Effect of moringa leaves powder on body weight, glycemic status, lipid profile, and blood pressure in overweight individuals with hyperlipidemia

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Abstract

Moringa leaf powder has demonstrated beneficial effects on body weight, lipid profiles,and blood pressure in animal studies. However, research on the impact of moringa on theseparameters in humans is limited. Therefore, the aim of this study was to examinethe effects of moringa on body weight, glycemic status, lipid profile, and blood pressure inhuman subjects. The study was designed as a randomized controlled parallel clinical trial. A total of 40 overweight, hyperlipidemic subjects (both sexes), aged 30 to 60 years, wereincluded. Participants were assigned to either the moringa group (n=20) or the control group. The moringa groupreceived capsules containing 0.5 g of powdered moringa leaves, while the control groupreceived capsules containing 0.5 g of corn starch, both administered twice a day for 12 weeks. Additionally, bothgroups were instructed to engage in moderate-intensity physical activity for 40 to 60 minutes. Anthropometric measurements, including weight,BMI, and waist circumference, were taken at baseline and after 12 weeks of intervention. Dietary intake wasassessed using the 24-hour dietary recall method at baseline and at the end of the intervention. Venous blood (5 ml) was collected at both time points to determine biochemical parameters, including lipidprofile and blood glucose levels. Blood pressurewas measured with a sphygmomanometer at baseline and after 12 weeks of intervention. Thefindings revealed a significant reduction in carbohydrate, energy, and cholesterol intake inthe moringa group compared to baseline values. Body weight, BMI, and waist circumference (WC) weresignificantly lower ($P \leq 0.05$) in the treatment group than in the control group. Additionally, there weresignificant differences ($P \leq 0.05$) in blood pressure, triglyceride levels, and LDL and HDL cholesterol levelsbetween the treatment and control groups. The findings of this study indicated that a 1 g doseof moringa over 12 weeks effectively reduced body weight, blood pressure, triglycerides,and LDL and HDL cholesterol levels, while a nonsignificant reduction in total cholesterol was observed inoverweight subjects with hyperlipidemia. Therefore, moringa may serve as a complementarytreatment alongside existing therapies to improve lipid profiles in hyperlipidemic patients.

