RESEARCH PAPER

Effects of a Comprehensive Lifestyle Medicine Intervention on Glycemic Control, Body Composition, Perceived Stress, and Sleep Quality Among Middle-Aged Women with Prediabetes and Type 2 Diabetes: A 12-Week Prospective Interventional Study

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ABSTRACT

Background: Lifestyle modification plays a pivotal role in the prevention and care of prediabetes and type 2 diabetes mellitus (T2DM). Many interventions, however, focus on diet and/or physical activity, with less focus on psychosocial stress, sleep quality, and autonomic regulation. In this study, a holistic 12-week lifestyle medicine program comprising nutritional therapy, resistance training, yoga, breathing exercises, vagal stimulation techniques, stress management, and sleep hygiene was evaluated in middle-aged women with prediabetes or T2DM.

Methods: The study was a prospective single-arm interventional study with 19 female patients aged 42 to 55 years who completed the 12-week lifestyle medicine program, after 6/25 patients withdrew due to poor adherence or incomplete follow-up. The intervention comprised a high-protein, low-glycemic diet; supervised resistance training three times per week; weekly yoga; daily diaphragmatic breathing and left nostril breathing exercises; mindful eating; and structured stress management and sleep hygiene education. Glycated hemoglobin (HbA1c) and fasting plasma glucose were primary outcomes. Secondary outcome measures were body weight, body mass index (BMI), perceived stress (PSS), and sleep quality (PSQI). All analyses were performed as paired analyses; normality of paired differences was assessed, and Wilcoxon signed-rank sensitivity analysis was applied if the normality of paired differences was not met.

Results: All measured outcomes showed significant improvement after 12 weeks. Mean HbA1c decreased from 6.49 ± 0.62% to 5.98 ± 0.62% (mean reduction 0.51 percentage points, 95% CI 0.39-0.63; paired t-test $P < 0.001$). Fasting plasma glucose decreased from 152.95 ± 34.66 mg/dL to 110.11 ± 20.52 mg/dL (mean reduction 42.84 mg/dL, 95% CI 30.17-55.51; $P < 0.001$). Body weight decreased from 68.16 ± 5.63 kg to 64.47 ± 4.99 kg, and BMI decreased from 27.21 ± 3.96 kg/m² to 25.71 ± 3.55 kg/m² (both $P < 0.001$). Significant reductions were also observed in PSS scores (27.79 ± 4.54 to 22.79 ± 5.40; $P < 0.001$) and PSQI scores (10.84 ± 3.78 to 8.37 ± 3.48; $P < 0.001$). Statistically significant improvements were found for all outcomes in the Wilcoxon sensitivity analyses.

Conclusions: A 12-week multidomain lifestyle medicine intervention was associated with significant improvements in glycemic control, body composition, perceived stress, and sleep quality among middle-aged women with prediabetes and/or T2DM. Due to the lack of a control group and the single-arm pre-post design, the results of the study should be viewed as provisional relationships, not necessarily causal. There is a need for more rigorous RCTs with longer follow-up to validate durability, clinical efficacy, and feasibility of implementation.

Keywords: *Lifestyle medicine; Prediabetes; Type 2 diabetes mellitus; Glycemic control; High-protein diet; Resistance training; Stress management; Sleep quality; Vagal nerve stimulation; Lifestyle intervention.*

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INTRODUCTION

Prediabetes and type 2 diabetes mellitus (T2DM) are public health problems as chronic dysglycemia is associated with microvascular and cardiovascular complications, disability and mortality [1]. Thus, prevention and long-term care of diabetes today focuses on weight management, individualized nutrition, physical activity, sleep health, psychological well-being, and diabetes self-management support as key elements [2]. Adapting the lifestyle plan to the person's preferences, the feasibility of sustained behavior change, and comorbidities and treatment burden is particularly important, as it is a person-centered approach [3]. However, many of the clinical programs continue to focus primarily on diet or exercise, while sleep disruption, perceived stress, autonomic regulation, or adherence support are less structured.

There is new evidence that long-term lifestyle interventions can prevent the progression of prediabetes to T2DM, especially if these interventions are structured, intensive and continue after the initial counseling sessions [4]. Lifestyle medicine guidance also involves extensive programs for adults with prediabetes or T2DM that integrate nutrition, physical activity, weight loss, good sleep, stress management and social support [5].

This strategy is based on nutrition quality. Dietary patterns with a low glycemic index or low glycemic load have been linked to improved glycemic control and reduced cardiometabolic risk factors in diabetes [6]. Glycemic index and glycemic load tables are also useful in clinical practice for dietary planning to manage postprandial glucose exposure by selecting foods and structuring meals [7].

