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Original Article

Evaluating the Anti-Obesity Effects of a Herbo-mineral Formulation in High-Fat Diet-Induced Obesity in Rats

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ABSTRACT

Background: Obesity is a multifactorial metabolic disorder associated with dyslipidemia, insulin resistance, increased risk of cardiovascular diseases and type 2 diabetes mellitus. The limitations of current therapies have highlighted the need for safer, effective strategies. **Objectives:** To evaluate the anti-obesity potential of a Medohara-based herbomineral formulation in a High-Fat Diet (HFD)-induced obesity male Wistar rat model. **Materials and Methods:** Male Wistar rats were divided into four groups (n=6): normal control, HFD control, HFD + orlistat (45 mg/kg), and HFD + herbomineral formulation (500 mg). Obesity was induced via HFD for 42 days. Parameters monitored includes body weight, food intake, fasting blood glucose, serum lipid profiles (TC, TG, HDL, LDL), and liver function markers (SGOT, SGPT). Histopathological examination of liver and adipose tissues was performed. **Results:** HFD feeding caused significant weight gain and dyslipidemia. Treatment with the herbomineral formulation significantly normalized body weight, glycemic status, and lipid profile parameters. Effects were comparable to orlistat. Histology revealed partial restoration of liver and adipose tissue architecture. **Conclusion:** The Medohara-based herbomineral formulation exhibited significant anti-obesity activity in HFD-induced obese rats.

Keywords: Herbomineral formulation, High-fat Diet, Lipid Profile, Medohara, Obesity.

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INTRODUCTION

Obesity is a chronic metabolic disorder characterized by excessive adipose tissue accumulation due to prolonged energy imbalance, leading to adipocyte hypertrophy and systemic metabolic dysfunction. It is strongly associated with dyslipidemia, insulin resistance, type 2 diabetes mellitus, hypertension and increased risk of cardiovascular diseases, thus representing a major global health burden (Shah *et al*., 2011).

According to estimates by International Obesity Task Force, over 300 million people are obese (BMI≥30 kg/m^2), and around 800 million are overweight (BMI 25-29.9 kg/m^2). In India, the prevalence of overweight and obesity has been steadily increasing, with national surveys reporting that approximately 20-30% of adults are overweight or obese, particularly in urban populations and a rising trend is also observed among children and adolescents due to sedentary lifestyle and unhealthy dietary habits (Kumar *et al*., 2013).

Synthetic anti-obesity drugs, including sibutramine and centrally acting appetite suppressants such as orlistat (Othman *et al*., 2022), are associated with notable adverse effects. These include gastrointestinal intolerance, hepatic dysfunction, cardiovascular risks such as hypertension, tachycardia and central nervous system-related effects including insomnia and mood disturbances. Furthermore, long-term administration is limited by poor patient adherence, risk of rebound weight gain following discontinuation and lack of sustained efficacy in addressing the multifactorial pathophysiology of obesity (Giri *et al*., 2025).

In this context, traditional Indian medicine (Ayurveda) describes obesity (Sthaulya/Medoroga) as a disorder of Meda dhatu metabolism caused by Kapha imbalance and impaired Agni, leading to pathological fat accumulation. Ayurvedic Medohara herbs are reported to modulate lipid metabolism, enhance energy expenditure and regulate appetite and insulin signaling pathways through multi-target mechanisms (Pandeya *et al*., 2021).

Medohara refers to a classical Ayurvedic concept describing herbs that help reduce excess "Meda" (adipose tissue or body fat). These drugs are traditionally used in the management of obesity

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and metabolic disorders. Medohara herbs are believed to improve lipid metabolism, enhance fat mobilization and restore energy balance in the body. Their therapeutic action is often attributed to the presence of bioactive phytoconstituents with anti-obesity, hypolipidemic and antioxidant properties (Kumari *et al*., 2013).

Medohara herbs such as *Azadirachta indica* (Nimba), *Tephrosia purpurea* (Sharapunkha), *Garcinia indica* (Vrukshamla), *Piper longum* (Pippali), *Zingiber officinale* (Shunthi), *Piper nigrum* (Maricha), *Terminalia chebula* (Haritaki), *Terminalia bellirica* (Bibhitaki), *Phyllanthus emblica* (Amalaki), *Achyranthes aspera* (Apamarga), *Plumbago zeylanica* (Chitraka), *Commiphora mukul* (Guggul), *Cyperus rotundus* (Musta), *Acorus calamus* (Vacha), *Bauhinia variegata* (Kachanara), *Cinnamomum zeylanicum* (Twak), *Embelia ribes* (Vidanga), *Andrographis paniculata* (Kalmegha), *Curcuma longa* (Haridra), *Ocimum sanctum* (Tulsi) and others may demonstrate anti-obesity potential through synergistic antioxidant, hypolipidemic and anti-inflammatory actions. Loha bhasma, a mineral if added may improve metabolic homeostasis and suppress adipogenesis.

Based on this rationale, the present study evaluates a Medohara-based herbomineral formulation for its anti-obesity potential in a high-fat diet-induced rat model.