Keywords: Cholesterol, BMI. Sphygmomanometer, HDL, Triglycerides

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Introduction

Hyperlipidemia refers to elevated levels of plasma lipids and various lipoproteins (Frerickson *et al*., 1967). Lipoproteins are classified into different types based on their size, density, and electrophoretic properties. The major classes of lipoproteins include LDL, HDL, VLDL, and chylomicrons. Each of these types plays a crucial role in the growth and metabolism of plasma lipids (Rall *et al*., 1984). Among these, LDL is particularly harmful due to its role in atherogenesis. LDL contributes to the accumulation of lipids at arterial sites and acts as a chemotactic factor, attracting monocytes to areas with established lesions. Epidemiological studies have shown a direct association between dietary fat intake and the development of atherosclerosis (Erkkila *et al*., 2008). The regulation of lipid and lipoprotein levels in the blood is influenced by the nutritional composition of the diet. Dysregulations in lipid metabolism, such as those seen in hyperlipidemia, and changes in serum lipoproteins, are key risk factors for coronary heart disease (CHD) (Munawar *et al*., 2019). Diets high in lipids are associated with various metabolic disorders, including obesity, hypertension, cardiovascular diseases, and insulin resistance(Marshall *et al*., 2002, Thanopoulou *et al*., 2003). These disorders contribute to the development of type 2 diabetes and dyslipidemia. Despite advances in modern treatments, diabetes and obesity remain leading causes of illness and mortality worldwide, causing significant social and health disruptions (El Sheikh *et al*., 2019). As a result, there is growing interest in using natural and safe herbal remedies to reduce obesity, offering an alternative to surgical interventions and synthetic pharmaceuticals. Historically, herbal medicines have been widely used across various regions of the world, including Asia, Africa, and Europe. These herbs are believed to help lower elevated blood cholesterol levels (Aattar *et al*., 2006). Moringa (*Moringa oleifera*) is a particularly beneficial herb with known medicinal properties. Belonging to the Moringaceae family, this "miracle tree" is recognized for its preventive effects and its ability to induce oxidative changes and morphological alterations. Moringa has been found to contain a variety of bioactive compounds with potential therapeutic benefits (Saini *et al*., 2016). The most commonly used and nutritious part of the moringa tree is its leaves, which are rich in a variety of nutrients, including vitamins, carotenoids, polyphenols, phenolic acids, flavonoids, alkaloids, glucosinolates, isothiocyanates, niazirin, niazirinin, beta-sitosterols, tannins, and even testosterone (Leone *et al*., 2015). Recent studies have shown that moringa leaf extracts can help prevent metabolic syndrome induced by dietary factors (Lopez *et al*., 2018). The leaves of the moringa tree are primarily used for human nutrition and medicinal purposes (Sivasankari *et al*., 2014). Moringa oleifera leaves have been found to be effective in treating hypercholesterolemia and are also recognized for their hypoglycemic properties (Dangi *et al*., 2002; Ghasi *et al*., 2000; Siddiqui and Khan, 1968). Natural antioxidant and anti-obesity effects of moringa leaves have also been reported (Abdelhalim *et al*., 2015). Moringa has been shown to reduce α-TNF and insulin resistance, particularly in experimental models of metabolic disorders associated with lipid accumulation (Lopez *et al*., 2018). In addition to its impact on cholesterol levels, moringa has been reported to significantly improve blood glucose levels in animal models (Attakpa *et al*., 2017), and it has been identified as an effective insulin modulator (Silashi *et al*., 2014). Animal studies on moringa have demonstrated that the leaves can increase fecal cholesterol excretion and reduce plasma cholesterol levels (Mehta *et al*., 2003). Moringa leaves have also been found to influence plasma lipid profiles, including lowering LDL, VLDL, and total cholesterol, while increasing HDL (Almatrafi *et al*., 2017). However, there is limited research on how moringa leaves impact these variables in hyperlipidemic human patients. Therefore, the aim of this study was to assess how moringa leaf powder affects body weight, glycemic status, and lipid profiles in overweight individuals with hyperlipidemia.

Materials and Methods

Research area

The research was conducted in a clinical laboratory at the Human Nutrition Department of the University of Agriculture Peshawar, as well as at the Weight Management Clinic, Muhammad Medical Complex, Hayatabad, Peshawar.

Study subjects

This study included 40 participants (both sexes), aged 18 to 60 years. All subjects were recruited through personal connections and a consultant physician. Participants were asked to provide written informed consent (Appendix-I) to take part in the study. The study focused on individuals diagnosed with hyperlipidemia and a BMI greater than 25 kg/m^2. Participants who were using estrogen, contraceptives, lipid-lowering medications, or had other comorbid conditions were included in the study. However, patients with conditions such as hepatic steatosis or fatty liver were excluded. Approval for the study was granted by the Human Ethics Committee of the Department of Human Nutrition, University of Agriculture Peshawar.

Treatment

The subjects in the study were randomly assigned to two groups: a treatment group (n=20) and a control

group (n=20). The treatment group received capsules containing 500 mg of powdered moringa leaf extract, taken twice a day, while the control group received capsules containing corn starch.

Capsule preparation

Fresh moringa leaves were harvested from Malakandher Farm. After being dried in the shade, the leaves were ground into a fine powder using a commercial grinder. The resulting powder was then encapsulated into 500 mg capsules, which were purchased from a nearby market.

