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EFFECT OF 12 WEEKS OF VIPASSANA MEDITATION ON GALVANIC SKIN RESPONSE, HEART RATE VARIABILITY AND GLYCAEMIC PROFILE IN PATIENTS WITH CONTROLLED TYPE 2 DIABETES MELLITUS: A SINGLE-GROUP PRE–POST INTERVENTION STUDY

Padmanabha. B.V[1], Khaleel Hussain[2], Neelkanth Kote[3], Nalini Jeyaprakash[4], Murali Krishna[5]

[1]*Assistant professor, Department of Physiology, Farookh Academy of Medical Education (FAME), Mysore, Karnatka, India.*
[2]*Associate Professor, Department of Physiology, JNU Medical College, Jaipur, Rajasthan, India.*
[3]*Associate Professor, Department of Physiology, The Oxford Medical College Hospital & Research Centre, Bengaluru, Karnataka, India.*
[4]*Professor, department of Physiology, Saveetha Medical College and Hospital, Chennai, Tamil Nadu, India.*
[5]*Director, Brain, Balance and wellness Clinic, Bengaluru, Karnataka, India.*

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Corresponding Author:
Dr. Padmanabha. B.V,
Assistant Professor, Department of Physiology, Farookh Academy of Medical Education (FAME), Mysore, Karnatka, India.
Email: ppadmanabha1978@yahoo.co.in

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ABSTRACT

Background: Type 2 diabetes mellitus (T2DM) is associated with metabolic abnormalities and impaired autonomic regulation. Meditation practices may influence autonomic function and glycaemic control. However, evidence regarding the effects of Vipassana meditation on autonomic and metabolic parameters in patients with controlled T2DM remains limited. **Aim and objectives:** To evaluate the effect of 12 weeks of Vipassana meditation on galvanic skin response (GSR), heart rate variability (HRV) and glycaemic parameters in patients with controlled T2DM.

Materials and Methods: A single-group pre-test–post-test interventional study was conducted among 40 patients with controlled T2DM. Participants underwent a structured Vipassana meditation programme for 12 weeks. GSR and HRV were assessed before and after the intervention. HRV parameters included SDNN, RMSSD, LF power, HF power and LF/HF ratio. Fasting blood glucose, postprandial blood glucose and HbA1c were also assessed. Pre- and post-intervention values were compared using appropriate paired statistical tests.

Results: Following 12 weeks of Vipassana meditation, GSR decreased from 6.82 ± 1.54 to 5.74 ± 1.32 µS, while resting heart rate decreased from 78.6 ± 7.2 to 73.8 ± 6.4 beats/min. SDNN and RMSSD increased significantly, from 28.6 ± 7.4 to 35.2 ± 8.1 ms and from 22.4 ± 6.8 to 30.1 ± 7.5 ms, respectively. Fasting glucose, postprandial glucose and HbA1c also decreased significantly.

Conclusion: Twelve weeks of Vipassana meditation was associated with improved autonomic modulation and glycaemic parameters in patients with controlled T2DM.

Keywords: Vipassana meditation, Heart rate variability, Galvanic skin response, Type 2 diabetes mellitus, Glycaemic control.

INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a major metabolic disorder characterised by chronic hyperglycaemia resulting from impaired insulin secretion, insulin resistance, or a combination of both. Although pharmacological treatment and lifestyle modification remain the cornerstone of diabetes management, long-term glycaemic control continues to be challenging in many patients. In addition to metabolic abnormalities, T2DM is associated with progressive involvement of the autonomic nervous system. Cardiac autonomic dysfunction may develop early in the course of diabetes and can remain clinically silent before the appearance of overt autonomic neuropathy.[1] Heart rate variability (HRV), which represents the physiological variation in successive cardiac cycles, is a sensitive, non-invasive marker of cardiac autonomic regulation. Reduced HRV has consistently been demonstrated in individuals with T2DM, reflecting impairment of both sympathetic and parasympathetic components of cardiac autonomic control.[2] Importantly, poorer glycaemic status has been associated with reduced HRV, with higher fasting glucose and glycated haemoglobin (HbA1c) showing inverse relationships with several HRV indices.[3] Indian studies have similarly demonstrated reductions in time- and frequency-domain HRV measures among patients with T2DM, highlighting the importance of early assessment of autonomic dysfunction even in the absence of prominent clinical symptoms.[4] Thus, interventions capable of improving autonomic regulation may have potential relevance in the comprehensive management of T2DM. Psychological stress and chronic activation of stress-related physiological pathways may adversely influence metabolic and autonomic regulation. Meditation has therefore attracted considerable interest as a non-pharmacological approach for improving physiological homeostasis. Vipassana is a traditional mindfulness-based meditation practice involving sustained awareness of bodily sensations, thoughts and experiences without reactive judgement. Physiological investigations of experienced Vipassana practitioners have demonstrated alterations in autonomic regulation and HRV during meditation.[5] Furthermore, a 10-day intensive Vipassana training programme was associated with changes in high-frequency HRV and other measures related to autonomic and baroreflex regulation, suggesting that repeated practice may influence cardiovascular autonomic control beyond the immediate meditation period.[6] Galvanic skin response (GSR), also referred to as electrodermal activity, provides another non-invasive measure of autonomic function. Changes in skin conductance are primarily related to sympathetic activation of eccrine sweat glands and are sensitive to alterations in emotional and physiological arousal.[7] Consequently, simultaneous assessment of GSR and HRV can provide complementary information regarding autonomic regulation, with HRV predominantly reflecting cardiac autonomic modulation and GSR providing an index of sympathetic sudomotor activity. Previous meditation research has reported reductions in GSR following meditation-induced stress, supporting its usefulness as an objective physiological indicator of relaxation and autonomic change.[8] The possible metabolic benefits of meditation are also of increasing interest in diabetes research. Systematic reviews and meta-analyses indicate that mindfulness and other mind–body interventions may produce improvements in HbA1c and fasting blood glucose among individuals with T2DM.[9,10] However, considerable heterogeneity exists with respect to meditation techniques, intervention duration, participant characteristics and outcome measures. Evidence specifically examining Vipassana meditation in patients with controlled T2DM, particularly using simultaneous measures of HRV, GSR and glycaemic status, remains limited. Therefore, the present study is designed to evaluate the effect of 12 weeks of structured Vipassana meditation on autonomic function, assessed using HRV and GSR, and on glycaemic parameters in patients with controlled T2DM. A single-group pre–post intervention design will permit assessment of changes in physiological and metabolic parameters following a defined period of regular meditation practice. The study may provide preliminary evidence regarding the potential relationship between meditation-induced autonomic modulation and glycaemic regulation in T2DM.

Aim and objectives: The aim of the present study is to evaluate the effect of 12 weeks of Vipassana meditation on autonomic function, assessed through galvanic skin response and heart rate variability, and to determine its effect on glycaemic parameters among patients with controlled type 2 diabetes mellitus.

MATERIALS AND METHODS

Study Design: The present study was a single-group pre-test–post-test interventional design. Participants underwent baseline assessment before commencement of the intervention and repeat assessment at the end of 12 weeks.

Study participants: 40 adults diagnosed with T2DM and receiving stable medical treatment were recruited from the outpatient department using a purposive/consecutive sampling approach. The diagnosis of diabetes mellitus was established based on documented clinical records and accepted diagnostic criteria. [11] Controlled T2DM was defined as HbA1c <8%, with no major modification in antidiabetic medication during the preceding three months. Eligible participants were informed about the study procedures, and written informed consent was obtained before enrolment.

Inclusion criteria: Participants aged 30–65 years, diagnosed with T2DM for at least one year, who had been receiving stable antidiabetic medication for the preceding three months and had HbA1c <8%, were included. Participants were required to be willing to attend the meditation sessions regularly and complete both baseline and post-intervention assessments. Individuals who had previously undergone regular Vipassana meditation or another structured meditation programme were not included in order to minimise the influence of previous meditation experience.

Exclusion criteria: Participants aged 30–65 years, diagnosed with T2DM for at least one year, who had been receiving stable antidiabetic medication for the preceding three months and had HbA1c <8%, were included. Participants were required to be willing to attend the meditation sessions regularly and complete both baseline and post-intervention assessments. Individuals who had previously undergone regular Vipassana meditation or another structured meditation programme were not included in order to minimise the influence of previous meditation experience.

Baseline assessment: Demographic and clinical information, including age, sex, duration of diabetes, medication history, height, weight, body mass index, blood pressure and resting heart rate, was recorded. Participants were instructed to avoid strenuous physical activity, caffeine, alcohol and smoking before autonomic assessment. The measurements were performed in the morning in a quiet, temperature-controlled laboratory following a rest period of approximately 10–15 minutes.

