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# Effect of Yoga on Arterial Stiffness, Serum HSP70, and Cardiovascular Risk Markers in Patients with Type 2 Diabetes Mellitus: A Prospective Controlled Study

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**Abstract:**Background: Type 2 diabetes mellitus (T2DM) is associated with accelerated cardiovascular remodeling, increased arterial stiffness, and altered expression of heat shock protein 70 (HSP70), contributing to increased cardiovascular morbidity. Yoga has emerged as a complementary lifestyle intervention with potential cardiometabolic benefits; however, evidence regarding its effect on arterial stiffness and HSP70 remains limited.Objective: To evaluate the effect of a 12-week yoga intervention on arterial stiffness, serum HSP70, glycaemic control, and hemodynamic parameters in patients with T2DM.Methods: This prospective comparative study included 116 patients with T2DM allocated to a yoga intervention group (n=58) and a control group (n=58). The intervention group underwent supervised yoga sessions (40–45 minutes/day, 5 days/week) for 12 weeks in addition to standard medical care, while controls received standard care alone. Baseline and post-intervention assessments included fasting blood sugar (FBS), postprandial blood sugar (PPBS), HbA1c, blood pressure, heart rate, pulse pressure, mean arterial pressure, brachial–ankle pulse wave velocity (ba-PWV), carotid–femoral pulse wave velocity (cf-PWV), arterial stiffness index (ASI), and serum HSP70.Results: Compared with controls, the yoga group demonstrated significant reductions in serum HSP70 (mean change 18.03±7.92 vs. 2.51±0.95 pg/mL; $p<0.001$), HbA1c ($p=0.008$), systolic blood pressure ($p<0.001$), heart rate ($p=0.002$), pulse pressure ($p=0.004$), and mean arterial pressure ($p=0.011$). Significant improvements were also observed in ba-PWV ($p<0.001$), cf-PWV ($p<0.001$), and ankle arterial stiffness index ($p=0.006$), indicating reduced arterial stiffness following yoga intervention.Conclusion: A structured 12-week yoga program significantly improved glycaemic control, cardiovascular hemodynamics, arterial stiffness, and serum HSP70 levels in patients with T2DM. These findings support the incorporation of yoga as a safe and effective adjunctive therapy for reducing cardiovascular risk in diabetes management.
Keywords:Type 2 diabetes mellitus; Yoga; Heat shock protein 70; Arterial stiffness; Pulse wave velocity; Cardiovascular remodeling; Glycaemic control.

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## Introduction

Type 2 diabetes mellitus (T2DM) is one of the leading noncommunicable diseases worldwide and remains a major cause of cardiovascular morbidity and premature mortality. Persistent hyperglycaemia promotes endothelial dysfunction, oxidative stress, chronic low grade inflammation, and vascular remodeling, which accelerate arterial stiffness and increase the risk of myocardial infarction, stroke, and heart failure. Cardiovascular disease accounts for nearly two thirds of deaths among individuals with T2DM, highlighting the need for interventions that improve both metabolic control and vascular health simultaneously[1,2].

The global burden of diabetes has increased substantially over the past two decades. According to the International Diabetes Federation (IDF) Diabetes Atlas 2025, approximately 589 million adults aged 20 to 79 years are living with diabetes worldwide, and this figure is projected to exceed 850 million by 2050 if current trends continue. India has one of the largest populations of individuals with T2DM. The Indian Council of Medical Research, India Diabetes (ICMR INDIAB) study estimates that more than 101 million adults have diabetes, while an additional 136 million have prediabetes[3,4]. Since cardiovascular complications remain the leading cause of disability and mortality in this population, identifying interventions that preserve vascular function has become a clinical priority.

Arterial stiffness, commonly assessed by pulse wave velocity (PWV) and related stiffness indices, is a well established marker of early vascular damage and an independent predictor of cardiovascular events in patients with diabetes. Chronic hyperglycaemia promotes the formation of advanced glycation end products, collagen cross linking, endothelial dysfunction, and vascular inflammation, resulting in progressive loss of arterial elasticity even before clinically evident cardiovascular disease develops. Heat Shock Protein 70 (HSP70), a stress inducible molecular chaperone, has received increasing attention because of its cytoprotective, anti inflammatory, and anti apoptotic properties. Altered circulating HSP70 concentrations have been associated with insulin resistance, oxidative stress, endothelial dysfunction, and cardiovascular remodeling in individuals with T2DM, suggesting its potential value as a biomarker of vascular health and disease progression[5,6].

Lifestyle modification remains a cornerstone of T2DM management, and yoga has emerged as a promising complementary intervention. Yoga integrates physical postures, breathing techniques, and meditation, offering benefits that extend beyond glycaemic control. Previous randomized controlled trials and systematic reviews have shown that regular yoga practice improves fasting blood glucose, glycated haemoglobin (HbA1c), blood pressure, autonomic function, lipid profile, and quality of life in individuals with T2DM. Despite these findings, most studies have focused primarily on metabolic outcomes, while relatively few have examined the effects of yoga on objective measures of vascular function such as arterial stiffness or on molecular biomarkers including HSP70. Consequently, the mechanisms through which yoga influences cardiovascular risk in diabetes remain incompletely understood[7].

