exercise mechanism.

In regards to the mental aspect of yoga practice, significant results in conjunction with participants’ statements during informal conversations in the quasi-experimental study provide support that brief periods of meditation practice such as 10-15 min, twice a week are effective in reducing perceived stress levels during everyday life. In addition, observations from the single-subject design study indicate that meditation for 10-15 min along with yoga movement practice may be effective in improving well-being after a single session. Further research is necessary to confirm these results and further examine the role that yoga practice may have on several dimensions of mental health.

Results from the quasi-experimental study support previous observations in the literature on the phenomenon of a blunted cortisol awakening response in T2DM patients. Overall, participants showed lower than normal salivary cortisol values in the morning. In addition, participants showed higher than normal salivary cortisol values in the evening, also observed in previous studies. This was also found in the single-subject study; some participants showed elevated salivary cortisol levels in the evening at the beginning of some intervention sessions. In combination, both studies support the premise of hormonal dysregulation in diabetes patients previously reported by the literature.
Furthermore, according to this author’s knowledge, the quasi-experimental study presented in this dissertation work is the first investigation that describes an abnormal salivary DHEA curve in T2DM patients. This curve showed a reverse pattern compared to salivary cortisol, with higher than normal salivary DHEA values in the morning. The implications of this finding on the glucose control and overall health of the patient with diabetes are unknown and hence guarantee further investigation.

Regarding the mechanism explored as a possible explanation for the potential benefits of yoga practice on glucose control of T2DM patients, the overall findings from this dissertation work partially support it. In the quasi-experimental study, a trend towards normal values in both salivary cortisol and salivary DHEA in the morning following the intervention suggest that yoga practice may have helped to ameliorate hormonal dysregulations in individuals with diabetes. In addition, significant associations between improvements in mental health and improvements in salivary cortisol and DHEA in the morning may indicate a relationship between mental health and endocrine function. However, since changes in the hormonal curves were not statistically significant, participant sample was low, and no comparison was possible with the control group because of budget limitations, the link between stress hormones and mental health in T2DM cannot be confirmed with present findings.

Also, in the quasi-experimental study no association between changes in mental health and changes in glucose, or between changes in stress hormones and changes in glucose was found. Hence, even when the association between stress hormones and mental health was partially supported, their impact on the glucose control of T2DM patients is still undetermined. It may be possible that a longer yoga intervention is required for cortisol and DHEA to exert their influence on glucose control, and in turn to observe significant associations between these
hormones and glucose levels, or simply that there is indeed no association between these biological variables; however, this is unlikely given the role of cortisol and DHEA in glucose metabolism.

In the single-subject design study, visual inspection of raw data and comparison of difference in scores indicated a concurrent decrease in glucose and salivary cortisol along with improvements in emotional health. Nonetheless, these observed associations were not consistent across participants nor across experimental sessions. Therefore, the acute effect of yoga on stress relief and glucose control in T2DM is still inconclusive. Results point towards a possible beneficial impact of yoga practice, but benefits may vary based on participants’ characteristics and the mode of yoga implementation. Further research is needed to clarify acute effects of yoga practice in diabetes mental and physical health.

Lastly, the present dissertation work provides useful guidelines and lessons learned for future investigators, especially for graduate students conducting theses and dissertations in the topic of T2DM within the constraints of time and resources. In general, the most important message of these lessons learned is the need to be flexible to adapt to unforeseen circumstances beyond personal control, and the need to be creative to find solutions that allow the research project to continue.

5.2.1 Translation into Public Health Practice

Even though the present dissertation work focused on the effect of yoga practice on the physical and mental health of people already diagnosed with a chronic disease, the findings have important implications for overall public health. Both studies found trends towards improvement in dimensions of mental health, specifically on perceived stress and emotional well-being. Additionally, both studies found trends towards improvement in the physiological response to
stress including a normalization pattern for the hormones cortisol and DHEA. Of particular relevance is the fact that these trends were observed following yoga practice of low-to-moderate intensity that was tailored for individuals who were previously sedentary for several years and had limited levels of flexibility, strength, and balance. Yoga can then provide important health benefits even if its practice is not vigorous and can be performed by a variety of populations including those who have low levels of fitness. Therefore, the findings from this study support the use of yoga as a discipline that promotes and fosters health for the general population, especially among individuals that are looking for an activity that provides not only physical benefits but also stress relief.