Study procedure and design

The study was designed as a parallel, randomized controlled trial, lasting a total of 12 weeks. Blood tests were conducted at the start of the study to confirm hyperlipidemia. At both the beginning and the end of the study, anthropometric measurements, including waist circumference (WC) and height, were recorded. Blood pressure and blood glucose levels were also assessed at baseline and at the study's conclusion. Participants received capsules, which they were instructed to take twice a day, before breakfast and dinner. They were also advised to engage in 30 to 40 minutes of moderate physical activity daily. All subjects were closely monitored during follow-up visits to ensure adherence to the study protocols. Compliance was further assessed by counting the number of capsules returned at each visit. Participants in both groups were advised to maintain their usual diet throughout the study. At the end of the research period, individuals were re-examined for the same parameters.

Dietary intake

The 24-hour dietary recall method was used to assess the food consumption of each participant. A 24-hour recall questionnaire was administered at both baseline and at the conclusion of the study to record all food intake data. Participants were asked to recall their food consumption from the previous 24 hours, including details about cooking methods and food recipes. The portion sizes of the consumed foods were also documented (Subar *et al*., 2012).

Anthropometric measurements

Anthropometric measurements were taken at both the beginning and end of the study period. These measurements included body weight, height, body mass index (BMI), and waist circumference. Weight was measured using a digital scale with an accuracy of 0.1 kg. Participants were instructed to remove heavy clothing, shoes, and any accessories (Viet and Verschuren, 2008). Height was measured using a portable stadio meter with calibrated rods up to 200 cm. Participants were asked to stand straight, with their feet together and facing forward. BMI was calculated using the formula: weight (kg) divided by the square of height (m^2). Waist circumference (in cm) was measured using a non-stretchable measuring tape, placed between the lower ribs and above the hips, exactly at the level of the navel, following standardized procedures.

Blood sample collection and processing to serum

To prevent blood from flowing back into the veins, a tourniquet was applied to the upper arm, and the venipuncture site was cleaned with an alcohol swab. A 5 ml blood sample was then drawn using a needle and collected in tubes for subsequent analysis (Thavasu *et al*., 1992).Following blood collection, the sample was immediately transferred into small test tubes with screw caps and left at room temperature for 15–20 minutes to allow it to clot. After clotting, the tubes were carefully placed in a centrifuge and spun for 10 minutes at 4000 rpm to separate the serum and remove any clots. Once centrifugation was complete, the serum was carefully extracted using a Pasteur pipette and transferred into clean Eppendorf tubes, which were then stored at −20°C for further analysis.

Fasting blood glucose

Fasting blood glucose levels were measured at both the beginning and end of the study using a laboratory glucose determination kit. For the assay, 1000 µL of glucose reagent was added to a blank test tube using a micropipette. For the standard, 1000 µL of glucose reagent and 10 µL of standard solution were added to the test tube. In the sample test tube, 10 µL of serum and 1000 µL of glucose reagent were added. Each tube was gently swirled to mix the reagent and serum. The mixture was then incubated at 37°C for 10 minutes. After incubation, the absorbance of the samples was measured using a spectrophotometer.

Lipid profile

The lipid profiles of all participants were assessed at both the start and end of the study to measure total cholesterol, triglycerides, and LDL levels using the method outlined by Mastoi *et al*. (2010). The LDL cholesterol concentration was calculated using the Friedewald equation. The concentrations of HDL cholesterol were determined using previously obtained values for total cholesterol, HDL, and triglycerides, as described by Kannan *et al*., (2014).

Blood pressure measurement

Blood pressure was measured using a mercury sphygmomanometer. Participants were asked to remove any excess clothing that could interfere with the blood pressure cuff and blood flow. The cuff was placed snugly around the upper arm, positioned above the brachial artery. A stethoscope was then placed over the brachial artery of the upper arm. The cuff was inflated rapidly to 180 mmHg using the cuff bulb. The sixth valve was gradually opened at a rate of 3 mm/sec to allow the Korotkoff sounds to be heard. The systolic blood pressure (SBP) was recorded when the first Korotkoff sound was heard, and the diastolic blood pressure (DBP) was noted when the last sound was detected. The blood pressure readings were then recorded on the measurement sheet.

