El papel de las dietas altas en proteínas y la actividad física en la pérdida de grasa y la salud metabólica: Implicaciones para sistemas alimentarios sostenibles

The Role of High-Protein Diets and Physical Activity in Fat Loss and Metabolic Health: Implications for Sustainable Food Systems

Authors

Umesh Zadgaonkar

Director and Fitness Consultant, Zadgaonkars' Fitness Center, Nagpur (Maharashtra), India

Corresponding author:
Umesh Zadgaonkar
umesh.zadgaonkar@gmail.com

How to cite in APA

Umesh Zadgaonkar. (2025). The Role of High-Protein Diets and Physical Activity in Fat Loss and Metabolic Health: Implications for Sustainable Food Systems. *Retos*, *66*, 1145–1153. https://doi.org/10.47197/retos.v66.114171

Abstract

Introduction: Obesity and related metabolic disorders, including type 2 diabetes and cardiovascular diseases, are increasing globally, making effective interventions crucial. High-protein diets and structured physical activity are promising strategies to combat these issues.
Objective: This study aims to evaluate the impact of high-protein diets combined with physical activity on fat loss, metabolic health, and the sustainability of food systems.
Methodology: A 12-week randomized controlled trial involving 60 participants assessed the effects of a high-protein diet (1.6-2.0 g/kg body weight) and structured physical activity (aerobic and resistance training) on body composition, glucose metabolism, and lipid profiles. The control group followed a balanced diet without exercise intervention. Data on anthropometry, biochemical markers, and adherence to protocols were collected.
Results: The intervention group showed significant reductions in body weight (6.2 kg), fat mass (4.8 kg), and waist circumference (8.5 cm). Fasting glucose levels and lipid profiles improved, with a 12% reduction in glucose and an 18% reduction in LDL cholesterol. The control group exhibited minimal changes.
Discussion: The combined intervention of high-protein diets and physical activity demonstrated synergistic effects on fat loss and metabolic health, highlighting the importance of integrated strategies for obesity management. gender-specific responses were also observed.
Conclusions: This study supported the efficacy of combined dietary and exercise interventions in promoting fat loss and improving metabolic health. However, further long-term studies are needed to evaluate sustainability and broader applications for public health.

Keywords

Fat loss; High-protein diet; Metabolic Health; Physical activity; Sustainability.

Resumen

Introducción: La obesidad y los trastornos metabólicos relacionados, como la diabetes tipo 2 y las enfermedades cardiovasculares, están aumentando a nivel mundial, lo que hace que las intervenciones efectivas sean cruciales. Las dietas altas en proteínas y la actividad física estructurada son estrategias prometedoras para combatir estos problemas.
Objetivo: Este estudio tiene como objetivo evaluar el impacto de las dietas altas en proteínas combinadas con actividad física en la pérdida de grasa, la salud metabólica y la sostenibilidad de los sistemas alimentarios.
Metodología: Un ensayo controlado aleatorizado de 12 semanas con 60 participantes evaluó los efectos de una dieta alta en proteínas (1.6-2.0 g/kg de peso corporal) y actividad física estructurada (ejercicio aeróbico y de resistencia) en la composición corporal, el metabolismo de la glucosa y los perfiles lipídicos. El grupo control siguió una dieta equilibrada sin intervención de ejercicio. Se recolectaron datos sobre antropometría, marcadores bioquímicos y adherencia a los protocolos.
Resultados: El grupo de intervención mostró reducciones significativas en el peso corporal (6.2 kg), la masa grasa (4.8 kg) y la circunferencia de la cintura (8.5 cm). Los niveles de glucosa en ayunas y los perfiles lipídicos mejoraron, con una reducción del 12% en glucosa y una reducción del 18% en colesterol LDL. El grupo control mostró cambios mínimos.
Discusión: La intervención combinada de dietas altas en proteínas y actividad física demostró efectos sinérgicos en la pérdida de grasa y la salud metabólica, destacando la importancia de las estrategias integradas para el manejo de la obesidad. También se observaron respuestas específicas por género.
Conclusiones: Este estudio respaldó la eficacia de las intervenciones combinadas de dieta y ejercicio en la promoción de la pérdida de grasa y la mejora de la salud metabólica. Sin embargo, se necesitan más estudios a largo plazo para evaluar la sostenibilidad y las aplicaciones más amplias para la salud pública.

Palabras clave

Pérdida de grasa; Dieta alta en proteínas; Salud metabólica; Actividad física; Sostenibilidad.