Yoga is easy to implement, it does not require expensive or sophisticated equipment, and it can be practiced at home once it has been learned by an experienced yoga instructor, which is appealing for those with a limited budget and restricted schedule. Conversely, yoga can be easily implemented across diverse community settings without the need of special facilities; yoga can be practiced seated on a chair in a library or classroom, between breaks at work or at school, or at the park.

Moreover, yoga can be permeated into other realms of everyday life beyond the actual practice. As explained in the literature review, yoga philosophy may help the practitioner to modulate his or her interpretation of life events that can potentially cause psychological distress which would decrease the overexposure to stress hormones that can negatively affect physical health. The results from the present dissertation work support the use of a holistic yoga program that incorporates yogic philosophy in addition to traditional components such as breath work, postures, and meditation. Participants reported that they enjoyed the holistic nature of the program and that the philosophy presented did not conflict with their personal religious beliefs.
Future research should continue to investigate the feasibility of implementing yoga practice, including its philosophy, across community settings with varied religious and cultural backgrounds.

5.2.2 Future Research Considerations

Future studies should continue to investigate the impact of yoga practice on the glucose control of T2DM patients following rigorous methodology. Variables that can potentially decrease the internal validity of the study such as changes in diet, medication, and physical activity should continue to be monitored for substantial changes during the intervention. Other factors that may affect validity of the results like age, sex, duration of diabetes, diabetes-related complications, and comorbidities should be controlled through specific inclusion/exclusion criteria or statistically.

Ideally, future studies should contain sufficiently large samples of participants that provide adequate statistical power that allow for the detection of potential effects of the intervention. Also, future studies should consider focusing on specific subgroups of T2DM patients, such as those with specific diabetes-related complications or following a specific medication therapy; this will not only minimize the impact of individual variability on statistical analyses but will also inform about the safety of yoga practice for patients with specific characteristics.

Finally, future studies should continue to employ the single-subject design as a useful research strategy for inquiries on the impact of yoga on the overall health of the diabetes patient. The field is still quite open for the exploration on the effect of a variety of yoga components and styles on a variety of health markers beyond glucose control. Additionally, the field can start moving from a focus on psychological stress towards an exploration on the impact of yoga
practice on positive dimensions of mental health like positive emotions and flourishing. The single-subject design strategy can serve as a start point in pilot studies that inform future large-scale investigations.
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elderly subjects with chronic type 2 diabetes mellitus- A randomized controlled trial. 


GLOSSARY

Acute – for the purposes of this dissertation, any period of yoga practice shorter than 2 hrs.

Asana – yoga postures.

CAR – cortisol awakening response; the dynamic cortisol secretion following awakening that is part of the normal circadian physiology of the human body. It refers specifically to the period immediately upon awakening and 30 min following awakening.

Chronic – for the purposes of this dissertation, any period of yoga practice longer than four weeks.

DHEA – dehydroepiandrosterone; hormone with anti-inflammatory and anti-oxidant properties that counter-regulates actions of the hormone cortisol.

FBG – fasting blood glucose; blood glucose levels during the fasting state.

HbA$_{1c}$ – hemoglobin A$_{1c}$; the non-enzymatic attachment of glucose molecules to the hemoglobin chain that reflects glucose levels in the last 2-3 months. It is used as a measure of long-term glycemic control.

HPA – hypothalamic pituitary adrenal axis; one of the primary systems involved in the stress response that begins from signals in the brain and culminates with the release of hormones in the adrenal glands such as epinephrine and cortisol.

PPG – post-prandial glucose; blood glucose levels 2 hours after eating a meal.

Pranayama – breathing component of yoga practice; also, the fourth step of the eight-limb path as delineated by Patanjali.

Sutras – philosophical statements through which the principles of yoga practice were described by Patanjali.