MATERIALS AND METHODS

Drugs and Chemicals

All crude drugs used in the formulation, namely Nimba, Sharapunkha, Vrukshamla, Trikatu (Ginger and two peppers), Triphala (Chebula, Bellirica, Amla), Apamarga, Chitraka, Guggulu, Musta, Vacha, Kanchanara, Twak, Vidanga, Kalmegh, Haridra, Tulsi, and Loha Bhasma were procured from Pentacare Ayurpharma, Bengaluru, India. The ingredients were selected based on their traditional Ayurvedic use as Medohara drugs described in *Bhavaprakasha Nighantu* and *Rasatarangini* (Bhavamishra, 2018; Shastri, 2019).

The botanical raw materials were authenticated by the Department of Botany, KLE Society's S. Nijalingappa College, Bengaluru, through standard taxonomical and morphological evaluation. Authentication was confirmed vide Certificate of Authentication dated 12 August 2025 issued by the Department of Botany and a voucher specimen deposited. The authenticated plant materials were subsequently used for formulation development and experimental studies.

Orlistat was purchased from Hansika Medicals, Bengaluru, India. Solvents such as water were of Analytical Grade (AR). Serum Cholesterol kit, Serum Triglyceride kit, Serum HDL-Cholesterol kit, Serum LDL-Cholesterol kit, Serum VLDL-Cholesterol kit, Blood-Glucose kits, Serum Glutamate Oxaloacetate Transaminase (SGOT) kit, and Serum Glutamate Pyruvate Transaminase (SGPT) kit were procured from Unitron Bio Medicals, Bengaluru, India.

Extraction and Formulation

The raw materials were subjected to aqueous extraction by boiling in a predetermined volume of water and maintaining sustained heating for 4-5 hr to facilitate efficient extraction of bioactive constituents. The extract was allowed to cool slightly and filtered to separate the liquid extract from the residues. The initial filtrate was collected, and the residues were repeatedly extracted with fresh water through successive boiling cycles to ensure exhaustive recovery of phytoconstituents. All filtrates obtained from each extraction cycle were pooled and concentrated under reduced pressure using a rotary evaporator until a semisolid mass was obtained. The concentrated extracts of individual plants were then mixed according to the proportions specified in Table 1 to obtain a homogeneous herbal blend.

This blend was mixed in Gomutra and Kashaya prepared by using equal quantities of coarse powders consisting of rhizomes of Haridra, seeds of Aranyajeeraka, seeds of Krishna Jeeraka, stem bark of Aragwadha, heart wood of Khadira, stem of Daruharidra, stem bark of Varuna, heart wood of Asana, stem bark of Kutaja and Lodhra and dried.

Loha Bhasma was incorporated at the terminal stage with continuous trituration to ensure uniform distribution throughout the formulation. In Ayurvedic literature, Loha Bhasma is regarded as an important herbo-mineral ingredient and is traditionally employed in formulations intended for metabolic disorders owing to its Deepana, Pachana, and Lekhana properties. Furthermore, Loha Bhasma has been reported to enhance the therapeutic efficacy of herbal formulations and may contribute to improved bioavailability and utilization of active phytoconstituents (Shastri, 2019). Therefore, its incorporation was considered appropriate in the present Medohara herbomineral formulation.

The final herbomineral formulation was homogenized thoroughly to ensure batch uniformity and to facilitate consistent delivery of both herbal phytoconstituents and mineral components during experimental administration.

Animals

Male Wistar rats (200-220 g, 6-8 weeks old) were sourced from VERTEBRETES, Magadi Road, Bengaluru, India. The animals were housed in polypropylene cages under controlled conditions, maintaining a 12-hr light/dark cycle and a temperature of 25°C±3°C for acclimatization. They were provided with a high-quality animal diet and ad *libitum*. The Institutional Animal Ethical Committee (IAEC) of CCSEA (Committee for the Control and Supervision of Experiments on Animals) approved this study, with approval number 17/MA/2025.

Diet

The High-Fat Diet (HFD) comprised casein, cholesterol, lard, soybean oil, corn starch, cellulose, sucrose and a vitamin-mineral

mixture. Experimental obesity was induced by administrating the animals with the HFD continuously for 42 days, while the normal control group was maintained on a standard laboratory diet throughout the experimental period.

Dose fixation: The human therapeutic dose of the herbomineral formulation (500 mg po) was derived from the classical Ayurvedic texts Rasatarangini and Bhavaprakasha Nighantu, which describe the herbs used in the formulation and their traditional usage. The human therapeutic dose was selected based on the traditional use of the constituent Medohara herbs and formulation expertise provided by the collaborating Ayurvedic pharmaceutical industry partner. The corresponding animal dose was calculated using the standard BSA-based interspecies dose conversion method. The dose of the herbomineral formulation was calculated by extrapolating the human therapeutic dose to rats using the Body Surface Area (BSA)-based conversion method described by Paget and Barnes. The human therapeutic dose of the formulation was 500 mg/day. The corresponding rat dose was calculated using the conversion factor of 0.018 for rats (Paget and Barnes, 1964; Rajput *et al.*, 2019).

$$\text{Rat dose} = \text{Human dose} \times \text{Conversion factor}$$

=500 mg × 0.018,

=9 mg/200 g Rat,

=45 mg/kg Body Weight.

Accordingly, the therapeutic equivalent dose administered to experimental animals was 45 mg/kg body weight, orally.

Experimental design and animal grouping

Rats were randomly divided into four groups, each comprising six animals. The study was conducted over a period of six weeks.

