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Yoga vs. Cardiovascular Exercise
for Complementary Management of Metabolic and Psychometric Parameters in Type II Diabetics

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ABBREVIATIONS

ACTH	adreno-corticotropic hormone
BMI	body-mass-index
BMR	basal metabolic rate
BP	blood pressure
CAD	coronary artery disease
CHD	coronary heart disease
COPD	chronic obstructive pulmonary disease
CRH	corticotrophin releasing hormone
FBG	fasting blood glucose
HADS	hospital anxiety and depression scale
HbA1c	hemoglobin A1c (Glycated hemoglobin)
HDL	high-density lipoprotein
HPA	hypothalamus-pituitary-adrenal
LDL	low-density lipoprotein
MBSR	mindfulness-based stress reduction
N/A	not applicable
PPBG	post-prandial blood glucose
PROCAM	*Prospective Cardiovascular Munster study*
SF-36	36-item short-form survey
SPSS	Statistical Package for the Social Sciences
sVYASA	Swami Vivekananda Kendra Yoga Research Foundation
TBARS	thiobarbituric acid reactive substance
VLDL	very low-density lipoprotein

INTRODUCTION

Diabetes mellitus type II is an increasingly recognized health hazard of modern lifestyle. Its incidence is highly correlated with obesity and fat-intake (Camastra et al. 1999), which, in turn, are well associated with industrialization and westernized lifestyle. Compared to other races, the prevalence of diabetes mellitus is very high amongst Asian Indians and especially among those residing in urban areas (Ramachandran et al. 1992, Ramachandran et al. 1999). Asian Indians seem to have a genetic susceptibility to developing type II diabetes which appears to become exposed when they migrate and/or improve their socio-economic status: non-resident Indians living abroad evince high incidences of diabetes as well (Omar et al. 1994, McKeigue et al. 1991, Mather and Keen 1985, Simmons et al. 1989, Dowse et al. 1990, Swai et al. 1990, Ramaiya et al. 1990).

Recent research suggests that India has *the* largest diabetic population and one of the highest diabetes prevalence rates in the world (Bjork 2003). This has been attributed to a generally high racial susceptibility to the illness as well as high familial aggregation, higher upper body density, more visceral adipose tissue and thereby more insulin resistance, and finally, lifestyle changes due to urbanization (Ramachandran et al. 1999, Snehalatha et al. 2003).

In India, lifestyles in the metropolitan cities are changing rapidly; it is becoming more modern and fast-paced which tends to support irregular, unhealthy eating habits and a more sedentary daily routine. The incidence of diabetes mellitus increases phenomenally as these changes take place (Ramachandran et al. 1992, Ramachandran et al. 1999). Most Indian diabetics face horrendous medical costs in a country where most of the population possesses no health insurance whatsoever.

A series of studies by Ramachandran et al. of the Diabetes Research Center in Chennai in South India have confirmed the high prevalence of diabetes in urban India: in a large-scale study across six major cities, the impaired glucose tolerance (IGT) rate was 14.0% and the diabetes rate was 12.1% (Ramachandran et al. 2001). Investigators have predicted that India will have the greatest increase in diabetes and steadily continue with the largest number of diabetic patients in the world; by the year 2030, India may have as much as 81 million diabetics (Bjork et al. 2003). These numbers increase exponentially if one considers the large pool of individuals with undiagnosed impaired glucose tolerance, many of whom will develop type 2 diabetes later in life.

Ethnic Indo-Asians living abroad are also well-recognized to have a particularly high incidence of not only insulin resistance (Stubbs et al. 1999, Hughes et al. 1989) but also dyslipidemia (Enas et al. 2005). Based on this, Indo-Asians have the highest rates of coronary artery disease (CAD) despite the fact that a large proportion of them follow a strict vegetarian diet. Traditional risk factors fail to fully explain the particularly high prevalence of the metabolic syndrome in Indo-Asians (Enas et al. 2005).

These findings lead to the inevitable confrontation with the serious long-term economic implications of diabetes mellitus type II. Thus, cost issues regarding diabetes provide a further incentive to search for inexpensive methods of prevention and treatment. Diabetes is a costly disease for everyone, but more so for the lower socio-economic strata of society. Studies show that families with the lowest incomes bear the highest relative financial burden of diabetes (Bjork et al. 2003, Ramachandran et al. 2007). In low-income U.S. families, estimates quote almost 10% of household expenses going to diabetes care, even if they are health-insured (Songer et al. 1997). In destitute Indian families, this figure increases to up to 25% of household expenditure (Shobana et al. 2000), making it difficult or virtually impossible for families to support their diabetic properly on a long-term basis. Surgery and hospitalization for diabetes complications appear to constitute the greatest proportion of diabetes costs, as demonstrated by studies in both developing and developed countries (Shobana et al. 2000, Bjork et al. 2003, Daviglus et al. 2004).

In the face of this, there is much scope for research in understanding the mechanisms and management of diabetes mellitus through indigenous methods that reach out to a wider array of India's population and can potentially dramatically lower treatment costs. A study published recently on mindfulness-based stress reduction (MBSR), which includes yoga, meditation, and breathing exercises (similar to those done by the yoga subjects in this study), suggest that MBSR may help contain health care costs by decreasing the number of visits made to primary care providers after completing the MBSR program (Roth and Stanley 2002). Hence, alternative and ancient relaxation methods, if proven effective, can help complement health care systems in the West as well, where they have been gaining in popularity.

Psychological stress has been demonstrated to be a destabilizing factor in the management of diabetes mellitus. Johnson's review article on psychosocial factors in juvenile diabetes expounds the results of several studies suggesting that poor social-emotional adjustment of the individual is more often associated with poor diabetes control (Johnson 1980). Chase and Jackson found similar results in their analysis of over 80 diabetic youth: common stress factors were related to increased HbA1c and serum glucose levels (Chase and Jackson 1981). Hanson and Pichert were able to show how increased levels of negatively perceived stress were correlated with higher blood sugar values in adolescent type 1 diabetics (Hanson and Pichert 1986). In a 14-year prospective study, Chandola et al. were able to strongly link chronic and prolonged work stress to a greater risk for metabolic syndrome. They found that this risk increased with a greater dose of stress. This increased level of risk was maintained after accounting for adverse health behaviors (Chandola et al. 2006).

We hypothesize in our study that yoga, as a deep relaxation technique, can reduce subjective psychosocial stress levels. Yoga has been shown to improve subjective well-being and quality of life (Malathi et al. 2000); it is therefore plausible that yoga as a stress reduction strategy may be helpful and valid for complementing conventional diabetic therapy in the clinical setting.

Yoga and other relaxation therapies are known to show a positive effect on several diseases (Haslock et al. 1994, Jain et al. 1993, Patel and North 1975), yet for diabetes mellitus, few such trials have proven the initial effect of yoga on the course of type II diabetes (Monro et al. 1992, Bijlani et al. 2005, Singh et al. 2004). One of the first studies on the effects of progressive relaxation on diabetic control was conducted in the early 1980s by Lammers et al. They employed the progressive muscle relaxation technique on 4 young diabetic men and measured their subjective stress and blood glucose levels. Their diabetic subjects evinced a significant treatment effect and overall positive impact of relaxation training on blood glucose levels (Lammers et al. 1980). They concluded that relaxation of the body and mind through yoga therapy can potentially greatly increase the quality of life of an adult diabetic but merits further research.

Bijlani et al.'s recent study (Bijlani et al. 2005) gave 77 type II diabetics a week-long lifestyle modification program based on yoga for the prevention and management of the chronic disease. The subjects were tested for fasting plasma glucose and serum lipid profile before and after the brief training program. Their results evinced significantly lower fasting blood glucose, total cholesterol, LDL, VLDL, total cholesterol:HDL ratio, and triglycerides plus a significantly higher HDL—these observations suggest that even a short lifestyle modification and stress management education program can lead to favourable metabolic effects in diabetic patients. This study was, however, not a controlled trial.

Another recent study examined the role of yoga in modifying certain cardiovascular functions in type 2 diabetics (Singh et al. 2004). This uncontrolled trial looked at yoga's effects on diabetic patients over a longer time period of 40 days. The researchers tested for fasting blood glucose, post-prandial blood glucose, glycated hemoglobin, pulse rate, BP, and corrected QT interval. QT lengthening is said to be linked to an increased risk of unexpected deaths in type 2 diabetes mellitus patients with severe autonomic neuropathy. Singh et al.'s results evinced a decrease in all of the measured parameters, thus confirming Bijlani et al.'s results in their week-long trial. This study was also not a controlled trial.

One of the first randomized trials on yoga as a complementary therapy for type II diabetics was done at the Royal Free Hospital in London (Monro et al. 1992). The study compared a yoga group with a non-intervention group. The main outcome measures were fasting blood glucose and glycated hemoglobin, noted before and after 12 weeks of yoga. The results showed that both the fasting blood glucose and the glycated hemoglobin levels decreased in the yoga group but increased in the controls. 3 out of 21 patients were able to reduce their dosage of oral medication. Hence, glucose homeostasis was improved in the yoga group compared to the non-intervention group.

The aim of the Royal Free Hospital study was to simply make a preliminary confirmation that yoga is feasible and beneficial. This having been done, it concluded that yoga therapy should further be studied to "a) optimize it, b) determine the extent to which the effects are due to exercise, relaxation, 'attention placebo', or other factors and c) compare its efficacy and range of applicability to those of other behavioral interventions." (Monro et al. 1992)

Our study basically commenced where the Royal Free Hospital study stopped--we decided upon an exercise group as our control group since exercise is a recognized practice for diabetes control (Tuomilehto et al. 2001). In order to determine the extent of yoga's effects on type II diabetes, we undertook the measurement of various parameters to determine where exactly the effect would be the greatest. In addition to serum fasting blood glucose and glycated hemoglobin, we also measured serum post-prandial blood glucose, cholesterol, triglycerides and fasting insulin. These variables make up the core components of the metabolic syndrome, also known as the insulin resistance syndrome (Nesto 2005).

We wished to test whether yoga could improve insulin uptake in the periphery (by measuring fasting insulin levels and undertaking the homeostasis (HOMA) model calculation) and whether improvements could be seen in the serum lipid profile (cholesterol, triglycerides, LDL, and HDL). We also collected saliva samples for cortisol tests, as prior extensive documentation indicates that exposure to chronic stress leads to an increased secretion of cortisol (Schulz et al. 1998, Evans and Streptoe 2001). Salivary levels of the hormone have been shown to reflect the serum concentration of free cortisol and have been used in other studies as a proxy for serum cortisol (Evans and Streptoe 2001, Aardal and Holm 1995, Hansen et al. 2003). Our hypothesis was that yoga's effect on the metabolic syndrome parameters would be mediated through a perceived reduction in stress, or, in other words, through deep relaxation.

At the end of the study, the Royal Free Hospital administered questionnaires by post to all 21 patients. We desired to broaden the scope of this by using 2 standardized questionnaires that specifically measure the health-related view of one's own quality of life (SF-36 questionnaire) as well as the psychological manifestations of anxiety and depression (HADS survey, see annex). More detail on these 2 questionnaires follow shortly, in the methods section.

YOGA THEORY

Yoga is a tradition of ancient lifestyle, health and spirituality that evolved in the Indian subcontinent over a period of 5000 years. Though yoga's origin is shrouded, evidence links the earliest yoga tradition back to the beginning of human civilization (Jayasinghe 2004). Early yoga and archaic shamanism had much in common as both sought to transcend the human condition. Archaic yoga was also community-oriented, as it attempted to comprehend the cosmic order through an inner vision, then to apply that order to daily living. Later, yoga evolved into a more inward experience, and *yogis*, or yoga masters, focused on their individual enlightenment. The first archaeological evidence of yoga's existence is found in stone seals excavated from the Indus valley. The *Yoga Sutra*, the first recorded history of the yogic culture, describes the philosophy of classical yoga (Stiles 2002). It was written by the Hindu philosopher Patanjali between 200 and 300 BC. Modern yoga arrived to the West during the late 1800's through the travels and work of Swami Vivekanada. Vivekanada was a student of the revered guru Ramakrishna, and was commissioned by his teacher to attend the Parliament of Religions in Chicago of 1893. Vivekanada's speech was well accepted there and he later traveled all around the United States to spread Hindu philosophy and the yoga tradition.

Over the last 20 years, yoga as a form of exercise and relaxation has achieved mainstream acceptance in the West. The concept of yoga as a form of therapy is, however, fairly new to the West, although it has always been an integral aspect of the traditional Indian notion of yoga (Ali and Brar 2002). For centuries, yoga masters used yoga techniques to harness the body's natural healing abilities for preventive and curative purposes.

The goal of any yoga practice in relation to the endocrine system is that of restoring and maintaining balance (Kraftsow 1999), thereby functioning as a homeostatic equalizer. The endocrine system is very complex, requiring a certain equilibrium for proper functioning. The general theory of yoga practice is to utilize techniques that stimulate the area of the body where the involved glands are located, and by doing so, increasing the circulation and the transport of nutrition and oxygen. Hence, we chose our yoga *asanas* (postures) for diabetics according to the principles of

- stimulation of the abdominal internal organs and
- increase in microcirculation generally throughout the body, but, when possible, specifically in the abdominal region.

The basis for an integrated approach to yoga therapy is rooted in the Indian scriptures, the Upanishads, as well as in several yogic texts. The yogic texts describe the five sheaths (or kosas) of existence in man: The first and the grossest, the physical frame, is called the *annamaya kosa*. The second, more subtle sheath as we move inwards is the *pranamaya kosa*, which features the predominance of the *prana*, or life energy or life breath. *prana* is supposed to flow through invisible channels in the body called *nadis*. The third sheath is the *manomaya kosa*, where the likes and dislikes of an individual strike a balance. The fourth sheath is the *vignanamaya kosa*, where one possesses the power to discern and discriminate based on the third sheath, *manomaya kosa*. The fifth and last sheath is the sheath of bliss, *anandamaya kosa*, the highest stage of evolution in man. Man crosses the sheaths of existence one by one during his journey in life; yoga accompanies him on this journey. Yoga aids man in reaching the innermost sheath, *anandamaya kosa*, by relieving himself from the bondage and constrictions of each sheath.

In *anandamaya kosa*, man is at his healthiest, at perfect harmony with himself. Imbalances begin at the *manomaya kosa* level, when likes and dislikes are in imbalance. When these imbalances are amplified, they result in mental illnesses called *adhis,* or primary disease. At this stage, there are no symptoms at the physical level. When these imbalances congeal in the *nadis* due to its long existence, they begin to manifest themselves externally. Gradually, they percolate to the physical frame. Eating unwholesome food, living in unhealthy surroundings, doing things at untimely hours, etc. are believed to come about when one is ignorant about his real state of bliss. This ignorance breeds physical disease called *vyadhi*. The *vyadhis* are also known as secondary diseases.

The *adhis*, or primary diseases, are made up of two components, the "ordinary", s*amanya*, and the "essential", the *sara*. The "ordinary" component includes the diseases incidental to the body while the "essential" component is the rebirth which Hindus believe man is subject to. The "ordinary" component is produced during the interactions with the world. These are what yoga theory describes as psychosomatic ailments or ailments exacerbated by the psyche. When dealt with suitable yoga techniques and a balanced environment, primary mental diseases of the ordinary type will vanish. Along with it, the physical manifestation of these ailments are destroyed, that is, the *vyadhis*, the secondary diseases, caused by the *adhis*, the primary diseases. The primary diseases of the "essential" type, which are caused by and cause the rebirth of an individual, can only be destroyed by reaching the level of *anandamaya kosa*, or the State of Bliss. This corresponds with the Hindu lifetime goal of attaining the state where one is merged with God, *moksha.*

Yoga theory states that when the mind is agitated during our interactions with the world at large--that is, it is stressed--the physical body follows in its wake. These agitations cause violent fluctuations in the flow of *prana*, or life force, in the *nadis*, the invisible channels through which they run. The *prana* rows in wrong paths without rhythm and harmony. The *nadis*, under such conditions, can no longer maintain stability and steadiness, and quiver. Food thus does not become digested properly. When the improperly digested food settles down in the body amidst such commotion, it results in exacerbation of already existing ailments or ailments of the psychosomatic type. And it is this that yoga aims to correct by balancing the *nadis* and setting the *prana* to flow properly again. It attempts to correct the possible cause of the problem, the agitation of the mind.

When treating diseases, and especially those known to be influenced by stress and the psyche, yoga therapy states it to be mandatory to work in all *kosa* levels of our existence. This integrated approach means not only dealing with the physical sheath, the results of which could at best be temporary, but also addressing the deeper problems lying within the other, more inward sheaths as well.

Hence, true yoga therapy consists of the following: *yoga asanas* (postures) for the physical sheath, *anandamaya kosa*; Breathing exercises, *pranayama*, for the *pranamaya kosa*, the second sheath; meditation for the *manomaya kosa*; theory lectures and scripture teaching for knowledge, necessary for the *vignanamaya kosa*. Here, *ananda mimamsa*, or a systematic happiness analysis, is included; and ultimately all of this should lead to the goal of the *anandamaya kosa*. Its goal is simply the realization that happiness is within, that each person in their causal state is *ananda*, or bliss, embodied. Knowledge burns the strong attachments, obsessions, likes and dislikes which are the basic reasons for the agitations of the mind. The *sara*, or essential, type of diseases can only be removed by this knowledge, known as *atma jnana*, or self-realization.

We focused on the first three sheaths for our study and thus included yoga *asanas*, *pranayama*, and meditation. We also held monthly lecture classes on yoga theory and thus adressed the *vignanamaya kosa* level.

OBJECTIVE AND HYPOTHESIS

The aim of this study was to validate the hypothesis based on earlier studies that:

1) Yoga can improve the quality of life for type II diabetes mellitus patients, as measured through standardized surveys on anxiety, depression and quality of life.