Therefore, the present prospective comparative study was undertaken to evaluate the effects of a structured 12 week yoga intervention on arterial stiffness, cardiovascular haemodynamic parameters, glycaemic control, and circulating HSP70 levels in patients with T2DM. By combining functional vascular assessment with molecular biomarker analysis, this study aims to provide mechanistic evidence supporting yoga as an adjunctive nonpharmacological strategy for reducing cardiovascular risk and improving vascular health in individuals with T2DM.

## Aim and objectives

### Aim

To evaluate the effect of a 12-week yoga intervention on arterial stiffness, serum Heat Shock Protein-70 (HSP70), glycaemic control, and cardiovascular hemodynamic parameters in patients with Type 2 Diabetes Mellitus.

### Objectives

**Primary Objective**

- To determine the effect of a 12-week yoga intervention on arterial stiffness parameters (brachial–ankle pulse wave velocity, carotid–femoral pulse wave velocity, and arterial stiffness indices) and serum HSP70 levels in patients with Type 2 Diabetes Mellitus.

**Secondary Objective**

- To evaluate the effect of yoga on glycaemic parameters (fasting blood glucose, postprandial blood glucose, and HbA1c) and cardiovascular hemodynamic parameters (heart rate, systolic blood pressure, diastolic blood pressure, pulse pressure, and mean arterial pressure) compared with standard medical care in patients with Type 2 Diabetes Mellitus.

## Materials and methods

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**Study design and setting**
This prospective comparative interventional study was conducted in the Departments of Physiology and General Medicine at BLDE (Deemed to be University), Shri B. M. Patil Medical College, Hospital and Research Centre, Vijayapura, Karnataka, India. The study was carried out after obtaining approval from the Institutional Ethics Committee, and all procedures were performed in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants before enrolment.

**Study participants**
Adult patients with established type 2 diabetes mellitus attending the outpatient departments were screened for eligibility. A total of 116 participants fulfilling the eligibility criteria were enrolled and allocated into two equal groups: a yoga intervention group (n = 58) and a control group (n = 58). The study evaluated the effect of a structured yoga intervention on cardiovascular remodeling assessed by arterial stiffness parameters and serum Heat Shock Protein-70 (HSP70) levels over a period of 12 weeks.

**Inclusion criteria**
Participants were eligible if they:

- were diagnosed with type 2 diabetes mellitus,
- were aged between 40 and 60 years,
- were receiving stable antidiabetic treatment,
- were willing to participate in supervised yoga sessions, and
- provided written informed consent.

**Exclusion criteria**
Participants were excluded if they had:

- type 1 diabetes mellitus,
- pregnancy,
- severe diabetic complications,
- established cardiovascular diseases likely to influence arterial stiffness,
- chronic inflammatory or autoimmune disorders,
- severe musculoskeletal disorders limiting yoga practice,
- psychiatric illness,
- active infection,
- malignancy, or
- previous regular yoga practice during the preceding six months.

**Baseline assessment**
After enrolment, demographic and clinical characteristics including age, sex, duration of diabetes, anthropometric measurements, and relevant medical history were recorded using a structured case record form. Baseline biochemical and cardiovascular assessments were performed before initiation of the intervention.

**Yoga intervention**
Participants allocated to the intervention group underwent a supervised structured yoga programme for **12 consecutive weeks**, consisting of **40–45 minute sessions**, **five days per week**, under the supervision of a qualified yoga instructor. The programme incorporated physical postures (asanas), breathing exercises (pranayama), meditation, and relaxation techniques.
Each session consisted of:

- Opening prayer (1 minute)
- Yogic Sukshma Vyayama (microcirculation exercises; 8 minutes)
- Yogic Sthula Vyayama (gross body exercises; 3 minutes)
- Surya Namaskar (3 rounds; approximately 5 minutes)
- Yogasanas (15 minutes), including standing, sitting, prone, and supine postures such as Tadasana, Trikonasana, Katichakrasana, Vakrasana, Ushtrasana, Sasankasana, Bhujangasana, Dhanurasana, Makarasana, Pavanamuktasana, Matsyasana, Sarvangasana/Viparitakarani, and Shavasana
- Optional Kapalabhati (10–20 strokes)
- Pranayama without breath retention (6 minutes), including Anulom-Vilom (Nadi Shodhana), Ujjayi, and Bhramari
- Meditation (5 minutes)
- Shanti Mantra (1 minute)

Participants attended supervised morning sessions and were periodically counselled regarding compliance and adherence throughout the intervention period.

**Control group**
Participants in the control group continued their routine medical management prescribed by their treating physician without yoga intervention. They were advised to maintain their usual lifestyle and avoid initiating any new structured exercise programme during the study period. Following completion of the study, participants in the control group received counselling regarding the benefits of yoga and were encouraged to practice it voluntarily.

**Outcome measurements**
Outcome assessments were performed at baseline and after completion of the 12-week intervention. The yoga group also underwent an intermediate assessment at six weeks for monitoring purposes; however, the primary comparative analysis was based on baseline and 12-week measurements.

**Glycaemic parameters**
Venous blood samples were collected after overnight fasting for estimation of fasting blood glucose and glycated haemoglobin (HbA1c). Postprandial blood glucose was measured two hours after a standard meal. Standard laboratory procedures were followed for biochemical analysis.

