Synergistic Effects of Aerobic Exercise and Moringa Oleifera Supplementation on Glycemic Control and Metabolic Health in Type 2 Diabetes Patients: A Randomized Controlled Trial

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KEYWORDS
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ABSTRACT
Background: The action of aerobic exercise and Moringa Oleifera supplementation on type 2 diabetes mellitus (T2DM) have been individually documented, but their combination remains unclear. This study evaluates the synergistic effects of a 12-week aerobic exercise program and Moringa supplementation on metabolic and inflammatory markers in T2DM patients. Methods: A total of 120 T2DM patients were randomly assigned to four groups: control, aerobic exercise, moringa supplementation (250mg/kg/day), and a combination. BMI, blood glucose, serum insulin, serum C-peptide, renal function tests, HbA1c, adiponectin, IL-6, and lipid profile, were assessed before and after the intervention. Blood glucose levels were monitored weekly. Results: All intervention groups showed significant improvements in HbA1c levels compared to the control group, with the combination group demonstrating the greatest reduction. Blood glucose levels decreased significantly in the exercise and combination groups, with the aerobic exercise group outperforming moringa alone. Serum insulin levels significantly decreased in the moringa and combination groups, while serum C-peptide levels decreased in all groups. Lipid profile improvements were noted in all intervention groups, with the combination treatment showing superior results in reducing total cholesterol and BMI. Both adiponectin levels increased and IL-6 levels decreased significantly in all intervention groups, particularly in the combination group. Renal function tests showed no adverse changes, with a significant reduction in BUN levels observed only in the combination group. Conclusion: The combination of aerobic exercise and moringa supplementation provides a synergistic therapeutic effect, significantly improving glycemic control, lipid profile, adiponectin levels in T2DM patients.

1. Introduction

Type 2 diabetes mellitus (T2DM) is a pervasive global health issue affecting millions of individuals worldwide(1). Characterized by chronic hyperglycemia, T2DM arises from insulin resistance and/or inadequate insulin secretion, leading to various complications such as cardiovascular diseases, neuropathy, retinopathy, and nephropathy, which significantly impact patients' quality of life and healthcare systems (2).

Physical activity, particularly aerobic exercise, is a cornerstone in managing T2DM(3). Aerobic exercise has been shown to improve insulin sensitivity, glycemic control, and cardiovascular health in individuals with T2DM (4). In addition to exercise, dietary interventions and nutritional supplements are increasingly explored for their potential benefits in diabetes management(5). Moringa oleifera, known for its rich nutritional profile and medicinal properties, has garnered attention for its potential antidiabetic effects(6).

Moringa leaves are rich in vitamins, minerals, and bioactive compounds that may help regulate blood glucose levels and improve overall health(7). Previous studies have provided insights into the benefits of Moringa supplementation for diabetic patients(8). For instance, a pilot clinical trial demonstrated that Moringa oleifera leaf powder could reduce post-prandial glycemia in diabetic patients, suggesting its potential as a complementary therapy for diabetes management(9). Another study highlighted the effectiveness of Moringa leaves in controlling blood sugar levels in patients with T2DM(10).

Despite these promising findings, there is a need for more comprehensive studies exploring the combined effects of exercise and Moringa supplementation on various health parameters in T2DM

patients. Most existing studies have focused on either exercise or dietary supplementation independently, leaving a gap in understanding the synergistic effects of these interventions.

This study aims to investigate the therapeutic impact of a 12-week aerobic exercise program combined with Moringa supplementation on several health markers in patients with T2DM. These markers include body mass index (BMI), blood glucose levels, serum insulin, serum C-peptide, renal function tests, HbA1c, adiponectin, IL-6, and lipid profile, with blood glucose measured weekly. By addressing this gap, the study seeks to provide valuable insights into integrated approaches for optimizing the management of T2DM.

2. Methodology

Study Design

This study was designed as a randomized controlled trial to assess the combined and individual effects of a structured aerobic exercise program and Moringa oleifera supplementation on various health outcomes in patients with type 2 diabetes mellitus (T2DM). The study spanned 12 weeks, involving four groups with 10 participants each.

Participants

A total of 40 patients with T2DM were recruited and randomly assigned to one of four groups:

Control Group: Continued their standard drug treatment without any additional training or Moringa supplementation.

Aerobic Exercise Group: Participated only in the aerobic exercise program without Moringa supplementation.