Yoga sutras of Patanjali – An ancient treatise composed by the sage Patanjali around 200 A.C. that later came to be regarded as one of the six classical schools of Indian philosophy. The text delineates a systematic method that allows the practitioner to train the mind in order to transcend his current psychological state. Also known as the Eight-limbed Path of Patanjali.
Appendix A: Characteristics of Previous Studies Investigating the Effects of Yoga Practice on Glycemic Control in T2DM Patients

<table>
<thead>
<tr>
<th>Authors</th>
<th>Year</th>
<th>Design</th>
<th>Sample size (N)</th>
<th>Sex</th>
<th>Type of control</th>
<th>Length of study</th>
<th>Frequency of intervention</th>
<th>Yoga Style</th>
<th>Yoga components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rajesh et al.</td>
<td>2013</td>
<td>Pre-post</td>
<td>120</td>
<td>males</td>
<td>N/A</td>
<td>100 days</td>
<td>Everyday</td>
<td>Hatha yoga*</td>
<td>Hatha yoga, Asanas, pranayama, bandhas</td>
</tr>
<tr>
<td>Vaislai</td>
<td>2012</td>
<td>Pre-post</td>
<td>15</td>
<td>Both</td>
<td>N/A</td>
<td>6 weeks</td>
<td>3x/week</td>
<td>Hatha yoga</td>
<td>Asanas, pranayama, and meditation</td>
</tr>
<tr>
<td>Madanmohan et al.</td>
<td>2014</td>
<td>Control trial</td>
<td>110</td>
<td>Both</td>
<td>NI</td>
<td>6 months</td>
<td>3x/week</td>
<td>Hatha yoga</td>
<td>Asanas, pranayama, and relaxation</td>
</tr>
<tr>
<td>Pujari et al.</td>
<td>2014</td>
<td>Control trial</td>
<td>40</td>
<td>Both</td>
<td>Standard care</td>
<td>6 weeks</td>
<td>Everyday</td>
<td>Hatha yoga*</td>
<td>Asanas, pranayama</td>
</tr>
<tr>
<td>Ilegde et al.</td>
<td>2011</td>
<td>Matched control</td>
<td>231</td>
<td>Both</td>
<td>Standard care</td>
<td>6 months</td>
<td>3-4 x/week</td>
<td>Hatha yoga</td>
<td>Asanas, pranayama, and relaxation</td>
</tr>
<tr>
<td>Mahapatra et al.</td>
<td>2010</td>
<td>Matched control</td>
<td>60</td>
<td>Both</td>
<td>Standard care</td>
<td>45 days</td>
<td>5x/week</td>
<td>Hatha yoga*</td>
<td>Asanas, pranayama</td>
</tr>
<tr>
<td>Gordon et al.</td>
<td>2008</td>
<td>Matched control</td>
<td>60</td>
<td>Both</td>
<td>Standard care</td>
<td>40 days</td>
<td>Everyday</td>
<td>Hatha yoga</td>
<td>Asanas, pranayama, and relaxation</td>
</tr>
<tr>
<td>Kyizom et al.</td>
<td>2010</td>
<td>Matched control</td>
<td>60</td>
<td>Both</td>
<td>Standard care</td>
<td>5 months</td>
<td>Everyday</td>
<td>Hatha yoga*</td>
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<td>Dash et al.</td>
<td>2014</td>
<td>RCT</td>
<td>60</td>
<td>Both</td>
<td>Standard care</td>
<td>3 months</td>
<td>Once or twice per week</td>
<td>Hatha yoga</td>
<td>Asanas, relaxation, pranayama, and diet</td>
</tr>
<tr>
<td>Monroe et al.</td>
<td>2003</td>
<td>RCT</td>
<td>154</td>
<td>Both</td>
<td>Standard care</td>
<td>&lt; 3 months</td>
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<tr>
<td>Agrawal et al.</td>
<td>2004</td>
<td>RCT</td>
<td>87</td>
<td>Both</td>
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<td>Everyday</td>
<td>Hatha yoga*</td>
<td>Asanas, pranayama, and relaxation</td>