**Hemodynamic assessment**
Resting heart rate, systolic blood pressure, and diastolic blood pressure were recorded after at least five minutes of seated rest using a calibrated automated sphygmomanometer. Pulse pressure was calculated as the difference between systolic and diastolic blood pressure, while mean arterial pressure was calculated using the standard formula:

**Mean arterial pressure = Diastolic blood pressure + 1/3 (Systolic blood pressure − Diastolic blood pressure).**

**Assessment of arterial stiffness**
Arterial stiffness was assessed using a validated Periscope® device under standardized laboratory conditions. Participants were examined in the supine position after an adequate resting period. The following indices were recorded:

- Brachial–ankle pulse wave velocity (baPWV)
- Carotid–femoral pulse wave velocity (cfPWV)
- Brachial arterial stiffness index (ASI)
- Ankle arterial stiffness index (ASI)

Pulse wave velocity was calculated automatically by the instrument using pressure waveforms obtained simultaneously from upper and lower limbs. The carotid–femoral pulse wave velocity was considered the primary indicator of central arterial stiffness, while brachial–ankle pulse wave velocity reflected both central and peripheral arterial stiffness.

**Serum HSP70 estimation**
Approximately 5 mL of venous blood was collected under aseptic precautions. Samples were centrifuged at 3000 rpm, and serum was separated and stored at **−80°C** until analysis. Serum HSP70 concentrations were quantified using a commercially available Human HSP70 enzyme-linked immunosorbent assay (ELISA) kit according to the manufacturer's protocol. Optical density was measured using a microplate reader, and HSP70 concentrations were calculated from the standard calibration curve. Laboratory personnel performing the assay were unaware of participants' group allocation.

**Outcome measures**
The primary outcomes were changes in serum HSP70 concentration and arterial stiffness parameters following 12 weeks of yoga intervention.
Secondary outcomes included changes in:

- fasting blood glucose,
- postprandial blood glucose,
- HbA1c,
- heart rate,
- systolic blood pressure,
- diastolic blood pressure,
- pulse pressure, and
- mean arterial pressure.

**Statistical analysis**
Data were entered into Microsoft Excel and analysed using Statistical Package for the Social Sciences (SPSS) software (IBM SPSS Statistics, Version 26.0; IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages.

Baseline characteristics between groups were compared using the independent Student's *t*-test for continuous variables and the chi-square test for categorical variables. Within-group comparisons between baseline and post-intervention values were performed using the paired *t*-test. Between-group comparisons after the intervention were analysed using the independent Student's *t*-test. All statistical tests were two-tailed, and a $p$ value $<0.05$ was considered statistically significant.

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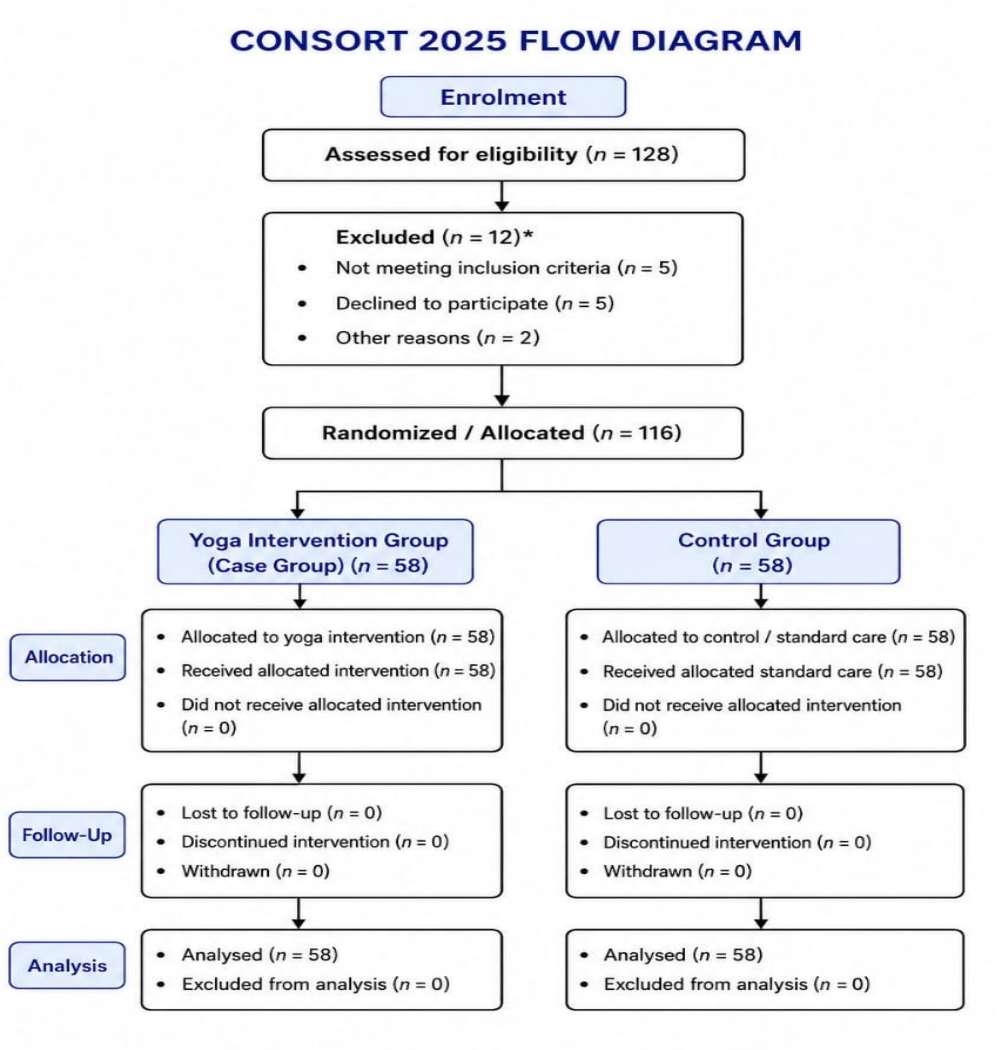