Moringa Supplementation Group: Received a daily dose of (250mg/kg/day) of Moringa, taken 30 minutes after breakfast.

Combination Group: Followed both the aerobic exercise program and Moringa supplementation regimen.

Ethical Approval

The study protocol for investigating the effects of aerobic exercise and herbal supplements on patients with type 2 diabetes mellitus over a 12-week period was reviewed and approved by the Erbil Polytechnic University Ethical Committee for Human Research Ethics (Approval No.:24/0025 HRE). All participants provided written informed consent prior to their enrollment in the study.

Aerobic Exercise Program

The aerobic exercise program spanned 12 weeks, with training sessions held three times per week on Saturdays, Mondays, and Wednesdays, resulting in a total of 36 training sessions. Each session lasted between 31 to 73 minutes, accumulating approximately 308 hours of training over the course of the program.

The exercise sessions were structured as follows:

Preparatory Phase: Incorporation of aerobic exercises to prepare participants for the main workout.

Main Phase: Low-resistance cycling and zero-incline treadmill exercises.

Cool-Down Phase: Light stretching and relaxation exercises to conclude the session.

Exercises were performed with musical accompaniment to enhance motivation and excitement. To ensure safety, mineral water, juices, and candy were provided to prevent hypoglycemia, and a blood sugar measuring device was available. A specialist doctor was present during all sessions.

Moringa Supplementation

Participants in the Moringa supplementation group and the combination group received a daily dose of 250 mg/kg of Moringa. The supplements were taken 30 minutes after breakfast.

Laboratory Estimations

ELISA Kits: ELISA kits were used for the precise quantification of serum insulin, C-peptide, adiponectin, and IL-6 levels. These assays were performed according to the manufacturer's instructions, involving sample preparation, antibody binding, and colorimetric detection to determine the concentration of the target proteins.

COBAS Analyzer: A COBAS automated chemistry analyzer was utilized for lipid profile and renal function tests. This high-throughput system provides accurate and reliable measurements of total cholesterol, triglycerides, LDL, HDL, serum creatinine, and BUN, ensuring consistent and reproducible results.

Statistical Analysis

Data were analyzed using GraphPad Prism version 9.01 software. The results were recorded as mean differences between pre-and post-intervention values. Statistical significance was determined using paired One-way ANOVA and Tukey's post-hoc test for group comparisons, with a significance level set at $p < 0.05$.

3. Results and discussion

The results were recorded by comparing the mean differences, calculated as the difference between pre-and post-treatment values. Significant reductions in HbA1c levels were observed in patients treated with the aerobic training program, herbal supplementation, and the combination of both, compared to the control group, which consisted of diabetic patients receiving only their prescribed medication. The combination treatment demonstrated a significant synergistic effect compared to both treatments alone, with the moringa herbal supplement showing better antidiabetic action than the aerobic training program (Figure 1a).

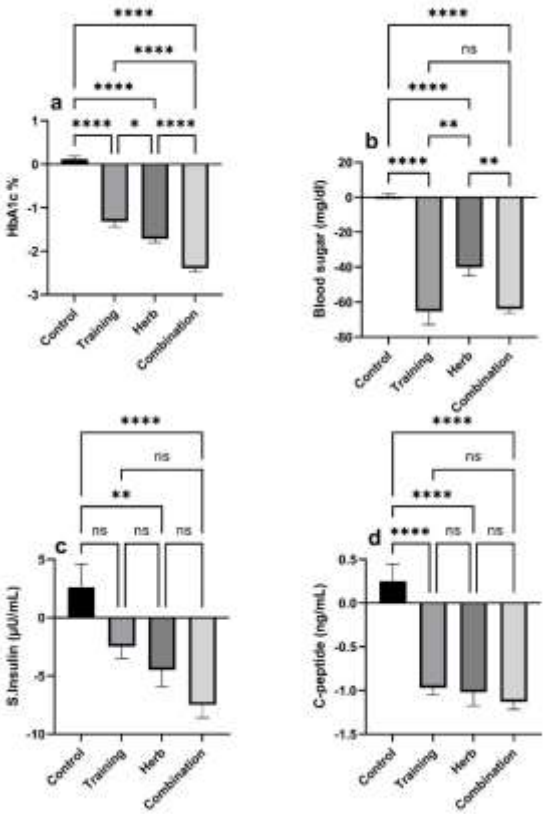

Figure 1. Effects of treatments on glycemic control before and after 12 weeks of intervention among the control group, aerobic training program group, moringa supplementation group, and combination treatment group. a) Comparison of mean HbA1c levels showed significant reductions were observed in all intervention groups compared to the control, with the combination treatment showing the greatest reduction. b) Comparison of mean random blood glucose levels was non-significant compared to the aerobic training alone. c) Comparison of mean serum insulin levels showed significant decreases were observed in the moringa supplementation and combination treatment groups. d) Comparison of mean serum C-peptide levels showed significant decreases in all treated groups compared to the control.