- **Group 1: Normal control (N):** Animals were fed normal rat chow throughout the experimental period.
- **Group 2: High fat diet:** This group served as High Fat Diet (HFD) for a period of 42 days.
- **Group 3: Standard:** This group received HFD for a period of 42 days + from 8th day Orlistat (45 mg/kg/bw po) was given for the period of 35 days.
- **Group 4: Herbomineral formulation:** This group received HFD for the period of 42 days + from 8th day herbomineral formulation (45 mg/kg bw po) was given for the period of 35 days (Umbarkar, 2022).

Dose fixation

The dose employed in the experimental study was based on both traditional Ayurvedic literature and established dose-conversion principles.

Measurement of food intake

The food consumption of each rat was first determined at baseline and subsequently on a weekly basis through the difference between the initial weights of the feed and those left over after 24 hrs and expressed in grams per week.

Measurement of Body weight and BMI

Body weight was recorded weekly using a digital weighing balance, and BMI was also measured at weekly intervals throughout the experimental period to monitor changes possibly associated with diet-induced obesity.

Measurement of Fasting Blood Glucose

Fasting blood glucose levels were monitored at weekly intervals throughout the experimental period to monitor changes possibly associated with diet-induced obesity.

Blood biochemical analysis

Blood samples were collected from all experimental groups at the end of the study using retro-orbital plexus puncture method. The samples were processed to obtain serum for biochemical analysis. Serum lipid profile parameters and lipoproteins were estimated using standardized, commercially available enzymatic diagnostic kits. The estimations were carried out by following the specific analytical procedures, reagent volumes, incubation conditions and calculation methods provided by kit manufacturer. In addition, liver function markers, namely SGOT and SGPT were analyzed to assess hepatic function and treatment-related effects.

Histopathological Study

Animals used in the *in vivo* experiments were sacrificed for histopathological evaluation of adipose and liver tissues. The excised tissues were washed with normal saline and fixed in 10% buffered formalin. Following fixation, the tissues were dehydrated through graded alcohol series, embedded in paraffin and sectioned into 4- 5 µm-thick slices. The sections were stained with Hematoxylin and Eosin (H&E) and mounted on glass slides for microscopic examination at 50× and 100× magnifications. H&E staining is routinely employed in histological analysis to differentially stain cellular and tissue components, enabling detailed visualization of tissue architecture.

Statistical data Analysis

Statistical analysis was performed using GraphPad Prism version 8.0 software. The *in vivo* data were presented as mean ± SD and analyzed using one-way ANOVA followed by Tukey's multiple range test, with a significance level of $p<0.05$ considered statistically significant.

RESULTS

Measurement of food intake

The food consumption of each rat was first determined at baseline and subsequently on a weekly basis through the difference between the initial weights of the feed and those left over after 24 hr. It was noted that animals fed with HFD consumed more when compared to control group.

Effect of Herbomineral formulation on body weight in HFD-induced obesity rats

HFD-fed animals showed a significant increase in body weight compared with the normal control group (##p<0.01) over 6 weeks, confirming successful induction of obesity. Treatment with orlistat (45 mg/kg) significantly reduced body weight (***p<0.001), while the herbomineral formulation also produced a significant reduction (**p<0.01) compared with the HFD control group. The observed reduction in body weight suggests the anti-obesity potential of the Medohara-based herbomineral formulation in HFD-induced obese rats (Figure 1A).

Effect of Herbomineral formulation on BMI in HFD-induced obesity rats

Animals fed with a High-Fat Diet (HFD) exhibited a significant increase in Body Mass Index (BMI) compared with the normal control group (##p<0.01), confirming successful induction of obesity. Treatment with orlistat significantly reduced BMI (***p<0.001), while administration of the herbomineral formulation also produced a significant reduction (*p<0.05) compared with the HFD control group. The reduction in BMI may be attributed to improved lipid metabolism, enhanced fat mobilization and inhibition of excessive lipid accumulation by the bioactive phytoconstituents present in the formulation. These findings suggest the anti-obesity potential of the formulation in lowering HFD-induced adiposity and metabolic alterations (Figure 1B).

Effect of Herbomineral formulation on fasting blood glucose of rats fed experimental diets for 6 weeks

Fasting Blood Glucose (FBG) levels were significantly elevated in the HFD-fed group compared with the normal control group (##p<0.01), indicating impaired glucose homeostasis

Table 1: Formulation table.

Sl. No.	Sanskrit Name	Botanical Name	Plant part used	Form	Amount
1.	Nimba	*Azadirachta indica*	Leaves	Extract	30 mg
2.	Sharapunkha	*Tephrosia purpurea*	Whole plant	Extract	40 mg
3.	Vrukshamla	*Garcinia indica*	Fruit	Extract	30 mg
4.	Trikatu (Three Pungents - Pippali, Shunthi, Maricha)	*Piper longum, Zingiber officinale, Piper nigrum*	Fruit &Rhizome	Extract	30 mg
5.	Triphala (Three Myrobalans- Haritaki, Bibhitaki, Amalaki)	*Terminalia chebula, Terminalia bellirica, Emblica officinalis*	Fruit	Extract	40 mg
6.	Apamarga	*Achyranthes aspera*	Whole plant	Extract	30 mg
7.	Chitraka	*Plumbago zeylanica*	Root	Extract	30 mg
8.	Guggul	*Commiphora mukul*	Oleo gum resin	Extract	30 mg
9.	Musta	*Cyperus rotundus*	Rhizome	Extract	30 mg
10.	Vacha	*Acorus calamus*	Rhizome	Extract	30 mg
11.	Kanchanara	*Bauhinia variegata*	Bark	Extract	50 mg
12.	Twak	*Cinnamomum zeylanicum*	Bark	Extract	20 mg
13.	Vidanga	*Embelia ribes*	Fruit	Extract	20 mg
14.	Kalmegha	*Andrographis paniculata*	Whole plant	Extract	20 mg
15.	Haridra	*Curcuma longa*	Rhizome	Extract	30 mg
16.	Tulsi	*Ocimum sanctum*	Leaves	Extract	20 mg
17.	Loha Bhasma	Calx of Iron	____	Mineral	20 mg