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<td>Agai &amp; Tawadi</td>
<td>2004</td>
<td>RCT</td>
<td>32</td>
<td>Both</td>
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<td>&gt; 3 months</td>
<td>Everyday</td>
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<td>Asanas, pranayama</td>
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<tr>
<td>Singh et al.</td>
<td>2008</td>
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<td>60</td>
<td>Both</td>
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<td>&lt; 3 months</td>
<td>Everyday</td>
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<tr>
<td>Amin et al.</td>
<td>2009</td>
<td>RCT</td>
<td>41</td>
<td>Both</td>
<td>Standard care</td>
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<td>Sinha-Konda et al.</td>
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<td>Pardasany et al.</td>
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<td>RCT</td>
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<td>Balaji et al.</td>
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<td>Asanas, pranayama</td>
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<tr>
<td>Vaishali et al.</td>
<td>2012</td>
<td>RCT</td>
<td>57</td>
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<td>&gt; 3 months</td>
<td>Everyday</td>
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<td>Asanas, pranayama</td>
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<tr>
<td>Nagarathna et al.</td>
<td>2012</td>
<td>RCT</td>
<td>277</td>
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<td>Subramaniyan et al.</td>
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<td>RCT</td>
<td>20</td>
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<td>Cokellie et al.</td>
<td>2013</td>
<td>RCT</td>
<td>211</td>
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<td>Lecture</td>
<td>&gt; 3 months</td>
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<td>Asanas, pranayama</td>
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<td>Bindra et al.</td>
<td>2013</td>
<td>RCT</td>
<td>100</td>
<td>Both</td>
<td>Standard care</td>
<td>&gt; 3 months</td>
<td>Everyday</td>
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<td>Asanas, pranayama</td>
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<td>Jyotis et al.</td>
<td>2014</td>
<td>RCT</td>
<td>120</td>
<td>Both</td>
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<td>&gt; 3 months</td>
<td>Everyday</td>
<td>Hatha yoga*</td>
<td>Asanas, pranayama</td>
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<tr>
<td>Kumar &amp; Kalidasan</td>
<td>2015</td>
<td>RCT</td>
<td>30</td>
<td>Both</td>
<td>Standard care</td>
<td>3 months</td>
<td>Everyday</td>
<td>Hatha yoga*</td>
<td>Asanas, pranayama</td>
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<tr>
<td>Sharma et al.</td>
<td>2015</td>
<td>RCT</td>
<td>278</td>
<td>Both</td>
<td>Standard care</td>
<td>&gt; 3 months</td>
<td>Everyday</td>
<td>Hatha yoga*</td>
<td>Asanas, pranayama</td>
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</tbody>
</table>