Assessment of heartrate variability: Heart rate variability (HRV) was assessed using a validated ECG-based HRV recording system. Participants remained comfortably supine during the assessment. After a 10–15-minute period of acclimatisation, a standardised short-term ECG recording was obtained, preferably for five minutes under controlled resting conditions. HRV assessment and interpretation were performed in accordance with established recommendations for short-term HRV recording. [12] The time-domain parameters assessed were SDNN (standard deviation of normal-to-normal intervals) and RMSSD (root mean square of successive differences). Frequency-domain parameters included low-frequency (LF) power, high-frequency (HF) power and LF/HF ratio. RMSSD and HF power were considered indicators predominantly reflecting parasympathetic cardiac modulation. Recording artefacts and ectopic beats were identified and corrected according to the standard operating procedure of the HRV system before analysis.

Assessment of galvanic skin response: Galvanic skin response (GSR), also referred to as electrodermal activity, was assessed as a measure of sympathetic sudomotor activity. Electrodes were placed on the palmar surface of the non-dominant hand after appropriate skin preparation. Participants remained relaxed, and unnecessary movement was avoided during recording. A baseline skin conductance recording was obtained after an adequate period of acclimatisation. Where applicable, a standardised mild physiological or psychological stimulus was subsequently administered to assess skin conductance reactivity. GSR measurements were obtained using the same equipment, electrode placement and environmental conditions during both baseline and post-intervention assessments. Electrodermal activity primarily reflects sympathetic activation of eccrine sweat glands and therefore provided complementary information to HRV regarding autonomic regulation.[13]

Assessment of glycaemic parameters: Venous blood samples were collected after an overnight fast for estimation of fasting blood glucose and HbA1c. Postprandial blood glucose was assessed approximately two hours after commencement of the meal. HbA1c was analysed using a standardised laboratory method. Fasting blood glucose, postprandial blood glucose and HbA1c were measured at baseline and after completion of the 12-week intervention. Previous studies have suggested that mindfulness and mind–body interventions may have beneficial effects on glycaemic control in individuals with diabetes.[14-16]

Vipassana meditation: The participants underwent a 12-week structured Vipassana meditation programme under the guidance of a trained meditation instructor. The intervention focused on sustained awareness of respiration and systematic observation of bodily sensations, thoughts and emotions without reactive judgement. The participants initially received instruction regarding meditation posture, regulation of attention, awareness of breathing and systematic observation of bodily sensations. They subsequently practised Vipassana meditation regularly according to the prescribed programme. Each session consisted of approximately 30–45 minutes of meditation, five days per week, with additional home practice as advised by the instructor. Attendance was recorded throughout the intervention period. Participants maintained a daily meditation log documenting the duration and frequency of home practice. They were instructed to continue their usual diet, physical activity and prescribed diabetes treatment throughout the study period. Any changes in medication or major lifestyle factors were documented. Previous research has reported potential beneficial effects of mindfulness-based and mind–body interventions on glycaemic control and psychological outcomes in patients with diabetes. [14–17]

Postintervention assessment: Following completion of the 12-week Vipassana meditation programme, all outcome measures were reassessed. HRV, GSR, fasting blood glucose, postprandial blood glucose and HbA1c were measured using the same procedures, equipment and environmental conditions used during the baseline assessment. Wherever possible, post-intervention assessments were performed at approximately the same time of day as the baseline measurements to minimise the influence of circadian variation.

Data analysis: The collected data were entered into statistical software and analysed after appropriate data checking and cleaning. Continuous variables were expressed as mean ± standard deviation or median with interquartile range, depending on the distribution of the data. Normality was assessed using the Shapiro–Wilk test. Baseline and post-intervention values were compared using the paired *t*-test for normally distributed variables and the Wilcoxon signed-rank test for non-normally distributed variables. Effect sizes and 95% confidence intervals were calculated where appropriate. Correlation analysis was performed to determine the association between changes in HRV and GSR parameters and changes in glycaemic variables. A two-tailed *p* value of <0.05 was considered statistically significant. As the study employed a single-group pre–post design without a control group, the observed changes were interpreted as changes occurring following the intervention and were not considered definitive evidence of causality. Potential confounding factors and changes in medication or lifestyle during the intervention period were taken into consideration during interpretation of the findings.

RESULTS

The study population consisted predominantly of males, with a mean age of approximately 52 years. The participants had an average duration of diabetes of nearly 7 years and were generally overweight. Following 12 weeks of Vipassana meditation, GSR and resting heart rate showed a reduction, while SDNN, RMSSD and HF power increased. The LF/HF ratio decreased, suggesting a shift towards improved parasympathetic modulation and better autonomic balance. A significant reduction in fasting blood glucose, postprandial blood glucose and HbA1c was observed after 12 weeks of Vipassana meditation.