2) Yoga can be used as a complementary non-pharmacological therapy for the better control of the diabetic state on top of their medication. This can be shown by the following parameters:

a) decrease in fasting blood glucose levels

b) decrease in post-prandial blood glucose levels

c) decrease in blood cholesterol levels.

d) decrease in blood triglyceride levels

e) decrease in blood insulin levels and increase in insulin sensitivity

f) decrease in salivary cortisol levels.

Our hypothesis here was that yoga reduces the physiological response to stress, thus causing cortisol levels to decrease. This in turn would lead to a decrease in blood glucose levels.

3) Yoga as a complementary therapy is at least as good as or more effective than exercise therapy for type II diabetes mellitus patients. This means, with yoga, as with exercise, both metabolic as well as psychosocial parameters can be better controlled in a sustainable way.

METHODS

Our study encompassed exactly 102 diabetic patients, divided into a yoga group (n=55) and an exercise, or control, group (n=47). The yoga patients were recruited through an advertisement in the local newspaper and upon recruitment, signed a written and informed consent form. The exercise group patients were largely chosen from the Samatvam Diabetes Clinic, a locally established private practice. Through the newspaper advertisement, we had hoped to recruit a sufficient amount of patients to be able to randomize them into 2 groups. However, this was not the case, so we put all of the newspaper-recruited patients into the yoga group; we then matched the yoga patients with the control group patients from the Samatvam Diabetes Clinic who had given us written and informed consent for participating in a yoga study. In order to reduce confounding bias for the effect of a special interest in yoga, we recruited the control group with the offer of a yoga class which was then organized for them *after* our 4-month study. The criteria used to match the yoga group with the exercise group were diabetes duration, age, and gender.

We arranged for a special clinic to screen the patients who had read the newspaper advertisement. Each potential patient underwent a check-up and consultation with a cardiologist, ophthalmologist and an endocrinologist specialized in diabetology. The patients were examined for exclusion criteria and when present, were not taken into the study. Exclusion criteria are described in the next section.

In addition to this, each patient consulted a dietitian to discuss eating habits and a healthy meal plan according to the schedule and lifestyle of each patient.

Once the groups were formed, the yoga classes began for the first group.

Next, we arranged a screening clinic for the Samatvam Diabetes Clinic patients who had shown an interest in practicing yoga. Those interested in the study after hearing about it in detail consented to participating. These patients were to be our exercise, or control group, for the duration of the 4-month study. At this screening session, just as for the yoga patients, a cardiologist, an ophthalmologist, and a diabetologist were present. Also, a diet consultation was given to each patient.

The exercise group was given 3-4 intensive introduction sessions. During the introduction sessions, we demonstrated the different exercises and handed out small diaries. Each patient was instructed to log down the time and duration of exercise completed each day, as well as their daily food intake.

The large majority of the patient collective continued to take their prescribed medication. The medicines were slightly adjusted for by the diabetologist so that the yoga and exercise groups would be more comparable to each other.

The study design was set for a duration of 4 months. The biochemical parameters were tested in blood samples given by both groups at 0 (time 0), 2 (time 60), and 4 (time 120) months. We measured 3 time points because we had funding for 3 sets of laboratory analyses per patient. In addition, 2 survey forms in English were handed to both groups--the

SF-36 quality of life questionnaire and the hospital anxiety and depression scale (HADS). The surveys were orally translated into Kannada by volunteers from sVYASA and answered in a one-on-one session with the sVYASA volunteers at time 0 and again by the same volunteers at time 120. Experienced sVYASA research staff went over each question with the volunteer staff before they assisted the study subjects in answering the questionnaires. We measured 2 time points for the psychosocial parameters.

1. Inclusion and exclusion criteria

The following criteria were tested for during the Sunday clinics organized for each group before beginning the study.

Inclusion criteria:

1. written and signed informed consent
2. confirmed cases of stable type II diabetes mellitus
3. age group 30-70 years
4. ability to comprehend instructions
5. both sexes
6. stable cardiac condition established by a cardiologist
7. stable ophthalmologic condition established by an ophthalmologist

Exclusion criteria:

1. any chronic end-stage renal disease/failure
2. history of proliferative retinopathy
3. active chronic infections like TB, etc.
4. recent myocardial infarct
5. peripheral vascular disease
6. diabetic foot
7. cerebral vascular disease

2. Biochemical parameters

We drew the patients' blood 3 times during the whole study: at time 0 months, 2 months, and 4 months for both groups. The following was tested for in the blood:

1. fasting blood glucose
2. post-prandial blood glucose
3. glycated hemoglobin
4. fasting insulin
5. cholesterol
6. triglycerides

In addition, we tested for fasting cortisol in the saliva.

Fasting and post-prandial blood glucose is a commonly measured parameter in diabetes monitoring and control (Sudhir and Mohan 2002). Post-prandial blood glucose measurements have taken on increased significance in recent years with the realization that the effect of the diabetic post-prandial glucose peak remains for several hours, leading to longer periods of hyperglycemia.

Cholesterol and trigylerides measurements were included in the study due to the high cardiovascular risk presented by type II diabetes mellitus patients (Nesto 2005). High triglycerides and LDL cholesterol levels as well as low HDL cholesterol levels are established independent risk factors for metabolic syndrome and cardiovascular disease.

Glycated hemoglobin is a commonly-used parameter by clinicians to check the stability of patients' blood glucose levels over a period of between 6 weeks and 3 months (Singer et al. 1989). The glycated hemoglobin value can indicate well whether the measured blood sugar level is representative of the patient's normal sugar level over the past few weeks.

As for insulin, we originally wished to do the glucose-clamp test as it is the gold standard for the measurement of insulin resistance (Lansang et al. 2001, Strączkowski et al. 2004, DeFronzo 1979). Due to cost and time constraints, we were forced to abandon this idea. Instead, we decided to simply check insulin levels in the serum. This is by no means a direct assessment of insulin resistance; however, it does give us a good idea of how efficiently body tissues are using insulin (Laakso 1993).

We decided to measure cortisol in the saliva rather than in serum because it reflects the unbound and biologically active form of circulating cortisol. Salivary cortisol also does not depend on the concentration of cortisol-binding globulin (Vining and McGinley 1987). Finally, saliva is easy to collect, non-invasive, and salivary cortisol tests are cheaper than serum cortisol tests.

Salivary cortisol concentrations were first correlated to blood cortisol levels roughly 50 years ago (Shannon and Prigmore 1959). Salivary cortisol has since been confirmed to be a valid and reliable indicator of the biologically active free fraction of serum cortisol concentrations. In adults at rest, high levels of correlations (between r=0.7 to r=0.99) have been reported (Del Corral et al. 1994) between salivary and serum cortisol levels.

Our rationale for measuring cortisol was founded on its effect on glucose metabolism: enhanced cortisol secretion impairs glucose tolerance (Hornnes et al. 1984, Hornnes 1985 b, Baxter and Forsham 1972, Stubbs et al. 1999, Panthakalam et al. 2004). Cortisol is a stress hormone with a circadian rhythm which shows effects at nearly all levels in the human body. Cortisol, like other glucocorticoids, inhibits glucose uptake in peripheral tissues, thus causing hyperglycemia. In addition, it enhances hepatic capacity for gluconeogenesis, increasing glucose production. In non-diabetic patients, the glucocorticoid-induced abnormal glucose tolerance is temporary and ultimately returns to normal levels due to insulin's response to hyperglycemia (Baxter and Forsham 1972). In type 2 diabetic subjects, however, insulin's capacities are impaired, leading to elevated early morning blood glucose levels. Elevated cortisol levels can lead to a redistribution of body fat characterized by truncal obesity, which in turn is a risk factor for type 2 diabetes. For example, patients with Cushing's syndrome, characterized by a sustained, excessive secretion of cortisol and a lack of response to normal physiological feedback mechanisms, show truncal obesity as well as diabetogenic metabolism (Howlett et al. 1985). By contrast, cortisol deficiency, as in Addison's disease, leads to impaired fat mobilization and utilization, weight loss and hypoglycaemia. Cortisol deficiency causes falls in the rate of gluconeogenesis, hepatic glucose production and glycogen synthesis (Burke 1985).

Extensive documentation indicates that exposure to repeated intensive stressors is mirrored in increased cortisol secretion (Schulz et al. 1998, Evans and Streptoe 2001, Goldman et al. 2005). Stress is often described as a state of threatened homeostasis (Chrousos and Gold 1998, Rosmond et al. 1998). Stressors include physical ones such as cold, trauma, and infection as well as psychological stressors such as anxiety and depression. Stress-related cortisol secretion is strongly related to anthropometric, metabolic and haemodynamic risk factors for diabetes mellitus (Rosmond and Björntorp 1998). Thus, we seek to test our hypothesis that by practicing yoga, one can reduce stress levels and thus reduce cortisol levels. This will ultimately demonstrate positive effects on laboratory parameters relevant to diabetes.

Fasting insulin levels were measured using Human Insulin ELISA Kit from Diagnostic Systems Laboratories (California, USA). Salivary cortisol concentrations were measured using a chemiluminescence immunoassay technique (CLIA; IBL Hamburg, Germany). Cholesterol assays were done with the enzymatic cholesterol oxidase ceroxidase method (DiaSys, Holzheim, Germany). Glycated hemoglobin was measured via high-performance liquid chromatography (DiaSys, Holzheim, Germany). Triglyceride assays were conducted with the enzymatic glycerol-3-phosphate oxidase method (DiaSys, Holzheim, Germany).

The control group was taught to do cardiovascular exercises as this has demonstrated immense benefit for glycemic control and for primary and secondary prevention of complications of diabetes mellitus such as ischemic heart disease (Jayasinghe 2004, Tsatsoulis and Fountoulakis 2006, Orchard et al. 2005, Knowler et al. 2002). Exercise, especially of moderate intensity, has also been proven to reduce insulin resistance and improve glucose tolerance, especially in type 2 diabetes mellitus subjects (Kriska 2003). The Finnish Diabetes Prevention Research Study demonstrated clear evidence supporting the protective role of exercise against diabetes mellitus and the metabolic syndrome (Tuomilehto et al. 2001). Their evidence shows that increasing the level of physical activity, combined with diet control, could reduce the risk of developing diabetes in individuals with impaired glucose tolerance by as much as 58%. Insulin resistance, body-mass-index, and waist circumference also decreased by a larger margin in their intervention (exercise) group.

The Diabetes Prevention Program Research Group found equally compelling evidence for exercise as a preventive and therapeutic measure for type 2 diabetes. Their results showed that lifestyle intervention, with exercise at its core, was able to reduce the incidence of diabetes more than metformin could, as compared to a placebo group (Orchard et al. 2005, Knowler et al. 2002). According to this study, intensive exercise therapy was able to restore post-prandial blood glucose values more effectively to normal levels than metformin could. The incidence of metabolic syndrome was also markedly lower in the exercise group as compared to the metformin group and the placebo group.

Several studies indicate that physically active individuals have a lower incidence of hypertension as well, across all age groups (Blair et al. 1984, Pereira et al. 1999, Suzuki and Ohta 2008). Blair et al. adjusted for possible confounding factors such as body-mass-index, age, sex, follow-up interval, and baseline blood pressure levels; they were still able to demonstrate that physical fitness was significantly associated with risk of hypertension. Kelley et al.'s meta-analysis echoes these results. They reviewed 47 published and unpublished studies on the effect of aerobic exercise on resting systolic and diastolic blood pressure (Kelley et al. 2001). Their results demonstrate overall decreases in resting systolic blood pressure of approximately 4% in hypertensives and 2% in normotensives. Decreases in resting diastolic blood pressure were approximately 5% in hypertensives and 1% in normotensives. Blair et al. suggest that the underlying cause may be an exercise-induced reduction in sympathetic nervous system activity, thus possibly mirroring the mechanisms by which yoga brings about a relaxation effect in the human body.

Some authors even argue that exercise might compensate for the lack of physical activity which has become an integral part of our daily lives in civilized urban societies -- Booth et al. propound the hypothesis that exercise might restore the gene expression pattern designed to sustain survival in the pre-civilized era. Our current genome, according to their topical review article, is maladapted to our current sedentary society since the human genome was principally regulated and defined during times of hunting and gathering. Our biological existence, then, is linked to obligatory physical activity, the lack of which leads to homeostatic disruption in the skeletal, cardiovascular, and endocrine systems (Booth et al. 2002).

Research has demonstrated that exercise training also has positive effects on psychological well-being, anxiety, and depression (Fuchs-Climent et al. 1999, Koukouvou et al. 2004, Karvinen et al. 2007, Schmitz et al. 2005). Hence, we included the SF-36 and the HADS questionnaires into the exercise group protocol as well.

3. Psychological parameters

Each patient filled out, at time 0 and time 120 (at the beginning and end of the study) 2 questionnaires: the SF-36 (36-item short form health survey) quality of life questionnaire and the Hospital Anxiety and Depression Scale (HADS) questionnaire. The SF-36 questionnaire is the most widely used health-related quality of life questionnaire. It is a short form 36-item (SF-36) health survey which enables patients to describe their health status from their own perspective (Ware and Sherbourne 1992). It is used in clinical practice and research to assess 8 main health concepts:

1) Physical functioning -- limitations in physical activities due to health problems;

2) Social functioning -- limitations in social activities due to physical or emotional problems;

3) Role-physical -- limitations in usual role activities due to physical health problems;

4) Bodily pain

5) Mental health -- general mental health (psychological distress and well-being);

6) Role-emotional -- limitations in usual role activities due to emotional problems;

7) Vitality -- energy vs. fatigue;

8) General health -- perceptions on general health

The aim of the SF-36 questionnaire (see annex) is to obtain data that can be objectively assessed concerning the patient's subjective experience of the disease and its treatment. The questions and responses as well as the scoring are standardized, which makes it an efficient way to measure health status. Each of the 8 main health concepts are scored separately, so in the end, there is one computed value for each health concept plus one physical and one psychosocial component score. The answers are plotted on a 100-point scale. These 8 health concepts together yield a profile of functional health and well-being scores as well as psychometrically-based physical and mental health summary measures and a preference-based health utility index (Ware and Sherbourne 1992).

The HADS (Hospital Anxiety and Depression Scale), on the other hand, is a more concise self-assessment questionnaire especially developed for physically ill patients and mainly focused on anxiety and depression as fundamental aspects of general psychosocial well-being. Its question items deal with psychological manifestations of (generalized) anxiety and depressive mood. The HADS questionnaire is designed to examine emotional distress apart from somatic symptoms (Evans and Streptoe 2001). It is also used to assess the influence of the treatment on feelings of anxiety and depression as well as the influence of anxiety and depression on the final results of the treatment. Each of the two subscales consists of 7 items rated on 4-point scales. The item scores are added, giving a possible subscale scores range from 0 to 21 with higher scores corresponding to greater anxiety and depression

(Crawford et al. 2001). HADS has been used in several hundred published studies and has been validated against psychiatric interviews (Hermann 1997).

In measuring psychological parameters, we were principally interested in the effect of relaxation induced by yoga. Anxiety and depression traits have been found to be associated with higher stress levels (Rosmond and Björntorp 1998, Rosmond et al. 1998, Salmon 2001, Chrousos and Gold 1998,). For example, Rosmond et al. examined a large population of middle-aged men by obtaining a series of salivary cortisol samples in parallel with measures of stress perception (Rosmond et al. 1998). Their analysis revealed that the increases in blood pressure and body mass index similar to those seen in the hypercortisolism of Cushing's syndrome, could also be seen in this general population of non-Cushingoid middle-aged men in correlation with the degree of stress perception and stress-related cortisol secretion. Thus, our hypothesis was that if relaxation can calm the body and mind, thereby decreasing the level of perceived stress, the quality of life in our yoga study group should improve and their anxiety and depression values should decrease. Yoga-induced relaxation can thus possibly lead to better diabetic control through reduced perceived stress.

4. Analysis

We used the SPSS (Statistical Package for the Social Sciences) software version 12.0 to do all statistical analyses. Any p values below 0.05 were seen as significant. Variables marked with one star (*) have a p value between 0.01 and 0.05. Variables marked with two stars (**) have a p value between 0.001 and 0.01. Variables with three stars (***) are highly significant, with a p value below 0.001.

We ran the Kolmogorov-Smirnov test on all variables to determine normal and non-normal distribution patterns. T-tests were performed to examine baseline differences with interval scale variables. Chi-square tests were used to examine baseline differences with categorical scale variables.

The general linear model for repeated measures was used to determine variances within subjects. Between-group comparisons were done using the Mann-Whitney U Test and the Wilcoxon signed ranks test. The analysis of covariance (ANCOVA) test was done for those variables with considerable baseline differences.

The yoga and exercise group variables were measured at 3 time points for the physiological parameters (time 0, 60, and 120) and at 2 time points for the psychological parameters (time 0 and 120).

5. Yoga course

The yoga course was offered 2 times a day, 7 days a week, but the patients were required to come only once a day, 6 days a week. One single yoga instructor took both the morning and evening class, that is, 6-7 a.m. and 6-7 p.m. The course duration was 4 months. Attendance was taken, according to which the compliance was noted down: "Intensive" compliance indicates 4-6 hours of yoga per week or 16-24 hours per month; "Intermediate" compliance indicates 2-4 hours of yoga per week or 8-16 hours per month; "Irregular" compliance indicates 0-2 hours of yoga per week or 0-8 hours per month. The yoga practices followed are described below.