The results for random blood glucose mirrored those of HbA1c, except that the training program reported better therapeutic action than the herbal treatment, and the combination treatment showed no significant difference compared to the aerobic training alone (Figure 1b).

Regarding the lipid profile, all treatments showed significant improvements in total cholesterol, triglycerides (TG), low-density lipoprotein (LDL), high-density lipoprotein (HDL), and BMI compared to the control group. The combination treatment recorded an efficient synergistic action against diabetic lipid-related complications. Serum cholesterol showed a significant decrease in all treated groups compared to the control, with the combination treatment showing a significant reduction compared to both treatments alone (Figure 2a). The training program was significantly more efficient than herbal treatment in reducing BMI, with the combination treatment recording the best results (Figure 2c). HDL and LDL levels showed significant improvement in both the training and herbal treatment groups, with no significant difference between them, while the combination treatment revealed significantly better results compared to both alone groups and the control group (Figures 2d & 2e).

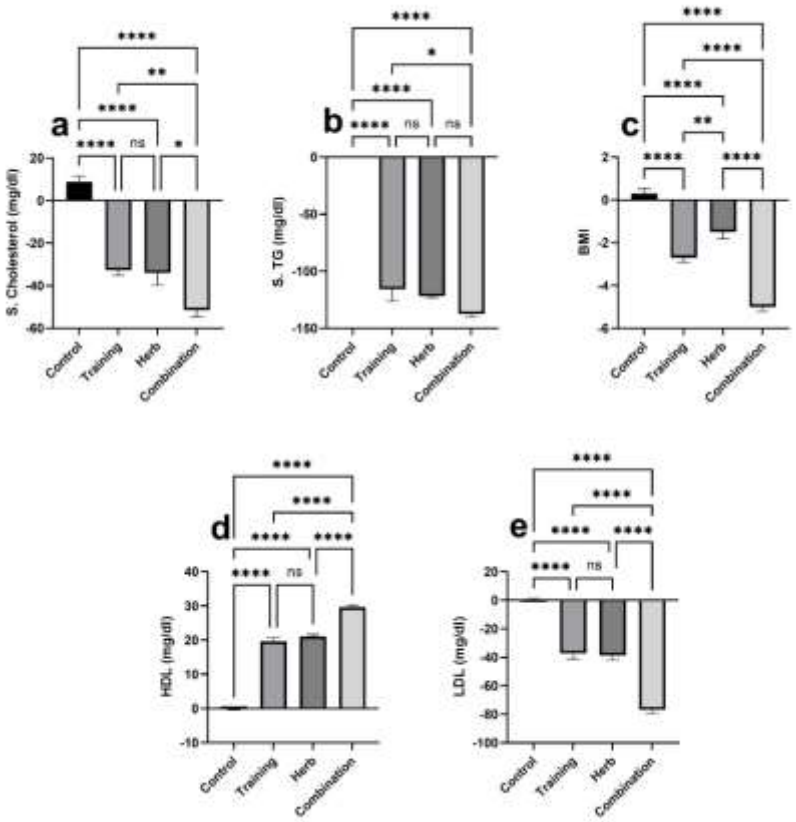

Figure 2: Therapeutic action of treatments on lipid profile and BMI before and after 12 weeks of intervention. Comparison of mean for A) Total cholesterol, b) Triglyceride, c) BMI, d) HDL and e) LDL levels showed significant changes in all treatment groups compared to the control, with the

combination treatment showing the greatest improvement.

Both the aerobic training program and herbal supplementation groups recorded significant elevations in serum adiponectin levels compared to the control group, with the highest elevation observed in the combination group, which was significant compared to all other groups (Figure 3a). Similarly, significant reductions in serum IL-6 levels were observed in the aerobic training and herbal supplementation groups compared to the control, with the highest reduction seen in the combination group, which was significant compared to all other groups (Figure 3b).