Introduction

Worldwide obesity and overweight prevalence continue to increase as a serious public health matter as it drives metabolic disease rates higher including type 2 diabetes and cardiovascular conditions (Koliaki et al., 2023). In 2022, The World Health Organization (WHO) estimates that 650 million people worldwide are fat and 1.9 billion are overweight. The chance of developing type 2 diabetes, cardiovascular disease, and other chronic conditions is significantly increased by these circumstances (Boutari & Mantzoros, 2022). The concerning obesity statistics have made lifestyle interventions including dietary modifications and physical activity become essential approaches for obesity prevention and its related health complications management. With growing health concerns, lifestyle interventions, namely dietary interventions and physical activity, have predominated in efforts to manage weight and regulate metabolism. High protein diets have recently received attention due to their capacity to promote fat loss and satiety while preserving calorie restriction, and lean body mass (Romano et al., 2024). Additionally, structured exercise has been demonstrated to enhance body composition and metabolic health when combined with dietary modifications (Willis et al., 2012), and simultaneously. Although various individual strategies maintain high interest, little is known as to what extent these strategies work in synergy with high protein diets combined with structured physical activity for the promotion of sustainable weight loss as well as metabolic improvements.

High-protein diets attract attention as they help people lose fat and feel full between meals while structured physical activity improves both metabolic health and body structure. Each of these interventions has independently been associated with improved metabolic health, but, very little research has been done to determine how these two factors may have synergistic effects on fat loss, metabolic function, and long-term health outcomes. Knowing these synergies is critical in developing better obesity prevention and management. The research shows that high-protein diets improve thermogenesis and satiety while studies lack exploration of their combined effects with physical activity which is well-documented to improve energy balance and insulin sensitivity (Moon & Koh, 2020). The lack of research on this topic prevents one from creating proper combined solutions for the prevention of obesity and metabolic conditions.

The intake of protein stimulates the secretion of hormones that control appetite, including glucagon-like peptide 1 (GLP-1) and peptide YY which reduces caloric intake (Hijová, 2024). Also, physical activity, exercising in particular whether in aerobic or resistance training, has been found to augment dietary intervention by raising energy consumption (by reducing energy intake) or visceral adiposity (by enhancing insulin sensitivity) (Bird & Hawley, 2017).

According to recent data, combining high-protein diets with structured physical activity results in additive or synergistic benefits, including fat mass reduction and improvement in metabolic health (Chen et al., 2021). However, there are still gaps in our understanding of the optimal composition of high-protein diets, the intensity and duration of physical activity needed, and the long-term sustainability of such interventions.

Despite the increasing literature, the interaction between dietary protein intake and physical activity for sustainable fat loss and improved metabolic health remains understudied. Additionally, the environmental and sustainability implications for a high-protein diet particularly ones that depend on animal protein sources have implications for our global food system (Springmann et al., 2018). Additionally, while high protein diets, and particularly diets high in animal proteins, have been proven to enhance fat loss and improve metabolic health, their environmental impact remains an issue. Such diets should be considered in terms of their broader implementation in public health strategies about their sustainability in terms of their ecological footprints and their long-term feasibility.

Objective

To evaluate the consequences of eating a lot of protein diets and structured physical activity on fat loss and metabolic health

To evaluate the possible implications of high-protein dietary interventions on sustainable food systems

Method

Study Design

The 12-week study was a controlled, randomized experiment. Participants were divided into groups based on their age, gender, and baseline body mass index (BMI), and they were then assigned at random to the high protein diet with physical activity (HPD+PA) or control group. Approval of the study by the institutional review board and clinical trials database was obtained.

Participant Recruitment and Inclusion Criteria

Recruitment was through online advertisements, posters at community centers, and referrals from healthcare providers. Adults aged 18 to 60 who lead sedentary lifestyles (less than 150 minutes of physical exercise per week) and have a BMI of 25 to 35 kg/m^2 met the inclusion criteria, and willingness to adhere to the study protocol. Individuals with metabolic disorders, severe chronic diseases, or dietary restrictions that precluded adherence to a high-protein diet were excluded.

Dietary Intervention

The HPD+PA group followed a high protein diet consuming 1.6-2.0 g of protein daily per kilogram of body weight. Lean meats, dairy, legumes, and plant-based alternatives were protein sources. The amount of daily energy restriction between 500 and 750 kcal was determined from Resting Metabolic Rate (RMR) measurements by indirect calorimetry and Physical Activity Level (PAL) calculations from accelerometer output. The dietary plans received individual modifications twice a month after evaluating weight changes and energy expenditure adjustments. The standard diet for the control group consisted of macronutrient distribution according to dietary guidelines. In particular, the control group was fed a diet that matched national nutritional guidelines, consisting of approximately 50-55% of carbohydrates, 15-20% of protein, and 25-30% of fat (Pranoto et al., 2024). The caloric intake was designed to preserve energy equilibrium while avoiding any specific energy deficit. A registered dietitian monitored meals biweekly to ensure adherence.