5.1. Preparatory breathing exercises

5.1.1) hand stretch breathing:

a) Sthiti: stand erect with the feet close together, the hands along the thighs, fingers stretched out

b) Raise the hand to the level of the chest with the palms facing downwards. Inhale slowly.

c) While exhaling, bring the hands to the side of the body

d) Repeat this 5-7 times

5.1.2) hand in out breathing:

a) Sthiti

b) Lift the hands from the body to the side with the palms facing the direction of sight

c) Bring both palms together in front of you. Inhale.

d) Exhale while bringing the hands back to Sthiti.

e) Repeat 5-7 times

5.1.3) tiger breathing:

a) sit in Vajrasana (the anide posture)--bend the right leg under the buttock. Then bend the left leg under the buttock. Keep the spine erect. Rest the palms on the knees. Close the eyes.

b) raise the buttocks and stand on the knees

c) lean forward and place the hands flat on the floor beneath the shoulders with the fingers facing forward

d) the arms, thighs, and heels should be about shoulder width apart.

e) the arms and thighs should be perpendicular to the floor

f) while inhaling, raise the head and look at the ceiling.

g) At the same time, depress the spine towards the ground. Hold this position for a moment.

h) While exhaling, arch the spine upwards and bend the head forward, bringing the chin towards the chest. Hold this position for a moment.

i) Repeat 10 times

This exercise is thought to improve the flexibility of the neck, shoulders, and spine. It is also supposed to improve the microcirculation all over the body, including the abdominal area.

5.1.4) sasankasana (moon posture) breathing:

a) Starting from a sitting position, slowly bend the right leg, and keep the heel tight under the buttock

b) bring the left leg under the left buttock. Keep the knees close to each other, spine erect, the head, shoulders, and buttocks in a vertical line. Rest the palms on the upper part of the thighs. Close the eyes.

c) catch the right hand with the left behind the back

d) bend forwards from the waist; rest the forehead on the ground in front of the knees. Breathe slowly and regularly, paying attention to the breathing

e) slowly come back to the original position

This *asana* (posture) is supposed to vitalize the organs in the abdomen and pelvis. It is also known to tone up the nervous system, especially in the lumbosacral areas.

5.1.5) ekapadasana (one leg posture) breathing:

a) stand straight on one leg. Adjust the heel of the raised leg on the thigh of the opposite leg near the groin

b) join hands together at the level of the sternum. Breathe normally but concentrate on the breathing.

c) do the same on the other side.

This technique is seen to encourage conscious breathing, rhythmically and calmingly. It is supposed to help in neuromuscular balance and endurance. This in turn is believed to increase neural stimulation of all internal organs.

5.2. Surya namaskar (Sun salutation)

a) Namaskārasana (worship posture): stand erect, shoulders back, close the hands together with the palms facing each other. The thumbs should press hard into the chest. Pull the stomach muscles in to support the upper body. Breathe normally. This posture is good for the toning of the stomach muscles and reduction of abdominal fat.

b) Urdhva Namaskārasana (Looking up to worship posture): The joined palms are pulled up above the head with the arms covering the ears. The body is bent backwards with the eyes looking towards the hands. Inhale. This posture is generally good for strengthening back and hip muscles and increasing blood circulation throughout the body, including the internal organs.

c) Adharasana: Bend the body down with the hands stretched down as far as possible to touch the ground. The head should touch the knees. Exhale.

This posture is good for strengthening the stomach muscles, arms, and knees.

d) Ekapāda Prasaranasana ("one leg behind" posture): Stretch one leg behind the body and lower the body. The two palms should be on the ground. The knee of the leg which is stretched should touch the ground. The head should look up. Inhale.

This exercises the legs, lower back, and the chest. It helps reduce body fat.

e) Dwipāda Prasaranasana ("both legs behind" posture): The leg that was forward should join the leg that was in the back. Both feet are joined together with the body in an inclined plane. Only the palms and the toes touch the ground. The head should be at a higher plane and the legs at a downward slope. The eyes should be looking straight. Remain like this for 15 seconds. Exhale.

By stretching the whole body, this posture is thought to activate blood circulation throughout the body.

f) Ashtānga Namaskārasana: Lower the body and touch the ground at the forehead, chest, and knees. The rest of the body should be up in the air supported by the forehead, chest and knees. Remain in this posture for 5 seconds.

This posture exercises the back, shoulder, and chest muscles.

g) Bhujangasana (serpent posture); inhale, release the tops of the feet to the floor and press them down. Slide chest forward and up keeping the hands exactly where they were. Roll the shoulders back and lift the chest higher, while keeping the low ribs on the floor.

h) Adhomukha Shvaasana: pull the body inward, with the palms and feet firmly on the ground. Press the feet so that the heels touch the ground. The knees should be straight. Pull the stomach in. Expand the chest while pushing the shoulders back. While pushing the head in, try to touch the chin to the chest. The body will look like a hill. Exhale.

This *asana* extends the spinal cord to the maximum. Thus, all the different nerves which go through the spinal cord are supposed to be stimulated. This, in turn, is believed to stimulate the various organs that these nerves innervate. Adhomukha Shvaasana is also good for exercising the thigh and hip muscles and helps reduce body fat.

i) Inhale while doing Ekapada Prasanasana

j) Exhale while doing Adharasana

k) Inhale while doing Namaskārasana

5.3. Yoga asanas (postures)

5.3.1) Ardhakati Cakrasana (lateral arc posture) on each side:

a)Sthiti

b) while inhaling, slowly raise the right arm sideways up above the side, above the head, until the arm touches the ear, palm facing left

c) bend slowly on the left side, slide the left palm down as far as possible along the left leg. Exhale while bending. The raised hand should not bend at the elbow. The knees should be straight. Breathing should be normal. This position should be maintained for about a minute.

d) return to position **a**, inhaling completely

e) bring the hand back down to Sthiti

f) repeat on the left side by bending towards the right

This *asana* was chosen mainly for its reputed benefits of improving the function of the liver and pancreas as well as increasing flexibility of the body for other *asanas*.

5.3.2) Ardha Cakrasana (wheel posture): Sthiti--lie supine on the ground with the legs together and the arms along along the body.

a) take the hands back; place the palms on the ground above the shoulders on either side of the head. The fingers face the shoulders. Bend the knees and fold the legs.

b) with the palms and soles as 4 points of support, raise the trunk, making an arch convex upwards to look like a wheel.

c) return to Sthiti slowly

This is known to be a very powerful back-bending posture in yoga. It aims at building a flexible back and reducing abdominal fat.

5.3.3)Pāda Hastasana (forward-bend posture):

a) Stand erect with the legs together, raise the arms parallel to the ground

b) Raise the hands. Inhale while going up. Stretch up the body from the coccyx

c) Making the back concave, bend forward until the body comes to a horizontal position. Attempt to push the bottom of the spine forward while bending. Breathe out while going down. Then inhale

d) While exhaling, go down, till the palms rest on the ground and the forehead touches the knees. Retain this position for about 2 minutes without allowing the knees to bend and return to Sthiti.

This *asana* is thought to improve microcirculation throughout the body, including the internal organs.

5.3.4)Bhujangasana (serpent posture):

a) Sthiti-- lie prone on the blanket, keeping the legs together, chin touching the ground, the soles facing up. Stretch the hands straight forward alongside the head resting the palms on the ground bring the arms back to the level of the last rib bone. Keep the hands bent at the elbows; very little pressure is to be exerted on the hands. Maintain the elbows touching the body; let it not spread out to the sides

b) raise the head first and then the upper portion of the trunk slowly, just as a cobra raises its hood, till the navel portion is about to leave the ground.

We added this *asana* into the yoga program due to its considerable putative benefits in reducing abdominal fat; adipose tissue, especially in the stomach region, and type II diabetes mellitus are highly correlated.

5.3.5)Dhanurasana (bow posture):

a) bend the knees and hold the feet by the hands

b) raise the head, chest, and thighs by tugging the hands and legs so that the spine is arched backwards like a bow. Stabilise the body on the abdomen. The elbows must not be bent. Look up. With practice, the knees should be brought very near. Maintain this position for 30 seconds while breathing normally.

c) slowly come back to the original position

We chose this *asana* for its assumed pancreas-stimulating characteristic. It is also seen to remove gastro-intestinal disorders and improves digestion. In addition, it hleps slim down abdominal fat.

5.3.6)Supta Vajrasana (the supine anide posture):

a) slowly bend the right leg, keep the heel tight under the buttock

b) bring the left leg under the left buttock. Keep the knees close to each other, spine erect, the head, shoulders and buttocks in a verticle line. Rest the palms on the upper part of the thighs. Close the eyes.

c) recline backwards, slowly, taking the body weight onto the right elbow first and then to the left.

d) lie flat on the back. Keep the hands crossed above the head. Keep the knees close together, touching the ground.

e) return to Sthiti

This *asana* improves microcirculation throughout the body, including the internal organs.

5.3.7)Ardha Matsyendrasana (the half-twist posture):

a) bend the right leg at the knee and place the heel tight against the perineum

b) keep the foot of the left leg by the side of the right thigh near the right knee

c) bring the right hand round the outer side of the left knee

d) take the left hand round the back and try to catch the right thigh. Look back over the left shoulder. The erect knee acts as a fulcrum to get maximum twist of the spine. Keep the trunk vertical. Do not sit on the heels. Maintain for a maximum of 2 minutes.

e) come back to Sthiti

f) repeat the same, on the other side

This posture tones up all the spinal nerves. It helps cure internal organ problems in the abdominal area: constipation, dyspepsia, diabetes, renal troubles. Abdominal girth is reduced.

5.3.8)Ustrasana (camel posture):

a) bend the right leg backwards

b) bend the left leg to come to Vajrasana

c) rise up, thereby making the trunk vertical

d) inhale and bend the body backwards and bring the hands to the heels

e) exhale while coming back to Sthiti

This *asana* increases blood flow to the brain. It makes the spine more flexible. It reduces abdominal fat.

5.4. Om meditation

This was done at the end of every class. It involves sitting in Padmasana (lotus posture) with the hands on the knees with the palms open. The technique of the lotus posture:

a) keep the right foot on the left thigh

b) take hold of the left foot with both hands, gently glide it over the crossed right leg and place it on the right thigh

c) the hands should be kept on the knees with the palms open, and the thumb and second finger of each hand should touch forming the letter O.

In this position, the yoga patients slowly repeat the sound "om" in a deep, low, quiet voice. The eyes are closed, the lights are turned off. The word "om" is used because it is believed to be the first word uttered in the universe, the primal sound or vibration from which all sound and form arises. It is supposed to induce calmness of the mind and thus, a state of mind and body conducive for meditation. This practice was done for about 10 minutes at the end of a yoga session.

6. Exercise group's exercises

The exercise group patients were instructed to do half an hour to one hour of any of the 10 cardiovascular exercises shown in the index. To complement this or as an alternative, they were to do brisk walking for half an hour or one hour. The total amount of time spent exercising would be one hour. Each patient was given a log book where they were to note down the exercises done per day and their daily food intake. During the Sunday clinics or blood draw sessions, we carefully checked these books. In addition, an employee of sVYASA was responsible for calling up each patient on a weekly basis to make sure the exercises were actually being done.

RESULTS

Our first goal was to analyze the comparability of the two groups in all the variables tested. In order to achieve this, we first had to describe the variables themselves and establish baseline data and differences between the two groups.

Table 1: Variable scales

Interval scale	Categorical scale
Not normally distributed	
fasting blood glucose	depressive mood pos.
post-prandial blood glucose	anxiety pos.
glycated hemoglobin	at least one pos.
cholesterol	sex
triglycerides	
fasting insulin	
salivary cortisol	
standard psychological scale	
standard physical scale	
bodily pain	
general health	
vitality	
social functioning	
role-emotional	
mental health	
role-physical	
physical functioning	
depressive mood	
anxiety	
diabetes duration	
body-mass-index	
age	

Basically, all the biochemical parameters and most of the psychosocial parameters are not normally distributed interval scale data. Depressive mood positive, anxiety positive, and at least one positive, and sex are categorical scale data.

For the interval scale variables, we initially did a Smirnov Adjustability Test to check if the variable was normally distributed. We then ran a Mann-Whitney non-parametric test on the non-normally distributed interval scale data. We ran a chi-square test on the categorical variables. These tests compared the yoga and exercise groups' baseline values for the applicable variable. Due to incomplete data on several of the patients, the number of subjects for whom we had data varies slightly for each variable. The results of these findings are shown on the following table:

Table 2: Averages of variables at Time 0 (Baseline data)

2.a.

Not normally distributed interval scale variables (Mann-Whitney Test)						
	Group	N	25th percentile	Median	75th percentile	P value
fasting blood glucose (mg/dl)	yoga	58	116.00	134.00	174.00	0.40
	exercise	45	123.00	146.50	174.50	
post-prandial blood glucose (mg/dl)	yoga	57	156.00	191.00	250.00	0.07
	exercise	41	185.25	212.50	263.50	
glycated hemoglobin (%)	yoga	52	5.80	7.30	9.10	0.43
	exercise	39	5.95	6.50	8.05	
cholesterol (mg/dl)	yoga	52	176.00	191.00	207.00	0.95
	exercise	39	162.75	191.50	220.25	
triglycerides (mg/dl)	yoga	52	118.00	176.00	240.00	0.96
	exercise	38	122.75	166.50	244.50	
fasting insulin (uIU/ml)	yoga	48	8.40	11.30	18.70	0.00***
	exercise	35	4.98	6.05	7.70	
salivary cortisol (µg/dl)	yoga	49	128.40	159.70	219.70	0.00***
	exercise	34	211.00	296.35	443.90	
diabetes duration	yoga	50	1.00	5.00	11.00	0.22
	exercise	36	0.50	4.00	7.00	
body-mass-index	yoga	58	21.80	23.30	25.62	0.00***
	exercise	45	24.15	26.18	28.75	
age	yoga	58	43.50	49.00	55.00	0.17
	exercise	47	47.25	54.00	59.50	
standard psychological scale	yoga	57	43.41	51.54	55.59	0.33
	exercise	30	36.84	45.38	53.34	
standard physical scale	yoga	57	38.90	44.54	51.54	0.47
	exercise	30	40.38	45.31	49.44	
SF-36 bodily pain (0-100)	yoga	56	56.00	74.00	84.00	0.74
	exercise	30	62.00	73.00	100.00	
SF-36 general health (0-100)	yoga	54	57.00	70.00	87.00	0.005*
	exercise	30	39.00	61.00	72.00	
SF-36 vitality (0-100)	yoga	57	60.00	75.00	80.00	0.005*
	exercise	30	42.50	62.50	72.50	
SF-36 social functioning (0-100)	yoga	57	56.25	62.50	75.00	0.76
	exercise	30	50.00	68.75	87.50	
SF-36 role emotional (0-100)	yoga	57	33.33	66.66	100.00	0.84
	exercise	30	8.30	66.66	100.00	
SF-36 mental health (0-100)	yoga	57	64.00	76.00	84.50	0.17
	exercise	29	52.00	68.00	79.00	
SF-36 role-physical (0-100)	yoga	55	50.00	70.00	85.00	0.81
	exercise	30	60.00	73.88	84.58	
SF-36 physical functioning (0-100)	yoga	56	50.00	75.00	100.00	0.78
	exercise	29	0.00	75.00	100.00	
HADS depressive mood	yoga	57	2.00	6.00	7.00	0.80
	exercise	27	3.00	4.00	7.50	
HADS anxiety	yoga	57	4.00	6.00	8.00	0.19
	exercise	27	5.25	7.00	12.75	

2.b.

	Categorical scale variables (chi-square test)				
	Group	N		Percentage	P value
HADS depressive mood positive	Yoga	57		12.3%	0.748
	Exercise	27		14.8%	
HADS anxiety positive	Yoga	57		10.5%	0.068
	Exercise	27		25.9%	
HADS at least 1 positiv	Yoga	57		14.0%	0.089
	Exercise	27		29.6%	
sex	Yoga	58	Male	86.2%	0.004*
			Female	13.8%	
	Exercise	47	Male	61.7%	
			Female	38.3%	

In summary, we measured significant differences (via the Mann-Whitney and chi-Square tests) in baseline values between the two groups for the following variables:

Table 3: Baseline value differences

Significant differences in baseline values	
biochemical parameters	fasting insulin*
	salivary cortisol***
psychometric parameters (SF-36)	health perception*
	vitality*
others	body-mass-index***
	sex*

Hence, the 2 groups were comparable at time 0 in all other variables except the above. This includes fasting blood glucose, post-prandial blood glucose, glycated hemoglobin, cholesterol, triglycerides, summarized standard psychological and physical scales, age, and diabetes duration.

Now that the baseline characteristics were established, our next objective was to compare the averages of the different variables

a) as they changed over time, that is, from time 0 to time 120

b) with regard to differences in changes over time between the two groups.

The results are displayed in the following tables:

Table 4: Progress of variables

4.a.

Not normally distributed interval scale variables: median of variables at times 0, 60 (if available), and 12	Time 0	Time 60	Time 120
fasting blood glucose (mg/dl)			
yoga	147.1	162.8	156.0
exercise	156.9	178.1	171.0
post-prandial blood glucose (mg/dl)			
yoga	210.1	248.0	236.4
exercise	227.5	262.1	255.5
glycated hemoglobin (%)			
yoga	8.8	7.0	8.0
exercise	6.9	7.3	7.7
cholesterol (mg/dl)			
yoga	193.0	196.8	188.6
exercise	198.2	192.5	182.5
triglycerides (mg/dl)			
yoga	195.6	178.9	178.5
exercise	235.1	214.1	179.5
fasting insulin (uIU/ml)			
yoga	16.7	9.3	8.4
exercise	9.3	9.4	23.4
salivary cortisol (µg/dl)			
yoga	1.8	1.6	1.3
exercise	3.2	1.5	2.4
standard psychological scale			
yoga	51.5	N/A	55.9
exercise	45.4	N/A	56.2
standard physical scale			
yoga	44.5	N/A	51.3
exercise	45.3	N/A	52.2
bodily pain			
yoga	74.0	N/A	84.0
exercise	73.0	N/A	100.0
general health			
yoga	70.0	N/A	80.0
exercise	61.0	N/A	80.0
vitality			
yoga	75.0	N/A	75.0
exercise	62.5	N/A	85.0
social functioning			
yoga	62.5	N/A	75.0
exercise	68.8	N/A	87.5
role emotional			
yoga	66.7	N/A	100.0
exercise	66.7	N/A	100.0
mental health			
yoga	76.0	N/A	80.0
exercise	68.0	N/A	80.0
role physical			
yoga	70.0	N/A	70.0
exercise	73.9	N/A	90.0
physical functioning			
yoga	75.0	N/A	100.0
exercise	75.0	N/A	100.0
depressive mood			
yoga	6.0	N/A	4.0
exercise	4.0	N/A	3.0
anxiety			
yoga	6.0	N/A	5.0
exercise	7.0	N/A	5.0

4.b.