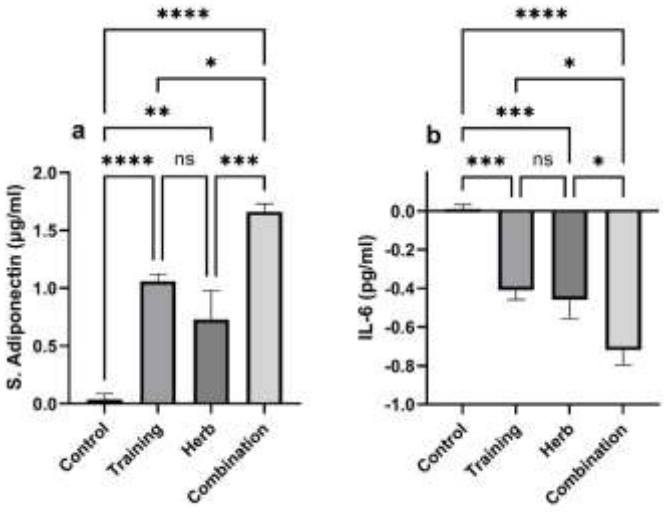

Figure 3. Action of treatments on adiponectin and IL-6 levels before and after 12 weeks of intervention. a) Comparison of mean serum adiponectin levels. Significant elevations were observed in both the aerobic training and moringa supplementation groups, with the combination treatment showing the highest elevation. b) Comparison of mean serum IL-6 levels showed significant reductions in both the aerobic training and moringa supplementation groups compared to the control, with the combination treatment showing the greatest reduction.

The results of renal function tests, including serum creatinine (Figure 4a) and blood urea nitrogen (BUN), showed no significant changes in any of the groups except for a significant reduction in BUN levels in the combination group compared to the control. The lack of significant changes was likely due to high variation in the data, as indicated by a high standard deviation (Figure 4b).

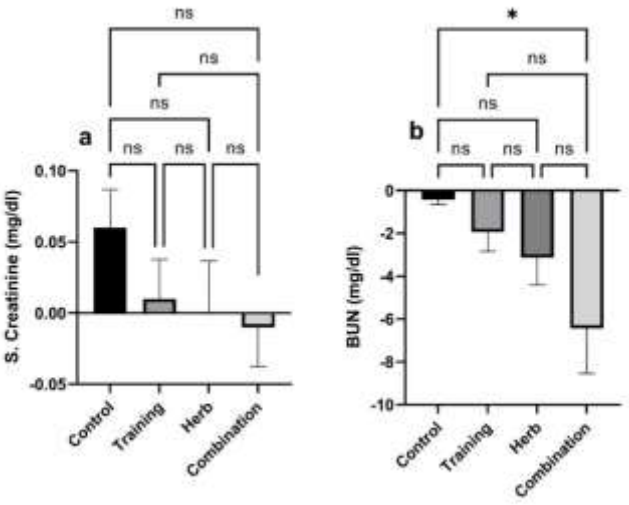

Figure 4: Effects of treatments on renal function tests before and after 12 weeks of intervention. a) Comparison of mean serum creatinine levels. No significant changes were observed in any of the groups. b) Comparison of mean BUN levels. A significant reduction was observed in the combination treatment group compared to the control, with high data variation indicated by a high standard deviation.

Throughout the study, all participants underwent weekly blood glucose level checks. Figure 5 illustrates the weekly changes in blood glucose levels across all study groups, clearly showing the glucose-lowering effects of the combination and training programs, followed by the herbal supplementation group.

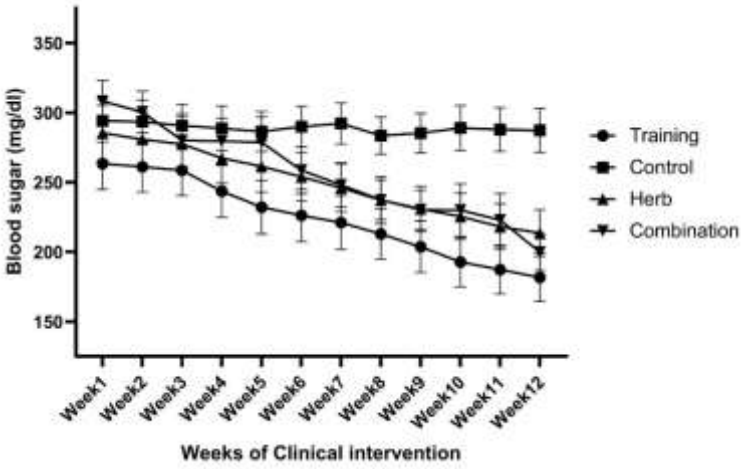

Figure 5: Weekly blood glucose level changes. The changes in blood glucose levels over the 12-week intervention period. The graph shows the glucose-lowering effects of the combination treatment and the aerobic training program, followed by the moringa supplementation group, with the control group showing the least change.