Physical Activity Protocol

Resistance training exercises targeted major muscle regions including legs, back, chest, and arms with 2-3 different sets of 8-12 repetitions at a strength level of 60-70% of each participant's one-repetition maximum (1RM). The training intensity rose step by step every 2-3 weeks throughout the program. The training exercises consisted of squats, leg presses, and bench presses followed by rows and shoulder presses. Resistance training and aerobic exercise were combined to form the physical activity component. Participants completed three times-weekly supervised workouts that consisted of 30 minutes of weight training and 30 minutes of cardiovascular exercise at a moderate level (e.g., walking, cycling) of major muscle groups. Attendance logs and heart rate monitors were used to monitor exercise adherence.

Data Collection

Anthropometric Measurements

The Participant's body weight was measured by using a calibrated digital scale with them in light clothing and no shoes. The height was measured with a wall-mounted stadiometer. A non-stretchable tape was used to measure waist circumference midway between the lower rib and iliac crest. Dual-energy X-ray absorptiometric (DXA) measurement was done for the assessment of body fat percentage and composition. Trained technicians performed all measurements at baseline and 4 weeks followed standardized protocols from the International Society for the Advancement of Kinanthropometry (ISAK) (Esteve Ibáñez et al., 2025). Dual-energy X-ray absorptiometry (DXA) was used to measure changes in body composition.

Biochemical and Metabolic Assessments

At baseline and end to assess glucose, insulin, lipid profiles (total cholesterol, LDL, HDL, and triglycerides), and indicators of inflammation (such as C reactive protein), fasting blood samples were taken for the study. The HOMA-IR index was used to measure insulin sensitivity.

Dietary and Activity Monitoring

A daily food-validated food diary app was used to record intake, and weekly analyses of calorie intake and macronutrient composition were conducted. Outside of the supervised sessions, accelerometers were utilized to track levels of physical activity.

Informed Consent Procedures

All participants received complete information regarding the research purpose, procedures, evaluation of risks, and study benefits before they joined. The participants signed written informed consent to demonstrate their voluntary participation in the study along with data confidentiality and their right to terminate the study at any time without negative consequences. Participants maintained the right to ask questions at any time throughout the study process according to what was stated in the consent form. The ethical standards were maintained ensuring participant rights privacy protection and confidentiality during all stages of the study.

Statistical Analysis

To analyze the data, SPSS version 28.0 was used. The mean ± standard deviation was used to express continuous variables. Independent t-tests or Mann-Whitney U tests were used for between-group comparisons of non-normally distributed data. Wilcoxon signed rank tests or paired t-tests were used to assess variations within groups. Changes over time were evaluated using repeated measures ANOVA. A p-value of less than 0.05 was considered to be statistically significant.

Results

Baseline Characteristics of Participants

The baseline characteristics of the members of the HPD+PA and Control Groups are shown in Table 1. The groups did not differ statistically significantly ($p > 0.05$ for any parameters) at the start of the study in terms of age, gender distribution, BMI, or fasting glucose levels. This suggests that the groups were well matched at baseline so that any effects seen during the study could be attributed to the interventions.

Table 1. Baseline Characteristics of Participants in the HPD+PA and Control Groups

Characteristic	HPD+PA Group (n=30)	Control Group (n=30)	p-value
Age (years)	40.3 ± 7.2	39.8 ± 6.9	0.78
Gender (M/F)	15/15	14/16	0.82
BMI (kg/m^2)	29.2 ± 2.5	28.8 ± 2.6	0.63
Fasting Glucose (mg/dL)	98.5 ± 10.3	97.8 ± 9.7	0.71

Significant differences, $p < 0.05$

Effects on Fat Loss

The body weight, fat mass, and waist circumference change were examined through repeated measures ANOVA. There was a significant decline in these three parameters in the HPD+PA group ($p < 0.001$) but the Control group experienced minimal changes ($p > 0.05$). Table 2 highlights the differences in body composition metrics between the HPD+PA and Control Groups, including body weight, fat mass, and waist circumference. In comparison to the Control Group, all parameters were significantly lower in the HPD+PA Group ($p < 0.001$ for all). Participants in the HPD+PA Group lost an average of 6.2 kg of weight, 4.8 kg of fat mass, and 8.5 cm at the waist, while the Control Group lost less (2.3 kg, 1.7 kg, and 3.2 cm respectively).