Physical activity

The General Practice Physical Activity Questionnaire (GPPAQ) was used to assess physical activity levels at both the beginning and end of the study. The GPPAQ is a validated screening tool commonly used in primary care settings to measure the physical activity levels of individuals. It categorizes physical activity into four levels: 1) sedentary, 2) moderately inactive, 3) moderately active, and 4) active (Pearson and Grace, 2012).

Statistical analysis

Statistical analysis was performed using SPSS (version 20). Categorical variables were compared using the chi-square test, while baseline values for quantitative variables were compared using the independent sample t-test. The nutritional intake, anthropometric measurements, blood glucose levels, lipid profiles, and blood pressure data within each group were compared using paired sample t-tests (baseline vs. 12 weeks). The net changes in anthropometric parameters, blood glucose levels, lipid profiles, and blood pressure readings between the control and moringa groups were compared using an independent sample t-test. A P value of 0.05 was considered statistically significant.

Results

Baseline characteristics

Table 1 presents the baseline characteristics of the study subjects. The average ages of the control group (42.45 years) and the moringa group (44.15 years) did notdiffer significantly. At baseline, anthropometric measurements, including weight, height, BMI, and waist circumference,

Table1. Subject baseline characteristics.

Variable	Control group (n = 20)	Moringa group (n = 20)	P Value
Age (years)	42.45 ± 1.74	44.15 ± 1.73	0.494**
Sex, n (%)			
Men	7 (35)	8 (40)	0.113***
Women	13 (65)	12 (60)	
Wt (kg)	84.18 ± 1.15	87.06 ± 1.37	0.117**
Ht (cm)	164.13 ± 1.15	165.40 ± 1.37	0.614**
BMI (kg/m^2)	30.67 ± 0.05	31.79 ± 0.73	0.161**
WC (inch)	37.17 ± 0.39	38.22 ± 0.43	0.083**
FBG (mg/dl)	102.85 ± 1.11	98.80 ± 1.87	0.071**
TGL (mg/dl)	213.80 ± 6.83	210.45 ± 10.15	0.786**
TC (mg/dl)	234.65 ± 9.10	225.55 ± 4.85	0.383**
HDL (mg/dl)	35.75 ± 0.86	33.85 ± 0.96	0.149**
LDL (mg/dl)	205.35 ± 2.81	194.55 ± 5.66	0.096**
SBP (mmHg)	135.50 ± 3.20	137.50 ± 3.06	0.654**
DBP (mmHg)	91.25 ± 1.44	92.00 ± 1.55	0.726**
PA, n (%)			
Inactive	9 (45)	11 (55)	0.799***
Moderately in-active	9 (45)	7 (35)	
Moderately active	2 (10)	2 (10)	
Strenuous	0	0	

The values are presented as the means ± SEMs for quantitative variables and as frequencies (percentages) for categorical variables. Wt: body weight; Ht: height BMI: body mass index; WC: waist circumference; FBG: fasting blood glucose; TGL: triglyceride; TC: total cholesterol; HDL: high-density lipoprotein; LDL: lowdensity lipoprotein; SBP: systolic blood pressure: DBP: diastolic blood pressure. PA: physical activity. **Obtained from independent samplet-test. ***Obtained from chi-square test.

showed no significant differences between the two groups. The effect of sexon physical activity was also not significant (P > 0.05). Cholesterol and triglyceride levels didnot differ significantly at baseline. Furthermore, the baseline study results for the lipid profilecomponents, HDL and LDL, were not significantly different between the groups. The mean triglycerideconcentration was 213.80 mg/dl in the control group and 210.45 mg/dl in the moringa group.

The systolic blood pressure at baseline did notdiffer significantly between the two groups. The mean systolic blood pressure was 135.50 mmHg in the control group and 137.50 mmHg in the moringa group. Similarly, the mean diastolic blood pressure did notshow a significant difference between the control group (91.2 mmHg) and the moringa group (92.0 mmHg). Regarding physical activity, 45% of participants in the control group

wereinactive, 45% were moderately inactive, and 10% were moderately active.

