

**Research Article**

**Effect of yoga therapy on anthropometry, metabolic parameters and cardiac autonomic function tests in type 2 diabetes mellitus patients**

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**Abstract**

The effect of yoga therapy on cardiac autonomic function tests in patients with Type-2 diabetes mellitus was studied. 120 known diabetic cases in the age group of 30- 60 years were selected. The total population was divided into two groups based on age, group I (GI) consisting of 30-45 years and group II (GII) consisting of 46-60 years. The yoga therapy consisting of asana, Pranayamas, bandhas and mudras was practiced by the patients enrolled in the study daily for one hour for 100 days. Fifty one subjects in group I and forty seven subjects in group II participated till the end of the study. Biochemical tests and cardiac autonomic function tests were performed before and after 100 days of therapy. The mean values of various parameters before and after the 100 days of therapy were as follows, fasting blood glucose changed from 155.6± 16.5 to 130.4± 14 in GI, 205.4± 48.9 to 174.6± 40 in GII, cardiac autonomic function score changed from 6.9±1.37 to 4.8±1.13 in GI, 7.06± 1.29 to 5.21± 1.71 in GII. From the study it is concluded that yoga therapy has a role in reduction of blood glucose and better cardiac autonomic functioning in patients with Type-2 diabetes mellitus in conjunction with medical therapy and the benefit is more pronounced when yoga therapy is started at an earlier age.

**Keywords:** CAN tests, Diabetes mellitus, Yoga therapy

**1. Introduction**

**1.1 Background**

Diabetes mellitus is a common disorder seen all over the world and has become a major health challenge. The modern life with its ever increasing stress and strain contributes to the rapid increase in the incidence of this condition. Cardiac Autonomic Neuropathy (CAN) is one of the major complications of diabetes mellitus. Studies are being carried out in our country to control the blood glucose levels and to prevent the complications of diabetes like CAN by yoga therapy<sup>1</sup>. Yoga therapy is an ancient practice to control number of diseases like hypertension, asthma, obesity, diabetes and other psycho-somatic diseases. Yogic practices are also supposed to change one's attitude towards the situation of life, by developing mental relaxation and balance. The benefits of yoga practice in Diabetes mellitus may be due to the possible mechanisms like increase in number of b-cells of pancreas that secretes insulin, increase in insulin sensitivity, decrease in insulin resistance, decreases in catecholamines and cortisol which are the stress hormones<sup>2</sup>. These cause both mental and physical relaxation. Yoga therapy is most useful in type-2 DM than in type-1 DM<sup>2</sup>. During asana, body twists and stretches the internal organs with increase in blood supply; this increases the function of organ systems. Above facts initiate to study the effects of yoga therapy on blood glucose and cardiac autonomic functioning in type-2 Diabetes in our study.

## 1.2 Objectives

To study the effect of yoga therapy on cardiac autonomic function in patients with type 2 Diabetes Mellitus. To study the effect of yoga therapy on fasting plasma glucose, serum lipid profile and HbA1c in patients with type 2 Diabetes Mellitus

## 2. Methodology

The study was done at Sri Venkateswara Institute of Medical Sciences, Tirupati, AP, India with the approval of the Institutional Review Board between September 2009 and August 2011. A random convenient sampling was done to recruit sixty known diabetic male cases in the age group 30- 45 years and sixty known diabetic male cases in the age group 46- 60 years. An informed consent was obtained from all the subjects of the study. Patients with habits like smoking, alcohol abuse, with systemic diseases (except autonomic functioning), carcinomas and infections were excluded from the study. The subjects were informed that they can continue their usual medication and regular food habits. All the subjects were divided randomly into four batches of 30 subjects each (includes subjects of both the study groups). This was done to ensure better yoga practice provided by trained personnel. Though we recruited sixty subjects in each group, we could end up with fifty one in group I and forty seven in group II. The overall participation rate was 81.67%. The following procedure was adopted for each batch of study subjects.

5ml of 10 hour fasting venous blood sample was collected from all the subjects following NCCLS guidelines<sup>3</sup> on the first day of the study. 1ml of sample was transferred to sodium fluoride coated polystyrene tube; plasma was separated by centrifugation at > 3000 rpm for 3 min. Fasting Plasma Glucose (FPG) was analyzed in the sample within 2 hrs. 1ml of the blood sample was transferred into EDTA tube and was used to assay HbA1c. 3 mL of venous blood sample is transferred into a plain polystyrene tube. It was allowed to stand for complete clot formation and then centrifuged for 3 min at  $\geq 3000$  rpm<sup>3,4</sup>. The serum so obtained was used to assay lipid profile. Following the collection of venous blood specimen, Cardiac Autonomic Neuropathy (CAN) tests were performed on the individuals and the scores were recorded.

