THE EFFECT OF YOGA PRACTICE ON GLYCEMIC CONTROL OF TYPE 2 DIABETES PATIENTS

MARICARMEN VIZCAINO

Department of Kinesiology

APPROVED:

George King, Ph.D., Chair

Rebecca Reed-Jones, Ph.D.

Rodolfo Rincones, Ph.D.

Benjamin Flores, Ph. D.
Interim Dean of the Graduate School

For my husband, whose immense love, support, and faith in me made the completion of this thesis possible. For my parents, for their constant encouragement in the realization of my goals and for their guidance in the world of reason since my childhood.

THE EFFECT OF YOGA PRACTICE ON GLYCEMIC CONTROL OF TYPE 2 DIABETES MELLITUS PATIENTS

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MARICARMEN VIZCAINO, BS

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ABSTRACT

The primary purpose of this study was to investigate the effect of yoga practice on glycemic control of Type 2 diabetes mellitus patients by evaluating changes in physiological and psychological stress measures. Participants (n=10) were non-insulin-dependent diabetes mellitus patients free of complications derived from diabetes. The 6-week intervention consisted of structured yoga classes with a registered yoga teacher three times a week. Assessments were completed at baseline and post-intervention. Glycemic control parameters under investigation included fasting blood glucose (FBG), glycated hemoglobin (HbA_{1c}), and insulin sensitivity (QUICKI). Psychological stress was assessed with the perceived stress scale (PSS) and the State-Trait Anxiety Inventory (STAI); while physiological stress was assessed by cortisol content at midnight. Additional measures included diabetes regimen adherence, quality of life, active range of motion, and balance. No significant changes were observed in any of the glycemic control parameters following the yoga intervention. Nonetheless, significant decreases in all stress measures were found following yoga practice. Similarly, significant improvements in regimen adherence, flexibility, and balance were found. The findings indicate that a longer and more frequent yoga practice may be necessary to induce significant improvements in glycemic control, and that this improvement may be mediated by decreases in anxiety and cortisol of diabetes patients.

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INTRODUCTION

The benefits that practitioners and teachers attribute to the practice of hatha yoga are numerous, including positive effects on chronic diseases such as diabetes mellitus. The majority of studies investigating the effect of yoga practice alone (Amita, Prabhakar, Manoj, Harminder, & Pavan, 2009; Gokal, Shillito, & Maharaj, 2007; Gordon et al., 2008; Malhotra, Singh, Tandon, & Sharma, 2005; Singh, Malhotra, Singh, Madhu, & Tandon, 2004; Singh et al., 2001) or combined with another non-medical intervention (Agrawal et al., 2003; Agte & Tarwadi, 2004; Jain, Uppal, Bhtanagar, & Talukdar, 1993) have shown potential benefits of this ancient practice on glycemic control of non-insulin-dependent diabetes patients by reporting reductions in fasting blood glucose (FBG) (Amita et al., 2009; Agrawal et al., 2003; Agte & Tarwadi, 2004; Gokal et al., 2007; Gordon et al., 2008; Jain et al., 1993; Malhotra et al., 2005; Singh et al., 2004; Singh et al., 2001), post-prandial blood glucose (Amita et al., 2009; Agte & Tarwadi, 2004; Malhotra et al., 2005; Singh et al., 2004; Singh et al., 2001), glucose tolerance (Jain et al., 1993), and even glycated hemoglobin (HbA_{1c}) (Agrawal et al., 2003; Singh et al., 2004; Singh et al., 2001). Nonetheless, data are still inconclusive because of the lack of control for confounding variables such as additional physical activity (Agrawal et al., 2003; Malhotra et al., 2005; Singh et al., 2004; Singh et al., 2001), failure to monitor diet or medication (Malhotra et al., 2005), poor description of the intervention (Gordon et al., 2008), or inadequate description of the sample population (Agrawal et al., 2003). Furthermore, some studies have reported no change in HbA_{1c} following yoga practice