Nutrient intake

Table 2 presents the dietary energy and nutrient consumption in both groups at the beginning and after 12 weeks of intervention. No significant variation (P > 0.05) in caloric intake was observed in the control group after 12 weeks compared to baseline. However, in the moringa group, energy intake was significantly lower (P < 0.05) at the end of the study compared to baseline. Carbohydrate intake in both the control and moringa groups did not differ significantly (P > 0.05) either at the start of the intervention or after 12 weeks. Protein consumption was also not significantly different (P > 0.05) between the two groups, both at the start and at the end of the study. In contrast, fat consumption in the control group decreasedconsiderably (P < 0.05) during the course of the 12-week intervention, compared to baseline fat intake. There were no significant differences (P > 0.05) in the consumption of cholesterol or dietary fiber between the groups at either the beginning or the end of the study. However, after 12 weeks of intervention, the dietary fiber intake in the moringa group was significantly higher (P < 0.05) than at baseline.

Anthropometric measurements

Table 3 presents the anthropometric data collected at the start of the trial and after 12 weeks. In the control group, there was no significant change in weight (P > 0.05) between baseline and 12 weeks. However, in the moringa group, weight measurements after 12 weeks differed significantly (P < 0.05) from baseline values. The mean weight of the control group was 84.18 kg at the beginning of the study and 82.94 kg at the end (P > 0.05). In contrast, the mean weight of the moringa group was 87.6 kg at baseline and decreased to 84.55 kg, showing a significant reduction (P < 0.05). There was no significant difference (P > 0.05) in BMI or waist circumference in the control group from baseline to 12 weeks. However, in the moringa group, both BMI and waist circumference showed significant reductions (P < 0.05) compared to baseline. The mean waist circumference values for the control group at baseline and after 12 weeks were 37.17 inches and 36.97 inches, respectively, while the moringa group had baseline and post-intervention values of 38.22 inches and 37.48 inches, respectively. After 12 weeks of intervention, the net changes in weight between the control and moringa groups were significantly different (P < 0.03), as shown in Table 4. Furthermore, after 12 weeks, the mean BMI and waist circumference in the moringa group were significantly different from those in the control group (P < 0.05).

Table 2. Energy and nutrient consumption in both groups' diets at the start and after 12 weeks.

Variables	Control group (n = 20)	Moringa group (n = 20)
Energy (kcal)		
Baseline	2273.55 ± 80.42	2309.85 ± 118.21
12 weeks	2329.95 ± 78.38	2110.15 ± 76.04
P value*	0.483	0.046
Carbohydrate (g)		
Baseline	315.10 ± 9.32	307.20 ± 15.95
12 weeks	313.30 ± 14.86	287.60 ± 12.07
P value*	0.917	0.287
Dietary Protein (g)		
Baseline	77.85 ± 2.20	82.75 ± 4.69
12 weeks	81.15 ± 2.70	79.40 ± 3.67
P value*	0.285	0.532
lipids (g)		
Baseline	79.75 ± 4.87	84.45 ± 5.35
12 weeks	83.85 ± 6.05	74.35 ± 4.76
P value*	0.417	0.020
Total Cholesterol (mg)		
Baseline	233.85 ± 11.31	206.85 ± 24.29
12 weeks	244.25 ± 25.47	184.60 ± 15.42
P value*	0.681	0.183
Dietary fiber (g)		
Baseline	12.55 ± 0.98	14.35 ± 0.69
12 weeks	13.00 ± 0.69	18.70 ± 1.46
P value*	0.692	0.003

Each value is the mean SEM. *P values are used to compare baseline and after 12 weeks values within each group, with a threshold of -P < 0.05 (paired t-test).