### 2.1 Fasting Plasma Glucose

FPG was assayed on Siemens Dimension clinical chemistry system (automated analyzer) that employs the principle of Hexokinase- Glucose 6 phosphate Dehydrogenase method, presented as general clinical laboratory method by Kunst et.al,<sup>5</sup>.

### 2.2 Lipid Profile

For all the lipid profile parameters, fasting serum sample is used.

#### (i) Serum Total Cholesterol:

Assayed on Siemens Dimension clinical chemistry system (automated analyzer) that employs the principle of cholesterol oxidase- peroxidase method which was first described by Stedman<sup>6</sup> and later modified by others<sup>7</sup>.

#### (ii) Serum Triglycerides:

The assay was performed on Siemens Dimension clinical chemistry system (automated analyzer). Glycerol-3-phosphate oxidase- peroxidase method is employed which is a bichromatic end point technique<sup>8</sup>.

#### (iii) Serum HDL Cholesterol

Assayed on Siemens Dimension clinical chemistry system (automated analyzer). Accelerator selective detergent methodology is employed. The method has been evaluated by and met the certification acceptance criteria of the cholesterol reference method laboratory network (CRMLN)<sup>9</sup>.

(iv) & (v) Serum LDL & VLDL: calculated using Friedwald's formula.

### 2.2 Quality Control

Quality check was done for the above parameters. The results were evaluated by comparison with standards of known concentration. Measures were taken for checking the kit to kit variability and the repeatability was checked by duplicate testing. The intra and inter assay coefficients of variation for all the parameters was maintained <5%.

### 2.3 BP Measurement

Three measurements were taken at 3- 5 minute intervals with an oscillometric digital sphygmomanometer (model: Omron Hem 780 N3). The instrument was validated against trained examiners using a mercury sphygmomanometer<sup>10</sup>. Calibration was checked periodically. The first measurement was taken after sitting comfortably on a chair for > 5 min, with the left arm at the level of the heart resting on a table. The mean of the last two measurements were used for analysis. In case where the second and the third measurements do not coincide within 10mm Hg, a fourth measurement is taken and the mean of the two closest values is used for analysis.

### 2.4 Anthropometry

Height and weight were measured on the subjects in standing position. The weighing scales and the measuring tapes were calibrated periodically. BMI was calculated from the formula,  $BMI = \text{weight (kg)} / \text{height}^2 (\text{m}^2)$ .

**2.5 Procedure For CAN Tests:** These tests include evaluating both parasympathetic and sympathetic functioning<sup>11</sup>.

#### 2.5.1 Parasympathetic tests

These tests are done by using the 12-lead ECG machine (model: BPL cardiact 108). Bipolar limb lead II recordings were used for evaluation of parasympathetic functioning based on the following tests.

1. Deep breathing difference (DBD):
2. Valsalva ratio (VR)
3. Postural tachycardial index (PTI)

#### 2.5.2 Resting Heart Rate

The R-R interval on ECG graph is noted and Resting HR is calculated as follows:

Resting Heart Rate =  $300 \div \text{No. of small squares in R-R interval}$

If the resting HR is > 100 beats/ min, it is considered abnormal.

#### 2.5.3 DBD

With the patient at rest and sitting (no overnight coffee (or) hypoglycemic episodes), the subject is asked to take breathing at 6 breaths / min and HR is monitored by ECG. Then DBD is expressed as the mean of the differences between the maximal and minimal HR in 6 respiratory cycles. A difference in HR of >15 beats / min is normal and < 10 beats / min is abnormal.  $DBD = \text{mean of HR difference in 6 breath cycles}$ . All indices of DBD are age dependent.

#### 2.5.4 VR

The subject is asked to forcibly exhale to 40mm of Hg for 15 secs during ECG monitoring into the mouth piece of a manometer. Subject develops tachycardia and peripheral vasoconstriction during strain and an overshoot bradycardia and rise in BP with release. The ratio of longest R-R interval and shortest R-R interval should be >1.2 is normal.

VR =

#### 2.5.5 PTI

During continuous ECG monitoring, the R-R interval is measured at beat 30 in lying and at beat 15 in standing. Normally, tachycardia is followed by reflex bradycardia. The 30:15 ratio is normally >1.03.

#### 2.5.6 Sympathetic tests

These tests are done by using the sphygmomanometer. These include

1. Fall in SBP test: BP changes from lying to standing.
2. Rise in DBP test: BP changes to sustained handgrip, done by hand-held dynamometer.