(Agte & Tarwadi, 2004; Mercuri, Olivera, Souto, & Guidi, 2003) and only two studies proposed potential mechanisms to explain the beneficial impact of yoga for Type 2 diabetes. Manjunatha, Vempati, Ghosh, & Bijlani (2005) proposed that yogic postures increase the rate of glucose utilization after observing a decrease in insulin levels immediately after practice, and Malhotra et al. (2005) suggested that yoga may increase glucose utilization by redistributing fat in diabetes patients. Finally, none of the studies reported control of factors that could affect the measurement of FBG, such as female hormones or ingestion of certain drugs, or factors that could affect the assessment of HbA_{1c} like red blood cell abnormalities or excessive doses of vitamin C and E (Unger, 2007).

Many authors have suggested that additional research is needed to clarify the potential benefit of yoga on glycemic control (Agte & Tarwadi, 2004; Gokal et al., 2007; Manjunatha et al., 2005; Singh et al., 2004). And most importantly, there is a need to explain the possible mechanism underlying the improvement in glycemic control that yoga may confer to Type 2 diabetes mellitus patients. A plausible explanation may stem from the effect that yoga generates by alleviating psychological stress of the diabetes patient. Psychological stress can act indirectly by influencing regimen adherence to diabetes self-care behaviors (Nakahara et al., 2006; Cohen & Kanter, 2004), or directly by the effect of stress hormones on glucose metabolism (Surwit & Feinglos, 1983, 1984).

Stress and self-care behaviors in diabetes

Nakahara et al. (2006) found that self-efficacy directly influenced adherence to self-care behaviors, which itself directly influenced HbA_{1c} levels of Type 2 diabetes patients. Self-efficacy was, in turn, positively influenced by social support and inversely influenced by daily hassles and diabetes-related distress. Similarly, Cohen and Kanter (2004) found that the less ability to cope with stress the greater the deterioration of diabetic regimen; that is, adherence to self-care behaviors such as regular clinic attendance, blood tests, medication, diet, and physical activity, was positively affected by the belief of self-efficacy and negatively affected by psychological distress. Hence, by the previous scientific evidence we can infer that psychological stress, lack of social support, and poor belief of having control over life's challenges or lack of self-efficacy indirectly impact the stability of glucose control in Type 2 diabetes by decreasing adherence to a proper diet regimen, exercise program, medication, or even consistent glucose monitoring. Accordingly, a way of maintaining constant and appropriate self-care behaviors from diabetes patients is to find venues to deal with everyday stress and major life events, along with a method to increase self-efficacy.

Anxiety and diabetes

Previous research has provided evidence of the relationship between psychological distress, in the form of anxiety, and glucose control of Type 2 diabetes patients. Okada, Hamada, Ishii, Ichiki, Tanokuchi, and Ota (1995) found significant reductions in anxiety levels, but most importantly, significant reductions in HbA_{1c} from

8.4% to 7.3% for Type 2 diabetes patients following a 12-week treatment with an anti-anxiety drug. Diet, exercise, and medical therapy remained constant for all participants throughout the study. Similarly, Lane, McCaskill, Ross, Feinglos, and Surwit (1993) found that subjects who demonstrated improvements in glucose tolerance after a pharmacological intervention to decrease anxiety, also improved in glucose tolerance after a progressive muscle relaxation (PMR) treatment. Furthermore, those subjects that showed a greater deterioration in blood glucose levels with an epinephrine infusion that resembled secretion during episodes of stress had a trend toward greater improvements in glucose tolerance after relaxation treatment. They concluded that relaxation therapy may produce significant improvements in glucose tolerance for those individuals who suffer from anxiety and are more susceptible to adrenergic stimulation by catecholamines (Lane et al., 1993). The influence of yoga practice on reductions in anxiety may then facilitate improved glucose tolerance. Yoga has been found previously to significantly reduce both, state anxiety and trait anxiety, in patients with a variety of medical problems including hypertension, obesity, and diabetes (Gupta, Khera, Vempati, Sharma, & Bijlani, 2006).