Biochemical and blood pressure measurements

Table 5 presents the mean values for blood pressure and biochemical parameters at baseline and after 12 weeks of intervention. The study findings revealed no significant difference in the control group's mean values at baseline or after 12 weeks of receiving the placebo (P > 0.05). However, in the moringa group, significant differences were observed in the mean blood lipid profile, fasting blood glucoselevels, and blood pressure after 12 weeks of intervention (P < 0.05). The highest mean fasting blood sugar (FBS) concentration in the control group was 102.85 mg/dl at baseline, with a slight decrease to 101.70 mg/dl after 12 weeks. In the moringa group, the mean FBS decreased significantly from baseline to 92.65 mg/dl after 12 weeks. In the control group, fasting blood glucose levels did not change significantly from baseline (P > 0.05).Similarly, the lipid profile components in the control group, including total cholesterol, triglycerides, HDL,

Table 3. Anthropometric measurements at baseline and after 12 weeks of intervention.

Variables	Control group (n = 20)			Moringa group (n =20)		
	Before treatment	12 weeks	P value*	Before treatment	12 weeks	P value*
Weight (kg)	84.18 ± 1.15	82.94 ± 1.30	0.170	87.06 ± 1.37	8 84.55 ± 1.42	0.001
BMI (kg/m^2)	30.67 ± 0.54	30.66 ± 0.53	0.896	31.97 ± 0.37	31.05 ± 0.37	0.001
WC (inch)	37.17 ± 0.39	36.95 ± 0.38	0.206	38.22 ± 0.43	37.48 ± 0.43	0.001

BMI: body mass index; WC: waist circumference. The means and ± SEMs of all values. P values are used to compare baseline and 12-week results for each group, with a threshold of P < 0.05. (paired t-test).

Table 4. Comparison of the two groups' differences in the modifications to their anthropometric measures.

Variables	Control group (n = 20)	Moringa group (n = 20)	P value*
Weight (kg)	–1.24 ± 0.87	–3.26 ± 0.27	0.034
BMI (kg/m^2)	–0.01 ± 0.09	–0.92 ± 0.08	0.001
WC (inch)	–0.22 ± 0.17	0.74 ± 0.17	0.039

BMI: body mass index; WC: waist circumference. The means and ± SEMs of all values. P values are used to compare changes in the control and moringa groups, with a threshold of P < 0.05. (independent sample t-test).

and LDL, did not show significant changes. Specifically, the mean values for total cholesterol, triglycerides, HDL (33.85 mg/dl), and LDL (194.55 mg/dl) remained stable in the control group throughout the study period (P > 0.05). In contrast, the moringa group demonstrated significant changes in lipid profile components. After 12 weeks, total cholesterol, triglycerides, and HDL levels were significantly altered, with HDL increasing from 33.85 mg/dl to 38.25 mg/dl, and LDL decreasing from 194.55 mg/dl to 176.45 mg/dl (P < 0.05). Blood pressure also showed significant changes in the moringa group. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) values in the moringa group were significantly reduced after 12 weeks (P < 0.05), indicating an improvement compared to baseline levels. In the control group, however, no significant changes were observed in either systolic or diastolic blood pressure.

Table 6 compares the net changes in blood pressure and biochemical parameters between the control group and the treatment (moringa) group after the 12-week intervention. The mean fasting blood sugar (FBS) values in both groups showed a significant difference (P < 0.02) after 12 weeks of treatment. Similarly, triglyceride levels in both the control and moringa groups were significantly different (P < 0.05) following the intervention. However, total cholesterol levels did not differ significantly between the two groups (P > 0.02). Other lipid profile components, including LDL and HDL, were significantly different between the two groups (P < 0.05) after the intervention, with the moringa group showing improved lipid levels. Furthermore, systolic blood pressure (SBP) values were significantly different between the two groups (P < 0.05). Diastolic blood pressure (DBP) also showed significant differences (P < 0.05) between the control and moringa groups after the 12-week period, indicating a notable reduction in blood pressure in the moringa group compared to the control group.