#### 2.5.7 SBP response to standing

SBP is measured in supine position. The subject stands and then SBP is measured after 30 secs. Normal response is a fall of <10 mm of Hg, borderline is a fall of 10-29 mm of Hg and abnormal is a fall of >30mm of Hg with symptoms.

#### 2.5.8 DBP response to isometric exercise

The subject squeezes a handgrip dynamometer to establish a maximum grip. Grip is then squeezed at 30% maximum for 5 min. The normal response for DBP is a rise of >16 mm of Hg in the other arm. A summary of parameters of CAN score, their reference ranges is given in table 1:

**Table 1: CAN Score parameters and reference ranges**

Parasympathetic tests (HR response tests)	Normal (Score-0)	Borderline (Score-1)	Abnormal (Score-2)
DBD	15 beats / min or more	11-14 beats / min	10 beats / min or less
VR	1.21 or more	1.11-1.20	1.10 or less
PTI	1.04 or more	1.01 – 1.03	1.00 or less
Sympathetic tests (BP response tests)			
Fall in SBP (BP response to standing)	10 mm of Hg or less	11-29 mm of Hg	30 mm of Hg or more
Rise in DBP (BP response to sustained handgrip)	16 mm of Hg or more	11-15 mm of Hg	10 mm of Hg or less

Total CAN score is estimated by adding the scores of individual parameters.

Following the estimation of blood parameters and CAN tests, the subjects were asked to report on the next day exactly at 5:45am. Yoga was practiced by all the subjects under the supervision and facilitation of trained personnel. The session began at 6 am exactly and yoga was practiced for the next 60 min. All the subjects were made to practice the following asana, bandhaas and Pranayamas for the next hundred days.

**Asana:** Sun salutation, Tadasana, Ardhamatsyendrasana, Halasana, Vakrasana, Bhujangasana, shalabhasana, Dhanurasana, katichakrasana, paschimottanasana, Pavanamuktanasana, sarvangasana, Chakrasana, shavasana.

**Pranayamas:** Naudisodhana, kaphalabhathi,

**Bandhas:** Udhyanu Bandha

The procedure of performing these asanas, bandhas and pranayama is explained elsewhere<sup>12,13,14</sup>. At the end of hundred days, fasting blood sample was again collected from each individual and serum/ plasma chemistry analyses were performed as described afore. CAN tests were also performed and the scores were recorded.

## 2.6 Data Analyses

The data was collected, entered and processed in MS- excel and analysed on graphpad online statistical calculator. The data was more or less normally distributed with little skewdness for some parameters. Hence, parametric tests were considered to be performed on the data. The results were statistically analyzed by the paired student t-test to compare means of the study parameters before and after yoga therapy in each study group and by unpaired student t-test to compare means of parameters between groups. A two tailed probability value of <0.05 was considered statistically significant.

## 3. Results

All the subjects selected were diabetic since past one to ten years as on the date of recruiting for the study. The subjects in group I were younger ( $38.63 \pm 3.86$  years) compared to the subjects in group II ( $53.05 \pm 6.26$  years). Table 2 shows the differences in BMI in both the groups before and after practising yoga.

**Table-2 Mean, SD, P values of BMI among GI, GII before and after yoga therapy**

Groups	BMI (kg/ m <sup>2</sup> )		Decrease in BMI (kg/ m <sup>2</sup> )	% decrease in BMI	p- value (before vs after)
	Before yoga therapy	After yoga therapy			
	Mean + SD (min- max)	Mean + SD (min- max)	Mean + SD (min- max)	Mean + SD (min- max)	
I (n = 51)	25.3 ± 2.54 (21- 30.9)	23.2 ± 2.65 (20- 28.65)	2.12 ± 0.35(1- 2.55)	8.4 ± 1.4 (4.8- 10.5)	<0.0001
II (n=47)	24.4 ± 2.14 (20- 28)	23.8 ± 2.5 (20- 28)	0.66 ± 1.05 (-0.2- 3.8)	2.7 ± 4.3 (-3.8- 16)	<0.0001
Total subjects (n= 98)	24.87 ± 2.39 (20- 30.9)	23.46 ± 2.48 (20- 28.65)	1.42 ± 1.06 (-0.2- 3.8)	5.69 ± 4.25 (-3.8 – 15.97)	<0.0001
p- value (Group I vs II)			<0.0001	<0.0001	

