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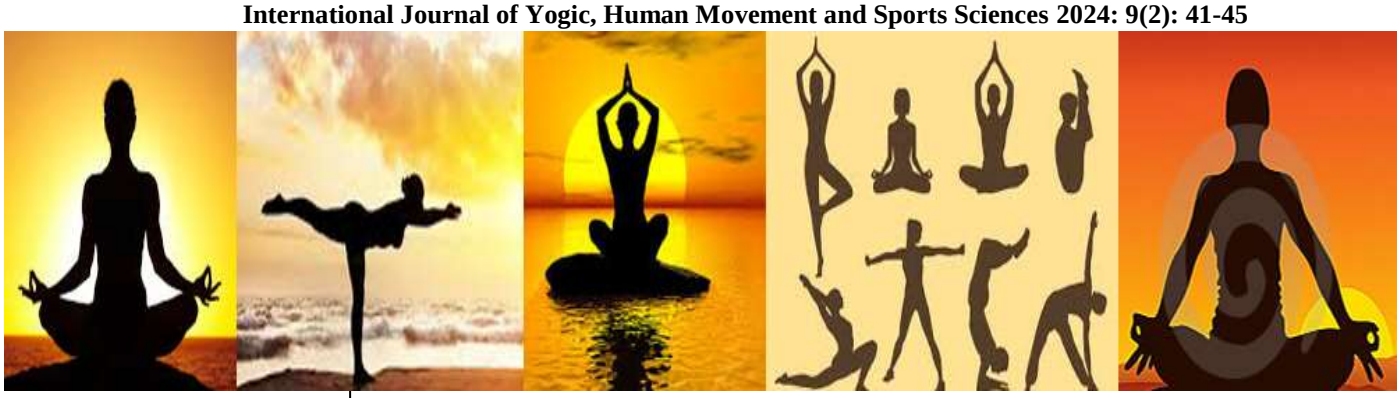

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Impact of yoga on glucose reduction: A pilot study

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Abstract
Background: In the rising burden of type 2 diabetes mellitus (T2DM) cases in India, there is a crucial need for an effective, low-cost, sustainable intervention controlling diabetes and preventing complications. *Yoga* is now considered complementary to self-management of many stress-related disorders like diabetes, coronary artery disease (CAD), etc. *Yoga* practices benefit adults with type 2 diabetes (T2DM) in this background the study was conducted to observe changes in serum glucose levels, Body Mass Index (BMI), waist circumference, and Diabetes Symptom Questionnaire (DSQ).
Methods: This study aimed to introduce and validate the *Yoga* module in diabetic patients to *Yoga*. An abridged version, "*Yoga* Capsule" (YC) which comprehends *Asana's* and *Pranayama*'s that are effective on diabetes was drafted with revisions subsequently made in consultation with renounced experts.
A pilot study (n = 30) was conducted to evaluate the role of *Yoga* Capsule (YC) as an add-on in reducing serum glucose levels in type 2 diabetes to assess HbA1c, changes in Body Mass Index (BMI), waist circumference, and Diabetic Symptoms Questionnaire (DSQ)**:** At baseline and the end of 84 days.
Results: As mentioned, the YC was designed to introduce *Yoga* to known diabetics who are not into exercise or *Yoga*. There was a significant decrease (<0.01) in PPBS, BMI, weight, and DSQ from baseline to the end of the trial. The other variables FBS, HbA1c, and waist circumference didn't change significantly.
Conclusion: In this study, 15 minutes of *Yoga* practice for 3 months showed changes in PPBS, BMI, weight, and DSQ variables, hence it can be concluded that *Yoga* practice helps prevent the onset of diabetes and its complications.