Notes: *Studies that did not specify yoga style. However, it was considered Hatha yoga if the intervention contained at least one, or a combination, of the components of Hatha yoga: asanas, pranayama, kriyas, bandhas, and meditation. RCT= randomized controlled trial. NI= no information provided.
<table>
<thead>
<tr>
<th>Authors</th>
<th>Year</th>
<th>Age range</th>
<th>Initial Glycemic Status</th>
<th>Initial BMI classification</th>
<th>Complications</th>
<th>Type of Medications</th>
<th>Duration of T2DM</th>
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<td>Rajesh et al.</td>
<td>2013</td>
<td>30-60</td>
<td>7.7 – 9.7%</td>
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<td>NI</td>
<td>NI</td>
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<td>Vizcaino et al.</td>
<td>2013</td>
<td>60-80</td>
<td>8.35 %</td>
<td>Overweight</td>
<td>No</td>
<td>Oral</td>
<td>1-15</td>
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<tr>
<td>Madammohan et al.</td>
<td>2012</td>
<td>36-63</td>
<td>160.07 ± 15.65 mg/dL</td>
<td>Overweight</td>
<td>No</td>
<td>Oral</td>
<td>1-15</td>
</tr>
<tr>
<td>Popli et al.</td>
<td>2014</td>
<td>30-60</td>
<td>8.0 – 8.4%</td>
<td>NI</td>
<td>No</td>
<td>None</td>
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<tr>
<td>Hegde et al.</td>
<td>2011</td>
<td>40-75</td>
<td>10.35 – 10.39 %</td>
<td>Overweight</td>
<td>Yes and No</td>
<td>Oral</td>
<td>NI</td>
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<tr>
<td>Mahapure et al.</td>
<td>2008</td>
<td>40-55</td>
<td>6.36 – 6.59 %</td>
<td>NI</td>
<td>No</td>
<td>Oral</td>
<td>1-10</td>
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<tr>
<td>Gordon et al.</td>
<td>2008</td>
<td>40-70</td>
<td>172.87-174.40 mg/dL</td>
<td>Overweight</td>
<td>No</td>
<td>Oral</td>
<td>1-10</td>
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<tr>
<td>Kyzior et al.</td>
<td>2010</td>
<td>35-60</td>
<td>178.53-200.03 mg/dL</td>
<td>Normal</td>
<td>No</td>
<td>Oral</td>
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<tr>
<td>Dash et al.</td>
<td>2014</td>
<td>40-60</td>
<td>8.9 - 10.3 %</td>
<td>NI</td>
<td>No</td>
<td>Oral</td>
<td>NI</td>
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<tr>
<td>Monroe et al.</td>
<td>1992</td>
<td>40-60</td>
<td>9.2 – 9.4 %</td>
<td>Overweight</td>
<td>NI</td>
<td>Oral, insulin</td>
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<tr>
<td>Agrawal et al.</td>
<td>2003</td>
<td>39-61</td>
<td>172.87 – 174.40 mg/dL</td>
<td>Overweight</td>
<td>No</td>
<td>Oral</td>
<td>1-10</td>
</tr>
<tr>
<td>Agte &amp; Tarwadi</td>
<td>2004</td>
<td>43-62</td>
<td>159.5 ± 12.3 mg/dL*</td>
<td>Normal</td>
<td>No</td>
<td>Oral</td>
<td>NI</td>
</tr>
<tr>
<td>Singh et al.</td>
<td>2008</td>
<td>35-60</td>
<td>7.0 – 7.01 %</td>
<td>NI</td>
<td>No</td>
<td>Oral</td>
<td>NI</td>
</tr>
<tr>
<td>Amma et al.</td>
<td>2009</td>
<td>50-70</td>
<td>8.93 – 9.06%</td>
<td>NI</td>
<td>No</td>
<td>Oral</td>
<td>NI</td>
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<tr>
<td>Skoro-Kondza et al.</td>
<td>2009</td>
<td>35-65</td>
<td>10.46 – 10.46%</td>
<td>NI</td>
<td>No</td>
<td>Oral, insulin</td>
<td>1-10</td>
</tr>
<tr>
<td>Pardasamy et al.</td>
<td>2012</td>
<td>30-78</td>
<td>8.1 – 8.4 %</td>
<td>NI</td>
<td>No</td>
<td>Oral</td>
<td>NI</td>
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<tr>
<td>Balaji et al.</td>
<td>2011</td>
<td>35-60</td>
<td>8.0 – 8.4 %</td>
<td>Overweight</td>
<td>No</td>
<td>Oral, insulin</td>
<td>1-10</td>
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<tr>
<td>Vaishali et al.</td>
<td>2012</td>
<td>61-69</td>
<td>10.3 – 10.8 %</td>
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<td>NI</td>
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<td>Nagarathna et al.</td>
<td>2012</td>
<td>30-78</td>
<td>8.1 – 8.4 %</td>
<td>NI</td>
<td>No</td>
<td>Oral, insulin</td>
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<td>Subrama-niyan et al.</td>
<td>2012</td>
<td>31-40</td>
<td>203.1 – 231.5 mg/dL</td>
<td>NI</td>
<td>No</td>
<td>Oral</td>
<td>NI</td>
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<tr>
<td>Cokolic et al.</td>
<td>2013</td>
<td>35-65</td>
<td>7.07 – 7.19%</td>
<td>NI</td>
<td>No</td>
<td>Oral</td>
<td>0-10</td>
</tr>
<tr>
<td>Bindra et al.</td>
<td>2013</td>
<td>36-61</td>
<td>7.06 – 7.08 %</td>
<td>NI</td>
<td>No</td>
<td>Oral</td>
<td>NI</td>
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<tr>
<td>Jyotsna et al.</td>
<td>2014</td>
<td>35-60</td>
<td>307.13 – 309.46 mg/dL</td>
<td>Overweight</td>
<td>No</td>
<td>Oral</td>
<td>1-10</td>
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<td>Kumar &amp; Katidasan</td>
<td>2015</td>
<td>35-55</td>
<td>9.3 – 9.6%</td>
<td>NI</td>
<td>No</td>
<td>Oral</td>
<td>1-10</td>
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<td>Sharma et al.</td>
<td>2015</td>
<td>23-73</td>
<td>7.6 – 8.6 %</td>
<td>Overweight</td>
<td>NI</td>
<td>Oral</td>
<td>1 – &gt;7</td>
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</tbody>
</table>