The mean BMI in both the groups together decreased by 1.42 kg/ m<sup>2</sup>. Also, when the data was stratified for age

into two groups, the decrease in BMI after practising yoga was statistically significant in both the groups. However, more significant decrease was shown in younger subjects ( $8.4 \pm 1.4\%$ ) than the older subjects ( $2.7 \pm 4.3\%$ ). Though the difference in BMI in group II was statistically significant ( $p < 0.0001$ ), there was only little decrease in BMI in that group ( $0.66 \pm 1.05 \text{ kg/m}^2$ ) when compared to decrease in BMI in group I ( $2.12 \pm 0.35 \text{ kg/m}^2$ ). The decrease in BMI in group II is thus significantly different from the decrease in BMI in group I ( $p < 0.0001$ ). In group II ten subjects showed a slight increase in BMI ( $0.2- 1.0 \text{ kg/m}^2$ ) after practising yoga which is unexplained.

The differences in serum/ plasma chemistry parameters before and after yoga therapy in both the groups is presented in table 3

**Table 3: Mean  $\pm$  SD (min- max) and p- values of Fasting plasma glucose, fasting serum lipid profile and HbA<sub>1C</sub>**

	Group I (n= 51)				Group II (n= 47)				Total (n= 98)			
	Before Yoga practice	After yoga practice	Difference (before-after)	p- value (before vs after)	Before Yoga practice	After yoga practice	Difference (before-after)	p- value (before vs after)	Before Yoga practice	After yoga practice	Difference (before-after)	p- value (before vs after)
FBS (mg/dL)	155.6 $\pm$ 16.5 (128- 191)	130.4 $\pm$ 14 (112-168)	25.16 $\pm$ 6.1 (12-43)	<0.0001	205.4 $\pm$ 48.9 (140-299)	174.6 $\pm$ 40 (118.5- 256.5)	30.8 $\pm$ 14.5 (0-54.5)	<0.0001	179.5 $\pm$ 43.58 (128- 299)	151.6 $\pm$ 36.8 (112- 256.5)	27.89 $\pm$ 11.25 (0- 54.5)	<0.0001
HbA1c (gm%)	7.7 $\pm$ 0.71 (7- 9.2)	6.9 $\pm$ 0.439 (6.3-7.7)	0.87 $\pm$ 0.51 (0-2.2)	<0.0001	9.7 $\pm$ 1.2 (7.5-11.6)	8.7 $\pm$ 1.35 (7-11.3)	0.94 $\pm$ 0.69(0-2.9)	<0.0001	8.63 $\pm$ 1.02 (7- 11.6)	7.72 $\pm$ 1.38 (6.3- 11.3)	0.9 $\pm$ 0.6 (0- 2.9)	<0.0001
Total Cholesterol (mg/dL)	183.1 $\pm$ 28.1 (135- 235)	174.5 $\pm$ 28 (115-222)	8.6 $\pm$ 6.8 (0-20)	<0.0001	189.3 $\pm$ 21.5 (155-227)	175.85 $\pm$ 23.3 (135- 213)	13.5 $\pm$ 6.3(0-24)	<0.0001	186.07 $\pm$ 25.23 (135- 235)	175.15 $\pm$ 25.72 (115- 222)	10.92 $\pm$ 6.98 (0- 24)	<0.0001
Serum TG (mg/dL)	152.9 $\pm$ 44.2 (100- 247)	141.6 $\pm$ 43.3 (95-236)	11.3 $\pm$ 8.7 (1-40)	<0.0001	186.3 $\pm$ 48.8 (115-297)	169.6 $\pm$ 45.5 (100-277)	16.7 $\pm$ 7.9 (0-30)	<0.0001	168.92 $\pm$ 49.2 (100- 297)	155.05 $\pm$ 46.35 (95- 277)	13.87 $\pm$ 8.7 (0- 40)	<0.0001
HDL (mg/dL)	39.2 $\pm$ 2.8 (33-44)	40.3 $\pm$ 2.5 (33-45)	-1.03 $\pm$ 1.74 (-5-2)	<0.0001	41.1 $\pm$ 2.5 (35-46)	44.14 $\pm$ 5.32 (33- 54)	-3 $\pm$ 3.6(-10- 4)	<0.0001	40.14 $\pm$ 2.86 (33- 46)	42.12 $\pm$ 4.52 (33- 54)	-1.98 $\pm$ 2.93 (-10 - 4)	<0.0001
VLDL (mg/dL)	30.6 $\pm$ 8.8 (20-49.4)	28 $\pm$ 8.7 (19-47.2)	2.5 $\pm$ 1.73 (0.2-8)	0.063	37.3 $\pm$ 9.8 (23-59.4)	33.9 $\pm$ 9.1 (20-55.4)	3.3 $\pm$ 1.57 (0-6)	<0.0001	33.78 $\pm$ 9.84 (20- 59.4)	31.01 $\pm$ 9.27 (19- 55.4)	2.77 $\pm$ 1.74 (0- 8)	<0.0001
LDL (mg/dL)	113.3 $\pm$ 29.7 (68-161)	106.2 $\pm$ 27.7 (53-146.4)	7.1 $\pm$ 8.1 (-4-21)	<0.0001	110.9 $\pm$ 22.8 (78.8- 149.6)	101 $\pm$ 22.5 (65-140)	9.9 $\pm$ 6.3(-5-21.6)	<0.0001	112.15 $\pm$ 26.52 (68- 161)	103.56 $\pm$ 25.39 (53-146.4)	8.59 $\pm$ 7.25 (-5 - 21.6)	<0.0001