**CONSORT 2025 FLOW DIAGRAM**

**Results**

**Table 1. Baseline Characteristics of Study Participants**

| Variable | Yoga (n=58) | Control (n=58) | p-value |
|---|---|---|---|
| Age (years), Mean ± SD | 48.97 ± 5.84 | 49.69 ± 6.22 | 0.519 |
| Age 40–50 years, n (%) | 37 (63.8) | 33 (56.9) | 0.569 |
| Age 51–60 years, n (%) | 21 (36.2) | 25 (43.1) | |
| Male, n (%) | 25 (43.1) | 31 (53.4) | 0.353 |
| Female, n (%) | 33 (56.9) | 27 (46.6) | |
| Duration of diabetes (years), Mean ± SD | 5.93 ± 2.95 | 4.67 ± 2.61 | 0.017 |

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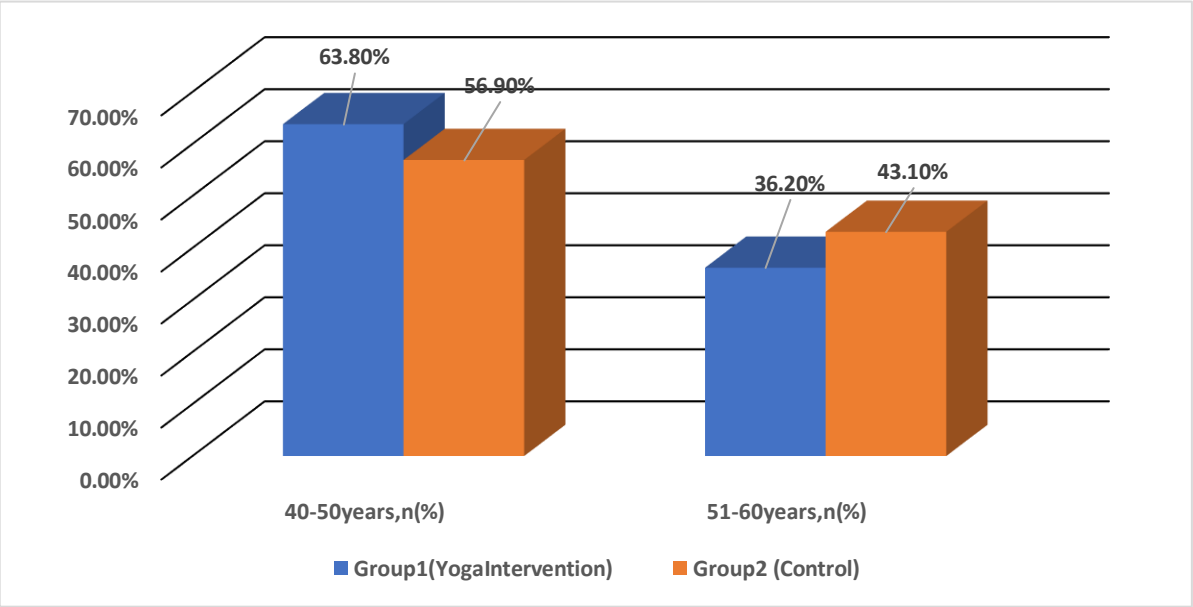
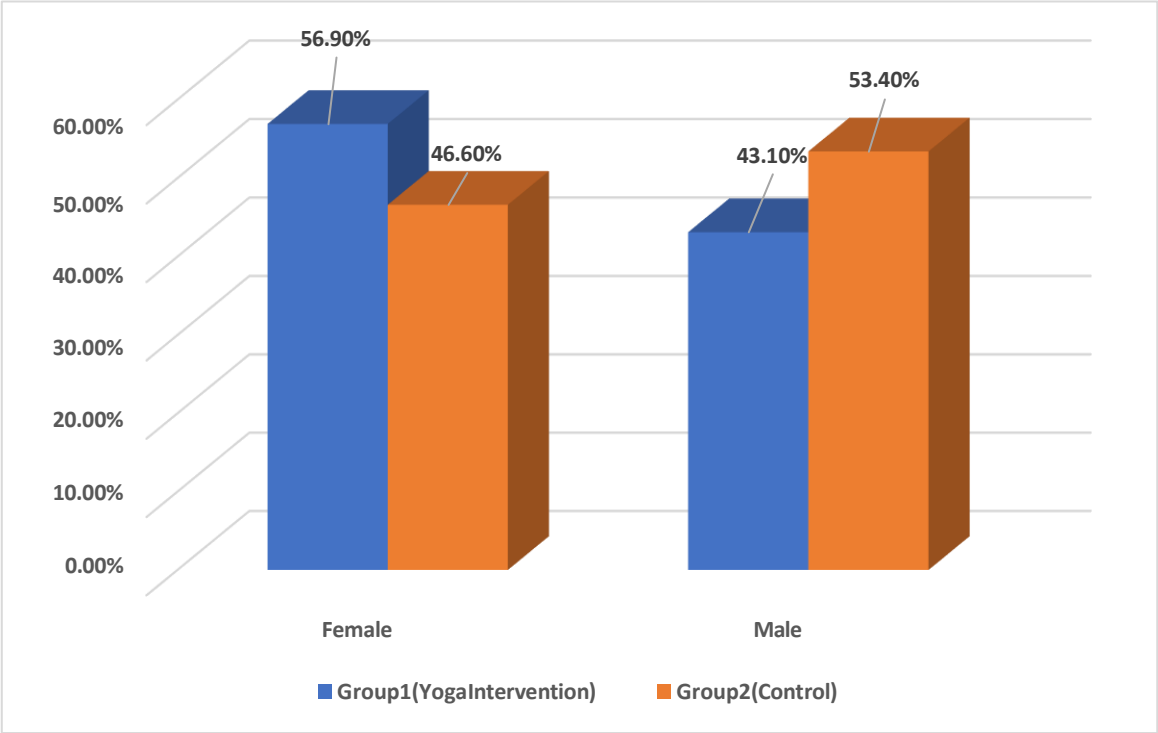
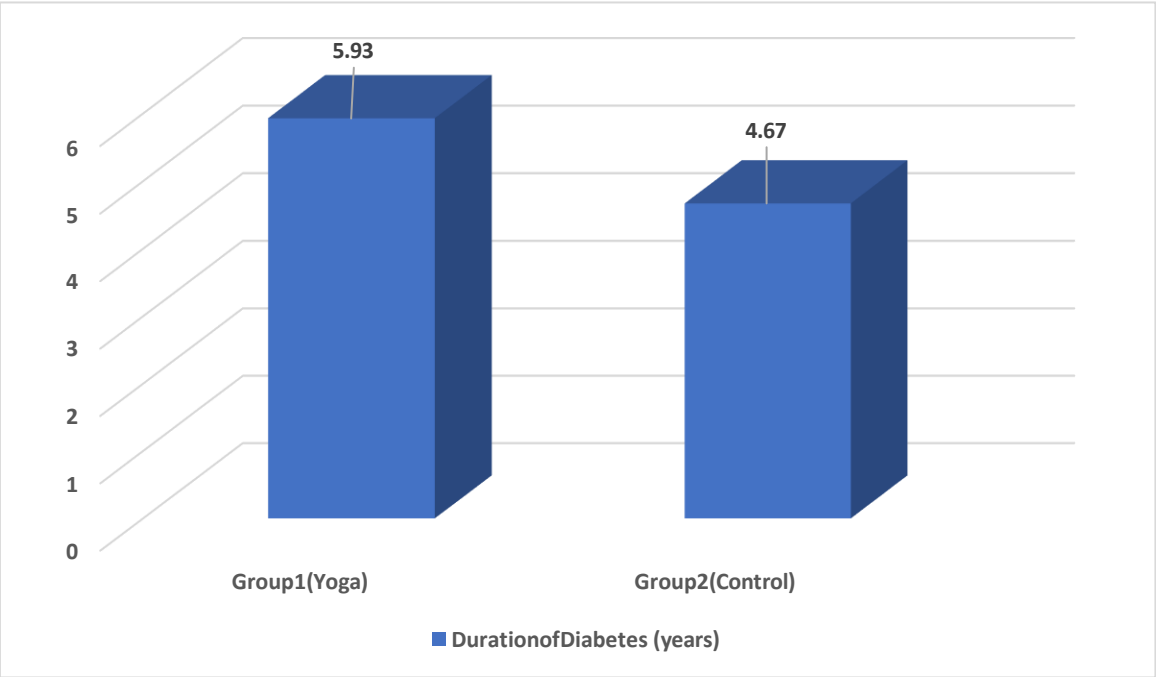



**Graph1:Age Distribution**




**Graph2:GenderDistribution**




**Graph3:Durationof Diabetes**

**Table 2. Comparison of Glycaemic Parameters Between Yoga and Control Groups**

| Parameter | Yoga (n=58) Baseline | Control (n=58) Baseline | Baseline p-value | Yoga (12 weeks) | Control (12 weeks) | Post-intervention p-value |
|---|---|---|---|---|---|---|
| Fasting Blood Sugar (mg/dL) | 158.72 ± 13.56 | 156.71 ± 15.56 | 0.461 | 152.35 ± 13.28 | 156.97 ± 16.07 | 0.094 |
| Postprandial Blood Sugar (mg/dL) | 215.47 ± 19.98 | 211.90 ± 21.22 | 0.353 | 207.76 ± 19.43 | 214.00 ± 21.84 | 0.107 |
| HbA1c (%) | 8.48 ± 0.58 | 8.58 ± 0.58 | 0.383 | 8.28 ± 0.56 | 8.57 ± 0.60 | 0.008 |