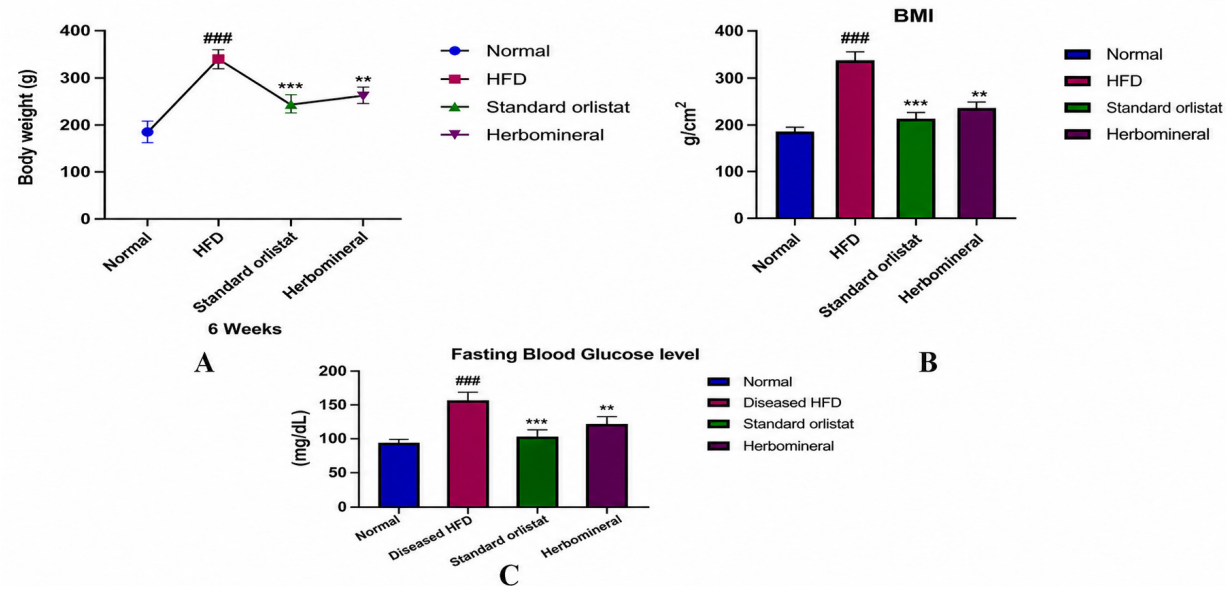


Figure 1: A: Effect of Extract on body weight in HFD-induced obesity rat. Data are expressed as mean ± SD (*n*=6). Statistical analysis was performed using one-way ANOVA followed by Tukey's multiple comparison test. ###*p*<0.001 vs Normal group; **p<0.01, ***p<0.001 vs HFD group. B: Effect of extract on Body Mass Index (BMI) in HFD-induced obese rats. Data are expressed as mean ± SD (*n*=6). Statistical analysis was performed using one-way ANOVA followed by Tukey's multiple comparison test. ##*p*<0.01 vs Normal group; **p<0.01, ***p<0.001 vs HFD group. C: Effect of extract on fasting blood glucose in HFD-induced obese rats. Data are expressed as mean ± SD (*n*=6). Statistical analysis was performed using one-way ANOVA followed by Tukey's multiple comparison test. ##*p*<0.01 vs Normal group; **p<0.01, ***p<0.001 vs HFD group.

possibly associated with diet-induced obesity. Treatment with orlistat significantly reduced FBG levels (***p<0.001), while the herbomineral formulation also produced a significant reduction (**p<0.01) compared with the HFD control group. The observed decrease in FBG levels suggests the beneficial effect of the Medohara-based herbomineral formulation in improving obesity-associated metabolic disturbances (Figure 1C).

Effect of Herbomineral formulation on lipid profile in HFD-induced obesity rats

The HFD-fed group exhibited a significant increase in total cholesterol (##p<0.01), triglycerides, and LDL levels (###p<0.001), along with a significant reduction in HDL levels (#p<0.05) compared with the normal control group, indicating obesity-associated dyslipidemia. Treatment with orlistat significantly improved lipid profile parameters (***p<0.001). Similarly, administration of the herbomineral formulation significantly reduced total cholesterol, triglycerides and LDL levels while increasing HDL levels (*p<0.05) compared with the HFD control group. These findings suggest the beneficial effect of the formulation in lowering HFD-induced lipid abnormalities (Figure 2A).