\* $p < 0.05$

There was a statistically significant decrease in fasting plasma glucose after practicing yoga in both the groups. However, there was more decrease in the younger age group than in the older age group ( $16.1 \pm 3.2\%$  in group I and  $14.7 \pm 5.8\%$  in group II). Similarly there was also a statistically significant decrease in the HbA<sub>1c</sub> values after yoga therapy in both the groups ( $p < 0.0001$  in both the groups) with more decrease in younger age group ( $10.9 \pm 5.54\%$ ) compared to the other group ( $9.8 \pm 6.9\%$ ). The changes in lipid parameters were also statistically significant in both the groups. With yoga therapy there was a decrease in serum total cholesterol ( $8.6 \pm 6.8 \text{ mg/dL}$  and  $13.5 \pm 6.3 \text{ mg/dL}$  in group I and group II respectively), LDL ( $7.1 \pm 8.1 \text{ mg/dL}$  and  $9.9 \pm 6.3 \text{ mg/dL}$  in group I and group II respectively), Triglycerides ( $11.3 \pm 8.7 \text{ mg/dL}$  and  $16.7 \pm 7.9 \text{ mg/dL}$  in group I and group II respectively) and a slight increase in HDL ( $1.03 \pm 1.74 \text{ mg/dL}$  and  $3 \pm 3.6 \text{ mg/dL}$  in group I and group II respectively). From these values it is clear that there was more decrease in cholesterol, LDL and triglycerides in older subjects than younger subjects. Further there was more improvement of HDL in older population.

One individual in group II did not show any change in fasting plasma glucose after practicing yoga. In three subjects in group II and two subjects in group I HbA<sub>1c</sub> remained unchanged even after practicing yoga. Ten subjects in group I and three subjects in group II did not show decrease in total cholesterol after yoga practice. Twenty six subjects in group I and seven subjects in group II did not show increase in HDL while two subjects in group I and seven subjects in group II showed a decrease in HDL with yoga practice. This may be secondary to decrease in serum total cholesterol which is usually seen in subjects treated with statins. In group I three subjects showed an increase in LDL by  $0.2 \text{ mg/dl}$ , two subjects by  $0.4 \text{ mg/dl}$ , six subjects by  $1 \text{ mg/dl}$  and one subject by  $2.2 \text{ mg/dl}$ , while in two subjects LDL remained unchanged even after yoga practice. Similarly in group II four subjects showed an increase in LDL ( $-3, -5, -3, -1.4 \text{ mg/dL}$

respectively). In five subjects in group II triglycerides remained unchanged.

The mean± SD and p- value of arterial blood pressure, Heart rate, tests for sympathetic and parasympathetic function and CAN score are presented in table 4.