Categorical scale variables at time 0 and 120			
	N	**Time 0**	**Time 120**
anxiety positive			
yoga	28	10.5%	3.6%
exercise	16	25.9%	5.3%
at least one pos.			
yoga	28	14.0%	10.7%
exercise	16	29.6%	21.1%
depressive mood pos.			
yoga	28	12.3%	7.1%
exercise	16	14.8%	15.8%

Table 5. Analytical statistics

5.a.

Group, time and group * time effect for all parameters					
	Group	N	Group effect (p)	Time effect (p)	Group * Time effect (p)
fasting blood glucose (mg/dl)	Yoga	36	0.4	0.6	0.5
	Exercise	20			
post-prandial blood glucose (mg/dl)	Yoga	36	0.8	0.2	0.4
	Exercise	18			
glycated hemoglobin (%)	Yoga	35	0.4	0.5	0.5
	Exercise	20			
cholesterol (mg/dl)	Yoga	36	0.4	0.1	0.6
	Exercise	20			
triglycerides (mg/dl)	Yoga	36	1.0	0.1	0.5
	Exercise	19			
fasting insulin (uIU/ml)	Yoga	30	0.4	0.001**	<0.001***
	Exercise	15			
salivary cortisol (µg/dl)	Yoga	27	<0.001***	<0.001***	<0.001***
	Exercise	14			
standard psychological scale	Yoga	32	0.3	<0.001***	0.1
	Exercise	19			
standard physical scale	Yoga	32	0.6	<0.001***	0.02
	Exercise	19			
bodily pain	Yoga	33	0.8	0.001**	0.4
	Exercise	19			
general health	Yoga	32	0.3	<0.001***	0.01*
	Exercise	19			
vitality	Yoga	32	0.8	<0.001***	<0.001***
	Exercise	19			
social functioning	Yoga	33	0.9	0.003**	0.1
	Exercise	19			
role emotional	Yoga	32	0.6	0.01*	0.8
	Exercise	19			
mental health	Yoga	32	0.3	<0.001***	0.03*
	Exercise	18			
role-physical	Yoga	31	0.2	<0.001***	0.1
	Exercise	19			
physical functioning	Yoga	32	0.3	0.005**	0.9
	Exercise	18			
depressive mood	Yoga	28	0.6	0.1	0.8
	Exercise	16			
depressive mood positive	Yoga	28	0.1	0.6	0.6
	Exercise	16			
anxiety	Yoga	28	0.3	0.001**	0.4
	Exercise	16			
anxiety positive	Yoga	28	0.03	0.007**	0.03*
	Exercise	16			
at least one positive	Yoga	28	0.01*	0.2	0.2
	Exercise	16			

Since the between-group comparison and the within group change for the yoga group for the variables fasting insulin and salivary cortisol were highly significant, we examined whether these changes remained statistically significant after adjusting for body-mass-index and sex. They did.

5.b.

Fasting insulin and salivary cortisol t0 -- t120, adjusted for BMI and sex				
	Group	**N**	**bmi (p)**	**sex (p)**
fasting insulin (uIU/ml) t0 -- t120	Yoga	38	0.14	0.42
	Exercise	18		
salivary cortisol (µg/dl) t0 -- t120	Yoga	35	0.93	0.13
	Exercise	19		

We then ran a series of analytical tests on the metabolic and psychometric variables (general linear model for repeated measures, Mann-Whitney *U* Test and the Wilcoxon signed ranks test) to verify the statistical significance of the trends across different time points in the progress of variables tables. We ran an analysis of covariance (ANCOVA) on those variables with baseline differences to confirm or refute statistical significance on the Mann-Whitney *U* Test/Wilcoxon signed ranks test.

5.c.

YOGA group: Trends across different time points		
Metabolic parameters	**Trend**	**P value**
fasting blood glucose 0 --> fasting blood glucose 60	⬆	0.01*
fasting blood glucose 60 --> fasting blood glucose 120	⬇	0.22
fasting blood glucose 0 --> fasting blood glucose 120	⬆	0.51
post-prandial blood glucose 0 --> post-prandial blood glucose 60	⬆	0.02*
post-prandial blood glucose 60 --> post-prandial blood glucose 120	⬇	0.30
post-prandial blood glucose 0 --> post-prandial blood glucose 120	⬆	0.24
glycated hemoglobin 0 --> glycated hemoglobin 60	⬇	0.38
glycated hemoglobin 60 --> glycated hemoglobin 120	⬆	0.00***
glycated hemoglobin 0 --> glycated hemoglobin 120	⬇	0.35
cholesterol 0 --> cholesterol 60	⬆	0.14
cholesterol 60 --> cholesterol 120	⬇	0.12
cholesterol 0 --> cholesterol 120	⬇	0.20
triglycerides 0 --> triglycerides 60	⬇	0.12
triglycerides 60 --> triglycerides 120	➡	0.61
triglycerides 0 --> triglycerides 120	⬇	0.13
fasting insulin 0 --> fasting insulin 60	⬇	0.00***
fasting insulin 60 --> fasting insulin 120	⬇	0.01*
fasting insulin 0 --> fasting insulin 120	⬇	0.00***
salivary cortisol 0 --> salivary cortisol 60	⬇	0.15
salivary cortisol 60 --> salivary cortisol 120	⬇	0.002**
salivary cortisol 0 --> salivary cortisol 120	⬇	0.003**

5.d.

YOGA group: Trends across different time points		
Psychological parameters	**Trend**	**P value**
standard physical scale 0 --> 120	↑	0.006**
standard psychological scale 0 -->120	↑	0.01*
bodily pain 0 --> 120	↑	0.007**
general health 0 --> 120	↑	0.09
vitality 0 --> 120	→	0.58
social functioning 0 --> 120	↑	0.04**
role emotional 0 --> 120	↑	0.06
mental health 0 --> 120	↑	0.09
role-physical 0 --> 120	→	0.02*
physical functioning 0 -->120	↑	0.02*
HADS depressive mood 0 -->120	↓	0.04*
HADS depressive mood positive 0 -->120	↓	0.56
HADS anxiety 0 --> 120	↓	0.02*
HADS anxiety positive 0 --> 120	↓	0.32
HADS at least 1 positive 0 --> 120	↓	0.65

5.e.

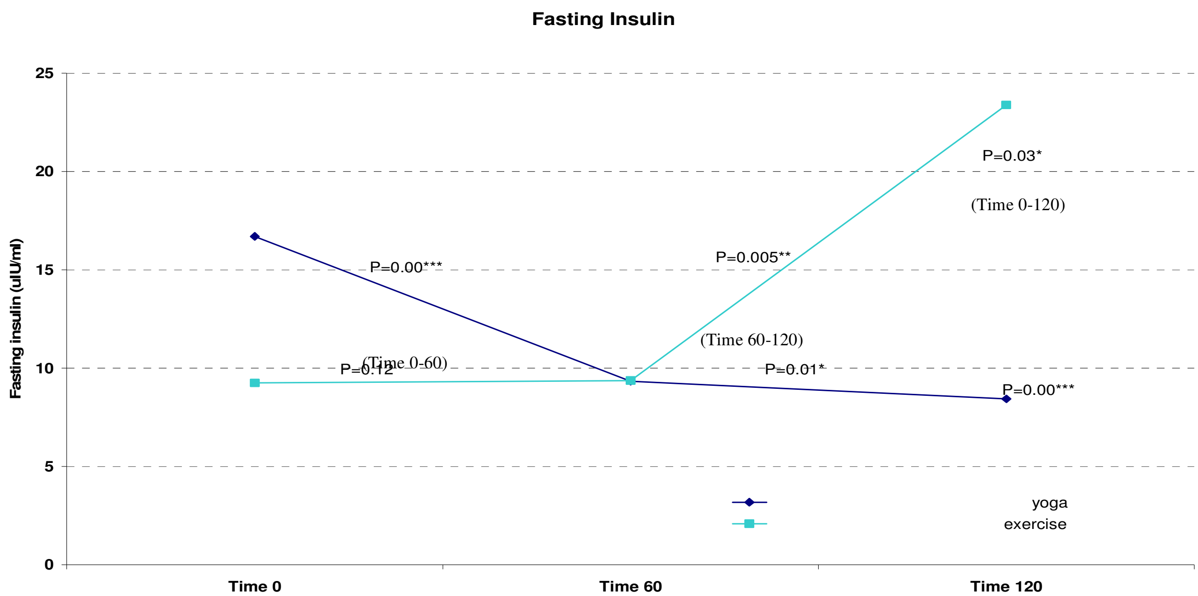
EXERCISE group: Trends across different time points		
Metabolic parameters	**Trend**	**P value**
fasting blood glucose 0 --> fasting blood glucose 60	⬆	0.26
fasting blood glucose 60 --> fasting blood glucose 120	⬇	0.59
fasting blood glucose 0 --> fasting blood glucose 120	⬆	0.13
post-prandial blood glucose 0 --> post-prandial blood glucose 60	⬆	0.24
post-prandial blood glucose 60 --> post-prandial blood glucose 120	⬇	0.41
post-prandial blood glucose 0 --> post-prandial blood glucose 120	⬆	0.09
glycated hemoglobin 0 --> glycated hemoglobin 60	⬆	0.53
glycated hemoglobin 60 --> glycated hemoglobin 120	⬆	0.003**
glycated hemoglobin 0 --> glycated hemoglobin 120	⬆	0.10
cholesterol 0 --> cholesterol 60	⬇	0.08
cholesterol 60 --> cholesterol 120	⬇	0.20
cholesterol 0 --> cholesterol 120	⬇	0.29
triglycerides 0 --> triglycerides 60	⬇	0.33
triglycerides 60 --> triglycerides 120	⬇	0.24
triglycerides 0 --> triglycerides 120	⬇	0.58
fasting insulin 0 --> fasting insulin 60	⬆	0.12
fasting insulin 60 --> fasting insulin 120	⬆	0.005**
fasting insulin 0 --> fasting insulin 120	⬆	0.03*
salivary cortisol 0 --> salivary cortisol 60	⬇	0.00***
salivary cortisol 60 --> salivary cortisol 120	⬆	0.02*
salivary cortisol 0 --> salivary cortisol 120	⬇	0.28

5.f.

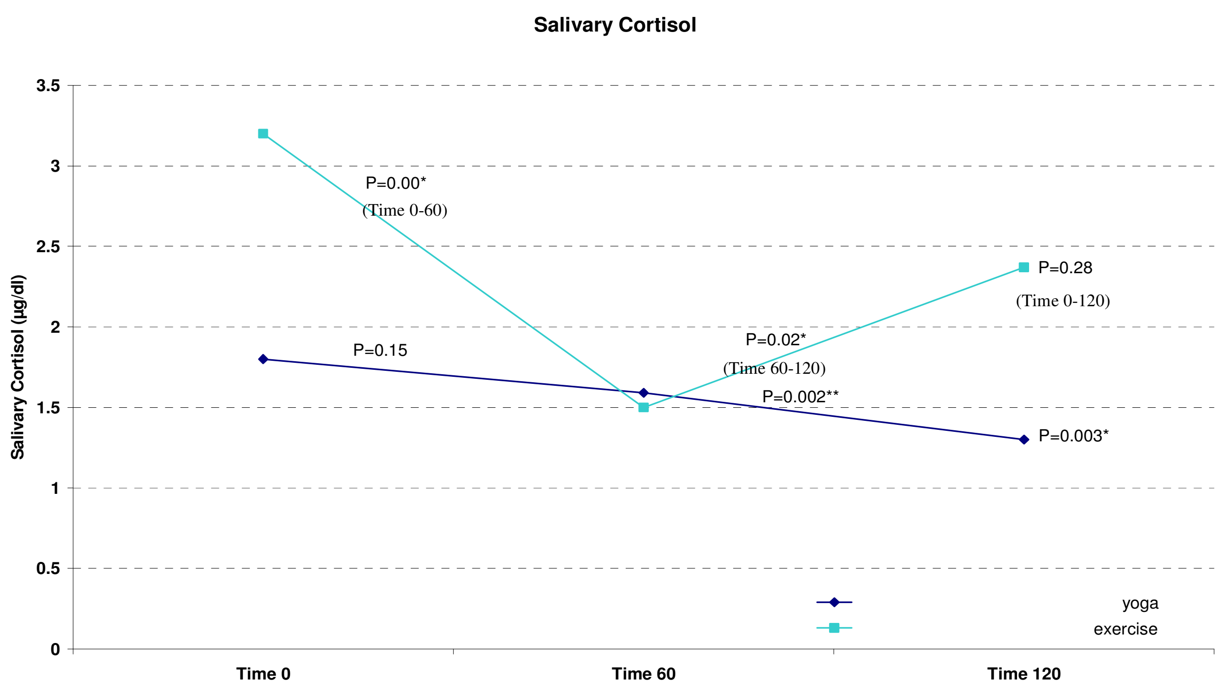
EXERCISE group: Trends across different time points		
Psychological parameters	**Trend**	**P value**
standard physical scale 0 --> 120	↑	0.003**
standard psychological scale 0 -->120	↑	0.04*
bodily pain 0 --> 120	↑	0.06
general health 0 --> 120	↑	0.002**
vitality 0 --> 120	↑	0.006**
social functioning 0 --> 120	↑	0.04*
role emotional 0 --> 120	↑	0.4
mental health 0 --> 120	↑	0.008**
role-physical 0 --> 120	↑	0.2
physical functioning 0 -->120	↑	0.003**
HADS depressive mood 0 -->120	↓	0.44
HADS depressive mood positive 0 -->120	↑	0.65
HADS anxiety 0 --> 120	↓	0.02*
HADS anxiety positive 0 --> 120	↓	0.01*
HADS at least 1 positive 0 --> 120	↓	0.26

Graph 1. Variables with <u>significant group * time effect</u>

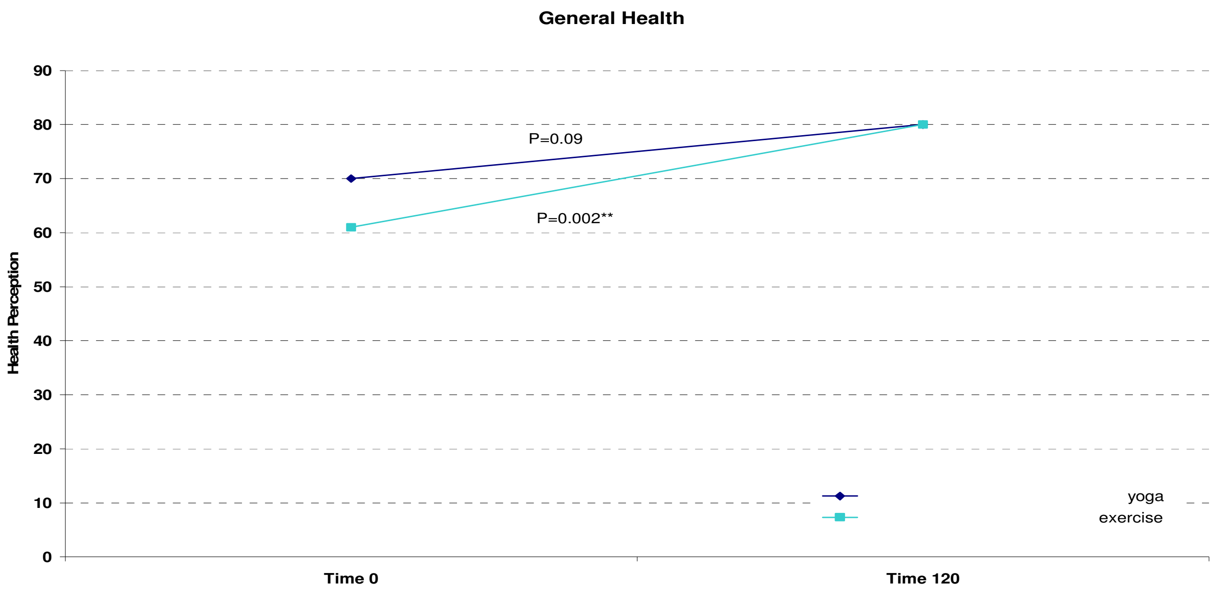
1.a.