Note: Initial glycemic status refers specifically to glycated hemoglobin (%) levels reported at the beginning of the intervention in the studies under review. Unless this variable was not examined by the study, fasting glucose (mg/dL) levels were reported. Classification of BMI was based on American College of Sports Medicine (ACSM) guidelines. NI = no information provided. Duration of diabetes was reported in years. *No information on control group provided.
Appendix B: Salivary Cortisol Pre- and Post- Yoga Intervention in Individual Subjects

Figure 2. Changes in salivary cortisol pre- and post- yoga intervention in subject Y4

Figure 3. Changes in salivary cortisol pre- and post- yoga intervention in subject Y6
Figure 4. Changes in salivary cortisol pre- and post- yoga intervention in subject Y7

Figure 5. Changes in salivary cortisol pre- and post- yoga intervention in subject Y8
**Figure 6.** Changes in salivary cortisol pre- and post- yoga intervention in subject Y10

**Figure 7.** Changes in salivary cortisol pre- and post- yoga intervention in subject Y12
Figure 8. Changes in salivary cortisol pre- and post- yoga intervention in subject Y13.
Appendix C: Salivary DHEA Pre- and Post- Yoga Intervention in Individual Subjects

Figure 10. Changes in salivary DHEA pre- and post- yoga intervention in subject Y4

Figure 11. Changes in salivary DHEA pre- and post- yoga intervention in subject Y6
Figure 12. Changes in salivary DHEA pre- and post-yoga intervention in subject Y7

Figure 13. Changes in salivary DHEA pre- and post-yoga intervention in subject Y10
Figure 14. Changes in salivary DHEA pre- and post- yoga intervention in subject Y12

Figure 15. Changes in salivary DHEA pre- and post- yoga intervention in subject Y13
Appendix D: Description of the Yoga Intervention

The following is a detailed description of the intervention based on the operational definition of yoga-based interventions by Schmalzl, Powers, & Blom (2015).

Movement (asanas)

For the asana component of the intervention the style that was used can be defined as classical-eclectic yoga, that is, hatha yoga generally taught in most yoga classes today (Kappmeier & Ambrosini, 2006). The term eclectic defines the style of hatha as generic or as a style that does not follow a strict method or set routine of poses; in contrast, it can combine elements from different yoga styles (Kappmeier & Ambrosini, 2006). The program was designed taking into account the initial characteristics of the participants and continued to evolve based on participants’ progression. Therefore, if participants lack sufficient flexibility to perform certain poses props will be used to achieve correct alignment like in the iyengar yoga tradition. Appropriate modifications will be provided when required based on varied levels of flexibility, strength, and balance.

Breath (pranayama)

Emphasis was placed on slow, coordinated movements that correspond to the flow of the breath. In general, expansive movements were matched with inhalations whereas contractive movements were matched with exhalations. Participants were instructed to hold every asana for a minimum of three breaths focusing on the sensations across the body as the asana was held while at the same time following the natural rhythm of the breath, which is believe to foster the connection between body posture and breathing. In addition, release of muscular tension and relaxation was instructed during every exhalation while the pose was sustained. This is in accordance with Patanjali’s description of asana, “Posture should be steady and comfortable (II.46).”

For the pranayama component of the intervention participants initially were taught conscious regulation of the breath through diaphragmatic breathing and equal ratios of inhalation, retention, and exhalation (1:1:1). Then, breath regulation progressed into more advanced ratios such as 1:1:2 and 1:2:2. Because the intervention was short and the overall emphasis of the program was to relieve stress, only
two specific pranayama exercises were included, diaphragmatic breathing (yogic breath) and alternate nostril breathing (anuloma viloma), which may be considered adequate for beginners due to its simplicity and relaxing nature.