**Table 4: Mean± SD (min- max) and p- values of CAN tests and CAN score**

	Group I (n= 51)				Group II (n= 47)				Total (n= 98)			
	Before Yoga practice	After yoga practice	Difference (before- after)	p- value (before vs after)	Before Yoga practice	After yoga practice	Difference (before- after)	p- value (before vs after)	Before Yoga practice	After yoga practice	Difference (before- after)	p- value (before vs after)
Resting SBP	125.8±6.89 (118-142)	121.26±6.5 (108-137)	4.5±3.4 (1-12)	<0.0001	128.2 ± 7.96 (118- 142)	124.7 ± 8.61 (108-138)	3.51 ±4.38 (0 – 12 )	<0.0001	126.89 ±7.49 (118-142 )	122.87±7.75 (108-138 )	4.02±3.9 (0-12)	0.0003
Resting DBP	88.3±4.49 (80-96)	84.7±4.28 (78-92)	3.5±1.5 (1-6)	<0.0001	87.8 ± 3.9 (78- 94)	84.23 ± 6.08 (68 -92 )	3.57 ± 6.05 (0 – 20 )	0.0002	88.06±4.2 (78-96)	84.5±5.2 (68-92 )	3.56±4.31 (0-20)	<0.0001
Resting Heart Rate	80.7±4.6 (72-90)	76.2±4.35 (67-86)	4.41±3.26 (0-10)	<0.0001	82.38 ± 9.25 (73- 102)	77.3 ±6.97 (66 -92 )	5.12 ± 4.35 (-4 – 14 )	<0.0001	81.9±70.2 (71-102)	77±6 (66-92 )	4.76±3.82 (-4-14)	<0.0001
DBD	10.1±4.29 (2-18)	12.7±3.69 (6-20)	2.64±2.31 (-7 -+2)	<0.0001	8.25 ± 2.97 (1- 14)	1.36 ±2.97 (7 -18 )	-3.1± 2.64 (-8 – 4 )	<0.0001	9.11±3.78 (1-18)	11.98±3.5 (5-20)	-2.86±2.47 (-8-4)	<0.0001
VR	1.064±0.134 (0.85 -1.35)	1.142±0.133 (0.89 -1.39)	-0.076±0.019 (-0.2 -0)	<0.0001	1.07 ± 0.13 (0.8 -1.34)	1.57 ±0.72 (0.85 -3.2)	-0.499 ±0.655 (- 1.93 -0 )	<0.0001	1.07±0.13 (0.8-1.35)	1.35±0.55 (0.85-3.2)	-0.28±0.50 (-1.93-0)	<0.0001
PTI	1.029±0.031 (0.95 -1.11)	1.043±0.025 (1 -1.11)	-0.015±0.014 (-0.06 -0.01)	<0.0001	1.01± 0.093 (0.5- 1.12)	1.09 ±0.15 (0.88 -1.9)	-0.086 ±0.158 (- 0.86 -0 )	0.0005	1.02±0.07 (0.5-1.12)	1.07 ±0.1 (0.88-0.9)	-0.05±0.11 (-0.86-0.01)	<0.0001
Fall in SBP	15.8±4.8 (7 -22)	12±4.05 (5 – 20)	3.8 ±2.08 (0 – 8)	<0.0001	17.53±4.63 (9 -26)	11.95 ± 3.85 (8 – 20)	5.57 ± 3.88 (0-15)	<0.0001	16.67±4.77 (7-26)	12.02±3.9 (4-5-20)	4.65±0.11 (-0.86-0.01)	<0.0001
Rise in DBP	9.6 ±3.3 (4 – 16)	13.06 ± 3.18 (8- 20)	-3.39 ± 2.81 (-8- 0)	<0.0001	7.19 ±2.17 (2 -11)	10.76 ± 2.69 (5-16)	- 3.57 ±2.61 (- 10 – 0 )	<0.0001	8.48±3.05 (2-16)	11.96±3.1 (5-5-20)	-3.48±2.70 (-10-0)	<0.0001
CAN Score	5.9 ± 1.66 (1- 9)	4.29 ± 1.68 (0- 7)	1.61 ± 1.29 (0- 6)	<0.0001	7.06± 1.29 (4 -10)	5.21 ± 1.71 (2 -9)	1.85 ± 1.44 (0 – 5)	<0.0001	6.46±1.6 (1- 10)	4.73±1.76 (0-9)	1.72±1.36 (0-6)	<0.0001

There was a significant decrease in the arterial blood pressure in all the subjects after yoga therapy compared to the values before ( $p= 0.0003$ ,  $<0.0001$ ,  $<0.0001$  in total subjects, group I and group II respectively). The decrease in SBP was more in younger patients ( $4.5 \pm 3.4$  mm Hg) when compared to the older ( $3.51 \pm 4.38$  mm Hg) while the decrease in DBP in group I is not much different from the decrease in DBP in group II. There was a statistically significant decrease in Resting Heart Rate in both the groups after yoga practice ( $p < 0.0001$  in both the groups). With yoga practice, there was a significant improvement in the parasympathetic function of both the groups represented by an increase in DBD, PTI and VR. The values of these parameters before and after yoga practice were higher in group I than in group II and though the parasympathetic functioning was thus better in group I compared to group II after yoga therapy, the improvement in group I look little compared to group II. These values were presented in table 3. There was also a statistically significant improvement in sympathetic functioning of both the groups after yoga practice which was indicated by a significant fall in SBP ( $p < 0.0001$  in both the groups) and rise in DBP ( $p < 0.0001$  in both the groups). There was also a significant decrease in CAN score in both the groups with yoga therapy ( $p < 0.0001$  in both the groups) indicating an improvement in Cardiac Autonomic Function. Nevertheless, the CAN score was lesser in group I than in group II after yoga therapy indicating a better cardiac autonomic function in group I than in group II. This data may be referred to values tabulated in table 4 above.