Keywords: Yoga capsule, diabetes, yoga, asana, pranayama

Introduction
Diabetes is a result of interaction between environmental and genetic factors. These factors include Physical activity and habitual energy intake expenditure. Diabetes is a chronic disease that occurs when the pancreas fails to produce the right quantity of insulin or when the body refuses to utilize the insulin produced [1]. It is one of the non-communicable diseases with a high mortality rate. Diabetes manifests in different forms *viz*. Type-1 Diabetes (Insulin Dependent Diabetes Mellitus or IDDM), Type 2 Diabetes (Non-Insulin Dependent Diabetes Mellitus or NIDDM), and Gestational Diabetes (Diabetes in Pregnancy). Chronic hyperglycemia in diabetes is associated with long-term damage and failure of various organs, especially the eyes, kidneys, nerves, heart, and blood vessels leading to various complications such as Diabetic retinopathy, Diabetic neuropathy, Diabetic cardiomyopathy, Diabetic vasculopathy, etc.
A healthy diet, engaging in regular physical activity (PA), maintaining a normal BMI range, and avoiding sedentary habits aids in treating and preventing the consequences of diabetes [1]. *Yoga* not only helps in preventing the onset of diabetes but also prevents its complications.
The benefits of *Yoga* in managing T2DM have been well established Yoga, rooted in antiquity, serves as a holistic practice aimed at fostering harmony and vitality across the physical, mental, emotional, and spiritual realms of one's being. *Yoga*'s primary emphasis is on gaining general well-being through integration, often incorporating three major components: held or sequences of physical postures, breathing exercises, and meditation. *Yoga* is about connecting the mind, body, and spirit [3]. A recent systematic review has also documented the considerable potential advantages of incorporating yoga interventions in the management of Type 2 Diabetes Mellitus (T2DM) [4]. Collectively, findings suggest that yogic practices may promote

significant improvements in several indices of T2DM management, including glycaemic control, lipid levels, body composition, and overall quality of life of diabetes patients [5, 6].

Table 1: anatomical effects of various yoga postures and breathing techniques

Yoga	**Anatomical effect**
Preparatory posture for *Yoga*	Calms down the mind and prepares the Individual to practice *Yoga*.
Hands in & out breathing (*Shithilikarana*)	Improves body flexibility.
Neck movements (*Greeva shakti vikasaka*)	Improves body flexibility.
Ankle stretch breathing (*Tadasana*)	It stretches the whole body and improves muscle strength.
Triangle pose (*Trikonasana*) [7]	Improves blood circulation. [7]
Half wheel posture (Ardha Chakras*ana*)	Exerts a stimulating and energizing effect
Standing forward bend (*Padahastasana*)	Massages and pressurizes the pancreas, stimulating insulin secretion.
Seated forward bend (*Paschimottasana*) [7]	Massages and pressurizes the pancreas, stimulating insulin secretion [7]
Half spinal twist pose/ diamond pose (*Vakrasana*) [7]	Squeeze the contents to prevent obstruction of colonic contents and improve the peristaltic movements of the intestine.
Frog Pose (*Mandukasana*)	Massages and pressurizes the pancreas, stimulating insulin secretion.
Cobra pose (*Bhujangasana*) [7]	Stimulates insulin secretion [7]
Crocodile pose (*Makarasana*) [7]	Improves blood circulation to the abdominal organs [7]
Alternate nostril breathing (*Nadishodana Pranayama*)	Augment cerebral blood flow and oxygenation improvising neuronal activities in the brain centres, including those present in limbic areas, and the hypothalamus, and improvises sympathicovagal outflow. Improves components of health-related fitness i.e., cardio-pulmonary endurance, flexibility, and body fat percentage [8]
Humming bee breath (*Bhramari Pranayama*) [7]	Soothing and calming effect on the mind, improves mental and physical health [8]
Nadaanusandana [9]	Stabilizes the brain, removes negative thoughts, increases energy, and improves mind and body relaxation within minutes of practice [9]

The present study aims to monitor the serum glucose levels in diabetes patients who are on stable anti -hypoglycaemic agents by introducing *Yoga* Capsule (YC). It encompasses different *Asana* and *Pranayama* which are effective in diabetes. (Table 1).

An evidence-based review is needed to recommend the use of adjuvant therapies. Hence the *Yoga* capsule was designed to introduce *Yoga* to known diabetes who are not physically active and observe the changes in their serum glucose levels.