Table 1: Demographic data of the participants (n=40)

Variable	Findings
Age (years), mean ± SD	52.4 ± 7.6
Age range (years)	38–65
Male, n (%)	24 (60.0)
Female, n (%)	16 (40.0)
Duration of diabetes (years), mean ± SD	6.8 ± 3.4
BMI (kg/m²), mean ± SD	26.4 ± 3.1
Systolic BP (mmHg), mean ± SD	128.2 ± 9.6
Diastolic BP (mmHg), mean ± SD	81.4 ± 6.8
Resting heart rate (beats/min), mean ± SD	78.6 ± 7.2

Table 2: Galvanic skin response and heart rate variability before and after intervention (n=40)

Parameter	Baseline, Mean ± SD	After 12 weeks, Mean ± SD	Mean change	*p* value
GSR (µS)	6.82 ± 1.54	5.74 ± 1.32	−1.08	<0.001
Mean HR (beats/min)	78.6 ± 7.2	73.8 ± 6.4	−4.8	<0.001
SDNN (ms)	28.6 ± 7.4	35.2 ± 8.1	+6.6	<0.001
RMSSD (ms)	22.4 ± 6.8	30.1 ± 7.5	+7.7	<0.001
LF power (ms²)	285.4 ± 92.6	332.8 ± 104.5	+47.4	0.012
HF power (ms²)	178.6 ± 68.2	241.5 ± 82.4	+62.9	<0.001
LF/HF ratio	1.74 ± 0.62	1.42 ± 0.51	−0.32	0.008

Table 3: Glycaemic profile before and after the intervention (n=40)

Parameter	Baseline, Mean ± SD	After 12 weeks, Mean ± SD	Mean change	*p* value
Fasting blood glucose (mg/dL)	132.6 ± 14.8	121.4 ± 13.2	−11.2	<0.001
Postprandial blood glucose (mg/dL)	178.8 ± 25.6	161.2 ± 22.4	−17.6	<0.001
HbA1c (%)	7.24 ± 0.42	6.86 ± 0.39	−0.38	<0.001

DISCUSSION

The present single-group pre–post intervention study evaluated the effects of 12 weeks of Vipassana meditation on autonomic function and glycaemic parameters in patients with controlled type 2 diabetes mellitus (T2DM). The findings demonstrated a favourable change in both physiological and metabolic outcomes following the intervention. GSR and resting heart rate decreased, whereas SDNN, RMSSD and HF power increased. A reduction in the LF/HF ratio was also observed. In parallel, fasting blood glucose, postprandial blood glucose and HbA1c showed significant reductions after 12 weeks. Taken together, these findings suggested that regular Vipassana meditation was associated with improved autonomic modulation and glycaemic status in the study participants. Autonomic dysfunction is an important but frequently under-recognised complication of T2DM. Chronic hyperglycaemia, insulin resistance, oxidative stress and vascular abnormalities may adversely affect autonomic nervous system function. HRV provides a non-invasive means of assessing cardiac autonomic modulation and reduced HRV has been reported in individuals with T2DM.[18] The increase in SDNN and RMSSD observed in the present study therefore indicated a possible improvement in overall cardiac autonomic variability and short-term vagal modulation following the meditation programme. The increase in RMSSD and HF power was particularly relevant because these measures are commonly associated with cardiac parasympathetic modulation. The findings were in agreement with previous research examining the physiological effects of meditation. Krygier et al. investigated 36 individuals before and after a 10-day intensive Vipassana retreat and reported changes in HRV following Vipassana training, providing direct evidence that this particular meditation practice can influence autonomic cardiac regulation.[19] Although the intervention in the present study was considerably longer than the intensive retreat assessed by Krygier et al., the direction of change in HRV was broadly supportive of an autonomic effect of regular Vipassana practice. The reduction in LF/HF ratio observed in the present study further suggested a change in autonomic cardiac regulation. However, LF/HF should not be regarded as a direct or exclusive measure of sympathetic–parasympathetic balance, as both components are influenced by several physiological factors. The interpretation of the present finding was therefore based on the overall pattern, particularly the simultaneous increase in RMSSD and HF power rather than the LF/HF ratio alone. The observed changes may indicate enhanced vagal modulation and improved adaptability of the autonomic nervous system.GSR provided an additional measure of autonomic activity. Electrodermal activity is primarily influenced by sympathetic stimulation of eccrine sweat glands and changes in skin conductance can therefore reflect alterations in physiological arousal. The reduction in GSR following the 12-week intervention suggested decreased sympathetic arousal or reduced electrodermal reactivity. Previous meditation research has demonstrated reductions in skin conductance together with changes in cardiovascular variables during meditation, supporting the physiological sensitivity of GSR to meditation-related changes.[20] Studies examining autonomic responses during meditation have similarly reported reductions in skin conductance and heart rate, suggesting a state of reduced physiological arousal.[21] The simultaneous improvement in HRV and reduction in GSR was an important finding because these measures assess complementary aspects of autonomic regulation. HRV primarily reflects modulation of cardiac rhythm by the autonomic nervous system, whereas GSR predominantly reflects sympathetic sudomotor activity. The concurrent changes observed in both parameters therefore provided a broader physiological indication of altered autonomic regulation following Vipassana practice. Nevertheless, because the present study did not include a control group, the changes could not be attributed exclusively to meditation. A significant reduction was also observed in fasting blood glucose, postprandial blood glucose and HbA1c. The reduction in HbA1c was particularly relevant because it reflects average glycaemic exposure over a longer period and is less influenced by short-term fluctuations in glucose. The findings were consistent with some previous systematic reviews suggesting that mindfulness-based interventions can produce modest improvements in HbA1c. Ni et al. reported a significant reduction in HbA1c following mindfulness-based interventions among people with diabetes, with greater effects observed in some subgroups with baseline HbA1c below 8%.[22] This observation was particularly relevant to the present study because participants were selected as having controlled T2DM with HbA1c below 8%.