#### 4. Discussion

Since the onset of diabetes is usually in the middle age and the complications like diabetic neuropathy are likely to appear after a considerable exposure to the disease, we have considered two groups of subjects of different age groups so as to see how early the yoga therapy will be beneficial in preventing/ reducing the complications of diabetes like neuropathy. The duration of diabetes was one to ten years in the subjects involved in the study with more duration of exposure to the

disease in group II than in group I. All the subjects practiced yoga for hundred days. A significant decrease in BMI was seen in yoga therapy in our study which was also seen in similar such studies. The duration of yoga practice in these studies ranged from as low as six weeks to as high as one year. All these studies reported a decrease in weight and BMI in subjects after yoga practice<sup>15, 16, 17, 18</sup>. In our study, the subjects were made to practice yoga for hundred days at the end of which, we found a significant decrease in weight and BMI. This may be due to reduction in the deposited fat in adipose tissue. However, a decrease in waist and hip circumference and waist to hip ratio was shown in few studies<sup>16, 18</sup> which were not done in our study since most of the subjects were not ready to remove clothing for waist and hip circumference measurements. Further, in group II ten subjects showed a slight increase in BMI after practising yoga which is unexplained. This may partly be due to dietary habits like co-incidental intake of more calorogenic food during the period of yoga practice or other confounding factors like stress due to some reasons during the period of study etc., whose history was not taken at the beginning of the study.

Many studies<sup>16,17,19,20</sup> reported a decrease in fasting plasma glucose with yoga practice. A similar observation was found in our study. The mean blood glucose values after yoga practice were 130.4 mg/dL and 174.6 mg/dL in group I and group II respectively. The mean decrease in fasting blood glucose was 16.1% in group I and 14.7% in group II. This suggests that there was more decrease in younger population than in the older. Since the subjects in group II were older and were diabetic for more duration than the other group, they must have been in a relatively catabolic phase and much pathological changes must have occurred compared to the other group. Hence in this group, there is a need to practice yoga for more duration to reduce the blood glucose further towards normal. We also found a reduction in glycosylated hemoglobin levels after yoga practice as with other similar studies<sup>20, 21</sup>. The post yoga therapy HbA1c levels in group I and group II respectively were 6.9 gm% and 8.7 gm% with a corresponding reduction of 10.9% and 9.8% respectively. Since glycosylated hemoglobin is an indicator of the control of blood glucose in past three months, these values suggest a better control with yoga practice. However, since the mean blood glucose values were much higher in group II (174.6 mg/dL) the corresponding HbA1c values were also higher. But, the decrease in HbA1c and blood glucose suggests a positive effect of yoga practice. One individual in group II did not show any change in fasting plasma glucose after practising yoga. In three subjects in group II and two subjects in group I HbA1c remained unchanged even after practising yoga. This may be secondary to stress or dietary inconsistencies which were not considered in our study.

We found a significant decrease in total cholesterol, LDL- cholesterol and triglycerides and a significant increase in HDL- cholesterol in both the study groups after yoga practice. Similar findings were also reported in other studies<sup>16,20,21,22</sup>. The pre and post yoga practice values of cholesterol, triglycerides, HDL- cholesterol and LDL-cholesterol were higher in group II as compared to group I. This may be because of much pathological changes that must have occurred in the elderly. The higher values of HDL- cholesterol in the elderly- pre and post yoga practice may be because of higher serum total cholesterol as compared to the younger group. Cross sectional studies<sup>23</sup> on the age related HDL values show higher values in the elderly group compared to the younger counterparts while longitudinal studies show a decrease in HDL with age<sup>24</sup>. Hence, it can be confirmed that HDL decreases with age; but however, the values would be high in the elderly at a given point of time in the community because the elderly must have lived in a better environment and had better dietary habits during their life time than the young. The same was seen even in our study. Ten subjects in group I and three subjects in group II did not show decrease in total cholesterol after yoga practice and twenty six subjects in group I and seven subjects in group II did not show increase in HDL. In these cases HDL: cholesterol ratio measurement should be a significant factor to show improvement in lipid profile status of those individuals. However since in this study we are interested in cardiac autonomic function, HDL: cholesterol ratio was not discussed here. Also two subjects in group I and seven subjects in group II showed a decrease in HDL with yoga practice. This may be secondary to a decrease in serum total cholesterol. Such decrease in HDL with total cholesterol is also seen when statins are given.