Methodology

After obtaining the written informed consent, the patient underwent a detailed screening including medical history (disease and drug), physical examination, and laboratory investigations like FBS, PPBS, HbA1c and, Hemogram. Eligible subjects were enrolled considering the inclusion criteria into 2 groups. In group A, the patients were made to practice 15 min *Yoga* according to YC (Table 2) twice daily as an additional intervention to the conventional treatment for 84 days regularly and monitored in the institute's *Yoga* hall or any online platform (if the patient was unwilling to attend the classes). In group B enrolled patients continued with the conventional treatment protocol. The patient was assessed for the Diabetes Symptoms Questionnaire ((DSQ) [10] at baseline, 28 days, 56 days, and 84 days. Necessary investigations like FBS, PPBS, HbA1c and, Hemogram were carried out before and after the intervention. Compliance with the protocol was measured on every visit. Adverse events (if any) were documented and necessary measures were taken for its management

Inclusion Criteria: Subjects of all gender categories, falling between 18-60 years, freshly diagnosed or known diabetics, with HbA1c of 5.7-9% (both values inclusive) on oral medication, individuals physically fit to practice *Yoga* protocol and who agreed to participate in the study and submit a written informed consent form were included.

Exclusion Criteria

Subjects diagnosed with type 1 Diabetes and haemoglobin percentage < 8 g/dl, with uncontrolled hypertension (with or without medication systolic >140 and/or diastolic >90 mmHg after 10 minutes of rest), established diagnosis of CAD or any other clinically significant cardiovascular disease and uncontrolled acute Pulmonary Dysfunction requiring inhalation or systemic steroids, pregnant / Lactating women, female subject of child bearing potential who do not agree to remain abstinent or use medically acceptable methods of contraception during the study therapy, Individual who has undergone major surgical interventions specifically abdominal surgeries in the past 2 years, on systemic or oral steroids, oral contraceptive pills or Oestrogen Replacement Therapy, current diagnosis of malignancy or in the last five years, suffering from major systemic illness necessitating long-term drug treatment (defined as more than 3 months), those who are not able to practice the *Yoga* protocol or any other condition that the Investigator thinks may jeopardize the safety of the subject were excluded from the study.

Table 2: Yoga practice routine with postures, breathing techniques, and meditation

1.	Preparatory posture for *Yoga*
2.	Neck movements – front and back, side bending, side twisting, Rotation-clockwise and anticlockwise. Each 3 rounds
3.	Hands in and out breathing – 5 rounds.
***Asana* (each *Asana* for 10s-30s)**	
4.	Ankle stretch Breathing (*Tadasana*)
5.	Triangle pose (*Trikonasana*)
6.	Half wheel posture (*Ardha chakrasana*)
7.	Standing forward bend (*Padahastasana*)
8.	Seated forward bend (*Paschimotanasana*)
9.	Half spinal twist pose/ Diamond pose (*Vakrasana*)
10.	Frog pose (*Mandukasana*)
11.	Cobra pose (*Bhujangasana*)
12.	Crocodile pose (*Makarasana*)
***Pranayama* (each 5 rounds)**	
13.	Alternate nostril breathing (*Nadishodana Pranayama*)
14.	Humming Bee breath (*Bhramari Pranayama*)
15.	*Nadaanusandana*
16.	Meditation and prayer

Details of *yoga* intervention

The *Yoga* training program was performed with keen supervision as per the protocol. No serious adverse effect was reported by the subjects. A total of 45 individuals were screened. Among them, 30 were enrolled, as per the inclusion criteria. The selected individuals were randomly allocated to either Group A (YC/*Yoga* module as an add-on to treatment) or Group B (treatment as it is/Control Group). One patient dropped out because of her ill health and four cases were withdrawn as one underwent emergency surgery, two lost contact and one could not be complainant to the study. (Figure 1).

The *Yoga* intervention was administered to Group A with treatment as it is. Experimental Group A engaged in a 3-month i.e., 84-day program, *Yoga Capsule* (YC) was practiced 15 min twice a day with general instruction, *YC* included Loosening exercises, *Asana's*- standing, sitting, prone postures, *Pranayama*, Meditation, and prayer.