The role of cortisol on glycemic control in diabetes

According to the General Adaptation Syndrome (GAS) theory by Hans Seyle, there are three phases of the body’s adaptation to stress, which are: alarm reaction, stage of resistance, and stage of exhaustion. Alarm reaction is the “fight or flight” response originally described by Canon, characterized by sudden elevations of

epinephrine and norepinephrine. During the stage of resistance there is a reduction of catecholamines; however, there is a marked increase in cortisol secretion in order to sustain heightened levels of functioning in the body (Asterita, 1985). It is this stage of the body response and adaptation to stress that may pose significant challenges to diabetes patients because of the effect of cortisol on glucose metabolism.

The work by Eigler, Sacca, and Sherwin (1979) demonstrated that cortisol maintains the elevated glucose production initially generated by epinephrine and glucagon, and that changes in glucose metabolism during simulated episodes of stress are a result of the synergistic interaction between these hormones and not just one hormone alone. Therefore, continuous elevations of cortisol produced from chronic stress are expected to be more detrimental to diabetes patients because they already have difficulty metabolizing plasma glucose due to insulin resistance or irregular insulin secretion, and consequently glycemic control will be compromised. Additionally, research has already provided some evidence of altered hypothalamic-pituitary-adrenal (HPA) axis and subsequent cortisol elevations in diabetes patients (Chiodini et al., 2007; Hudson et al., 1984; Roy, Collier, & Roy, 1990). Previous research has also reported a significant correlation between elevated cortisol levels at midnight and poor glycemic control and diabetes complications (Chiodini et al., 2007).

In light of the previous scientific evidence, we can hypothesize that individuals with glucose intolerance and elevated cortisol levels, such as diabetes patients, may be even more susceptible to the negative effects of stress. Therefore, it can be postulated that a reduction in psychological stress, similar to that incurred through yoga practice,

may be beneficial for diabetes patients by decreasing adrenal-cortical activity and consequently cortisol levels.

Surwit and Feinglos (1983) analyzed the effect of PMR training and biofeedback sessions on glucose tolerance among non-insulin dependent diabetes patients. All participants were hospitalized and provided with weight-maintenance diets for 5 days; however, only the treatment group practiced PMR twice a day during that week. At the end of the study significant decreases in the area under the curve were observed during an oral glucose tolerance test (OGTT) for the relaxation group; however, there was no change in the control group. Insulin sensitivity, as measured by an insulin tolerance test (ITT), also showed a trend towards improvement but the observed changes failed to achieve statistical significance. Furthermore, significant decreases in plasma cortisol were reported for the PMR treated patients during post-testing whereas cortisol was significantly increased for the control patients; catecholamines remained unchanged for both groups (Surwit & Feinglos, 1984). The authors suggested that relaxation training may be related to decreases in adrenal cortical activity; specifically, that variations in plasma cortisol levels could alter adrenergic receptor sensitivity to circulating catecholamines thereby changing glucose tolerance (Surwit & Feinglos, 1984).

Nonetheless, another study examining the effect of PMR on metabolic control of diabetes patients found no significant improvements in glucose tolerance (Jablon, Naliboff, Gilmore, & Rosenthal, 1997). One of the main differences between this study and that of Surwit and Feinglos (1983) was patient compliance; while Surwit and Feinglos (1983) closely monitored the twice daily practice of PMR in a hospital setting,

Jablon et al. (1997) used an outpatient protocol in which subjects were instructed to practice twice a day on their own. A lack of PMR practice compliance could affect the ultimate results of the study. Moreover, Jablon et al. (1997) did not find significant differences in anxiety scores, as measured by the State-Anxiety Inventory (STAI), between the PMR group and the control group at the end of the study. In addition, subjects responded to a subjective relaxation ability scale where 0 represented “not at all able to relax” and 10 “able to relax extremely well.” Despite significant improvement in the scale response (pre: 3.4 vs. post: 5.7), the average values may indicate that the PMR group did not achieve proficiency in their relaxation ability.