**Table 3. Comparison of Hemodynamic Parameters Between Yoga and Control Groups**

| Parameter | Yoga Baseline | Control Baseline | Baseline p-value | Yoga (12 weeks) | Control (12 weeks) | Post-intervention p-value |
|---|---|---|---|---|---|---|
| Heart Rate (bpm) | 84.10 ± 5.74 | 86.02 ± 5.58 | 0.071 | 82.41 ± 5.77 | 85.78 ± 5.55 | 0.002 |
| SBP (mmHg) | 135.97 ± 5.64 | 135.45 ± 5.12 | 0.606 | 131.78 ± 5.58 | 135.97 ± 5.20 | <0.001 |
| DBP (mmHg) | 87.76 ± 4.77 | 86.60 ± 4.03 | 0.162 | 86.03 ± 4.87 | 86.47 ± 4.01 | 0.604 |
| Pulse Pressure (mmHg) | 48.21 ± 6.70 | 48.84 ± 6.64 | 0.608 | 45.74 ± 6.87 | 49.50 ± 6.78 | 0.004 |
| Mean Arterial Pressure (mmHg) | 103.83 ± 3.98 | 102.89 ± 3.11 | 0.158 | 101.28 ± 3.96 | 102.97 ± 3.08 | 0.011 |

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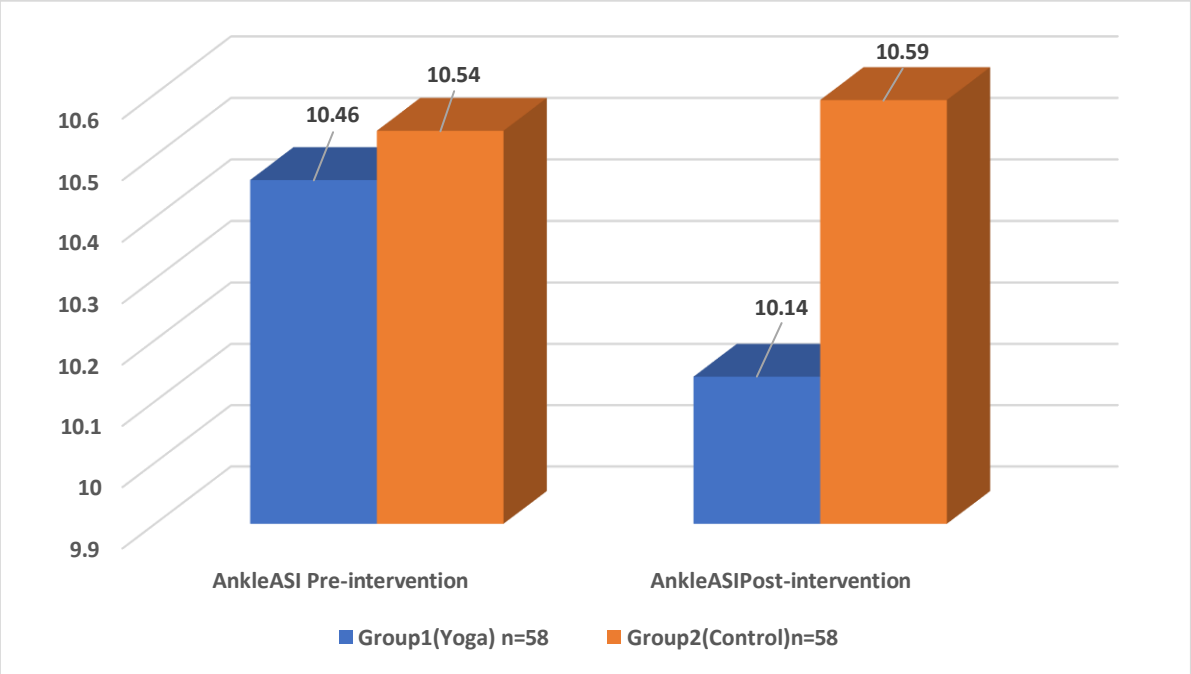
**Table 4. Comparison of Arterial Stiffness Parameters Between Yoga and Control Groups**

| Parameter | Yoga Baseline | Control Baseline | Baseline p-value | Yoga (12 weeks) | Control (12 weeks) | Post-intervention p-value |
|---|---|---|---|---|---|---|
| Brachial–Ankle PWV (m/s) | 15.82 ± 1.20 | 15.96 ± 1.16 | 0.519 | 15.24 ± 1.20 | 16.07 ± 1.16 | <0.001 |
| Carotid–Femoral PWV (m/s) | 11.31 ± 0.85 | 11.49 ± 0.85 | 0.254 | 10.97 ± 0.85 | 11.55 ± 0.87 | <0.001 |
| Brachial ASI | 9.58 ± 0.79 | 9.54 ± 0.91 | 0.812 | 9.37 ± 0.79 | 9.50 ± 0.89 | 0.346 |
| Ankle ASI | 10.46 ± 0.82 | 10.54 ± 0.87 | 0.623 | 10.14 ± 0.83 | 10.59 ± 0.89 | 0.006 |




**Graph 4:AnkleArterialStiffnessIndex (ASI)**

**Table 5. Effect of Yoga on HSP70 Levels**

| Parameter | Yoga (n=58) | Control (n=58) | p-value |
|---|---|---|---|
| HSP70 Baseline (pg/mL) | 109.28 ± 41.57 | 102.71 ± 39.38 | 0.383 |
| HSP70 at 12 weeks (pg/mL) | 91.25 ± 41.77 | 100.20 ± 37.43 | 0.230 |
| Change in HSP70 (pg/mL) | 18.03 ± 7.92 | 2.51 ± 0.95 | <0.001 |