Attention (withdrawal of the senses, concentration, meditation)

Awareness of bodily sensations was highlighted in every class as participants were encouraged to place attention to their breath, heart rate, and body position. Throughout the intervention participants were instructed to maintain this body awareness so they can modify their own body position and regulate their breath if necessary. As the intervention progressed, participants were instructed to disregard irrelevant information coming from the senses, such as external sounds in or around the classroom, and instead placed their attention on the flow of the breath during relaxation or shavasana. Then, participants will be instructed to avoid reaction to perceived sensory, emotional, or cognitive events as they remained immersed in the present-moment experience. Hence, the contemplative practice was initially based on focused attention and then progress to open monitoring.
Sample yoga session I

1. Philosophy
   1.1. What is yoga?
      1.1.1. Spiritual path, ancient practice, not a religion
      1.1.2. Brief mention of union with universal spirit
   2. Practice
      2.1. Brief meditation ~5 min
      2.2. Warm-up
         2.2.1. Neck and shoulder rolls, side stretches, movement circles
      2.3. Asanas
         2.3.1. Cross-legged forward bend
         2.3.2. Head-to-knee
         2.3.3. Modified marichi’s pose
         2.3.4. Wide angle seated forward bend
         2.3.5. Modified forward bend
         2.3.6. Knees-to-chest
      2.4. Closure
         2.4.1. Savasana

Sample yoga session II

1. Philosophy
   1.1. Moral foundation of yoga
      1.1.1. Explanation of niyamas
      1.1.2. Examples in everyday life
   2. Practice
      2.1. Brief meditation ~7-8
      2.2. Warm-up
      2.3. Pranayama
         2.3.1. Diaphragmatic breathing
         2.3.2. Ratio 1:1:1
      2.4. Asanas
         2.4.1. Head-to-knee
         2.4.2. Modified marichi’s pose
         2.4.3. Cat-cow
         2.4.4. Warrior I
         2.4.5. Modified intense side stretch
         2.4.6. Warrior II
         2.4.7. Tree pose on the wall
         2.4.8. Dancer’s pose on the wall
         2.4.9. Modified boat
         2.4.10. Modified boat II
         2.4.11. Knees-to-chest
      2.5. Closure
         2.5.1. Savasana
Sample handout on yogic philosophy

Moral foundations of yoga II- Niyamas

1. Purity (shauca). This principle refers to purity of the entire being. Purity of the body, purity of though, and purity of speech. Purity of the body is achieved through appropriate diet, breath control, cleansing techniques, and asanas. Purity of both thought and speech is a continuation of the yamas; you shouldn’t wish harm to those around you and you should be careful with the manner you express yourself so that you don’t offend people with your comments.

2. Contentment (samtosha). This observance refers to a life of simplicity, which is also an extension of the yama non-attachment. When we are no longer obsessed about the possession of material things, social status, and so on, we can experience true happiness that does not depend on external circumstances. This is turn also translates to the cultivation of calmness and equanimity of mind. When you are no longer anxious or desperate to obtain everything you don’t have, or striving to achieve the standards of beauty or thinness established by the media, you have the capacity to experience calmness because you accept yourself just as you are and you already have all you need...the universal spirit that resides within you.

3. Austerity (tapas). This observance refers to ascetic practices such as fasting, complete silence for long periods of time, and stillness. Literature also explains it as the energy that is produced within oneself through discipline and abstinence. These practices have the purpose to strengthen the character of the practitioner by training the will. Nonetheless, in this particular niyama you should be careful given that extreme ascetic practices such as fasting for a very long time can weaken your body. Hence, you should always practice a balance between a practice that develops your determination and a practice that may harm your health.

4. Study (svadhyaya). This observance refers to both the study of ancient scriptures and to self-study. The latter is usually the most difficult. Many of us are accustomed to study in one way or another, for a degree, for a certification, for an exam, at church, etc. But rarely do we engage in a deep examination of what motivates our actions, the origin of our thoughts or our emotions, or certain habits that may be detrimental to the cultivation of inner peace. For instance, through this practice we are able to see with clarity and we can realize that what produces anger within us does not make any sense most of the time; hence, we can let go of this destructive emotion and find that peace within ourselves.

5. Devotion (ishvara-pranidhana). This observance may be familiar to anyone that follows a particular religion. Devotion refers to the dedication of your pure inner states and your actions to the universal spirit, God, Allah, or the Lord. Hence, this niyama embraces all religions and fosters the cultivation of union between the Highest being and yourself.
Sample handout for home practice

Week 7

This week we will continue practicing anuloma viloma pranayama (or alternate nostril breathing).