This is germane to the current intervention, since the dietary plan was to provide a high-protein, low-glycemic diet rather than restrict calories. There are also broader meta-analytic data indicating that reduced-GI diets might be beneficial for lowering HbA1c, fasting blood glucose, body weight, and BMI in the metabolic disease population [8].

Resistance exercise is also biologically and clinically relevant for T2DM, as it enhances muscular strength, improves glucose uptake and HbA1c, and meta-analytical evidence shows it reduces HbA1c in adults with T2DM [9]. The dose-response evidence also suggests that variables in progressive resistance training should be considered when designing exercise programs to improve glycemic status [10].

Mind-body methods have also been investigated as complementary therapies in diabetes treatment. A systematic review and meta-analysis found that mind-body-based interventions had beneficial effects on HbA1c and fasting blood glucose in T2DM, and reviews of the effects of yoga on glucose and lipid outcomes showed short-term benefits [11, 12].

The relevance of breathing-based autonomic regulation lies in the fact that HRV (a non-invasive marker of autonomic modulation) has been demonstrated to be affected by voluntary slow breathing [13]. Evidence from slow deep breathing also suggests it has the potential to acutely affect vagal tone and anxiety-related outcomes, thus providing a plausible rationale for integrating breathing practice into stress regulation [14].

Stress and sleep are now known to be clinically relevant factors of dysglycemia. Poor sleep quality has also been associated with poor glycemic control in adults with T2DM, supporting the measurement of sleep quality and the practice of sleep hygiene in the lifestyle management of diabetes [15].

Psychological distress can also negatively impact diabetes self-management and metabolic control. The meta-analytic evidence indicates that psychological interventions can reduce diabetes distress, with effects on glycemic measures depending on the type of intervention and the length of follow-up [16]. Depression and diabetes distress have also been shown to be linked with poorer glycemic control and with less healthy coping behaviors, making it important to consider psychosocial issues along with metabolic targets [17].

In the present study, a comprehensive 12-week lifestyle medicine intervention was delivered in a real-world outpatient clinical setting. The intervention consisted of nutrition therapy, resistance training, yoga, breathing-based vagal stimulation exercises, stress management, mindful eating and sleep hygiene. The main goal was to evaluate the improvements in HbA1c and FPG. Secondary goals included assessing alterations in body weight, BMI, perceived stress and sleep quality. The study further sought to determine whether the statistical outcomes were consistent, clinically meaningful, and suitable for a single-arm pre-post design.

MATERIALS AND METHODS

Study Design and Setting

This is a prospective, single-arm interventional study to examine the relationship between a comprehensive lifestyle medicine program and changes in glycemic control, anthropometric measures, perceived stress, and sleep quality in middle-aged women with prediabetes or T2DM. The intervention took place at the House of Nature Medical Center in Abu Dhabi, United Arab Emirates (UAE) over 12 weeks. All participants were seen for outpatient clinical care at baseline and follow-up. The intervention was intended to be a systematic yet practical lifestyle medicine intervention implementable in a standard clinical practice.

Study Population

Twenty-five women were originally recruited who met the inclusion criteria. Six subjects dropped out because they could not consistently follow the lifestyle recommendations or due to lack of follow-up assessment. Of the 25 participants who completed baseline and 12-week evaluations, 19 participants (76.0%) had complete paired baseline and 12-week data. The subjects were women with prediabetes or T2DM (laboratory criteria) aged 42-55 years. The study population was primarily composed of people interested in a non-pharmacological or lifestyle-supported strategy to improve metabolic health.

To take part in the study, the participants had to be female, of any ethnic group, with prediabetes or type 2 diabetes mellitus (T2DM) confirmed by laboratory results, and aged between 42 and 55 years. Participants also had to be willing to take part in the 12-week lifestyle intervention and agree to follow the dietary, exercise, stress management, and sleep recommendations provided. All participants had written informed consent before study participation. Pregnant or lactating women, those with severe cardiovascular, renal, hepatic, and other systemic diseases that might interfere with their participation, and those with physical limitations that prevented the ability to participate in resistance training were excluded. People were also excluded if they needed immediate medical treatment that would make a lifestyle program inappropriate, or if they were unable to follow the lifestyle program or follow-up evaluations.

Lifestyle Medicine Intervention

Participants were provided with a 12-week extensive lifestyle medicine program focusing on nutrition, physical activity, stress management, breathing-based autonomic practices, mindful eating, and sleep hygiene. One-to-one counseling and follow-up were offered during the intervention to help boost adherence and maintain behavior change.