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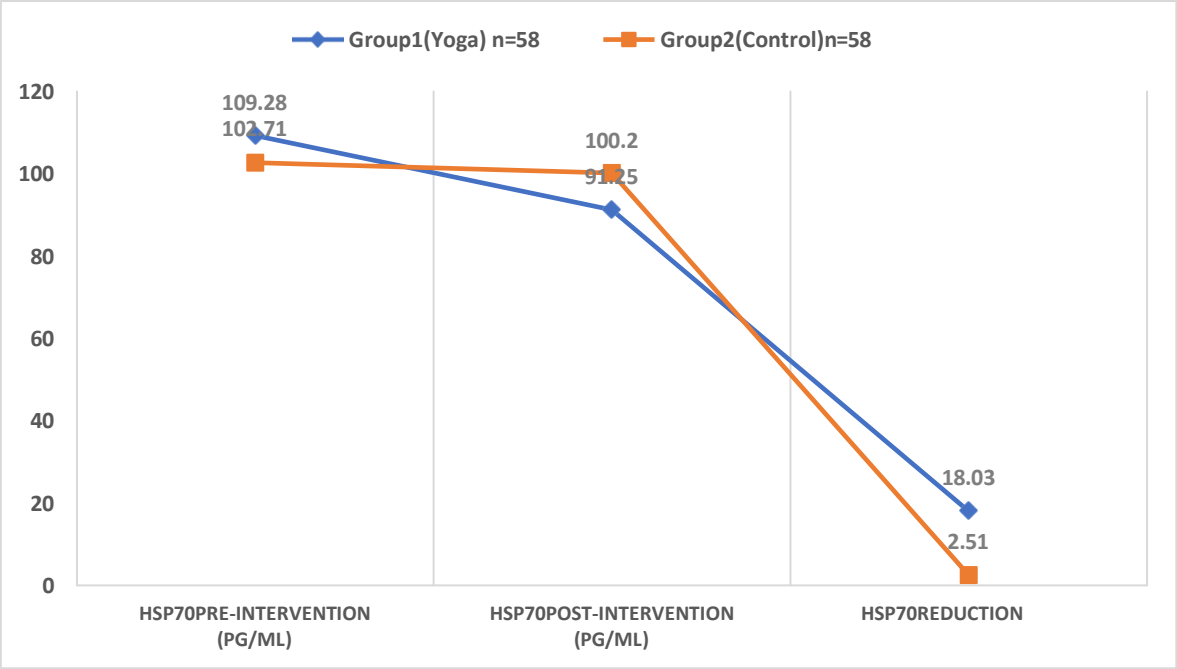


**Graph 5:Molecularparameters-HSP70 ANALYSIS**

**Discussion**

The present prospective comparative study evaluated the effects of a structured 12 week yoga intervention on glycaemic control, haemodynamic parameters, arterial stiffness, and serum Heat Shock Protein 70 (HSP70) levels in patients with type 2 diabetes mellitus (T2DM). Baseline demographic and clinical characteristics, including age, sex distribution, body mass index, and duration of diabetes, were comparable between the yoga and control groups, indicating appropriate group matching and reducing the likelihood of confounding. Comparable baseline characteristics have also been reported by Gordon et al., supporting the validity of post intervention comparisons in studies evaluating yoga among individuals with T2DM[8].

The present study demonstrated a significant reduction in glycated haemoglobin (HbA1c) following 12 weeks of yoga practice, whereas fasting blood glucose and postprandial blood glucose showed modest but statistically non significant reductions compared with the control group. HbA1c reflects average glycaemic control over the preceding two to three months and is therefore considered a more reliable indicator of sustained metabolic improvement than single blood glucose measurements. The observed reduction suggests that regular yoga contributes to improved long term glycaemic regulation through multiple physiological mechanisms. These findings are consistent with those of Hegde et al., who reported significant reductions in HbA1c after a three month yoga programme in patients with T2DM[9]. Similarly, Singh et al. demonstrated that integrated yoga therapy improved glycaemic control by enhancing insulin sensitivity, reducing sympathetic nervous system activity, increasing skeletal muscle glucose uptake, and improving pancreatic beta cell function[10]. The relatively modest changes in fasting and postprandial glucose observed in the present study may reflect differences in baseline glycaemic status, concomitant pharmacological treatment, dietary adherence, and the limited duration of the intervention.

Significant improvements were also observed in cardiovascular haemodynamic parameters. Participants in the yoga group exhibited reductions in resting heart rate, systolic blood pressure, pulse pressure, and mean arterial pressure, whereas diastolic blood pressure remained unchanged. These findings indicate improved autonomic regulation and reduced cardiovascular workload. The reduction in resting heart rate is likely attributable to enhanced parasympathetic activity and suppression of sympathetic overactivity induced by regular yoga practice. Cohen et al. similarly reported significant reductions in systolic blood pressure and heart rate following yoga interventions, which they attributed to improved autonomic balance and decreased stress related neuroendocrine activation[11]. Wolff et al. also demonstrated clinically meaningful reductions in blood pressure among adults with metabolic disorders after structured yoga practice[12]. The absence of a significant reduction in diastolic blood pressure in the present study may be explained by relatively normal baseline diastolic values and the greater responsiveness of systolic arterial function to lifestyle modification.