• First, come into a comfortable sitting position on the floor or in a chair.
• Make sure back is straight, chest opened, top of your head aligned with the base of your spine, and arms relaxed by the side.
• Close your eyes and start listening to your breath….
  - Feel the gentle rising and falling of your chest
  - Feel the flow of your breath through your throat and nostrils
  - Allow the breath to become deeper and slower by allowing your entire abdomen to expand freely along with your rib cage

Picture 1  Picture 2

• Once you feel your mind centered on your breath, begin your pranayama…
• Starting with your right hand, close your right nostril with your thumb (as shown in Picture 1), and inhale slowly through your left nostril.
• Close both nostrils (thumb closing right nostril, last two fingers closing left nostril) and hold your breath.
• Keep your left nostril closed and exhale slowly through right nostril (as shown in Picture 2).
• Now go in reverse, inhale through right nostril while keeping left nostril closed (as shown in Picture 2).
• Close both nostrils and hold your breath.
• Keep right nostril closed, open left nostril and exhale slowly (as shown in Picture 1).
• This completes one cycle.
• Try to complete at least 3 cycles.
• After you finish, leave both nostrils opened, relax your arms by the side and allow some time for your breath to return to its normal rhythm.
• Stay in silence for a few minutes.

*Remember, every breath should be slow, smooth and controlled.
*Ideally, in every breath start by expanding your abdomen followed by the rib cage and then lastly your chest.
Appendix E: Sample Presentation for Exercise Session in the Single-Subject Design Study
Tips to prepare for exercise

- What activities do you like?
- Do you like to exercise on your own or in the company of others?
- Do you want something competitive or non-competitive?
- What facilities do you need?
- What equipment/clothes do you need?
- How intense do you want your exercise to be?
- Talk to your doctor!

Tips to get started and keep exercising

- I do not have time!
  - Schedule your exercise
  - Think about the things you need to cut down to make time for exercise
  - Plan to exercise when it works best for you
  - Take a walk during your breaks

Exercise hurts!

- Proper warm-up and cool down
- Start slowly
- Always focus on proper technique
- Always exercise with caution and use common sense

Exercise is boring!

- Combine exercise with favorite activities
  - Music
  - Autobooks
  - TV shows and movies
  - Spend time with family and friends
- Vary your routine
- Cross-train

I have no motivation!

- Remember all of the benefits that you will be receiving
- Enjoy the process
- Set concrete goals
- Write a contract
  - Exercise:
    - Goal of week 1: Walking for 30 minutes, 3x/week
    - Goal of week 2: Walking for 40 minutes, 3x/week

Precautions during exercise

- Check your glucose before exercise
  - If below 100, take a snack
  - If above 300, skip exercise or exercise lightly with caution
- Learn individual responses to different types of exercise
- Always inspect your feet after exercising
- Talk to your doctor about insulin/medication adjustments
- Be aware of diabetes-related complications!
CURRICULUM VITA

Maricarmen Vizcaíno Campos was born in Chihuahua, Mexico. The only child of Jesus Vizcaíno Blanco and Carmen Campos Quintana. She moved to Juárez, Mexico at the age of ten where she graduated from High School from Colegio Latinoamericano Teresiano in the Spring of 2001. She enrolled at the University of Texas at El Paso (UTEP) in the Fall of 2001, where she graduated with a Bachelor’s degree in Kinesiology, with concentration in Exercise Science, in the Fall of 2005. She received her certifications as registered yoga teacher (RYT) and personal trainer (NSCA-CPT) in 2006, and has been working ever since as a yoga instructor for a variety of settings and populations. She received a Master’s degree in Kinesiology in the Spring of 2010, also from UTEP. During her graduate studies she worked as a graduate assistant for UTEP’s Track and Field team and as a laboratory instructor for biomechanics. She started the PhD in Interdisciplinary Health Sciences program in the Fall of 2011. During her doctoral studies she work as a research assistant for her chair, Dr. Kathleen O’Connor, and for the social work department under the supervision of Dr. Candice Berger. She published several articles as first and second author, and presented her research at several national conferences. She also continued teaching yoga for faculty and staff, and for the physical education courses at the university. She is married to Pedro Lopez Gomez and has three dogs. She was expecting baby Isabel as she conducted this research and finished writing this dissertation.

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