Discussion

A significant decrease in energy and fat intake was observed in the treatment group after 12 weeks of intervention compared to baseline values. This could be attributed to the greater satiety effect of moringa leaves. A previous study investigated how moringa leaves can prevent rats from becoming obese from a high-fat diet. The results showed a significant decrease in body weight and food intake following treatment with moringa (Othman *et al*., 2019). A previous human study in which moringa was incorporated into cookies showed changes in appetite parameters that ultimately resulted in less food intake by the study subjects (Ahmad *et al*., 2018). Therefore, the decrease in energy intake in the moringa group in the present study could be attributed to the satiety-enhancing effect of moringa leaves. The findings of the present study demonstrated that consuming 1000 mg of moringa daily for 12 weeks significantly decreased body weight, BMI, and WC. In a prior investigation into the ability of the miracle tree moringa to fight obesity, several in vivo, in vitro and clinical trials showed that the anti-obesity effects of moringa are potentially associated with decreased body weight and improved plasma lipids (Redha *et al*., 2021). Treatment of the obese group with the ethanolic extract of the moringa plant led to a considerable reduction in body weight, according to another study of the plant's multi-mechanistic approach for managing obesity in rats, including reductions in WC and BMI (Ahmad *et al*., 2014). A previous study revealed that the administration of moringa leaf extract

Table 5. Measurements of biochemical markers and blood pressure before and after an intervention of 12 weeks.

Variables	Control group (n = 20)			Moringa group (n =20)		
	Baseline	12 weeks	P value*	Baseline	12 weeks	P value*
FBG (mg/dl)	102.85 ± 1.11	101.70 ± 1.41	0.265	98.80 ± 1.87	92.65 ± 2.16	0.001
TGL (mg/dl)	213.80 ± 6.83	209.75 ± 6.69	0.225	210.45 ± 10.15	176.55 ± 6.25	0.008
TC (mg/dl))	234.65 ± 9.10	226.05 ± 6.65	0.106	225.55 ± 4.85	210.60 ± 4.30	0.002
HDL (mg/dl)	35.75 ± 0.86	36.15 ± 0.98	0.546	33.85 ± 0.96	38.25 ± 0.91	0.001
LDL (mg/dl)	205.35 ± 2.81	206.55 ± 2.64	0.805	194.55 ± 5.66	176.45 ± 9.29	0.002
SBP (mmHg)	135.50± 3.20	133.50 ± 2.54	0.677	137.50 ± 3.06	124 ± 1.368	0.001
DBP (mmHg)	91.25± 1.44	92.00 ± 2.24	0.720	92.00 ± 1.55	86.00 ± 1.68	0.001

FBG: fasting blood glucose; TGL: triglyceride; TC: total cholesterol; HDL: high density lipoprotein; LDL low density lipoprotein; SBP: systolic blood pressure: DBP: diastolic blood pressure.
All values are means± SEMs. *P values are for comparing baseline and after 12 weeks values within each group, P < 0.05 (paired t-test).

Table 6. Comparison between changes in biochemical parameter and blood pressure measurements between the two groups.

Variables	Control group (n = 20)	Moringa group (n = 20)	P value*
FBS (mg/dl)	–1.15 ± 4.47	–6.15 ± 4.97	0.002
TGL (mg/dl)	–4.05 ± 3.32	–33.90 ± 11.38	0.016
TC (mg/dl))	–8.60 ± 5.06	–14.95 ± 4.03	0.333
HDL (mg/dl)	0.40 ± 0.65	4.40 ± 1.01	0.002
LDL (mg/dl)	1.20 ± 4.78	–18.1 ± 5.18	0.009
SBP (mmHg)	–2.0 ± 4.73	–13.5 ± 2.74	0.042
DBP (mmHg)	0.75 ± 2.06	–6.0 ± 1.52	0.012

FBS: fasting blood glucose; TGL: triglyceride; TC: total cholesterol; HDL: high-density lipoprotein;
LDL; low-density lipoprotein; SBP: systolic blood pressure DBP: diastolic blood pressure. The means and SEMs of all values.
*P values are used to compare changes in the control and moringa groups, with a value of P < 0.05. (independent sample t-test).