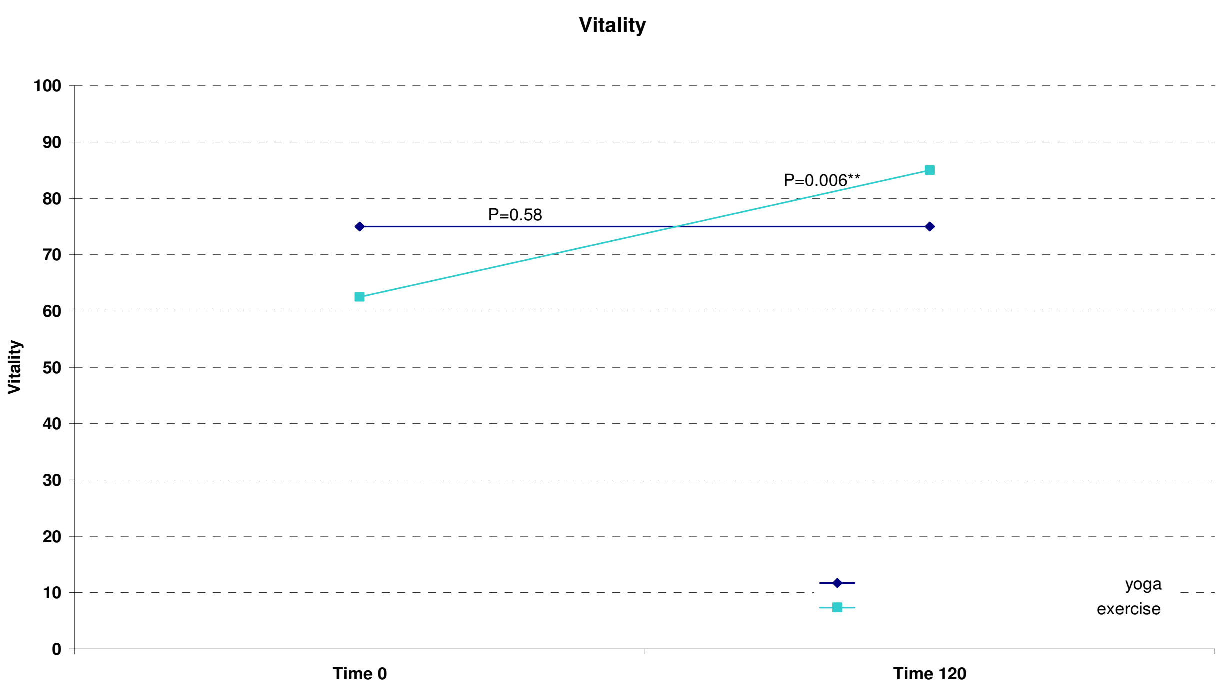
1.b.



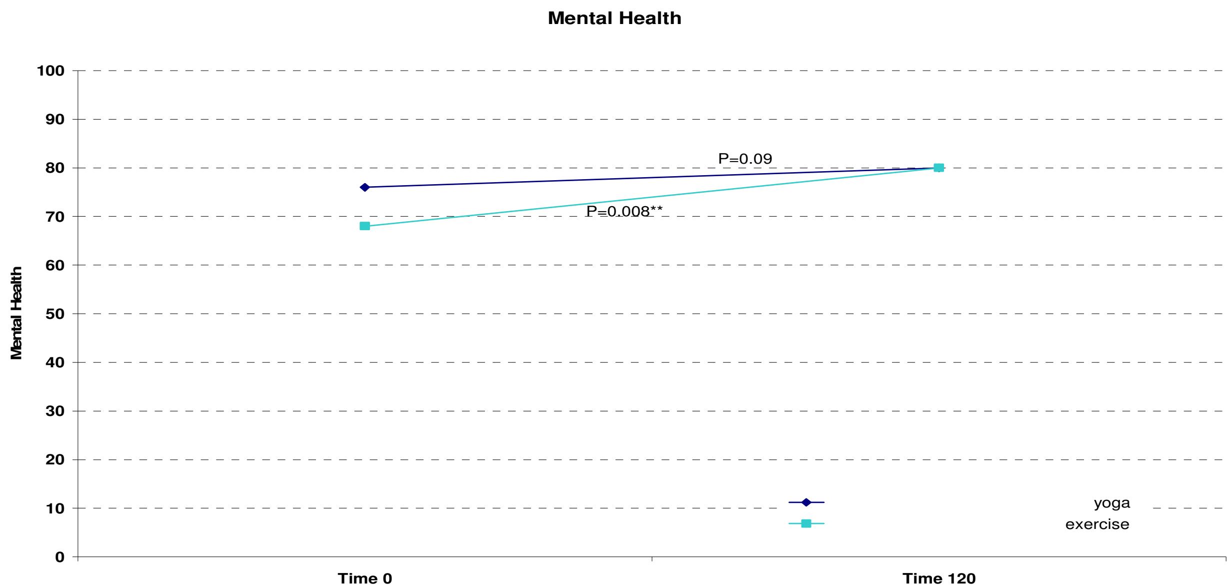
1.c.


General Health
Health Perception
90
80
70
60
50
40
30
20
10
0
P=0.09
P=0.002**
yoga
exercise
Time 0
Time 120

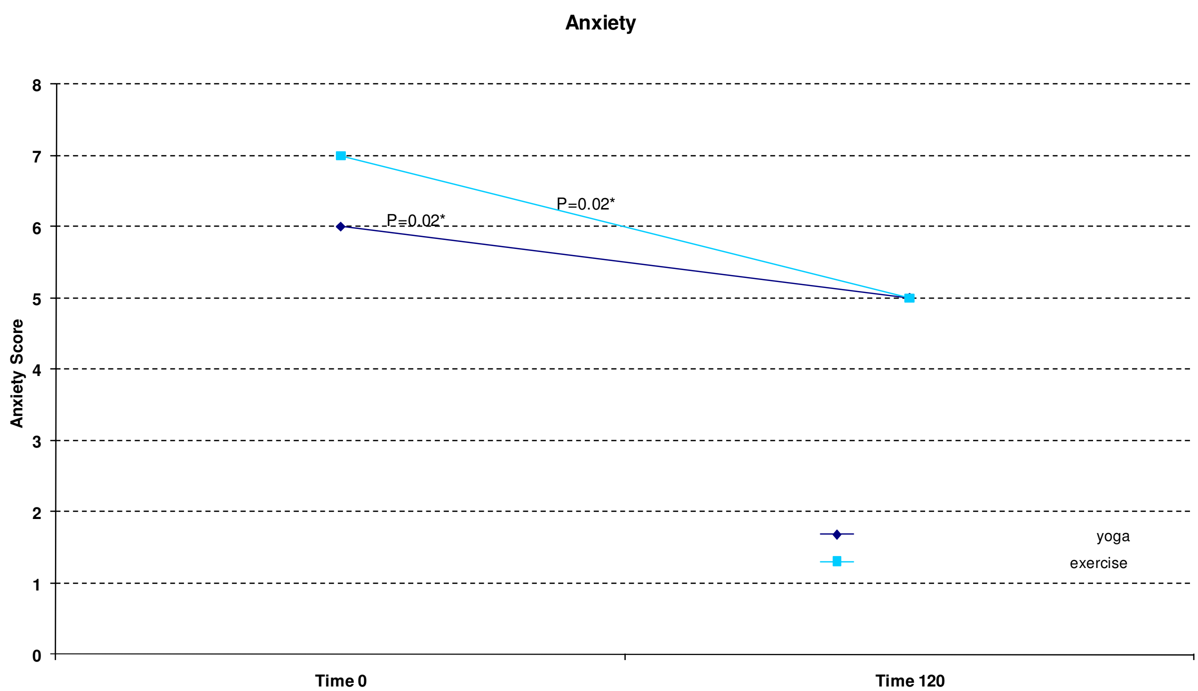
1.d.


Vitality
Vitality
100
90
80
70
60
50
40
30
20
10
0
P=0.006**
P=0.58
yoga
exercise
Time 0
Time 120

1.e.


Mental Health
100
90
80
70
60
50
40
30
20
10
0
Mental Health
P=0.09
P=0.008**
yoga
exercise
Time 0
Time 120

1.f.


Anxiety
8
7
6
5
4
3
2
1
0
Anxiety Score
P=0.02*
P=0.02*
yoga
exercise
Time 0
Time 120

Baseline data on the yoga and exercise groups revealed that, at time 0, the 2 groups were comparable in most parameters (anxiety, depressive mood, standard psychological scale, standard physical scale, mental health, emotional functioning, social functioning, physical pain, physical functioning, and physical functioning capacity, fasting blood glucose, post-prandial blood glucose, cholesterol, triglycerides) except sex, body-mass index, salivary cortisol, fasting insulin, general health and vitality.

An **effect over time** was highly significant for *salivary cortisol* and *fasting insulin* in the yoga group -- both values decreased. In the exercise group, *salivary cortisol* values demonstrated no significant change from time 0 to time 120 although there was a highly significant decrease from time 0 to time 60 and then a significant increase from time 60 to time 120. *Fasting insulin* values actually increased significantly in the exercise group, from time 60 to 120 and overall, from time 0 to time 120. The difference between the 2 groups in insulin levels from time 0 and time 120 was significant ($p=<0.001$ ANCOVA) even after adjusting for baseline differences.

The baseline insulin resistance on HOMA (homeostasis model assessment) calculation by the Matthews method was 5.8 ± 4.4 for the yoga group and 3.7 ± 4.9 for the exercise group, confirming the presence of insulin resistance (HOMA>3.16 = IR). After 4 months, the HOMA was 2.9 ± 2.5 in the yoga group ($p<0.05$, ANCOVA) and 8.7 ± 6.2 ($p=0.02$, ANCOVA) in the exercise group.

In the yoga group, the *fasting and post-prandial blood glucose* values, as well as *glycated hemoglobin* values, largely stayed the same from time 0 to time 120, with no significant change. These blood values did, however, fluctuate significantly for the yoga group -- for fasting and post-prandial blood glucose, there was a significant increase from time 0 to time 60 ($p=0.01$ and 0.02 respectively). For glycated hemoglobin, this was the case from time 60 to time 120 (p=0.00). However, no significant change from time point 0 to 120 could be seen for any of the 3 parameters.

In the exercise group, the *fasting and post-prandial blood glucose* values, as well as the *glycated hemoglobin* values, also largely remained stable. A slight increase was seen overall which did not reach statistical significance. Only the glycated hemoglobin value from time point 60 to 120 increased significantly but overall, from time 0 to 120, the increase was not significant.

A significant improvement from time 0 to time 120 was seen in the yoga group for the variables *anxiety, depressive mood, standard psychological scale, standard physical scale, social functioning, bodily pain, physical functioning,* and *role-physical*. Significant improvements were seen in the exercise group in the variables *standard psychological scale, standard physical scale, general health, vitality, social functioning, mental health, physical functioning, anxiety* and *anxiety positive*.

A **significant difference** in the **progression of variables between the 2 groups** could be seen in: *fasting insulin, salivary cortisol, general health, vitality, mental health* and *anxiety positive*. Of these, only in the variables mental health and anxiety positive were the yoga and exercise groups comparable at time 0. Both groups' mental health and general health values increased although the exercise group's increase reached statistical significance while the yoga group's did not. Both groups' anxiety positive values decreased and here also, the exercise group's increase reached statistical significance while the yoga group's did not.

The *vitality* values remained stable over time for the yoga group and increased for the exercise group.

The difference between the yoga group’s fasting insulin value drop and the exercise group’s insulin increase was highly significant, and remained so after adjusting for baseline differences. A significant difference between the 2 groups could also be found in the overall decrease in cortisol values in both the yoga and the exercise groups, although the statistical significance was lost after adjusting for baseline differences. The individual cortisol value drop reached statistical significance in the yoga group while the exercise group's did not..

DISCUSSION

Taken together, the above data indicate that yoga is at least as beneficial and potentially more beneficial than cardiovascular exercise in regulating hormone levels in diabetic patients. The data also indicate that yoga as well as cardiovascular exercise is beneficial for diabetic patients for most of the psychological parameters tested in the SF-36 and HADS questionnaires, with the exercise group benefitting from a comparatively stronger effect.

In the following discourse, each of the major parameters is discussed in detail for both the yoga and exercise groups.

CORTISOL

Yoga group

A highly significant decrease over time (time 0 to time 120), as well as between all progressive time points, to the lower end of the norm range, was seen in salivary cortisol for the yoga group. This value decreased overall in both the yoga and exercise groups from the beginning to the end of the study but only the yoga group showed a p value below 0.05. This cortisol level decrease in the yoga group remained significant after adjusting for BMI and sex.

A significant difference in this general decrease of salivary cortisol values between the 2 groups was also noted. The exercise group's salivary cortisol levels evinced an interesting pattern: they decreased highly significantly ($p=0.00$) between time 0 and 60, and then increased significantly ($p=0.018$) between time 60 and 120. Yet the overall decrease in the exercise group from time 0 and time 120 was not significant ($p=0.28$) at all. In the yoga group, on the other hand, the cortisol levels decreased steadily between 0 to 60 and 60 to 120, reaching statistical significance between time 60 and time 120 ($p=0.002$) and in the overall decrease as well from time 0 to time 120 ($p=0.003$).

Cortisol was measured in both groups in the early morning hours, when the cortisol level is known to increase in the blood stream (Wilhelm et al. 2007, Aardal and Holm 1995). The reference values for salivary cortisol in the morning hours range between 1.3-19 µg/l (Aardal and Holm 1995, Trilck et al. 2005). Neither the yoga nor the exercise group's cortisol values exceeded the maximum value of the reference range.

Cortisol secretion increases with repeated exposure to stressors, or at least, when an event is perceived to be stressful (Rosmond and Björntorp 1998, Schulz et al. 1998, Evans and Streptoe 2001, Goldman et al. 2005). The body's reaction to stress and relaxation fall at opposite extremes on the continuum of nervous system activity, that is, the sympathetic and parasympathetic reactions. Stress hormones increase heart rate, blood pressure, blood glucose levels, among its several other effects. Relaxation spurns on parasympathetic activity, thereby reducing heart rate and blood pressure and increasing blood flow. In our yoga patients, the cortisol levels in the saliva decreased possibly due to a relative decrease in sympathetic activity, mediated through yoga's relaxation effect.

Indeed, one of the main effects attributed to yoga is the relaxation effect (Singh et al. 2004, Damodaran et al. 2002). Udupa et al. undertook a measurement of excitability, aggressiveness, openness and emotionality in yoga practitioners before and after doing yoga postures (Udupa et al. 1975). Their findings show lower scores on average after yoga practice, perhaps indicating a deeper level of relaxation. Damodaran et al. studied hypertensive patients—many of whom were diabetic patients as well—on yoga therapy. They measured pulse rate, respiratory rate, blood pressure, catecholamine excretion (urinary vanillylmandelic acid) and cholinesterase values. The yoga patients evinced a shift to a relative parasympathetic dominance from an earlier sympathetic dominance: their heart and respiratory rate were lower, the urinary excretion of catecholamines was lower, and their cholinesterase values were higher (Damodaran et al. 2002). A decreased sympathetic tone compared to baseline levels following yoga-guided relaxation was confirmed by Vempati and Telles (Vempati and Telles 2002). They assessed various autonomic variables, including oxygen consumption, breath volume, heart rate, skin conductance, and heart rate variability. These variables were lower following yoga-guided relaxation. Subjects with a higher level of baseline sympathetic tone showed a significant decrease in the low frequency component of the heart rate variability spectrum, indicating a reduction in sympathetic activity.

Sympathetic activity induces hormonal secretions related to the 'fight or flight' response which also involves a state of insulin resistance in liver and skeletal muscles (Tsatsoulis and Fountoulakis 2006). This response was probably necessary for survival in ancient times; however, in today's industrialized societies, the threat of physical aggression from other creatures has disappeared but the body's protective response to stress has remained the same-- even though the nature of the stress is more likely to be emotional or social rather than physical. The excess energy and insulin in the bloodstream is not used up for a 'fight or flight' response and lingers on to be stored by visceral fat depots. Yoga probably enters this cycle at the level of the emotional or social stress: by reducing the psychosocial stress felt by the mind and body, it hinders the mobilization of energy and the subsequent state of insulin resistance. Our yoga group’s cortisol levels were brought down to the lower end of the norm range—if the body’s basal cortisol is low, it may be protected against the stress reaction leading to hypercortisolemia.

A further explanation for the reduction of cortisol levels in our yoga patients lies in the hypothalamus-pituitary-adrenal (HPA) axis. The HPA axis is known to become hypersensitive in depressed patients and can cause increased cortisol secretion (Rosmond et al. 1996, Young et al. 2001). A central HPA axis overdrive in severe depression has been confirmed by several studies (Young et al. 2001, Carroll et al. 2007). Hypercortisolemia caused by increased adreno-corticotropic hormone (ACTH) adds to the increased baseline component of cortisol secretion (Young et al. 2001). Carroll et al. echoed this hypothesis by concluding in their study of 12 depressed patients and 17 healthy volunteers that although depressed patients exhibit elevated ACTH levels, their hypercortisolemia is strongly compounded by an ACTH-independent, disorderly basal cortisol release which they attribute to physiological stress (Carroll et al. 2007). Hence, it appears as if feelings of depression are influenced by both mental stress and high ACTH levels. Further studies are necessary to study whether yoga influences ACTH levels directly via central mechanisms and thus contributes to lower cortisol levels. This would be particularly interesting given the HPA axis' possible key role in insulin resistance (Pasquali et al. 2006).

Interestingly, insulin resistance and subsequent glucose intolerance caused by hypercortisolemia could already be detected upon dexamethasone induction in normoglycemic relatives of type II diabetes patients (Henriksen et al. 1997). This implies that blood glucose levels are very sensitive to glucocorticoids even in non-diabetic relatives of type II diabetic patients. This hypothesis was echoed in Panthakalam's more recent study on the prevalence of hyperglycemia in rheumatoid arthritis patients on steroid therapy (Panthakalam et al. 2004). Nine out of over 100 patients developed frank diabetes mellitus during steroid treatment. As their study was a retrospective one and no fasting blood glucose nor glucose tolerance tests had been done, one can only guess at the number of patients who developed impaired glucose tolerance on steroid therapy.