Effect of Herbomineral formulation on liver function enzymes (AST and ALT) in HFD-induced obese rats

In the present study, the HFD-fed group exhibited a significant increase in AST and ALT levels compared with the normal control group (##p<0.01), indicating hepatic dysfunction possibly associated with high-fat diet-induced obesity. Treatment with orlistat significantly reduced the elevated enzyme levels (***p<0.001) compared with the HFD control group. Similarly, administration of the herbomineral formulation significantly decreased AST and ALT levels (*p<0.05), suggesting its hepatoprotective potential against HFD-induced hepatic alterations. These findings indicate that the formulation may help restore liver function impaired by high-fat diet consumption (Figure 2B).

Histopathology Study of Liver

Histopathological evaluation of liver sections revealed distinct alterations across the experimental groups. The normal control group exhibited preserved hepatic architecture with well-organized hepatocytes, intact sinusoids, and a clearly defined portal triad, with no evidence of pathological lesions. In contrast, the High-Fat Diet (HFD) control group demonstrated marked hepatic alterations characterized by degeneration of hepatocytes, cytoplasmic vacuolation, sinusoidal obstruction and prominent lymphocytic infiltration, indicating significant hepatic injury.

Administration of the standard drug (orlistat) to HFD fed rats resulted in restoration of near-normal hepatic architecture, with well-arranged hepatocytes and a distinct portal region, showing no significant pathological abnormalities. The group treated with the herbomineral formulation along with HFD exhibited moderate improvement, as evidenced by the presence of cytoplasmic vacuolization and mild lymphocytic infiltration, indicating partial protection against HFD-induced damage.

In contrast, the herbomineral treatment group demonstrated near-complete restoration of normal hepatic histology, with well-defined hepatocytes, intact vascular architecture and absence