Discussion

The present study investigated the therapeutic impact of a structured aerobic exercise program combined with moringa supplementation on various metabolic and inflammatory markers in patients with type 2 diabetes mellitus (T2DM) over 12 weeks. The results demonstrated significant improvements in glycemic control, lipid profile, adiponectin levels, and IL-6 levels, with the combination treatment often showing superior outcomes compared to individual treatments alone.

The significant reduction in HbA1c levels across all intervention groups, particularly the combination group, underscores the effectiveness of aerobic exercise and moringa supplementation in improving long-term glycemic control. These findings align with previous research highlighting the role of physical activity in enhancing insulin sensitivity and reducing HbA1c (11, 12). Additionally, moringa's antidiabetic properties, attributed to its bioactive compounds that enhance insulin secretion and glucose uptake (13, 14), complement the benefits of exercise.

Random blood glucose levels followed a similar pattern to HbA1c, with notable improvements observed in all intervention groups. Interestingly, the aerobic training program exhibited better therapeutic action on random blood glucose compared to moringa supplementation alone, indicating that exercise might have a more immediate effect on glucose regulation. This aligns with studies showing that aerobic exercise enhances glucose transport and utilization in muscle cells (15).

The significant decrease in serum insulin levels observed in the moringa and combination groups suggests improved insulin sensitivity (16, 17), a critical factor in managing T2DM. The non-significant change in the aerobic training group alone may reflect the complexity of insulin dynamics, which are influenced by multiple factors including exercise intensity and duration (18).

All treatment groups showed significant reductions in serum C-peptide levels compared to the control, indicating reduced beta-cell stress and improved insulin production efficiency(19). This finding is consistent with evidence that both exercise and certain dietary supplements can preserve beta-cell function(20, 21).

The improvements in lipid profile parameters (total cholesterol, triglycerides, LDL, HDL, and BMI) across all treatment groups highlight the comprehensive metabolic benefits of the interventions(22). The combination treatment's superior performance in reducing total cholesterol and BMI suggests a synergistic effect of exercise and moringa on lipid metabolism(23). Regular aerobic exercise is known to positively influence lipid metabolism by increasing HDL levels and decreasing LDL and triglycerides(24, 25). Moringa supplementation has been reported to exert lipid-lowering effects through its high antioxidant content and influence on lipid absorption and metabolism(26, 27).

The elevated adiponectin levels in the intervention groups, particularly the combination group, indicate enhanced anti-inflammatory and insulin-sensitizing effects(28). Adiponectin, an adipokine with anti-inflammatory properties, is known to improve insulin sensitivity and glucose regulation (29). The significant reduction in IL-6 levels further supports the anti-inflammatory impact of the interventions(30). Chronic inflammation, marked by elevated IL-6 levels, is a known contributor to insulin resistance and T2DM progression (31).

Renal function tests, specifically serum creatinine and BUN levels, showed no significant adverse effects, indicating that the interventions did not negatively impact kidney function. The significant reduction in BUN levels in the combination group, despite high data variation, suggests potential renal benefits(32), possibly due to improved overall metabolic health and reduced oxidative stress(33).

Weekly monitoring of blood glucose levels revealed consistent improvements across the intervention period, with the combination of treatment and aerobic training program showing the most pronounced glucose-lowering effects. This trend reinforces the importance of sustained lifestyle modifications in managing T2DM (34).

4. Conclusion and future scope

In conclusion, the combination of aerobic exercise and moringa supplementation offers a promising integrative approach to managing T2DM, with significant benefits observed in glycemic control, lipid profile, adiponectin levels, and inflammation markers. Future studies with larger sample sizes and longer follow-up periods are warranted to further elucidate the mechanisms and long-term benefits of these interventions.

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