The above research results serve to underline the fact that high levels of glucocorticoids, whether endogenously increased due to stress, or exogenously induced by steroid therapy, can pre-dispose to glucose intolerance and type II diabetes mellitus. If yoga can help bring down glucocorticoid levels by reducing perceived stress and increasing physical relaxation, it can possibly be used as a preventive measure early on for those who are at risk for developing impaired glucose tolerance.

Exercise group

The highly significant decrease in cortisol values in the exercise group between time 0 and time 60 (p=0.00) with an overall insignificant decrease from time 0 to 120 (p=0.28) suggests that cardiovascular exercise may have a short-term lowering effect on cortisol, but is not able to maintain the low cortisol value in the long-term. The exercise group's cortisol values also display a high level of vacillation with a significant increase from time 60 to 120 ($p=0.02$). Yoga, then, may have a more lasting and more stable relaxation effect, probably due to the above-mentioned decrease in sympathetic tone. The data also implies that exercise's effect on cortisol may take time to show and that a longer study time frame may have been necessary to better assess its effects.

Reduced cortisol levels following exercise has been found by other researchers as well, although overall, the data is contradictory. Starkweather's recent study on the effect of physical activity intervention on various parameters related to immune system function among 10 adults aged 60-90 demonstrated a decrease in cortisol levels across the board over a 10-week period (Starkweather 2007). However, the overall decrease was insignificant, reflecting our study's results. Vega et al.'s study on the cortisol response to varying intensity exercises demonstrated an augmentation of plasma cortisol immediately following exercise to exhaustion (Vega et al. 2006). However, short-term and prolonged moderate exercise did not immediately alter cortisol concentrations. Although Vega and colleagues recorded post-exercise cortisol and not basal cortisol as in our study, their results follow our trend.

Corral et al. studied 10 pre-pubertal male children's serum and salivary cortisol levels. They found a significant increase in cortisol levels 30 minutes after submaximal exercise at 70% of maximal oxygen uptake (Corral 1994). These findings reflect Vega et al.'s results following exercise to exhaustion. Hence, exercise intensity and time of measurement in relation to time of exercise are relevant when considering corresponding cortisol values. Our exercise group practiced moderate-level exercise and their salivary cortisol was measured long after or before exercising. A decreasing trend in cortisol measured under these conditions would insinuate reduced basal cortisol secretion.

Bosco et al.'s investigation of well-trained male sprinters evinced significantly lower cortisol levels immediately following exercise (Bosco et al. 2000). They do not mention basal cortisol levels. Their results differ from the above-mentioned studies but this may be due to the excellent physical condition of Bosco et al.'s study group. Krzeminski et al.'s study group found no change in serum cortisol immediately before and after exercise to exhaustion (Krzeminski et al. 2003), as did Sotsky et al. (Sotsky et al. 1989). The varying results of these investigations highlight the need for further research into hormonal responses to cortisol, both basal and post-exercise.

A further possible explanation for the differing cortisol results in the exercise group as compared with the yoga group could be the anaerobic threshold at which each group was practicing their respective physical activities. Kindermann et al. suggest that elevated cortisol levels are seen in adults when the exercise intensity corresponds with their personal aerobic threshold level (Kindermann et al. 1982). Other studies suggest that after a certain threshold value for maximal oxygen uptake (60%) during exercise, cortisol levels increase (Davies 1973). Kindermann et al's study subjects found that aerobic exercise at an intensity of 75% of maximal oxygen uptake elicits a stronger cortisol response (Kindermann et al. 1982). Whether anaerobic threshold or maximal oxygen uptake, these numbers vary according to the individual thus offering a possible explanation to the above studies' differing results.

INSULIN, GLUCOSE, AND HEMOGLOBIN

Yoga group

The fasting insulin values in the yoga group decreased significantly from time 0 to time 120 ($p=0.000$) as well as between all progressive time points, but stayed well within the reference range (3-27 µIU/ml); in the exercise group, the insulin level increased slightly without reaching statistical significance overall from time 0 to time 120. The exercise group's insulin values at time 120 were at the higher end of the reference range. Since insulin and blood sugar values are closely linked, it is necessary to take a closer look at the fasting and post-prandial glucose values as well as the blood levels for glycated hemoglobin.

In the yoga group, the fasting and post-prandial blood glucose values largely stayed the same, with no significant change overall from time 0 to time 120. However, the values were unstable at the beginning, increasing significantly from time 0 to time 60, before decreasing again (without reaching statistical significance) from time 60 to 120. The glycated hemoglobin value slightly decreased overall from time 0 to time 120, although insignificantly. Some instability in the glycated hemoglobin values can be seen as well, with a highly significant increase between time 60 to 120 without affecting the overall glycated hemoglobin level decrease. The data here implies that yoga may take time to show any effect on glucose and glycated hemoglobin levels and that a longer study time frame may have been necessary to better assess its effects.

In the exercise group, the fasting and post-prandial blood glucose values also largely remained steady. The glycated hemoglobin value slightly increased, albeit insignificantly. Here again, instability in the glycated hemoglobin values can be seen, with a highly significant increase between time 60 to 120 without affecting the overall glycated hemoglobin level decrease. A longer study duration may have been necessary to analyze the effect of cardiovascular exercise on glucose levels in the long run.

In summary, both the exercise and yoga group did not differ in their fasting blood glucose and post-prandial blood glucose levels overall; however, the yoga group's corresponding insulin levels were significantly lower, even when adjusted for BMI and sex. The HOMA calculation for insulin resistance confirmed reduced insulin resistance in the yoga group following the yoga intervention.

Insulin resistance leads to higher plasma insulin levels, given the corresponding blood glucose concentration. It can be extrapolated that the significant decrease in fasting insulin values in the yoga group as well as a slight decrease in the glycated hemoglobin value, combined with a largely steady fasting and post-prandial glucose levels in the same group, is perhaps a sign of a more efficient insulin response at the tissue level. Basically, this suggests that less insulin is possibly needed or being metabolized by the body to maintain the same level of blood glucose and glycated hemoglobin in the yoga subjects. However, the significant increase in fasting and post-prandial blood glucose levels within the first 60 days of this study may imply that the body needs some time initially to adjust to a considerable drop in insulin before finding its insulin-glucose balance.

Only one study to date has examined insulin sensitivity in yoga practitioners -- Chaya et al. undertook a study with 30 young, healthy male subjects (Chaya et al. 2008). Exactly half of them had been regular yoga practitioners for at least 1 year, the other half were matched controls. A hyperinsulinaemic-euglycaemic clamp test on all study subjects revealed a significantly lower fasting plasma insulin in the yoga subjects; in addition, they were significantly more insulin sensitive, even after adjusting for age. This trial backs up our study findings and supports the hypothesis that yoga practice can lead to decreased insulin resistance.

Our relatively steady blood glucose results were different to the majority of other studies' findings; most of them, in fact, had discerned a decrease in fasting and post-prandial glucose values following yoga practice. Damodaran et al.'s study, for example, focused on 20 hypertensive subjects whose blood glucose values decreased following 3 months of yoga practice (Damodaran et al. 2002). However, their study was not exclusively on diabetic subjects and the research team measured random blood sugar values. It is possible that random blood glucose values show a trend to decrease after yoga, contrary to fasting or post-prandial blood sugar. Post-prandial blood glucose is, however, a more specific indicator for those that are at risk for type 2 diabetes mellitus and hence, is more accurate for appraising glucose tolerance. The increase in post-prandial blood glucose levels in diabetics appears to be due to the impaired first-phase insulin release specific to patients who already show pathological glucose tolerance values or already have manifest diabetes mellitus (Sudhir and Mohan 2002).

However, further investigations have demonstrated post-yoga decreases in fasting and post-prandial blood glucose. Singh et al.'s study of 24 type 2 diabetic patients over a period of 40 days (Singh et al. 2004) also showed a statistically significant improvement in fasting and post-prandial blood glucose levels, contrary to the findings from our study. In our study, the first measurement was taken after 60 days of yoga and showed a slight increase in fasting and post-prandial glucose levels; however, there was no statistically significant overall change in either fasting or post-prandial blood glucose levels from time 0 to time 120. It is possible that the blood glucose levels fluctuate initially and then level off afterwards as the body adjusts to new yoga postures. Perhaps Singh's blood glucose testing after 40 days was too soon or he happened to conduct his measurements in the fluctuating falling phase in blood sugar levels. Further research is necessary to more accurately comprehend the details of the interaction between glucose levels and yoga activity.

Lane et al. conducted a study in 1993 comparing 2 diabetic groups with 16 subjects each (Lane et al. 1993). One group received intensive standardized diabetes education and clinical management; the other group received biofeedback-assisted relaxation training in addition to intensive therapy. Patients were followed up for 48 weeks to assess long-term effects. Their metabolic parameters included fasting blood glucose, post-prandial blood glucose, glycated hemoglobin, glucose tolerance (measured by conducting an oral glucose tolerance test), 24-hour excretion of glucose, catecholamines and cortisol. Lane et al. also measured psychometric variables such as anxiety, emotional lability and locus of control. Neither treatment was associated with average improvements in glucose tolerance. However, both groups showed average improvements in glycated haemoglobin, suggesting average improvements in blood glucose levels as well. Lane et al. do not mention specific results on fasting and post-prandial blood glucose levels for their study. Their conclusion was that both the relaxation and control groups improved in their glucose metabolism, but not in their glucose tolerance, and did not differ significantly in their improvements from each other.

It is difficult to compare Lane et al.'s study subjects to ours. It may be possible to compare their intensive standardized therapy group to our exercise group but their intervention group received both intensive standardized diabetes education and clinical management and relaxation therapy. Hence their positive results regarding average blood sugar levels could probably be attributed to the very effective intensive standardized therapy; the incremental effect of relaxation training only is difficult to judge. Nevertheless, since both groups evinced average improvements in their blood glucose level, it would seem that the incremental effect of biofeedback-assisted relaxation training is negligible.

One study, by Cohen et al., followed a small group of 26 metabolic syndrome patients over 10 weeks (Cohen et al. 2008). They founds a slight increase in fasting blood glucose levels and trends to improvement in post-prandial blood glucose, cholesterol, and triglycerides, without reaching statistical significance on any of their metabolic parameters. It is interesting to note the fasting blood sugar increase in a study which lasted about 2.5 months -- roughly the same period within which our yoga group's blood glucose values increased, before decreasing again after 2 months and level off to approximately the starting point value.

The above findings from the various studies regarding fasting and post-prandial blood glucose, and glycated haemoglobin, exposes the fact that more thorough randomized, controlled, long-term trials are needed to adequately study yoga's effect of blood glucose levels.

Insulin and glucose levels are not only dependent on each other but also on cortisol levels. Hornnes' studies reveal enhanced concentrations of total plasma cortisol, fasting insulin and fasting blood glucose in pregnant women (Hornnes 1985 b). A further longitudinal study conducted by him evinced a significant positive correlation between the decrease in glucose tolerance in pregnant women and a notable increase in their cortisol levels (Hornnes et al. 1984). Although Hornnes' trials were all on pregnant women, he sheds light on the physiological interaction between insulin, glucose, and cortisol. He concludes that glucocorticoids probably interfere with insulin receptors and thus induce an inhibition of insulin action, leading to an impaired glucose uptake in peripheral cells.

Pasquali et al.'s review of the role of glucocorticoids in obesity and the metabolic syndrome clearly elucidates the emerging body of evidence supporting this causal association between functional hypercortisolism and the metabolic syndrome, including insulin resistance (Pasquali et al. 2006). They hypothesize that insulin resistance could underlie the association between all other features of the metabolic syndrome. Increased hypothalamo-pituitary-adrenal axis activity may thus be a decisive factor in the pathogenesis of impaired insulin resistance.

The above conclusions on the relationship between cortisol, glucose, and insulin suggest that the significantly lower cortisol levels measured in our yoga group might be at least partly responsible for the yoga group patients needing less insulin for maintaining approximately the same level of blood glucose compared to before beginning yoga practice. It could thus be an indication of lowered insulin resistance. Through significantly lower cortisol levels, the yoga subjects were perhaps able to reduce cortisol's interference with insulin receptors; this supports the assumption that the yoga group's low insulin levels were sufficient to keep up the same levels of blood glucose as the exercise group. The exercise group, however, needed higher insulin levels to achieve similar blood glucose levels.

The interaction between cortisol, insulin and glucose tolerance is further supported by Stubbs et al.'s analysis of 148 patients with myocardial infarction: their results demonstrated plasma cortisol and insulin levels to be both significantly positively correlated with glucose concentration (Stubbs et al. 1999). This suggests that, in patients with impaired glucose tolerance—as in patients with myocardial infarct or diabetic patients—high insulin levels are correlated with high glucose levels due to insulin resistance. Our yoga patients had lower insulin levels with the same glucose levels they had prior to yoga practice, insinuating improved insulin usage at the peripheral level in these subjects.

Yoga thus may to lead to decreased insulin resistance by decreasing the effects of chronic stress exposure; this would support the assumption that high perceived stress levels and poor coping mechanisms to stress are mediated by a dysregulation of the HPA axis and the sympathetic nervous system. Neuroendocrine dysregulation might, then, prove to be a decisive factor in the pathogenesis and maintenance of insulin resistance and the metabolic syndrome. The fact that insulin resistance at cellular level (in vitro) and on the whole body level (in vivo) can be reversed renders support to this hypothesis (Buren and Eriksson 2005).

Exercise group

The exercise group's fasting and post-prandial blood glucose levels basically stayed stable over the 4-month study period. The HbA1c level increased slightly overall, albeit non-significantly. A significant increase in the glycated hemoglobin level between time 60 and 120 did not lead to an overall increase which reached statistical significance.

The lack of significant improvement in glycemic control in our study's patients compared to other studies can possibly be attributed to the short study period. Most other exercise and lifestyle intervention studies on diabetics followed up on the patients for several months to years. Eriksson et al.'s study, for example, observed an impaired glucose tolerance group vs. a reference group; they were able to demonstrate lower 2-h insulin and glucose concentrations in the former group over the 5-year follow-up (Eriksson and Lindgärde 1991). In their first study year, the Diabetes Prevention Program Research Group found reductions in mean fasting glucose and glycated hemoglobin values in their lifestyle intervention group, whereas the values rose in their placebo group. They also found that, after an average follow-up period of almost 3 years, lifestyle intervention was as effective as other groups in restoring normal fasting glucose values and more effective than the other groups in restoring normal post-load glucose values (Knowler et al. 2002).

LIPID PROFILE

Yoga group

The lipid profiles in both the yoga and the exercise groups improved but failed to reach statistical signifcance. Bijlani et al.'s 2005 analysis had similar results, although their patient base was a heterogeneous one consisting of patients with hypertension, coronary artery disease, diabetes mellitus and a variety of other illnesses, and their improvement in various lipid values reached statistical significance (Bijlani et al. 2005). Bijlani et al's brief 10-day study demonstrated significantly lower values in the variables total cholesterol, LDL, VLDL, total cholesterol:HDL ratio and triglycerides in their subjects practicing yoga. Bijlani's patients were subjected to an intensive lifestyle-modification program for prevention and management of chronic disease in addition to yoga training; this supplementary in-depth counselling may have contributed to the more significant improvement in lipid profiles. Furthermore, many patients who would have been excluded from our study were included in theirs; many of Bijlani et al.'s subjects may have been in a worse or more complicated metabolic state with much more room for more marked improvement compared to our study group's patient base.

Cohen et al.'s trial of 14 yoga group patients with metabolic syndrome also saw a trend in improvement of cholesterol and triglyceride levels, without reaching statistical significance (Cohen et al. 2008). They also measured low-density lipoprotein (LDL) and high-density lipoprotein (HDL) in addition to total cholesterol and triglycerides and all of the lipid values decreased over the 2.5-month study period. In the control group of healthy subjects receiving no intervention but wait-listed for a yoga course, lipid levels actually rose, although also not reaching statistical significance. Cohen et al.'s study duration was fairly short but without in-depth counseling as in Bilani's study.

Damodaran et al.'s study on 20 hypertensive patients also demonstrated an improved serum lipid profile after a time span of 3 months (Damodaran et al. 2002). However, they do not mention any significance values and there was no control group to the study design. Nevertheless, his results confirm the trend in improvement in cholesterol and triglyceride values in subjects practicing regular yoga.

Both the yoga and exercise group's trend to decrease in triglyceride levels after 4 months is compelling since evidence from the past few years indicates that triglycerides may be an independent and critical risk factor for coronary heart disease. The Prospective Cardiovascular Munster (PROCAM) study analyzed data from 4849 middle-aged men who were followed up for 8 years to record the incidence of coronary heart disease events according to known risk factors (Assmann et al. 1998). Their study showed that fasting levels of triglycerides were an independent risk factor for CHD events, irrespective of cholesterol levels. Another independent predictor of CHD is diabetes mellitus (Assmann et al. 1998). Other more recent studies have also been able to confirm the independent predictive value of triglyceride on CHD mortality in different populations (Mazza et al. 2005, Tseng et al. 2006, Iso et al. 2005, Fontbonne et al. 1989). Hence, altogether, yoga may be as beneficial as a complementary therapy as exercise for those generally at high risk for coronary events, especially diabetic patients with high triglyceride levels. Further research is necessary here to confirm and explore these results in more depth.

Jayasinghe, in his meta-analysis of yoga therapy for cardiac patients, hypothesizes that the mechanism of yoga's lipid-lowering effect might be similar to that of statin drugs. Since statin activity is linked to increased nitric oxide concentrations in the vascular endothelium, endothelium-dependent relaxation is enhanced. It has been demonstrated that yoga decreases sympathetic activity and enhances relaxation; it may do so via nitric oxide. Hence, neurohormonal mechanisms may mediate the change in internal endothelial cell milieus in yoga-practicing subjects (Jayasinghe 2004). Confirmation of this requires further physiological research.