In the study by Surwit and Feinglos (1983), the lack of psychological stress assessment of participants was the major weakness; however, under highly controlled conditions it was demonstrated that the treatment itself, and not extraneous variables such as modifications in diet or additional physical activity, produced the significant improvements in glucose tolerance and decreases in physiological markers of stress like cortisol. Nevertheless, subsequent studies are challenged to establish a more clear relationship between psychological stress and glucose control in diabetes.

STATEMENT OF PURPOSE

Yoga has been previously investigated as an alternative therapy for glycemic control in non-insulin dependent diabetes patients (Amita et al., 2009; Agrawal et al., 2003; Agte & Tarwadi, 2004; Gokall, et al., 2007; Gordon et al., 2008; Jain et al., 1993; Malhotra et al., 2005; Mercuri et al., 2003; Singh et al., 2004; Singh et al., 2001). Research has provided evidence of the potential benefit of yoga on glycemic control parameters (Amita et al., 2009; Agrawal et al., 2003; Agte & Tarwadi, 2004; Gokall et al., 2007; Gordon et al., 2008; Jain et al., 1993; Malhotra et al., 2005; Singh et al., 2004; Singh et al., 2001); nonetheless, results are inconclusive since the majority of research had no control over extraneous variables, especially those factors that may affect fasting glucose and glycated hemoglobin measurement. Furthermore, there is no consensus within the literature to explain the improvement in glycemic control after yoga practice. Therefore, the primary purpose of this study was to investigate the effect of yoga practice on glycemic control of Type 2 diabetes mellitus patients under controlled conditions. The second purpose of the study was to investigate the physiological and psychological impact of yoga practice on glycemic status for these patients by evaluating changes in the stress hormone cortisol and psychological stress measures. It is hypothesized that yoga may act indirectly by increasing measures of regimen adherence, and directly by decreasing measures of stress and anxiety and consequently decreasing measures of physiological stress such as cortisol. Hence, it is expected that following the yoga intervention, measures of both short-term and long-term glycemic control will improve in patients.

The hypotheses are as follows:

H_1: FBG will decrease following 6 weeks of yoga practice

H_2: HbA_{1c} will decrease following 6 weeks of yoga practice

H_3: Cortisol will decrease following 6 weeks of yoga practice

H_4: Perceived stress and anxiety will decrease following 6 weeks of yoga practice

H_5: Measures of quality of life and regimen adherence will improve following 6 weeks of yoga practice

H_6: Additional benefits such as increased flexibility and balance will be observed following 6 weeks of yoga practice

METHODS

Participants

Participants (n=10) were recruited from the university and surrounding community through campus announcements, brochures at medical clinics, presentations at El Paso Diabetes Association, and a public service announcement in a local newspaper. Interested individuals were pre-screened with a health questionnaire to determine qualification to participate in the study. Inclusion criteria were the following: (1) women had to be post-menopausal and not taking any kind of hormone replacement therapy; (2) no complications derived from diabetes such as neuropathy, retinopathy, nephropathy, etc; (3) no cardiovascular disease such as coronary heart disease, cerebrovascular disease, peripheral arterial disease, deep vein thrombosis, etc; (4) no conditions that alter the 120-day life-span of red blood cells such as hemolytic anemia, kidney disease, liver disease, sickle-cell disease, recent blood loss, or folate deficiency as these conditions can affect the accuracy of the HbA_{1C} measurement; (5) no major musculoskeletal disorders or injuries, especially of the spine; (6) being able to stand unassisted for at least 30 minutes; (7) sedentary, defined as no more than once a week of moderate exercise and no vigorous exercise during the previous three months; and (8) no previous experience with yoga or meditation practice. All participants were previously diagnosed by their personal physician with Type 2 diabetes mellitus; none of them were undergoing insulin therapy and therefore were non-insulin dependent. Characteristics of participants are shown in Table 1. A written statement from their personal physician providing clearance to participate in an exercise program was provided by all participants before the beginning of the intervention and all participants

provided written informed consent to participate. This entire study was approved by the Institutional Review Board for research involving human subjects of the University of Texas at El Paso.