Nutritional Intervention

The diet plan provided to the participants was high-protein, low-glycemic. The diet emphasized the use of about 1.1 g/kg/day of protein, 3 structured meals/day (when possible, about 28 g protein per meal), moderate amounts of healthy fats, fewer amounts of refined sugars and ultra-processed foods, no sugar-sweetened beverages or refined carbohydrates, and preference for foods that were prepared at home and less processed and more nutrient-dense. No severe calorie-restriction protocol was given.

Exercise Intervention

The participants engaged in 3 resistance exercise training sessions per week, each lasting about 45 minutes. The training aimed to improve progressive resistance principles while focusing on working the major muscle groups in accordance with the individual's capacity. In addition, the participants undertook 1 supervised 60-minute yoga session weekly, with an emphasis on flexibility, mobility, breathing and relaxation.

Stress Management and Vagal Activation Practices

Stress reduction was included as an integral part of the intervention. All participants were asked to practice diaphragmatic breathing for about 20 minutes per day, breathe in and out through the left nostril, pay attention to eating during mealtime, and adopt behavioral techniques to support their emotional well-being, such as social support and counseling, if clinically indicated. The purpose of these techniques was to decrease perceived stress and promote activation of the parasympathetic system.

Sleep Hygiene

All participants were provided with a uniform sleep hygiene protocol: a sleep routine; eating the evening meal before 8:00 PM when practical; minimizing activities that may negatively affect sleep; and using magnesium glycinate, to be determined by the treating practitioner.

Outcome Measures

Assessments were made at the beginning and the end of the 12-week intervention. The main outcomes measured were HbA1c (%), and fasting plasma glucose (mg/dL). Secondary outcomes included body weight (kg), BMI (kg/m²), perceived stress (PSQI), and sleep quality (PSS). The PSS was chosen to assess the degree to which life situations are appraised as stressful, and the PSQI was chosen to provide a self-rated assessment of sleep quality and disturbances in the previous month [18, 19]. The lower the PSS value, the lower the perceived stress level; the lower the PSQI value, the better the sleep quality.

Data Verification and Statistical Analysis

The raw spreadsheet was double-checked before analysis. There were 19 complete paired log records for all six outcomes, and no missing paired values among participants included in the final analysis. Data were analyzed descriptively, reporting the mean and standard deviation of the pre- and post-measures. All mean reductions were calculated as the difference between baseline and post values, so positive values indicate improvement.

The paired differences were tested for normality using the Shapiro-Wilk test. Mean changes, 95% confidence intervals, and two-sided P values for paired pre-post changes were estimated using paired t-tests. Wilcoxon signed-rank tests were also performed (as sensitivity analyses) because Shapiro-Wilk testing showed that the paired differences for weight, BMI, and PSS were not normally distributed. All interpretations were based on statistical significance and clinical plausibility, with $P < 0.05$ (two-tailed) considered statistically significant. Cohen's dz were used as effect sizes for paired comparisons (i.e., the mean paired difference divided by the standard deviation of the paired differences).

Since this was a single-arm, pre-post study without a randomized control group, statistical analyses were interpreted as changes within participants during the intervention period, not as proof of cause and effect.

RESULTS

Participant Flow and Completion

Twenty-five women were enrolled; 19 completed the 12-week program and were included in the final paired analysis. Six subjects withdrew due to insufficient adherence or follow-up. The final sample analyzed thus included participants who had complete outcome data at both baseline and post-intervention.

Statistical Assumption Testing

Shapiro-Wilk testing showed that paired differences were approximately normally distributed for HbA1c (W = 0.978, P = 0.920), fasting plasma glucose (W = 0.950, P = 0.391), and PSQI (W = 0.947, P = 0.351). Normality assumptions were not fully met for weight (W = 0.861, P = 0.010), BMI (W = 0.807, P = 0.001), and PSS (W = 0.895, P = 0.039). Wilcoxon signed-rank sensitivity analyses were therefore applied to ensure that the results for outcomes with non-normal paired differences were robust.

Changes in Metabolic, Anthropometric, Stress, and Sleep Outcomes

After 12 weeks, a significant improvement was observed for all measured outcomes among participants (Table 1). HbA1c decreased by 0.51 percentage points (95% CI 0.39-0.63; P < 0.001; Cohen's dz = 2.01), indicating a large within-participant effect. Fasting plasma glucose decreased by 42.84 mg/dL (95% CI 30.17-55.51; P < 0.001; dz = 1.63), also representing a large effect.

There were very positive anthropometric results. Mean body weight decreased by 3.68 kg (95% CI 2.90-4.47; P < 0.001; dz = 2.25), and BMI decreased by 1.49 kg/m² (95% CI 1.14-1.85; P < 0.001; dz = 2.04). Wilcoxon sensitivity analyses showed that both weight and BMI were statistically significantly reduced (P<0.001).