Yoga's beneficial effect on the lipid profile in coronary risk subjects without manifest diabetes mellitus has been documented by several studies. Mahajan et al. conducted a 3 ½ month randomized, controlled trial on 93 male subjects who had either documented angina pectoris or evinced risk factors for coronary artery disease (Mahajan et al. 1999). None of their subjects received lipid-lowering drugs. The patients were randomly assigned to either a yoga group or a control group. The control group was managed with conventional therapy with diet control and moderate aerobic exercise. The two groups' physical activity level and medical management of patients were very similar to our study. Mahajan et al. found consistent significant decreases in LDL, cholesterol, and triglycerides in the yoga group. The exercise group's changes were inconsistent and insignificant in all lipid values including triglycerides. The significant decrease in the triglyceride value in only the yoga group and not in the control group corresponds with results from our study. Our yoga groups' lipid profile improved as well, although without significance. This may be explained by the difference in patient base: ours had diabetes mellitus which, with its complications and associated metabolic syndrome, is a major risk factor for coronary artery disease; however, their predominant medical problem was not CAD. Mahajan et al.'s patient base had mainly angina pectoris and manifest coronary artery disease. In their group of patients without angina but with a large number of risk factors for CAD, there is no mention of diabetes mellitus as one of those risk factors. The lack in significance in our yoga group LDL and cholesterol reduction may also be due to the difference in yoga postures practiced. Mahajan's team trained their yoga patients in tadasana and pachimottanasana which our subjects did not do. In addition, Mahajan et al.'s patients were taught pranayama techniques (special breathing exercises). Little research has been done on the therapeutic differences between the different yoga postures and pranayama techniques; this may be the next level of yoga research in the future.

Manchanda et al.'s prospective, randomized, controlled trial with 42 men with CAD over one year further support Mahajan et al.'s results (Manchanda et al. 2000). Manchanda's study subjects did not take any lipid-lowering agents. The subjects were randomly divided into a yoga group and a control group. Here, the yoga group also demonstrated significant reduction in lipid profile in addition to a reduction in the number of anginal episodes per week, less frequent revascularization procedures, and significantly more regressed lesions upon coronary angiography.

Exercise group

Our exercise group's triglyceride values decreased over time although they did not reach the level of significance. Other studies also demonstrate lipid profile improvement by exercise training (Kraus et al. 2002, Horber et al. 1996, Lazarevic et al. 2006). Individuals who undertake regular exercise also demonstrate lower levels of triglycerides, VLDL, LDL, and higher levels of HDL, especially in comparison to those with a sedentary lifestyle. High cholesterol and LDL levels can be lowered with exercise training; the higher the level of exercise, the greater the effect on lipid measures (Kraus et al. 2002). Kraus et al. investigated the effects of exercise training not only on the standard lipid profile but also on the concentrations of LDL particles, small LDL particles, large HDL particles, and large very-low-density-lipoprotein (VLDL) particles. They were able to demonstrate marked improvements in these parameters as well, which are not routinely tested for in the standard lipid panel. Halverstadt et al. also investigated plasma lipoprotein subfractions in addition to the conventionally measured plasma lipoprotein lipid levels, in middle- to older-aged subjects (Halverstadt et al. 2007). They were able to show an independent beneficial effect of exercise training on improvements in the standard lipid profile as well as the size and concentrations of lipoprotein subfractions. These improvements can probably be attributed to increased fatty acid uptake by muscle tissue with increased contractile usage of the muscle (Achten and Jeukendrup 2004). Adipose tissue is also redistributed with regular physical exercise, thus preventing the changes in body composition normally associated with ageing (Horber et al. 1996).

Graham's meta-analysis (Graham 2004) on the effect of various forms of exercise on triglyceride levels also demonstrates an exercise-related reduction in triglyceride levels. In fact, he concludes that even light and/or intermittent exercise has a positive effect, albeit without mention of significance values. Lazarevic et al conducted a study on the effect of exercise on 30 diabetic males vs. a control group of non-diabetic healthy subjects (Lazarevic et al. 2006). Both groups underwent the exercise intervention. They were able to demonstrate a significant between-group improvement in triglyceride levels over a period of 6 months. Several other studies on diabetes patients, combining rigorous and high-volume exercise with or without a strict diet have been able to show greater decreases in triglyceride levels (Walker et al. 1999, Kraus et al. 2002).

Perhaps our exercise group lipid panel results did not reach the level of significance due to the shorter duration of our study (4 months); most of the above-mentioned studies had longer study durations. In addition, our exercise group also practiced more moderate cardiovascular exercises and/or brisk walking -- perhaps the nature of the different types of exercises in the various studies make them difficult to compare directly with our study. Several of the above-mentioned studies included directly observed exercise in a gymnasium setting; the fact that patients are supervised can have a substantial effect on the quality and effort behind study subject's exercise levels.

The trend in lipid profile improvement, however, can be seen throughout all the various studies, which is consistent with the steady improvement in our exercise group subjects' lipid levels.

PSYCHOLOGICAL PARAMETERS

Yoga group

Both the yoga and exercise groups showed significant improvements in most of the psychological parameters tested by the SF-36 questionnaire and the Hospital Anxiety and Depression Scale (HADS). Both groups evinced significant improvements in the overall composite scores 'standard physical scale' and 'standard psychological scale'. In most of the other SF-36 parameters, the exercise groups' improvement was more marked than the yoga group's -- the exercise group's SF-36 values often began lower than the yoga group's but ended at the same level of improvement.

The yoga group saw significant improvement in bodily pain, social functioning, physical functioning, and role physical from the SF-36 questionnaire and the HADS variables depressive mood and anxiety. An improvement was clearly noted in the SF-36 variables general health and mental health although the p-values were above the level of significance.

Past studies reflect our results (Damodaran et al. 2002, Malathi et al. 2000, Harinath et al. 2004). Damodaran et al.'s analysis showed that the psychological profile on their 20 hypertensive study subjects improved following yoga, with increased mean positive scores and decreased mean negative scores. Damodaran et al. used a non-standardized personal orientation inventory and a subjective well-being questionnaire. Their results from personal orientation inventory data demonstrated a significant chance in variables such as time competence, inner directedness, self-regard, self-acceptance, synergy and intimate contact, implying harmony within the individual psyche. Although Damodaran et al.'s questionnaires were not standardized or the same as the ones we used, his positive results for psychologically-based variables support our findings (Damodaran et al. 2002).

Harinath et al. found that his study subjects' psychological parameters (measured by the Minnesota Multiphasic Personality Inventory) evinced no significant change in both the yoga and control groups. However, just the well-being inventory score showed a significant increase in the yoga group. It is important to note here that the subjects selected for their study were all very healthy, young army soldiers with no endocrine or metabolic disease whatsoever (Harinath et al. 2004). Cohen et al.'s 2.5-month study on subjects with metabolic syndrome showed a clear trend in improvement of SF-36 well-being scores but did not reach statistical significance (Cohen et al. 2008).

Sharma et al. studied 77 patients with various chronic diseases, diabetes included, who were given a yoga-based lifestyle intervention program for a short period of 10 days (Sharma et al.

2008). They observed significant improvements in the intervention group in 'subective well-being inventory' (SUBI) scores; a matched-control group, however, showed no significant change during the same time period. A sub-analyses of diabetic patients showed considerable well-being score improvement but did not reach statistical significance as did a sub-analysis of patients with cardiac disease.

Mindfulness-based stress reduction (MBSR) which is principally based on yoga techniques such as breathing awareness, meditation, and yoga postures has been shown to decrease the average number of visits to the primary care physician among middle-class populations in inner city areas across the United States. Reported changes in patients who have completed an MBSR course include greater peace of mind, more patience, less anger, fewer temper outbursts, and a marked improvement in overall well-being (Roth and Stanley 2002).

Yoga's relaxation effect on the autonomous nervous system and the subsequent relative parasympathetic dominance probably play the central role in improving psychological well-being and anxiety levels. Being relaxed makes one feel good and less stressed. Harinath et al. studied the effects of yogic postures on the psyche (Harinath et al. 2004). Their subjects' well-being scores showed a significant correlation to the nightly rise in melatonin. Thus, the relaxation effect through yoga appears to be mediated through an interaction between the autonomic nervous system and endocrine system, wherein pineal secretion of melatonin may take on a crucial role.

Alterations in autonomic balance were documented after yoga practice by Joseph et al. over 30 years ago (Joseph et al. 1981). They carried out their study on 20 healthy subjects who were soldiers in the Indian Army, for a period of 3 months. Their results demonstrated significant reductions in heart rate and blood pressure as well as in dopamine-ß-hydroxylase concentrations, a sign of elevated adrenomedullary hormone synthesis. An increase in the activity level of acetyl cholinesterase was also noted which, taken all together, further supports the hypothesis that yoga leads to a predominance of the parasympathetic nervous system which leads to the feeling of relaxation and well-being.

Chaya et al.'s recent study at the same residential yoga education and research center in Bangalore, India, where this research was conducted (sVYASA) showed a significantly reduced basal metabolic rate (BMR) in a group of long-term (6 months) yoga practitioners compared to non-yoga practitioners leading similar lifestyles (Chaya et al. 2006). This points to a probable reduced arousal rate in those who practice yoga, as the BMR is primarily regulated by the hypothalamus which controls the autonomic nervous system.

If yoga practice can dampen the sympathetic overdrive, it then mimics the mechanism of beta blockers (Jayasinghe 2004), thus facilitating protection against ischemic heart disease and myocardial infarction, all strongly associated with the insulin resistance syndrome.

Yadav et al. propose that this sense of relaxation and well-being following yoga practice can reduce oxidative stress (Yadav et al. 2005). They hypothesize that psychological stress increases oxidative stress whereas relaxation decreases it. In 104 subjects who underwent a 10-day yoga lifestyle intervention program, Yadav et al. measured thiobarbituric acid reactive substance (TBARS), a measure of lipid peroxidation, which is an indicator of oxidative stress. Their results showed significant lowering of TBARS levels before and after the yoga lifestyle intervention, suggesting that yoga can reduce oxidative stress.

Positive feelings of well-being and reduction of psychosocial stress can have a significant impact on risk factors for type II diabetes mellitus and the insulin resistance syndrome. For example, recent publications demonstrate substantial evidence that psychosocial stress promotes intra-abdominal obesity (Dallman et al. 2004, Dallman et al. 2003, Drapeau et al. 2003, Björntorp 2001). Dallman elucidates the association between stress, increased hypothalamo-pituitary-adrenal axis activity, the resulting elevated cortisol concentrations, increased sweet, high-fat food intake and insulin resistance. Her research conclusions demonstrate that elevated stress leads to elevated glucocorticoid concentrations which then lead to overeating, particularly of ‘comfort foods’ with high fat and sugar content, and redistribution of stored calories into abdominal fat. Type 2 diabetic patients, who normally have high BMI, have higher circulating insulin concentrations; hence, the specific increase in intraabdominal fat stores in these patients can be seen as a consequence of both elevated insulin and elevated cortisol. Elevated glucocorticoids can be generated locally in omental fat, thus adding to the vicious cycle (Dallman et al. 2004, Nesto 2005). Reducing the level of glucocorticoids in the blood stream can perhaps assist in breaking this vicious cycle; one way of doing so is by relaxation exercises and yoga. One could then postulate that yoga can ultimately facilitate reduction of abdominal adipose tissue through its stress-reducing, relaxation effect, thereby abating a serious risk factor for type 2 diabetes mellitus and its accompanying complications.

Stress is closely linked to the activity of the hypothalamo-pituitary-adrenal (HPA) axis on the one hand and the sympathetic nervous system on the other hand. The central sympathetic nervous system, with its regulating centers in the brain stem, sends signals to several peripheral branches. The HPA axis is regulated from hypothalamic areas via corticotrophin releasing hormone (CRH), adrenocorticotropin (ACTH), and cortisol. Long-term severe hypercortisolemia, such as in Cushing's syndrome, is associated with activation of the central sympathetic nervous system. It is often activated in parallel to cortisol/HPA axis which demonstrates their strong functional coupling (Björntorp 2001).

Cortisol and adipose tissue evince another interesting interconnection: visceral adipose tissue seems to be particularly sensitive to cortisol's lipid-accumulating effects (Rosmond et al. 1996). This hints that with reduced weight and less visceral adipose tissue, cortisol levels may not be as high. Hence, cortisol and intra-abdominal obesity may influence each other in both ways.

Cortisol's tight association with obesity is further linked to two proteins: lipoprotein lipase, which regulates lipid accumulation in adipocytes, and leptin, which is secreted by adipocytes und evinces an inhibitory effect on appetite. Furthermore, as mentioned earlier, in the presence of insulin, cortisol inhibits lipid mobilization into the bloodstream. Clinical experience indicates that patients with elevated cortisol levels have voracious appetites; a large percentage of them become obese. Evidence suggests that glucocorticoids also diminish leptin sensitivity, thereby inducing overeating and obesity despite elevated leptin levels. Hence, obesity in general and visceral obesity in particular are causally associated with high cortisol levels, which is often due to chronic stress (Björntorp 2001).

Evolutionarily, it makes sense that chronic stress leads to elevated glucocorticoids and increased intake of sweet and fatty foods. High glucocorticoid levels achieve continued responsiveness to stress on the behavioral, autonomic, and neuroendocrine levels; Eating high fat, so-called 'comfort foods' improves the mood and allows a heightened sense of well-being and thereby, better functioning in day-to-day life (Dallman et al. 2003). Another theory that has been postulated is that fat accumulation in the deep abdominal area occurs so that the body can buffer the increased glucocorticoid level associated with stress. This suggests that visceral fat gain in response to stress might be a necessary physiological adaptation to enhance cortisol clearance and thereby the body's ability to deal with stress (Drapeau et al. 2003). Unfortunately, this vicious cycle ultimately leads to abdominal obesity, which has a causal relationship to type 2 diabetes mellitus, cardiovascular disease, and the metabolic syndrome. Yoga, by reducing perceived stress levels and allowing deep relaxation, can perhaps halt the chain of reactions leading to abdominal obesity and diabetes mellitus.

A recent study examined the physical activity level—including yoga—as well as diet, height, and weight of 15 550 adults, aged 53 to 57 years, during the preceding 10 years (Kristal et al. 2005). All measures were, however, based on self-reporting and past weight was retrospectively ascertained. Regular yoga practice was associated with attenuated weight gain, most strongly among individuals who were overweight. The odds of weight maintenance compared to weight gain increased modestly across categories of intensity of yoga practice in Kristal's study, and the trend reached statistical significance among those who were overweight at age 45. Although the number of yoga practitioners in this study was small and the data was retrospective, these results are consistent with the hypothesis that regular yoga practice can benefit individuals, such as diabetics, who are placed at higher risk for several illnesses by overweight, a high body-mass-index or a high waist-hip-ratio. The possible mechanism through which this phenomenon occurs may be through stress reductions and lower cortisol levels.

The reduction of visceral fat is a crucial aspect in type 2 diabetes mellitus prevention and treatment. If stress is a vital component in visceral weight gain, weight loss will not effectively occur in the same stressful environment. Hence, stress management and relaxation therapy in the form of yoga may complement treatment of diabetes and obesity as well as increase its effectiveness. Furthermore, deep relaxation and measures to cope with stress such as is found in yoga practice may increase the efficacy of prevention of such public health problems such as diabetes, obesity, and cardiovascular disease.

In our study, both the yoga and the exercise groups showed significant decreases in BMI. Their waist-hip-ratios showed insignificant minor changes. Both groups also showed significant improvement in psychological well-being and anxiety scores. This demonstrates that yoga can be as good a complementary measure to reduce weight in diabetes mellitus patients as exercise can be.

The interaction between positive affect or well-being and biochemical parameters is further exemplified in Strepto et al.'s research. Their study involved over 200 middle-aged men and women, in whom they assessed affect as it related to cortisol levels, blood pressure, heart rate, and fibrinogen stress responsiveness. They were able to demonstrate that positive affect is inversely related to cortisol output over the day, independent of age, gender, socioeconomic position, body mass, and smoking. Happiness was also inversely related to heart rate and the level of plasma fibrinogen stress response, independent of effects of psychosocial distress (Steptoe et al. 2005). These results render further credence to the hypothesis that one of the possible mechanisms through which yoga could improve biochemical measures is via its apparent influence on psychological well-being to a more positive affective state. Steptoe's cortisol results may also assist in explaining the fairly dramatic fall in cortisol levels in our study subjects who practiced yoga, i.e., via improved affect. They elucidate on the possible psychological mechanisms by which this would take place (Steptoe et al. 2005). Affect, according to this hypothesis, influences and stimulates biological and biochemical systems and processes via the central nervous system. The central nervous system connects with the autonomic nervous system as well as the neuroendocrine and immune system. Thus we come full circle from psychosocial well-being to the various biological systems in the body.

Exercise group

More pronounced improvements in the quality of life parameters were seen in the exercise group compared to the yoga group in our study. The exercise group improved across the board in all SF-36 parameters, reaching statistical significance for the following parameters: general health, vitality, social functioning, mental health, physical functioning, and the 2 composite scores, standard physical scale and standard psychological scale. The exercise group also evinced significant improvements in the HADS variables anxiety and anxiety positive.

This phenomenon of improved psychosocial and psychosocial well-being following a period of regular exercise is fairly well-established by several studies studying various patient cohorts. However, few studies exist on the association between exercise and quality of life specifically in diabetic patients.