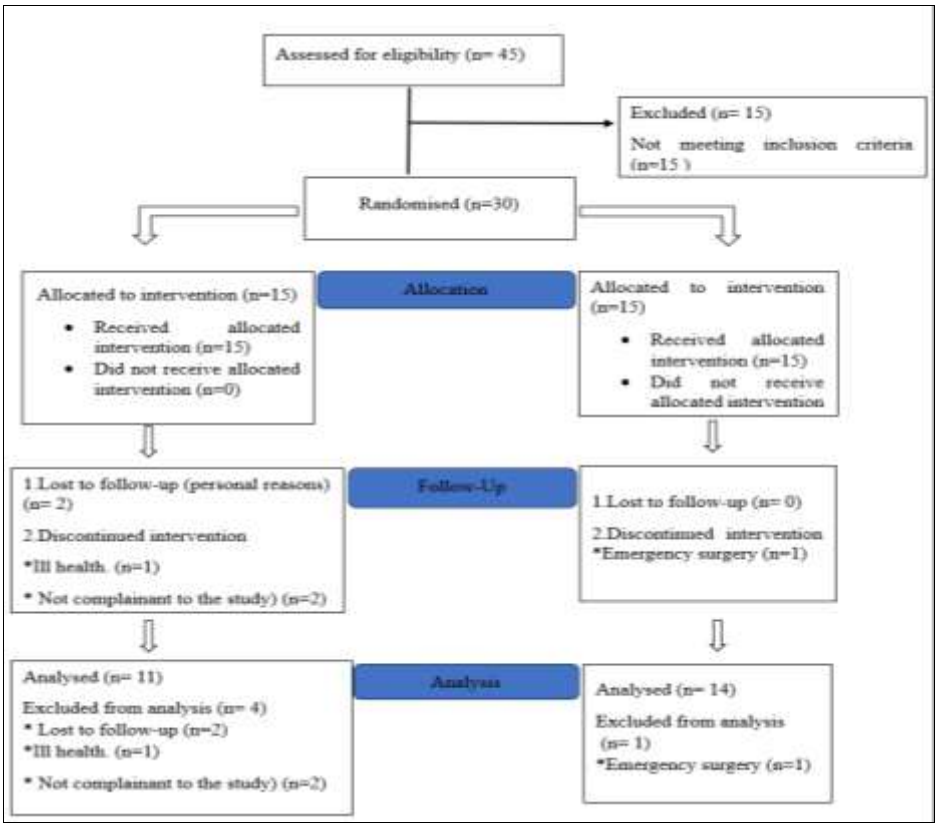

Fig 1: CONSORT Flow Diagram

Statistical Analysis

All analyses were conducted using Stata/SE 18.0 software. Results were reported as percentages, means, and standard deviations (SD). The difference in means before and after *Yoga* training within the group was assessed using a paired Student t-test. A p-value of less than 0.01 was considered statistically significant.

Results

The demographic characteristics, including age, height, weight, BMI, and baseline biochemical parameters, were comparable between both groups. The age range of participants was 26-56 years and the mean age of the participants in the treatment group was 45.18 (SD 9.7) years with 54.5% male and 45.6% female participants. The control

group consisted of 71.43% men and 28.6% women, with a mean age of 46.9 (SD 6.6) years (Table 3). The mean HbA1c of the *Yoga* group was 7.1±1.10, the mean FBS was 140.5 mg/dl (SD 36.53), and the mean PPBS was 188.3 mg/dl (SD 59.8).

Table 3: Effect of '*Yoga* capsule'

Variables	Baseline mean ± SD	After 3 months mean ± SD	Mean difference	t value	P value
Weight					
Yoga Group	64.8± 5.92	63.8± 5.57	-0.98	-1.58	0.14
Control Group	72.1± 13.8	73.21±13.69	1.135	0.906	0.38
Waist circumference (cm)					
Yoga Group	88.8± 5.2	89.9± 4.6	1.21	1.14	0.28
Control Group	88.4± 6.9	88.8± 6.35	0.457	0.704	0.49
BMI, Kg/m^2					
Yoga Group	25.6± 2.7	25.24±2.63	-0.381	-1.603	0.14
Control Group	25.3± 4.3	25.83±6.35	0.558	0.966	0.35
HB					
Yoga Group	13.61± 1.63	13.68± 1.51	0.0636	0.3209	0.75
Control Group	14.42± 1.31	14.57± 1. 26	0.15	1.0919	0.29
HbA1c (%)					
Yoga Group	7.1± 1.24	7.34± 1.45	0.247	1.902	0.08
Control Group	7.31± 1.03	7.55± 0.92	0.238	0.715	0.48
FBS, mg/dl					
Yoga Group	140.5± 42.2	142.62± 27.3	2.09	0.2309	0.82
Control Group	140.2± 33.1	141.65± 28.8	1.46	0.142	0.88
PPBS, mg/dl					
Yoga Group	188.3±59.8	187.7± 74.7	-1.3	-0.050	0.96
Control Group	237.2± 73.8	259.7± 66.7	22.58	0.993	0.33
DSQ					
Yoga Group	8.27± 3.8	3.63± 2.8	-4.63	-4.04	0.0023**
Control Group	8.78±8.7	4.92± 4.90	-3.85	-3.40	0.004**