Psychological and sleep outcomes also were improved. Mean PSS score decreased by 5.00 points (95% CI 3.00-7.00; P < 0.001; dz = 1.20), while mean PSQI score decreased by 2.47 points (95% CI 1.26-3.69; P < 0.001; dz = 0.98). All sensitivity analyses using Wilcoxon tests showed significant improvements in PSS (P < 0.001) and PSQI (P = 0.002).

Table 1. Baseline and post-intervention outcomes after the 12-week lifestyle medicine program.

Outcome	Baseline Mean ± SD	Post-intervention Mean ± SD	Mean reduction (95% CI)	Paired t-test P value	Wilcoxon P value	Cohen's dz
HbA1c (%)	6.49 ± 0.62	5.98 ± 0.62	0.51 (0.39-0.63)	<0.001	<0.001	2.01
Fasting plasma glucose (mg/dL)	152.95 ± 34.66	110.11 ± 20.52	42.84 (30.17-55.51)	<0.001	<0.001	1.63
Body weight (kg)	68.16 ± 5.63	64.47 ± 4.99	3.68 (2.90-4.47)	<0.001	<0.001	2.25
BMI (kg/m²)	27.21 ± 3.96	25.71 ± 3.55	1.49 (1.14-1.85)	<0.001	<0.001	2.04
Perceived Stress Scale (PSS)	27.79 ± 4.54	22.79 ± 5.40	5.00 (3.00-7.00)	<0.001	<0.001	1.20
Pittsburgh Sleep Quality Index (PSQI)	10.84 ± 3.78	8.37 ± 3.48	2.47 (1.26-3.69)	<0.001	0.002	0.98

The mean difference was calculated as the baseline –post-intervention value. Positive values are considered improvement. The standard deviation of the paired differences was used to calculate Cohen's dz. Sensitivity analyses were performed using Wilcoxon signed-rank tests, which yielded the same level of statistical significance for all outcomes.

DISCUSSION

This prospective single-arm study showed that a comprehensive 12-week lifestyle medicine intervention was correlated with statistically significant improvements in glycemic control, body weight, BMI, perceived stress, and sleep quality in adult women with prediabetes and/or T2DM. Internal consistency was confirmed for all metabolic, anthropometric, and psychosocial outcomes, and sensitivity analyses showed that the results remained significant when non-parametric tests were performed for variables with non-normal paired differences.

The reduction in HbA1c seen in the observations is clinically significant as HbA1c provides an indicator of glycemic exposure over the previous three months or so. The co-occurring decrease in fasting plasma glucose is consistent with the interpretation that glucose control improved during the intervention period. Still, causality cannot be determined in the absence of a control group. The results of this study are supported by evidence that low-GI diets can contribute to glycemic control and that resistance training is effective in reducing HbA1c in adults with T2DM [6, 9].

The weight and BMI losses are also clinically relevant as excess adiposity is strongly associated with insulin resistance, chronic low-grade inflammation, and cardiometabolic risk. The intervention focused on the importance of protein consumption, minimally processed foods, and progressive resistance training, which might help to maintain dietary compliance and lean mass during weight loss while inducing satiety. This is especially important among middle-aged women, as other metabolic factors may decline during age-related muscle loss.

Also supporting the relevance of the multidomain lifestyle medicine approach are the improvements in perceived stress and sleep quality. The effects of poor sleep quality and psychological distress on glycemic regulation may occur through behavioral and/or neuroendocrine mechanisms, including reduced self-care, sympathetic activation, and changes in appetite [15, 17]. However, mechanisms such as diaphragmatic breathing, left-nostril breathing, yoga, mindful eating, social support, and sleep hygiene may have played a role in the emotional regulation, parasympathetic activation, and sleep restoration observed in the present study, but these were not directly measured.

The intervention's strength was that it reflected real-world lifestyle medicine practice, not just a single behavior. There may be synergies between these different types of interventions, such as nutrition and resistance exercise, stress and breathing interventions, yoga and sleep hygiene, and behavior interventions; for instance, improved sleep may enhance exercise motivation and dietary compliance, and reduced stress may inhibit emotional eating and aid glucose control.

The findings of the current study are generally consistent with evidence that structured lifestyle interventions reduce the risk of diabetes and confer cardiometabolic benefits. However, because this was a single-arm study, the reported improvements may have resulted from regression to the mean, increased clinical attention and/or medication changes, self-monitoring, and participant motivation [4, 5].