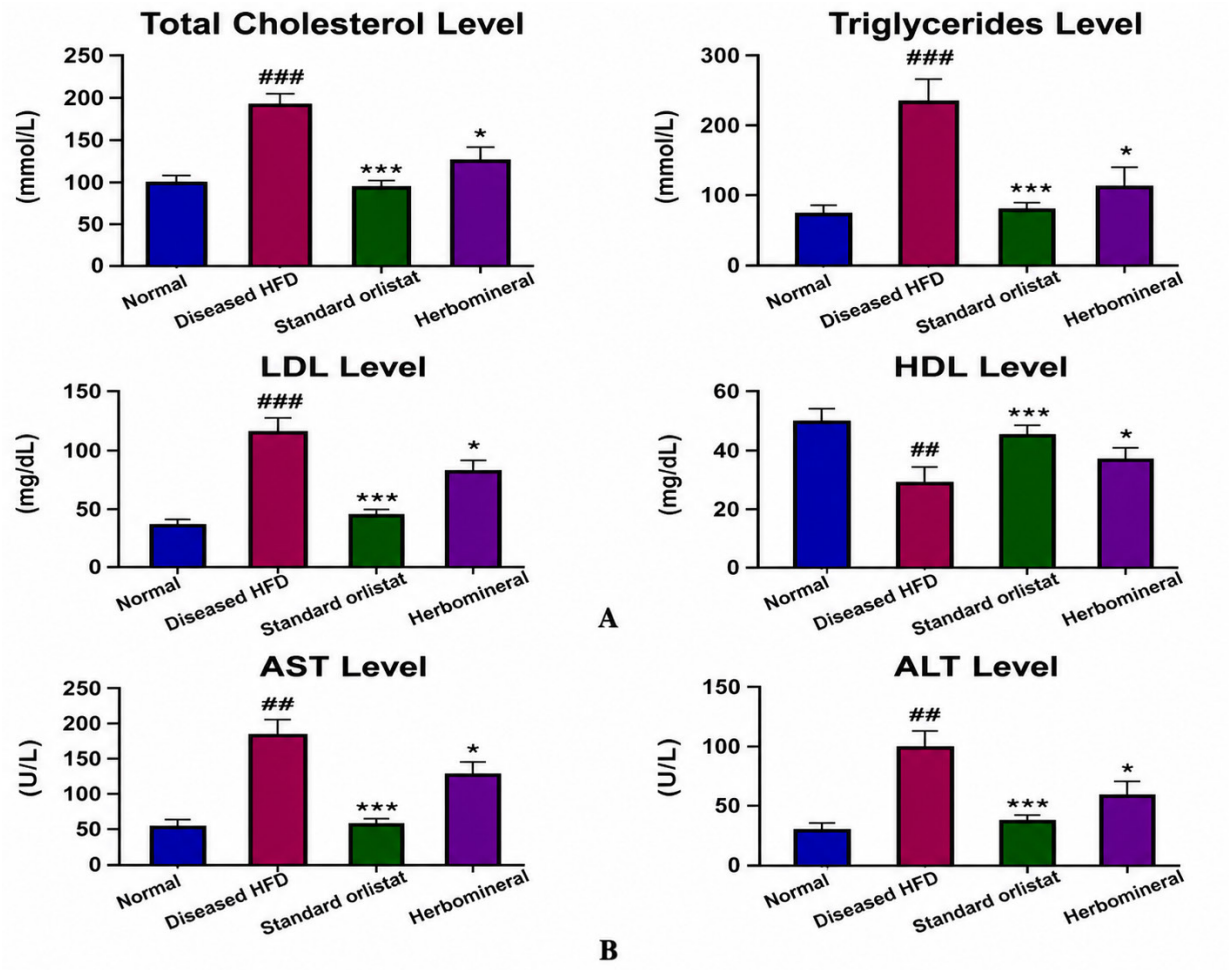


Figure 2: A: Serum lipid profile parameters including total cholesterol, triglycerides, HDL, and LDL/VLDL were evaluated following treatment in HFD-induced obese rats. Data are expressed as mean ± SD (n=6). Statistical analysis was performed using one-way ANOVA followed by Tukey's multiple comparison test. For total cholesterol, ##p<0.01 vs normal control group; for triglycerides and LDL/VLDL, ###p<0.001 vs normal control group; and for HDL, #p<0.05 vs normal control group. In comparison with the HFD control group, the standard-treated group showed ***p<0.001, while the herbomineral formulation showed *p<0.05. B: Serum AST (SGOT) and ALT (SGPT) levels were evaluated following treatment with the standard drug and the Medohara-based herbomineral formulation in HFD-induced obese rats. Data are expressed as mean ± SD (n=6). Statistical analysis was performed using one-way ANOVA followed by Tukey's multiple comparison test. For both AST and ALT levels, the HFD group showed significant elevation compared with the normal control group (##p<0.01). In comparison with the HFD control group, the standard-treated group showed ***p<0.001, while the herbomineral formulation showed *p<0.05.

of significant inflammatory changes, suggesting enhanced hepatoprotective efficacy compared to the herbomineral formulation (Figure 3).

Histopathology Study of Adipose Tissue

Histopathological evaluation of adipose tissue sections showed clear, group-wise differences in tissue morphology. The normal control group exhibited well-organized adipocytes with uniform cell size, intact cell membranes and minimal intercellular space, indicating healthy adipose architecture without any pathological changes. In contrast, the High-Fat Diet (HFD) control group showed marked alterations characterized by adipocyte hypertrophy, irregular cell size, increased lipid accumulation and disrupted tissue architecture. Inflammatory cell infiltration and enlarged adipocyte vacuoles were also observed, indicating significant adipose tissue dysfunction possibly associated with HFD-induced metabolic stress.

Treatment with the standard drug (orlistat) in HFD-fed rats resulted in noticeable improvement in adipose tissue structure, with reduced adipocyte size, partial restoration of normal architecture and decreased inflammatory infiltration, suggesting a protective effect against HFD-induced adipose alterations.

The group treated with the herbomineral formulation along with HFD showed moderate restoration of adipose tissue histology, with reduced inflammatory changes, indicating partial reversal of HFD-induced damage (Figure 4).

DISCUSSION

The global increase in obesity is largely attributed to excessive consumption of high-fat diets, sedentary lifestyle and associated metabolic disturbances, which collectively promote adipogenesis and abnormal lipid accumulation. Obesity is strongly linked with several comorbid conditions, including type 2 diabetes mellitus, hypertension, cardiovascular diseases, and Non-Alcoholic Fatty Liver Disease (NAFLD).

In the present study, obesity was successfully induced using a High-Fat Diet (HFD) model in Wistar rats, which closely resembles human obesity in terms of increased body weight, adiposity, dyslipidemia and hepatic dysfunction. The HFD-fed group exhibited significant alterations in body weight, body mass index, adipose tissue mass and lipid profile parameters, thereby confirming the establishment of obesity. The standard treatment group administered with Orlistat (45 mg/kg) demonstrated a significant reduction in body weight and lipid parameters, validating the role of pancreatic lipase inhibition as a key therapeutic approach in obesity management.

The objective of the present study was to evaluate the anti-obesity activity of a herbomineral formulation developed based on Ayurvedic principles and traditional knowledge quoted in the classical Ayurvedic texts Rasatarangini and Bhavaprakasha Nighantu. The formulation was developed by collaborating with Ayurvedic pharmaceutical industry partner, and the study was intended as an initial scientific validation of the complete formulation. Future studies may investigate the contribution of individual ingredients and compare alternative combinations to further understand their respective roles.

The observed anti-obesity activity of the Medohara-based herbomineral formulation may be attributed to the presence of diverse bioactive phytoconstituents derived from specific plant parts. Flavonoids and polyphenols, including quercetin, kaempferol and catechins, present in the leaves of Nimba and Tulsi and the fruits of Triphala components, may contribute significantly to antioxidant activity and regulation of lipid metabolism. Phenolic acids such as Ellagic acid and gallic acid further aid in reducing oxidative stress and improving metabolic homeostasis.

Hydroxycitric acid present in the fruit rind of Vrukshamla plays a crucial role in inhibiting lipogenesis, while guggulsterones from the resin of Guggul enhance lipid metabolism and cholesterol reduction. Plumbagin from the root of Chitraka, along with piperine and gingerol from the fruits and rhizome components of Trikatu, may contribute to enhanced digestion, thermogenesis, and improved bioavailability of phytoconstituents.