to obese female subjects caused weight loss due to the presence of bioactive compounds such as isothiocyanate, which inhibits 3-hydroxy-3-methylglutaryl coenzyme A reductase in the cholesterol synthesis pathway; hence, moringa leaf extract acts as an antiobesity and hypolipidemic agent (Metwally *et al*., 2017). According to a previous study review, there is a strong positive association between leptin concentration in the body and the production of reactive oxygen species (ROS), and moringa has the capacity to scavenge free radicals, with the goal of inhibiting the lipid-regulating hormone leptin in the blood (Khanna *et al*., 2015). A previous study on rats investigated the antiobesity and hypolipidemic effects of moringa ethanolic extract. Research has shown that moringa extract dramatically decreased the body weight of the study subjects, suppressed appetite, and attenuated the atherogenic index of lipids without affecting food intake (Bais *et al*., 2014). In another human study on how powdered moringa leaf consumption reduces postprandial BP, 41 subjects were evaluated, and the results of this study revealed significant changes in postprandial blood pressure, BMI, and waist circumference (Chun Sun *et al*., 2019). A previous study investigated the effects of moringa on waist circumference, BMI, lipid profiles, and improved blood vessel endothelial integrity caused by obesity (Madkhali *et al*., 2019). Additionally, conflicting evidence on the ability of moringa to alter anthropometric measurements and prevent obesity has been reported (Seriki *et al*., 2015).According to some studies, *Moringa oleifera* contains bioactive phytoconstituents such as beta-sitosterol and beta-sitosteron, which are structurally similar to cholesterol and can inhibit dietary cholesterol absorption by lowering the plasma concentration of LDL, while simultaneously increasing endogenous blood cholesterol excretion in feces in the neutral steroid form. Similarly, nitrile glycosides such as niazirin and niazirinin, which are uniquely present in moringa, have shown hypotensive and hypoglycemic effects by decreasing blood glucose and blood pressure. Therefore, the antioxidant composition of moringa can reduce total cholesterol, LDL, HDL, triglyceride levels, and blood pressure. Most animal studies and some human investigations have demonstrated that moringa has a positive effect on lowering blood lipid profiles and blood pressure. The results of the present study revealed significant differences in fasting blood glucose, cholesterol, LDL, high-density lipoprotein (HDL), triglyceride levels, and blood pressure, which supports the findings of various previous animal studies. In a previous study, 400 mg/day of atorvastatin was given to albino rats, which resulted in decreased total cholesterol, LDL, HDL, and triglyceride levels in the blood of the rats (Aborhyem *et al*., 2016). Another study showing that moringa leaf intake decreases postprandial blood pressure in human subjects found that the consumption of moringa leaf powder lowered 2-hour postprandial blood pressure. This indicated a potential decreasing effect on both systolic and diastolic BP, even

after the subjects had consumed high amounts of salt (7 g/day) (Chan Sun*et al*., 2014). The findings of the present study, in comparison to those of the control group, indicated that moringa was not effective at lowering the total blood cholesterol levels of the study subjects. The Moringa group showed changes in the mean total cholesterol (8.60 mg/dl in the control group and -14.95 mg/dl in the treatment group) after 12 weeks of treatment, but the difference was not significant. This may be due to the small sample size and the fact that dietary intake outcomes in the present research showed an increase in fat consumption. A high intake of unhealthy fats or trans fats is a major source of increased exogenous cholesterol in the human body. The results of previous studies have also not been promising in regard to total cholesterol (Seriki *et al*., 2015).

Conclusion

The Moringa group had significantly decreased caloric and fat intake after 12 weeks compared with baseline values. Additionally, there was a significant increase in fiber intake after 12 weeks in the Moringa group. Moringa supplementation significantly decreased body weight, BMI, and waist circumference (WC) after 12 weeks compared to baseline values. Moreover, the net changes in body weight, BMI, and WC between the two groups were significantly different. The intake of Moringa leaf powder for 12 weeks significantly decreased blood glucose levels, improved the lipid profile, and decreased blood pressure compared to baseline values.

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Author Contributions

All authors contributed equally to this article.

Conflicts of Interest

The authors declare no conflicts of interest.

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Declaration of Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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