Table 2. Changes in Body Composition Parameters Between HPD+PA and Control Groups

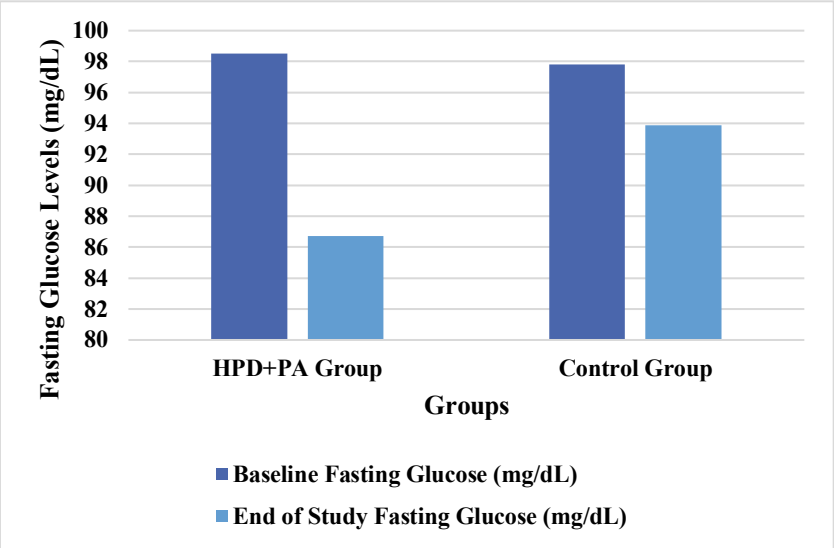
Parameter	HPD+PA Group (Change)	Control Group (Change)
Body Weight (kg)	-6.2 ± 1.8	-2.3 ± 1.1
Fat Mass (kg)	-4.8 ± 1.5	-1.7 ± 1.0
Waist Circumference (cm)	-8.5 ± 2.3	-3.2 ± 1.5

Significant differences, p< 0.001

Impact on Metabolic Health Markers

The HPD+PA group demonstrated significant improvements in glucose metabolism and lipid profile. Repeated measures ANOVA was used to evaluate fasting glucose level changes throughout the experiment period. The HPD+PA group demonstrated a statistically significant reduction in fasting glucose levels ($p < 0.01$) during the trials but no time-based changes occurred within the Control Group ($p > 0.05$).

Figure 1. Changes in fasting glucose levels



The HPD+PA group had a 12% decrease in fasting glucose levels while 4% in the Control group ($p < 0.01$) illustrated in Figure 1. Fasting glucose levels of the Control group decreased from 97.8 ± 9.7 mg/dL to 93.9 ± 9.5 mg/dL, while the HPD+PA group decreased from 98.5 ± 10.3 mg/dL to 86.7 ± 8.1 mg/dL. This suggests that the HPD+PA intervention had a major effect on glucose metabolism. These findings indicate that a high-protein diet and regular exercise have synergistic effects on glucose management, with the HPD+PA Group showing a notable improvement over the control group. On the other hand, the slightly lesser degree of reduction seen in the Control Group suggests that other factors, perhaps standard dietary or lifestyle habits, may have played a role in blunting the effect. These findings highlight the importance of intervention targeted at better glucose control and perhaps prevent outbreaks of metabolic disorders, including diabetes, through diet and structured physical activity

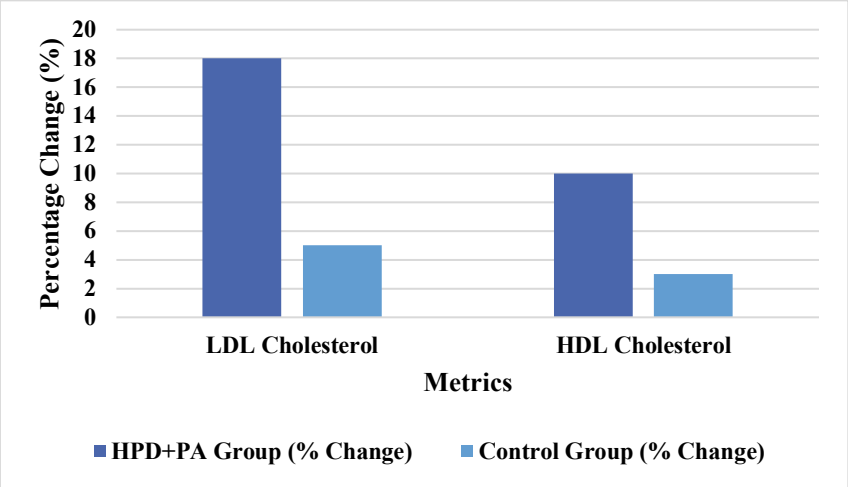
The fasting glucose levels in the HPD+PA group were significantly lower than that of the Control group ($p < 0.01$) with a 12% reduction compared with a 4% reduction in the Control group mentioned in Table 3. These findings suggest that the high-protein diet and physical activity intervention is superior to standard control in improving glucose metabolism.