In addition, curcumin from the rhizome of Haridra and andrographolide from the whole plant of Kalmegh exhibit potent anti-inflammatory and antioxidant activities, thereby attenuating obesity-associated inflammation. Flavonoids and rotenoids present in the whole plant of Sharapunkha may contribute to hepatoprotective and lipid-regulating effects. Cinnamaldehyde from the bark of Twak improves insulin sensitivity and glucose metabolism. Embelin from the fruit of Vidanga exhibits significant

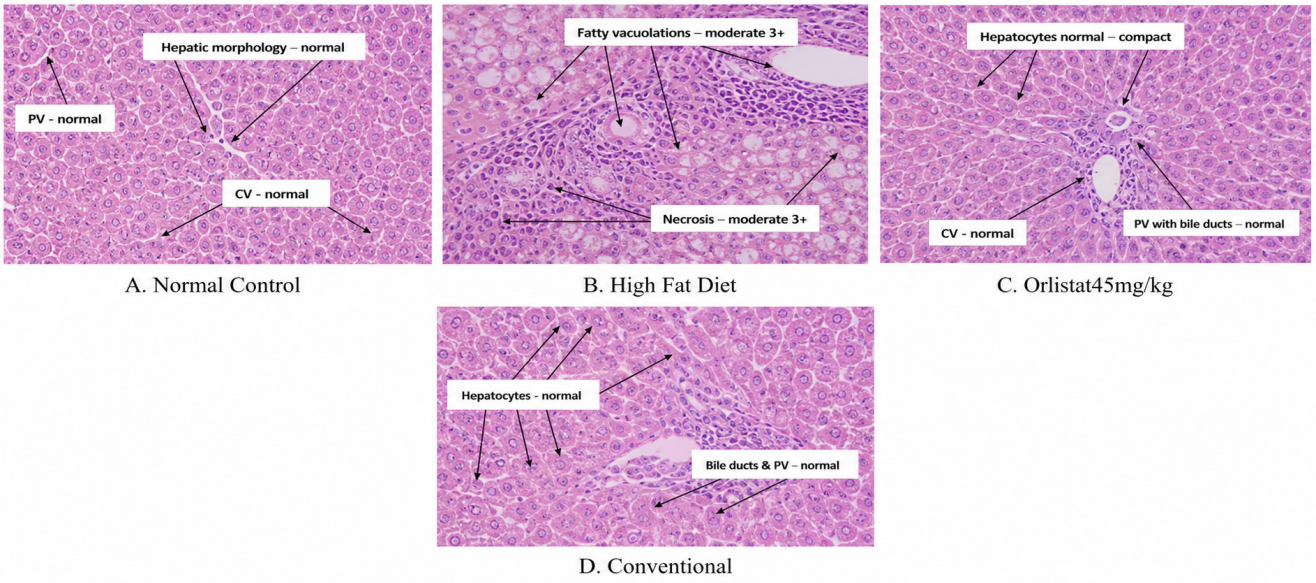


Figure 3: a. Normal Control: This group demonstrated normal hepatic morphology with intact portal vein, central vein and preserved hepatocellular architecture, indicating normal liver histoarchitecture, b. HFD group: This group exhibited moderate fatty vacuolations (3+) along with moderate necrotic changes (3+), reflecting significant hepatocellular degeneration and disruption of normal hepatic architecture, c. Standard group: The Standard (Orlistat) treated group showed normal, compact hepatocytes with a well-preserved central vein and normal portal region containing bile ducts, indicating restoration and maintenance of normal hepatic structure, d. Herbomineral group: The herbomineral formulation treated group revealed normal hepatocytes with intact portal vein and bile ducts, suggesting preservation of near-normal liver histoarchitecture, {H & E, 40X}.