One of the major strengths of the present investigation is the comprehensive evaluation of arterial stiffness. Significant reductions in brachial

ankle pulse wave velocity, carotid femoral pulse wave velocity, and ankle arterial stiffness index were observed after the yoga intervention, indicating improved vascular compliance and reduced arterial stiffness. Increased arterial stiffness is an established predictor of cardiovascular morbidity and mortality in patients with diabetes because it reflects progressive endothelial dysfunction, collagen deposition, vascular inflammation, and loss of arterial elasticity. Improvement in pulse wave velocity suggests restoration of vascular function and reduced cardiovascular risk. Similar findings were reported by Patil et al., who demonstrated reductions in pulse wave velocity following yoga training through enhanced endothelial nitric oxide bioavailability and reduced vascular sympathetic tone[13]. Ross and Thomas also reported improvements in vascular function and arterial elasticity following regular yoga practice, suggesting reductions in oxidative stress and chronic inflammation as key underlying mechanisms[14]. The absence of a statistically significant improvement in the brachial arterial stiffness index may indicate that peripheral muscular arteries respond less rapidly than central elastic arteries during short term interventions.

The most distinctive finding of the present study was the significant reduction in circulating serum HSP70 levels following yoga intervention. Heat Shock Protein 70 is an important molecular chaperone involved in maintaining protein homeostasis during cellular stress. Elevated circulating HSP70 concentrations have been associated with oxidative stress, chronic inflammation, endothelial dysfunction, insulin resistance, and cardiovascular remodeling in individuals with T2DM. Therefore, the observed reduction in serum HSP70 may reflect attenuation of cellular stress responses and improved vascular homeostasis. These findings agree with those of Rodrigues Krause et al., who demonstrated favourable modulation of heat shock proteins after structured exercise interventions in individuals with metabolic disorders[15]. Garg also reported reductions in inflammatory mediators and oxidative stress biomarkers following yoga practice, suggesting improved cellular adaptation to chronic metabolic stress[16]. The decline in HSP70 observed in the present study is likely mediated through improved autonomic balance, reduced cortisol secretion, enhanced antioxidant defence, improved mitochondrial function, and suppression of chronic inflammatory pathways.

Collectively, the findings of the present study demonstrate that yoga improves cardiovascular health at multiple levels, including metabolic regulation, haemodynamic function, vascular compliance, and molecular stress responses. While previous studies have primarily focused on glycaemic control or blood pressure, the present investigation simultaneously evaluated arterial stiffness and circulating HSP70, providing a broader understanding of the cardiovascular benefits of yoga in T2DM. These findings support the integration of yoga into routine diabetes management as a safe, low cost, and evidence based complementary intervention for reducing cardiovascular risk and improving overall vascular health.

**Limitations of the Study**

The present study has several limitations that should be considered while interpreting the findings.

First, the intervention period was limited to 12 weeks. Although significant improvements were observed in glycaemic control, haemodynamic parameters, arterial stiffness, and serum HSP70 levels, longer follow up is required to determine whether these benefits are sustained over time and whether they translate into reductions in major cardiovascular events.

Second, this was a single centre study involving a relatively small sample of 116 participants. Consequently, the findings may not be fully generalizable to the broader population of individuals with T2DM, particularly those from different ethnic, geographical, and socioeconomic backgrounds.

Third, molecular assessment was limited to serum HSP70. Additional biomarkers related to inflammation, oxidative stress, endothelial dysfunction, and vascular remodeling, including high sensitivity C reactive protein, interleukin 6, tumour necrosis factor alpha, nitric oxide metabolites, advanced glycation end products, and oxidative stress markers, were not evaluated. Inclusion of these biomarkers would have provided a more comprehensive understanding of the biological mechanisms responsible for the cardiovascular benefits of yoga.

**Conclusion**

The present prospective comparative study demonstrates that a structured 12 week yoga programme, when practiced alongside standard medical therapy, significantly improves cardiovascular health in patients with type 2 diabetes mellitus. Yoga produced significant reductions in HbA1c, resting heart rate, systolic blood pressure, pulse pressure, mean arterial pressure, brachial ankle pulse wave velocity, carotid femoral pulse wave velocity, ankle arterial stiffness index, and circulating serum HSP70

levels. These findings indicate favourable effects on long term glycaemic control, vascular function, haemodynamic regulation, arterial elasticity, and cellular stress responses.

The beneficial effects of yoga appear to be mediated through multiple complementary mechanisms, including improved autonomic balance, enhanced endothelial function, reduced arterial stiffness, attenuation of oxidative stress, suppression of chronic inflammation, and modulation of molecular pathways involved in cardiovascular remodeling. By simultaneously improving metabolic and vascular health, yoga addresses key mechanisms responsible for the increased cardiovascular risk associated with T2DM.

Given its safety, affordability, ease of implementation, and absence of significant adverse effects, yoga represents an effective complementary non pharmacological strategy for reducing cardiovascular risk and improving overall cardiovascular health in individuals with T2DM. Future multicentre randomized controlled trials with larger sample sizes, longer follow up, and comprehensive molecular profiling are warranted to confirm these findings and further establish yoga as an integral component of evidence based diabetes management.

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