Table 1. *Mean (± SD) characteristics of Type 2 diabetes patients at baseline and following the 6-week yoga intervention.*

	Pre-intervention	Post-intervention
Age (yrs)	61.40 ± 6.68	61.40 ± 6.68
Length of disease (yrs)	6.10 ± 6.33	6.10 ± 6.33
Height (cm)	161.50 ± 10.12	161.50 ± 10.12
Body Mass (kg)	95.25 ± 24.48	94.73 ± 24.11
BMI (kg/m^2)	36.26 ± 7.55	36.07 ± 7.42
Waist circumference (cm)	108.50 ± 16.29	107.60 ± 15.37
Systolic pressure (mmHg)	140.60 ± 20.64	136.50 ± 18.26
Diastolic pressure (mmHg)	77.30 ± 15.16	75.70 ± 12.37
Body fat (%)	46.62 ± 6.31	47.88 ± 6.33
Fat mass (kg)	40.10 ± 12.21	41.00 ± 12.39
Lean mass (kg)	44.90 ± 9.18	43.50 ± 8.23
Bone mineral content (kg)	2.26 ± 0.47	2.29 ± 0.39

No significant differences between pre- and post-intervention (p>0.05).

Yoga Intervention

The 6-week intervention consisted of hatha yoga classes composed of asanas (physical poses), pranayama (breathing exercises), relaxation, and meditation exercises. Classes were taught by a qualified registered yoga teacher (RYT) and were held in the Biomechanics Laboratory on the University of Texas at El Paso campus. The duration and frequency of classes were approximately 50-60 minutes, three days per week. Because all participants were previously sedentary, overweight, and above the age of 50 years, all poses were modified to accommodate limited levels of flexibility, balance, and strength. Props such as chairs, belts, or blankets were used for such modifications to allow for appropriate alignment, technique, and balance, and especially to provide participants the opportunity to obtain full benefit from the asanas within their particular limitations (see Appendix). During each class, participants were instructed to center their attention on their breathing throughout the practice session and to increase the awareness of their body position in each pose. Some of the classes had the focus of a particular topic such as “Yoga for the neck and shoulders,” “Yoga for the back,” “Yoga for insomnia,” and “Yoga as a meditative practice.” For instance, during the session of insomnia participants were taught restorative yoga poses which consisted of modified supine poses. Participants placed blankets underneath the lower back and rolled blankets underneath the neck so they could have their spine supported and they could relax completely into the poses while at the same time stretching certain areas of the body. The closure of each session consisted of a relaxation exercise in which participants were asked to scan their entire body to locate any tension still present in

their muscles and to relax those specific muscles with every exhalation emphasizing focus on the natural pattern of breathing and its sound.

Yoga mats were provided to all participants throughout the intervention, as well as chairs for modifications. However, other props such as belts, towels or blankets were brought from home by the participants. Handouts with yoga poses and meditation exercises were provided approximately every 2 weeks so that participants could continue practice at home and after the end of the intervention.

Finally, although hypoglycemia is uncommon during exercise in individuals who are not treated with insulin (ADA, 2010), such as the participants of this study, caution was implemented at all times. All participants were encouraged to check their glucose levels before each yoga class and were instructed to ingest a carbohydrate snack if their glucose levels were below 100 mg/dL. In addition, glucose tablets (Reli On®, CanAm Care, LLC., Alpharetta, GA) were available during yoga classes as a preventive measure for the unlikely occurrence of a hypoglycemic event. Four of these glucose tablets provide 15 grams of carbohydrate as suggested by the ADA to offset a sudden drop in circulating plasma glucose (ADA, 2010). No hypoglycemic events occurred during this intervention.

Each participant completed a battery of assessments at baseline and following the 6-week yoga intervention. To assess the overall effectiveness of the yoga program, anthropometric, body composition, blood pressure, flexibility, range of motion, and balance were measured. The effect of the intervention on markers of glucose control was assessed from fasting blood samples, while alterations in perceived stress, anxiety,