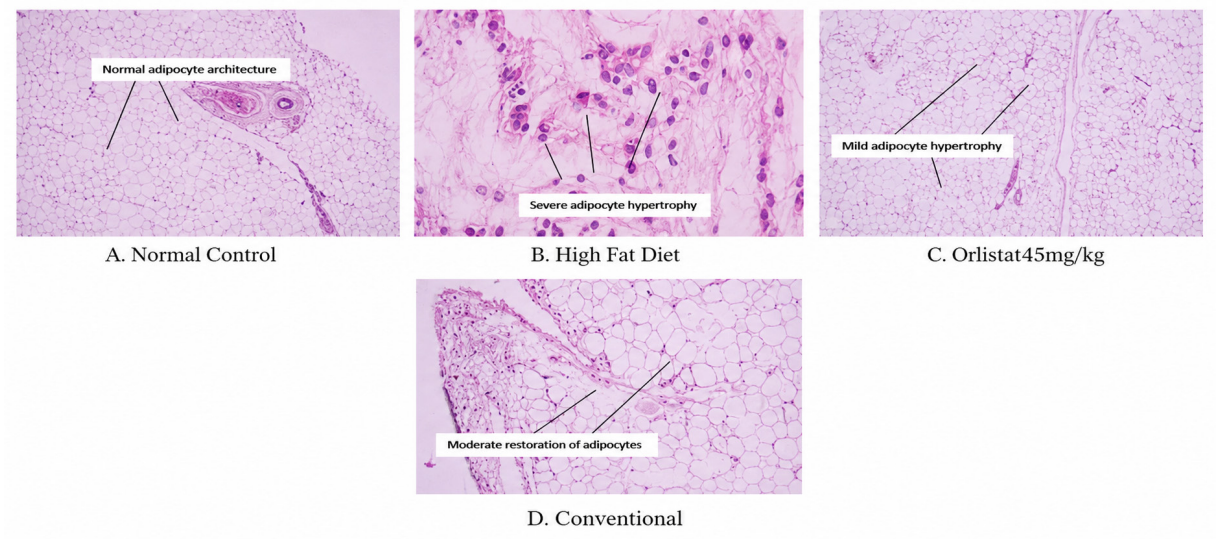


Figure 4: a. Normal Control: This group showed normal adipose histology, with uniformly sized adipocytes, intact cell membranes, and minimal intercellular space indicating healthy lipid storage architecture, b. HFD group: This group showed adipocyte hypertrophy (enlarged fat cells with expanded lipid vacuoles), disrupted tissue architecture, and inflammatory cell infiltration between adipocytes indicating adipose tissue dysfunction, c. Standard group: The Standard (Orlistat) treated group showed near-normal adipose histology, with moderately restored adipocyte size, improved cellular arrangement, and reduced inflammatory infiltration compared to negative control, d. Herbomineral group: The Herbomineral formulation treated group revealed partial restoration with persistent adipocyte hypertrophy (unevenly enlarged fat cells), mild intercellular inflammatory infiltration and moderately disorganized adipose structure indicating restored adipose integrity {H & E, 40X}.

lipid-lowering activity, while flavonoids and tannins from the bark of Kanchanara aid in reducing adiposity and metabolic imbalance. Furthermore, saponins and alkaloids present in Apamarga, Musta and related components may contribute to overall metabolic regulation. The inclusion of Loha Bhasma further supports metabolic processes and physiological balance.

Treatment with herbomineral formulation of the polyherbal combination resulted in a significant reduction in body weight, body mass index, adipose tissue mass and lipid parameters when compared to the HFD control group, which may be attributed to improved bioavailability, enhanced absorption and efficient delivery of phytoconstituents at the cellular level.

Histopathological evaluation revealed that the HFD control group exhibited hepatic alterations such as cytoplasmic vacuolation, hepatocyte degeneration, and inflammatory cell infiltration. In contrast, treatment groups, particularly the herbomineral formulation, showed marked improvement in hepatic architecture with reduced lipid accumulation, indicating significant hepatoprotective activity.

The pharmacological activities attributed to the various phytoconstituents discussed above are supported by published literature (Haslam., 2005; Kopelman., 2000; Liu, 2004). However, since the present study primarily focused on evaluating the anti-obesity activity of the herbomineral formulation, comprehensive phytochemical investigations and experimental confirmation of individual bioactive constituents within the finished formulation were beyond the scope of the current investigation. Therefore, the mechanistic interpretations presented herein are based on literature evidence and the known pharmacological properties of the constituent herbs rather than direct experimental confirmation of individual compounds in the test formulation. Future studies involving detailed phytochemical profiling and marker-based standardization may further substantiate these observations.

Overall, the findings of the present study suggest that the Medohara-based herbomineral formulation exerts significant anti-obesity effects through multiple mechanisms, including inhibition of pancreatic lipase, suppression of lipogenesis, enhancement of lipolysis, antioxidant activity and improvement of hepatic function. These effects are primarily mediated by the synergistic action of its diverse phytoconstituents.

CONCLUSION

From the results and discussion, treatment with the herbomineral formulation, particularly at dose of 45 mg/kg, significantly reduced body weight gain and calorie intake, indicating a pronounced anti-obesity effect. The treatment also effectively improved lipid profile parameters, reduced blood glucose levels and decreased serum levels of AST and ALT, suggesting improved metabolic and hepatic function.

Histopathological evaluation of liver tissue further revealed a marked improvement in fatty liver changes and hepatic steatosis in animals treated with the herbomineral formulation compared to the high-fat diet control group. The findings were comparable to the standard drug-treated group receiving Orlistat, supporting the therapeutic potential of the formulation.

Overall, it can be concluded that the Medohara-based herbomineral formulation exhibits promising anti-obesity activity, which may be attributed to its ability to regulate lipid metabolism, reduce fat accumulation and improve hepatic function. The enhanced efficacy observed in the herbomineral formulation suggests its promising anti-obesity potential.

However, detailed studies are required to elucidate the exact molecular mechanisms involved and to establish its potential as a safe and effective anti-obesity therapy. Also nano dosage form of the herbomineral formulation may give better effect similar to standard under study as it may increase the bioavailability. Further studies on these would be helpful.

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ABBREVIATIONS

ALT: Alanine Aminotransferase; **AST:** Aspartate Aminotransferase; **BMI:** Body Mass Index; **FBG:** Fasting Blood Glucose; **HDL:** High-Density Lipoprotein; **HFD:** High-Fat Diet; **LDL:** Low-Density Lipoprotein; **SGOT:** Serum Glutamic Oxaloacetic Transaminase; **SGPT:** Serum Glutamic Pyruvic Transaminase; **TC:** Total Cholesterol; **TG:** Triglycerides; **VLDL:** Very Low-Density Lipoprotein.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

SUMMARY

This study evaluated the anti-obesity effects of a Medohara-based herbomineral formulation in male Wistar rats with High-Fat Diet (HFD)-induced obesity. Rats were divided into four groups: normal control, HFD control, HFD plus orlistat, and HFD plus the herbomineral formulation. After 42 days, HFD-fed rats showed significant weight gain, elevated blood glucose, dyslipidemia, and impaired liver function. Treatment with the herbomineral formulation significantly reduced body weight, improved glycemic control, normalized lipid profile parameters, and lowered liver enzyme levels. Histopathological analysis demonstrated partial restoration of liver and adipose tissue architecture. The findings suggest that the formulation possesses promising anti-obesity activity comparable to orlistat and may serve as a safer therapeutic option for obesity management.

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