We found a significant decrease in resting SBP, DBP and resting HR in both the groups with yoga practice. Similar findings were reported in other studies. B.K. Sahay<sup>25</sup> reported that BP changes due to meditation are mainly dependent on peripheral resistance. BP may not change acutely during meditation. It leads to an improvement in the vagal tone, as shown by a decrease in the voluntary control over heart beat. Researchers reported that the parasympathetic tone is expressed in terms of decrease in HR, SBP and DBP after yoga practice<sup>26</sup>.

Bhargava et.al,<sup>27</sup> reported that pranayamic breathing decreases baseline HR and BP by improving vagal tone and by decreasing sympathetic discharge. In the present study, there is a significant decrease in basal HR after hundred days of practicing yoga. This indicates that the yoga practice improves vagal activity. Probably the above reasons are the cause for changes in resting SBP, DBP and HR values.

We also found a significant improvement in parasympathetic function in both the groups after yoga practice represented by an increase in DBD, PTI and VR. We also found a significant decrease in sympathetic discharge in both the groups after yoga practice which was indicated by a significant fall in SBP and rise in DBP. Telles. S<sup>28</sup> reported that pranayamic type of slow breathing increases oxygen consumption that improves autonomic functions. Studies<sup>29</sup> reported that during and after valsalva maneuver, changes in the cardiac vagal efferent and sympathetic vasomotor activity occur, resulting from stimulation of carotid sinus and aortic arch baroreceptors and other intra thoracic stretch receptors. Previous studies also<sup>29</sup> reported that slow breathing exercises reduce chemo reflex response to both hypoxia and hypercapnia but increase baroreflex sensitivity. Studies reported<sup>26</sup> changes in autonomic nervous system during 'yoga', and reported that vagal tone increases and sympathetic tone decreases after yoga practice. In the present study, the immediate rise in HR in response to standing is achieved at lower beat. The maximum fall in HR and stabilization of HR in less time in response to standing indicate an improvement in autonomic functions. Probably the above reasons are the cause for changes in autonomic functions in the present study. We found a significant decrease in CAN score in both the groups with yoga therapy indicating an improvement in Cardiac Autonomic Function as was found in similar other studies. The score depends on improvement of the autonomic functions, thereby, the higher score indicates abnormality and the lesser score indicates the recovery and improvement in autonomic functions.

Thus from the observations it can be concluded that yoga therapy is beneficial and can be used as an adjunct to reduce the complications of Diabetes mellitus in conjunction with allopathy and the effects are better pronounced when yoga therapy is started at an earlier age than at an older age by which time comparatively more pathological changes must have taken place.

Previous studies did not attempt to show how early yoga therapy should be started to reduce the complications of diabetes while such an attempt was made in our study by splitting the study population into two groups which differed significantly in their mean ages. In Malhotra study<sup>20</sup>, the age of the subjects ranged from 30- 60 years as was in our study. However, in their study, though an improvement in cardiac function was shown with yoga practice, the authors did not split the study population age wise, while the same was made in our study. However since the prevalence of diabetes is much less in adolescents and younger population and more in middle and old age groups we have considered the subjects between 30 and 60 years only. We did not stratify the subjects based on the duration of exposure to diabetes which was a limitation of our study. We also did not take the dietary history of the patients involved in the study and hence we could not explain the exact cause for why there was no decrease in glucose and cholesterol and increase in HDL in few cases though an assumption was made why such values must have obtained. We also did not study, due to financial constraints, the activities of enzymes involved in carbohydrate and lipid metabolism like lipoprotein lipase, hormone sensitive lipase, hepatic lipase, LCAT, and antioxidants whose moderations due to yoga therapy were proposed to have caused an improvement in these subjects. Peripheral resistance and corrected QT interval was also not included in the study.

Future prospects for similar such studies include finding the age at which yoga practice should be started to prevent the complications of diabetes (the subjects of this study already had complications), the age at which yoga practice should be started and duration of practice to prevent the onset of diabetes, the role of yoga practice in postponing or preventing diabetes and its complications in subjects with genetic predisposition to diabetes and its risk factors and plausible mechanisms by which yoga acts. Studying the mechanism by which life style management and yoga practice alter or moderate the enzymes of lipid metabolism in subjects with or without a genetic component would give a better insight for the physicians and yoga teachers to create awareness of the beneficial effects of yoga practice among the public.

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