*SD-Standard Deviation, BMI- Body Mass Index, HB- Haemoglobin, FBS- Fasting Blood Sugar, PPBS- Post Prandial Blood Sugar, DSQ-Diabetic Symptom Questioner, **<0.01

The treatment group exhibited a marginal reduction in weight and BMI relative to their initial/baseline measurements. The analysis of each group's baseline and end-line biochemical variables (Table 4) unveiled a decrease in PPBS from 188.3±59.8 mg/dl to 187.7± 74.7 mg/dl in the intervention group. Conversely, the control group experienced a 10% elevation in PPBS from baseline. FBS increased by only 1% in the *Yoga* group with a nonsignificant disparity between groups. There was a highly significant decrease (p<0.01) in the mean values of diabetic symptom scores in both groups after three months of *Yoga* practice compared to before. Notably, the control group exhibited no notable alterations in any variables after three months compared to baseline values.

Table 4: Baseline characteristics of the participants in the intervention and control group

Characteristics	*Yoga* Group N = 11	Control group N = 14
Age (years)	45.18±9.75	46.9±6.63
Gender		
Male, n (%)	6(54.55)	10(71.43)
Female, n (%)	5(45.45)	4(28.57)
Weight (kg)	64.8± 5.92	72.1±13.8
Height (cm)	159.3±8.4	168.7±9.8
Waist circumference (cm)	88.8± 5.2	88.4±6.9
BMI, Kg/m^2	25.6± 2.7	25.3±4.3
Hb(g/dl)	13.61± 1.63	14.4±1.3
HbA$_1$c (%)	7.1±1.24	7.31±1.03
FBS (mg/dl)	140.5±42.2	140.2±33.1
PPBS (mg/dl)	188.3±59.8	237.2±73.8

*BMI- Body Mass Index, Hb- Haemoglobin, HbA$_1$c- Glycated hemoglobin, FBS- Fasting Blood Sugar, PPBS- Post Prandial Blood Sugar

Discussion

The present study aimed to introduce *Yoga* to diabetic patients who don't engage in *Yoga/exercise* and to know the effect of *Yoga* on serum blood sugar in the elderly for 3 months. The selected *Yoga* practices can have a positive impact on the health parameters of diabetic adults specifically post-prandial blood sugar (PPBS) levels, weight, body mass index (BMI), and diabetic symptomatic changes. The observed reduction in PPBS levels and other changes suggests that individuals who were not practicing *Yoga* later observed a good improvement with 15-minute *Yoga* practices twice daily. Previous Studies Have Incorporated Comparable Asanas [11]. Similarly, a significant decrease in FBS and PPBS after *Yoga* practice has been demonstrated in T2DM patients on oral hypoglycaemic agents (OHA) [12]. The holistic nature of *Yoga*, compounding many physical postures, breathing exercises, and meditation contributes synergistically to the observed benefits thereby contributing in regulating hormonal levels, boosting circulation, reducing stress from the body while stimulating metabolism, and also progresses the health of a diabetic patient in both physiological and psychological aspects. (Table 2). These findings support the importance of *Yoga*'s therapeutic potential and emphasize the importance of lifestyle interventions in managing diabetes. Practicing *Yoga* regularly helps maintain, and prevent complications of diabetes and is also an accessible means for individuals to maintain their health and well-being [13].

To fully appreciate the scope of this study, it's important to recognize various factors such as time constraints, maintaining work-life balance, and the sustainability of *Yoga* practice. Moving forward, there's an exciting opportunity for

further research to delve deeper into the scientific mechanisms behind *Yoga*'s positive impacts. Exploring aspects like frequency, duration, and the diverse range of *Yoga* practices promises to enrich our understanding and maximize its potential benefits.

Conclusion

The *Yoga* intervention (YC) proved effective in yielding clinical improvements among the enrolled subjects but did not significantly impact glycaemic control. Further investigations with increased duration and sustained *Yoga* practice, involving a larger sample size may yield better results.

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