Fuchs-Climent et al. studied over 30 chronic-obstructive lung disease (COPD) patients following 3 weeks of intense exercise therapy and health education sessions (Fuchs-Climent et al. 1999). Their results showed marked improvements in quality of life measures, although they failed to discern any correlation to physiological measures. In another study, Koukouvou et al. came up with similar results in over 25 chronic heart failure (CHF) patients—following a 6-month exercise training program, their patients' anxiety and depression scores as measured by HADS significantly decreased (Koukouvou et al. 2004).

They also, however, failed to find a significant correlation between physiological and psychosocial parameter gains. Karvinen et al. studied responses from over 500 bladder cancer survivors on their exercise levels and subjective feelings of quality of life. They also concluded that exercise is positively associated with quality of life in their patient cohort, and more interestingly, the increase in subjective quality of life levels was dose-related to the amount of exercise (Karvinen et al. 2007). Schmitz et al. conducted a meta-analysis on physical activity interventions in cancer survivors and found that the quality of life improved post-exercise in all the articles they reviewed (Schmitz et al. 2005).

In this study, the exercise group's improvement in psychosocial parameters was more marked compared to the yoga group. Both the yoga and exercise groups showed significant improvements in the 2 overall composite scores, standard psychological and standard physical scale. In the former, however, the exercise group's score started lower and progressed more steeply than in the yoga group and ended at the same level. One of the explanations for the difference between the 2 groups in psychosocial improvement may be that the exercise group started off with poorer scores on almost all the SF-36 variables and simply had more room for change. Indeed, in 2 out of the 3 variables where a significant between-group difference existed, a significant difference in baseline variables was also noted (see table 2a).

In the standard physical scale composite, both groups progressed similarly, indicating that the 2 groups were comparable in their psychosocial well-being based on SF-36's physical measures. However, in 3 out of the 4 *individual* physical measures, the exercise group's improvement was more pronounced: bodily pain, physical functioning capacity, and mental health. The yoga group's improvement in the bodily pain score reached statistical significance while the exercise group's did not; this was most likely due to the smaller exercise group sample size since the exercise group's bodily pain score progression improved from the same time 0 level as the yoga group's to a much higher level than the yoga group's. For the mental health score, a significant between-group difference can be seen; the exercise group clearly begins with a lower score than the yoga group and progress to the same level as the yoga group. For the role-physical item, the yoga group's score does not change from beginning to end of the study. The exercise group's scores improve, although without reaching statistical significance.

The mechanism by which exercise improves psycho-social well-being is unclear and our study indicates that it may not be primarily due to a improved state of relaxation as the exercise group's cortisol levels did not significantly decrease overall. Fuchs-Climent and Koukouvous's studies on chronic disease patients on exercise therapy were unable to find any correlation between salient improvements in quality of life measures and physiological measures. (Fuchs-Climent et al. 1999, Koukouvou et al. 2003). The mechanism by which cardiovascular exercise training leads to improved psychosocial well-being remains to be investigated.

CONCLUSION

Yoga is at least as beneficial as exercise therapy for several different aspects of diabetes control. It may prove to be more favorable than exercise in regulating blood sugar levels in the long term, possibly via the deep physical relaxation effect, thereby bringing down cortisol levels. According to this study, yoga practice proved significantly effective in bringing down insulin and cortisol levels and thus improving insulin resistance as calculated by the HOMA model and decreasing perceived stress in peripheral tissues. As for psychosocial well-being in diabetic patients, both yoga and exercise were beneficial. However, exercise seemed to have a larger effect on psychosocial parameters in our diabetic cohort. When analyzing all the psychometric and physiological measures together and observing the variables as sums of a whole, we can state that based on our small, non-randomized study, yoga is comparable to exercise as a complementary, non-pharmacological therapy for type II diabetes management and can perhaps be used instead of exercise in those patients where exercise proves difficult.

The key mechanism by which yoga practice works on the body's tissues may be through its relaxation effect. Deep relaxation of the body leads to a decrease in the sympathetic overdrive and subjective stress. This in turn can lead to a decrease in cortisol levels whose interaction with insulin may lead to a decrease in insulin levels. In our yoga group, low insulin levels corresponded with steady blood glucose levels, indicating augmented and improved usage of insulin at tissue level. The various parameters studied, in turn, influence each other: insulin and cortisol, blood glucose and insulin, insulin and serum lipids. Perceived stress and cortisol levels also seem to be strongly associated with intra-abdominal obesity, a salient risk factor for diabetes and the insulin resistance syndrome. The yoga group subjects were also able to significantly reduce their triglyceride concentration which is probably an independent risk factor for coronary heart disease.

Type II diabetes mellitus is inherently linked to the insulin resistance syndrome, also known as syndrome X or metabolic syndrome. The insulin resistance syndrome is a crucial risk factor for myocardial infarct and thus contributes to increased mortality rates. If yoga is able to influence several of the fundamental elements of the insulin resistance syndrome—that is, insulin, cortisol, blood glucose, triglycerides, perceived stress—in a positive way, it should, at the very least, be seriously considered as a complementary or alternative therapy for this patient group.

Our study was also able to confirm some beneficial effects of moderate cardiovascular exercise on type II diabetes mellitus subjects. Cortisol concentrations decreased over time, although it did not reach the level of significance. Fasting insulin levels, although elevated after 120 days of exercise, remained within the norm range. Triglyceride and cholesterol level trends decreased overall; blood glucose and glycated hemoglobin concentrations remained steady. The most prominent effect of exercise that our study was able to demonstrate was on our exercise subjects' significant amelioration of psychological well-being as well as anxiety and depression scores. Taken together, exercise training can help diabetic patients become more resilient towards life's constant stressors and thus also improve feelings of well-being. The mechanism by which this takes place at a physiological level is an areas which must be further explored. We were unable to repeat other studies' reports of improved glucose metabolism following exercise. A longer study duration and a more closely monitored exercise therapy may have led to more positive results in this group.

Our study conclusions must be interpreted with caution. The study sample was small and the study design non-randomized. Furthermore, some data points were missing which led to varying numbers of cases for the different sets of statistical analyses.

Further investigations are duly necessary to elucidate the mechanisms by which yoga can influence risk factors for the insulin resistance syndrome; in addition, research on the various types of *asanas* for different patient and disease profiles could prove clinically useful for the future.

SUMMARY

Background

The prevalence of diabetes mellitus is very high among Asian Indians and especially among those residing in urban areas. Investigators have predicted that India will have the largest number of diabetic patients in the world by 2030.

In the face of this, there is much scope for research in understanding the mechanisms and management of diabetes through indigenous methods such as yoga.

Methods

55 diabetics attended a 1-hour daily yoga class for 4 months. A matched-pair control group of 47 diabetics undertook cardiovascular exercises for the same time period. Insulin, cortisol, lipid profile, glucose, and HbA1c were measured at 3 time points during the study. Psychosocial parameters were measured with the HADS and the SF-36 questionnaire

Results

A significant change from baseline to 4 months was found for salivary cortisol, fasting insulin, and triglycerides in the yoga group but not for the exercise group. However, the exercise group showed a significant drop in salivary cortisol after 2 months, which then increased again to yield no significance between 0 and 4 months. In the yoga group, the fasting and post-prandial blood glucose values, as well as glycosylated hemoglobin values, largely stayed the same, with no significant change. This was also the case for the exercise group.

A significant improvement from 0 to 4 months was seen in the yoga and exercise group for a variety of HADS and SF-36 psychosocial variables. However, the exercise group's improvement in these variables was more marked.

The yoga group's fasting insulin values decreased while the exercise group's values increased between 2 and 4 months dramatically. The cortisol values decreased overall in both the yoga and the exercise groups.

Conclusion

Insulin levels in the yoga group dropped significantly with corresponding steady blood glucose and HbA1c values. The exercise group's insulin values increased dramatically also with steady blood glucose and HbA1c values. It seems that the yoga group was able to keep steady blood glucose values with significantly less insulin, indicating improved insulin sensitivity.

The exercise group seems to have benefitted more on psychosocial well-being than the yoga group, although both showed significant improvement. However, the non-randomised design of our study and marked baseline differences between both groups limit the generalisabilty of our findings and call for future randomized trials of yoga and exercise or their combination in diabetic patients.

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CURRICULUM VITAE

Am 3. November 1977 wurde ich in Arlington/USA geboren. Mein Vater war Universitätsdozent, meine Mutter Allgemeinärztin. Ich habe 2 jüngere Schwestern.

Meine Familie zog 1981 nach Houston um, wo ich den Großteil meiner Schuljahre absolvierte. Einen Teil der Schulzeit habe ich jedoch in Indien verbracht sowie ein Austauschjahr in Deutschland.

1996 bis 1998 studierte ich International Business in Paris an der Schiller International University und schloß dies mit einem Bachelor ab. 1998 fing ich in Göttingen das Medizin-Studium an und erhielt 2005 meinen qualifizierenden Abschluß.

Schon während des Studiums interessierte ich mich für Public Health und Medizin in Entwicklungsländern. Ich belegte Tropenmedizinkurse in der vorlesungsfreien Zeit, famulierte in Indien, absolvierte einen Teil des praktischen Jahres in Südafrika und verbrachte mehrere Monate bei der Doktorarbeitsforschung in Indien.

Für den Großteil meiner beruflichen Laufbahn arbeitete ich für die Weltgesundheitsorganisation (WHO) in Genf, bis auf kurze Tätigkeiten beim Schweizer Tropeninstitut in Basel und der US-amerikanischen Nicht-Regierungs-Organisation Real Medicine Foundation im Jhabua und Bangalore/Indien.

Bei der WHO beschäftige ich mich mit Gesundheitssystemanalysen in Entwicklungsländern und erarbeite zusammen mit den lokalen Gesundheitsministerien öffentliche Gesundheitsstrategien. Ich beabsichtige, in dem Bereich Public Health weiterhin zu arbeiten.

Mein großes Hobby ist der südindische klassische Tanz ‚Bharatha Natyam', den ich intensiv ausübe und den ich teilweise selbst aufführe. Außerdem organisiere ich gerne Tanzveranstaltungen für indische Künstler in Europa.

Ich bin verheiratet und habe eine Tochter.

ANNEXURE:

Annex 1: Short-Form 36 Health Survey (SF-36)

Your Health and Well-Being
This survey asks for your views about your health. This information will help keep track of how you feel and how well you are able to do your usual activities. Thank you for completing this survey!

For each of the following questions, please mark the response which best describes your answer.

1. In general, would you say your health is:

Excellent Very Good Good Fair Poor

2. Compared to one year ago, how would you rate your health in general now?

Much better now than one year ago

Somewhat better now than one year ago

About the same as one year ago

Somewhat worse now than one year ago

Much worse now than one year ago

3. The following items are about activities you might do during a typical day.
Does your health now limit you in these activities? If so, how much?

a Vigorous activities, such as running, lifting heavy objects, participating in strenuous sports
Yes, limited a lot
Yes, limited a little
No, not limited at all

b. Moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf
Yes, limited a lot
Yes, limited a little
No, not limited at all

c. Lifting or carrying
Yes, limited a lot
Yes, limited a little
No, not limited at all

d. Climbing several flights of stairs
Yes, limited a lot
Yes, limited a little
No, not limited at all

e. Climbing one flight of stairs
Yes, limited a lot
Yes, limited a little
No, not limited at all

f. Bending, kneeling, or stooping
Yes, limited a lot
Yes, limited a little
No, not limited at all

g. Walking more than a mile
Yes, limited a lot
Yes, limited a little
No, not limited at all

4. During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of your physical health?

Cut down on the amount of time you spent on work or other activities

yes no

b Accomplished less than you would like

yes no

c Were limited in the kind of work or other activities

yes no

d Had difficulty performing the work or other activities (for example, it took extra effort)

yes no

5. During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of any emotional problems (such as feeling depressed or anxious)?

a Cut down on the amount of time you spent on work or other activities

yes no

b Accomplished less than you would like

yes no

c Did work or other activities less carefully than usual

yes no

6. During the past 4 weeks, to what extent has your physical health or emotional problems interfered with your normal social activities with family, friends, neighbors, or groups?

Not at all Slightly Moderately Quite a bit Extremely

7. How much bodily pain have you had during the past 4 weeks?

None Very mild Mild Moderate Severe Very Severe

8. During the past 4 weeks, how much did pain interfere with your normal work (including both work outside the home and housework)?

Not at all A little bit Moderately Quite a bit Extremely

9. These questions are about how you feel and how things have been with you during the past 4 weeks. For each question, please give the one answer that comes closest to the way you have been feeling.

How much of the time during the past 4 weeks:

a. Did you feel full of pep?

All of the time
Most of the time
A good bit of the time
Some of the time
A little of the time
None of the time

b. Have you been a very nervous person?

All of the time
Most of the time
A good bit of the time
Some of the time
A little of the time
None of the time

c. Have you felt so down in the dumps that nothing could cheer you up?

All of the time
Most of the time
A good bit of the time
Some of the time
A little of the time
None of the time

d. Have you felt calm and peaceful?

All of the time
Most of the time
A good bit of the time
Some of the time
A little of the time
None of the time

e. Did you have a lot of energy?

All of the time
Most of the time
A good bit of the time
Some of the time
A little of the time
None of the time

f. Have you felt downhearted and blue?

All of the time
Most of the time
A good bit of the time
Some of the time
A little of the time
None of the time

g. Did you feel worn out?

All of the time
Most of the time
A good bit of the time
Some of the time
A little of the time
None of the time

h. Have you been a happy person?

All of the time
Most of the time
A good bit of the time
Some of the time
A little of the time
None of the time

i. Did you feel tired?

All of the time
Most of the time
A good bit of the time
Some of the time
A little of the time
None of the time

10. During the past 4 weeks, how much of the time has your physical health or emotional problems interfered with your social activities (like visiting friends, relatives, etc.)?

All of the time
Most of the time
Some of the time
A little of the time
None of the time

11. How TRUE or FALSE is each of the following statements for you?

a. I seem to get sick a little easier than other people

Definitely true
Mostly true
Don't know
Mostly false
Definitely false

b. I am as healthy as anybody I know

Definitely true
Mostly true
Don't know
Mostly false
Definitely false

c. I expect my health to get worse
Definitely true
Mostly true
Don't know
Mostly false
Definitely false

d. My health is excellent

Definitely true
Mostly true
Don't know
Mostly false
Definitely false

Annex 2: Hospital Anxiety and Depression Scale (HADS)

Hospital Anxiety and Depression (HAD) SCALE

Name: ………………………………………………… Date:…………………………

Doctors are aware that emotions play an important part in most illnesses. If your doctor knows about these feelings he will be able to help you more.

This questimmaire is designed to help your doctor to know how you feel. Read each item and place a firm tick in the box opposite the reply which comes closest to how you have been feeling in the past week.

Don't take too long over your replies: your immediate reaction to each item will probably be more accurate than a long thought-out response.

Tick one box in each section

I feel tense or 'wound up:			**I feel as if I am slowed down**		
Most of the time ……….		[redacted]	Nearly all the time ……………		[redacted]
A lot of the time ……….		[redacted]	Very often …… …….. ………. .		[redacted]
Time to time, occasionally.		[redacted]	Sometimes …………….. …… .		[redacted]
Not at all ……………….		[redacted]	Not at all …. …………………		[redacted]
I still enjoy the things I used to enjoy:			**I get a sort of frightened feeling like 'butterflies' in the stomach**		
Definitely as much ………	[redacted]		Not at all …………………….		[redacted]
Not quite so much ……….	[redacted]		Very often … . ….. …………		[redacted]
Only a little ………………	[redacted]		Occasionally ………. ………. .		[redacted]
Hardly at all ………………	[redacted]		Quite often . …………………..		[redacted]
I get a sort of frightened feeling as if something awful is about to happen:			**I have lost interest in my appearance**		
Very definitely & quite badly		[redacted]	Definitely … …………………	[redacted]	
Yes, but not too badly ……		[redacted]	I don't take so much care as I should	[redacted]	
A little, but it doesn't worry me.		[redacted]	I may not take quite as much care	[redacted]	
Not at all ……. …. . ………		[redacted]	I take just as much care as ever	[redacted]	
I can laugh and see the funny side of things:			**I feel restless as if I have to be on the move:**		
As much as I always could	[redacted]		Very much indeed ……………		[redacted]
Not quite so much now ….	[redacted]		Quite a lot ……………………		[redacted]
Definitely not so much now	[redacted]		Not very much .. . ……………		[redacted]
Not at all …………………	[redacted]		Not at all …………………….		[redacted]

Worrying thoughts go through my mind:			**I look forward with enjoyment to things:**		
A great deal of the time			As much as ever I did		
A lot of the time			Rather less than I used to		
From time to time but not too often			Definitely less than I used to .. .		
Only occasionally			Hardly at all		
I feel cheerful:			**I get sudden feelings of panic:**		
Not at all			Very often indeed		
Not often			Quite often		
Sometimes			Not very often		
Most of the time			Not at all		
I can sit at ease and feel relaxed:			**I can enjoy a good book or radio or TV programme:**		
Definitely			Often		
Usually..............			Sometimes		
Not often			Not often		
Not at all			Very seldom		

Do not write below this line
A-(8-10) ....
D-(8-10) ....

HAD SCALE SCORE SHEET

		A		D	
		3		3	
		2		2	
		1		1	
		0		0	
	D				A
	0				0
	1				1
	2				2
	3				3
		A		D	
		3		3	
		2		2	
		1		1	
		0		0	
	D				A
	0				3
	1				2
	2				1
	3				0
		A		D	
		3		0	
		2		1	
		1		2	
		0		3	
	D				A
	3				3
	2				2
	1				1
	0				0
		A		D	
		0		0	
		1		1	
		2		2	
		3		3	

FOR PHYSICIAN/ NURSE USE Patients Name/No:

D (8-10) ... .

A (8-10) ....

HAD Scores of over 10, change of duties and refer to OHP

HAD Scores of over 21. ask whether panic attacks have occurred.