Future research should include larger RCTs with longer follow-up to determine whether the changes will last and whether the intervention is effective compared with usual care or other lifestyle programs. Medication use, dietary records, attendance at exercise sessions, continuous glucose monitoring, objective sleep measures, body composition, inflammatory markers, insulin resistance indices, and measures of autonomic function should also be included in studies to aid understanding of mechanisms and causal inference.

STRENGTHS AND LIMITATIONS

Strengths

This study has several strengths. First, it assessed a holistic lifestyle medicine program integrating several components designed to improve metabolic health: nutrition, resistance exercise, yoga, stress management, breathing-based vagal activation exercises, and sleep hygiene. Second, both objective metabolic measures and validated psychosocial outcomes were evaluated, giving a more comprehensive evaluation of health improvement than glycemic outcomes alone. Thirdly, the raw data were rechecked independently, and the statistical analysis was adjusted to provide assumption testing and non-parametric sensitivity analyses as appropriate. Lastly, the intervention was implemented in a natural clinical (outpatient) environment, providing a translational context.

Limitations

There are some caveats to note. A single-arm, pre-post study design with no random assignment to a control group was used, which may restrict causal inferences. The sample size was small, and participants were from a single clinical center, which may limit generalizability. Only completers were included in the final analysis, which may overestimate effectiveness if people with lower adherence were less likely to complete follow-up. The intervention was 12 weeks, which didn't allow for assessment of long-term sustainability. The statistical data did not include information on medication use, diagnosis subgroup, diet, exercise attendance, or objective adherence. Other parameters, such as body composition, inflammatory markers, insulin resistance indices, continuous glucose monitoring, and objective sleep and physical activity measurements, were also unavailable. There are limitations to these trials that should be overcome in future controlled trials.

Clinical Implications

The results suggest that extensive lifestyle medicine programs might be helpful as a complement to non-pharmacological management for prediabetes or T2DM in women. This is in line with data showing that team-based, multi-component care is effective in improving and maintaining glycemic control among patients with T2DM in a structured clinical environment [20]. Together, nutrition education, resistance exercise, mind-body practice, stress management, and sleep education can help manage some of the behavioral, psychological, and physiological factors associated with metabolic dysfunction.

From a clinical perspective, the results validate an approach to patient treatment that extends beyond glycemic goals. Factors that may affect adherence, quality of life, engagement, and metabolic outcomes include stress, sleep, dietary habits, and physical activity/behavior change. Scalable lifestyle medicine interventions in primary care/community settings have the potential to reduce the burden of diabetes and diabetes-related complications; future research is needed to assess cost-effectiveness, implementation fidelity, and sustainability.

CONCLUSION

The 12-week comprehensive lifestyle medicine intervention was associated with substantial reductions in HbA1c, FPG, body weight, BMI, perceived stress, and sleep quality in middle-aged women with prediabetes or T2DM. The reported mean differences, CIs, P values, and effect sizes were verified against the raw data using a statistical verification procedure. Additional assumption testing and sensitivity analyses, including Wilcoxon signed-rank tests for outcomes with non-normally distributed paired differences, were incorporated into the revised analysis to assess assumptions and confirm the robustness of the findings.

The results of the study suggest the benefit of multidomain lifestyle medicine. Still, they should be interpreted with caution due to the small sample size, single-center recruitment, completer-only analysis, short follow-up period, and lack of a control group. Larger RCTs evaluating the clinical effectiveness, durability, feasibility of implementation, and mechanisms of how nutrition, resistance exercise, stress regulation, sleep hygiene, and glycemic benefits are related would be beneficial.

ETHICS AND DECLARATIONS

Ethics Approval and Consent to Participate

Written informed consent was obtained from all participants before participation. Ethical approval details were not available in the source materials reviewed for this revision. Before journal submission, the author should insert the name of the approving ethics committee or institutional review body, approval number, and approval date, or provide a documented waiver if the relevant authority waived formal ethical review.

Consent for Publication

Not applicable, as the manuscript does not report identifiable individual participant data.

Availability of Data and Materials

The de-identified dataset supporting the findings of this study is available from the corresponding author on reasonable request, subject to applicable ethical and institutional requirements.

Competing Interests

The author declares that there are no competing interests.

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Author Contributions

Dr. Saranya Mayadevi Sankara Pillai conceptualized the intervention, supervised clinical implementation, collected participant data, interpreted the findings, and prepared the manuscript. Statistical verification and editorial revision were completed using the de-identified dataset supplied for manuscript preparation.

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Trial Registration

Trial registration information was not provided in the source materials. If the target journal requires registration for prospective interventional studies, the author should include the registration number or state the reason for non-registration in accordance with the journal's policy.

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