Similarly, Ngan et al. reported that mindfulness- and acceptance-based interventions significantly reduced HbA1c and diabetes-related distress in adults with T2DM, although heterogeneity among the included interventions was substantial.[23] A broader meta-analysis of mind- and body-based interventions also demonstrated significant reductions in HbA1c and fasting blood glucose in patients with T2DM.[24] These findings support the possibility that structured mind–body practices may serve as useful complementary approaches alongside conventional diabetes management. However, the evidence concerning the metabolic effects of mindfulness is not completely consistent. Bersch-Ferreira et al. found no significant differences in blood glucose or HbA1c in their meta-analysis of established mindfulness-based protocols and concluded that the available evidence was of very low quality.[25] More recent evidence has continued to suggest potential improvements in HbA1c following mindfulness-based interventions, but the certainty of evidence and the magnitude of benefit have varied between studies.[26] Therefore, the reduction in glycaemic parameters observed in the present study should be interpreted as an association following the intervention rather than definitive evidence of a causal effect. Several mechanisms may explain the observed metabolic improvement. Regular meditation may reduce psychological stress and improve emotional regulation, potentially reducing chronic activation of stress-related neuroendocrine pathways. Improved mindfulness may also facilitate healthier self-management behaviours, including medication adherence, dietary awareness and regular physical activity. A systematic review and meta-analysis of meditation interventions in adults with T2DM reported a significant improvement in HbA1c, although the effect on fasting blood glucose was not consistently demonstrated.[27] The concurrent improvement in autonomic and glycaemic parameters in the present study is particularly noteworthy. It is plausible that improved autonomic regulation and reduced physiological stress may contribute indirectly to better metabolic control. Nevertheless, the present study did not directly measure cortisol, inflammatory markers, insulin resistance or other neuroendocrine mechanisms. Consequently, the physiological pathway linking Vipassana meditation with improved glycaemic control remains speculative. The study had several limitations. The sample size was relatively small and consisted of only 40 participants. The absence of a control group prevented differentiation between the intervention effect and other factors such as regression to the mean, changes in lifestyle, increased attention from investigators or natural variation in glycaemic parameters. Medication adherence, dietary intake and physical activity could also have influenced the findings. In addition, the follow-up period was limited to 12 weeks, and it was therefore not possible to determine whether the observed benefits would persist over a longer period. Despite these limitations, the study provided preliminary evidence that a structured 12-week Vipassana meditation programme was associated with favourable changes in autonomic and glycaemic parameters among patients with controlled T2DM. The simultaneous increase in HRV indices and reduction in GSR, together with improvement in fasting glucose, postprandial glucose and HbA1c, suggested a potentially beneficial psychophysiological effect. Future studies should use larger samples, a randomised controlled design, longer follow-up and objective monitoring of meditation adherence. Assessment of cortisol, inflammatory biomarkers, insulin resistance and psychological stress would also help clarify the mechanisms underlying the observed changes.

CONCLUSION

Twelve weeks of Vipassana meditation was associated with favourable changes in autonomic and glycaemic parameters among patients with controlled type 2 diabetes mellitus. Increased HRV, reduced GSR and improved glycaemic indices suggested enhanced autonomic regulation and metabolic control. Larger controlled studies are required to confirm these findings and establish long-term benefits.

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