Table 3. Change in Fasting Glucose Levels for HPD+PA and Control Groups

Group	Baseline Fasting Glucose (mg/dL)	End of Study Fasting Glucose (mg/dL)
HPD+PA Group	98.5 ± 10.3	86.7 ± 8.1
Control Group	97.8 ± 9.7	93.9 ± 9.5

Significant differences, p< 0.01

Figure 2. Changes in lipid profiles



LDL cholesterol was reduced by 18% in the HPD+PA group compared to 5% in controls ($p<0.01$). Figure 2 shows the percentage change in lipid profile metrics (LDL cholesterol and HDL cholesterol) between the HPD+PA Group (High-Protein Diet and Physical Activity group) and the Control Group. The Control Group showed a 5% decrease in LDL cholesterol levels compared to an 18% decrease in the HPD+PA Group. As with the HPD+PA Group, the Control Group had a 3% increase in HDL cholesterol levels, while the HPD+PA Group increased by 10%. The findings suggest that a high protein diet and regular physical activity are more effective at lowering 'bad' cholesterol (LDL) and increasing 'good' cholesterol (HDL) more than the control condition. The integration of dietary modification with structured physical activity is highlighted as a potential means of cardiovascular benefit.

Adherence to Intervention

In the HPD+PA group, adherence rates were 92% for dietary protocols and 88% for exercise sessions, compared to 88% for dietary protocols and 81% for exercise sessions in the group under control ($p<0.05$). In the intervention group, self-reported energy intake matched targeted caloric deficits.

Subgroup Analysis

Gender-specific analysis revealed that males had greater reductions in fat mass and females had greater improvements in HDL cholesterol levels ($p<0.05$). Outcomes were not significantly influenced by age.

Discussion

Interpretation of Key Findings

The current investigation highlights how Structured Physical Activity (PA) in conjunction with a High-Protein Diet (HPD) results in significant changes in cardiovascular risk factors, body composition metabolic health, and the distribution of body fat. On average, participants in the HPD+PA group lost 6.2 kg of body weight throughout 12 weeks, 4.8 kg fat mass, and 8.5 cm in waist circumference. In stark contrast to the control group, these outcomes were less substantial. It also shows that the intervention is more effective in driving fat loss and improving body composition. In addition, fasting glucose levels (12% reduction) and lipid profiles (18% reduction in LDL cholesterol and 10% increase decrease in HDL cholesterol) in the group with HPD+PA emphasize the importance of combining dietary and physical activity interventions. Repeated measures ANOVA confirmed these parameters to be statistically significant ($p < 0.05$) whereas significant changes in these parameters were observed within the HPD+PA group relative to the control group.

Adherence to the intervention was high (92% compliance with dietary protocols and 88% adherence to physical activity sessions). Taken together, these results indicate that such an intervention is feasible and practical for implementation in real-world settings, especially for individuals at risk of obesity-

related metabolic disorders.

Comparison with Existing Literature

This paper finds that the study findings are largely consistent with what already exists in the literature for high-protein diets and physical activity. High protein diets have been shown consistently to promote fat loss, increase satiety, and preserve lean muscle mass during energy restriction (Leidy et al., 2015; Romano et al., 2024). Structured physical activity, such as resistance training and aerobic exercise, is important in the improvement of metabolic health as a component of managing obesity (Oppert et al., 2021).

The synergistic approach of combining these two interventions is what makes this study different. The results data demonstrate that a high-protein diet and structured physical activity produce superior synergistic effects than the control group. For example, while earlier studies have shown modest improvements in glucose metabolism with either dietary or exercise interventions, this study shows a more pronounced reduction in fasting glucose levels and insulin sensitivity with the combined approach.

The findings of this study also contribute to the growing body of literature with gender-specific findings. In the HPD+PA group, males had greater reductions in fat mass, and females had greater improvements in HDL cholesterol levels. These results are consistent with previous findings of gender-specific metabolic responses to diet and exercise (Gorini et al., 2025).

Mechanistic Insights into High-Protein Diets and Physical Activity

Several underlying mechanisms account for the observed metabolic and body composition improvements. It is known that high-protein diets stimulate thermogenesis, increase satiety hormones like GLP-1 and peptide YY, and decrease ghrelin, the hunger hormone (Westerterp-Plantenga et al., 2012). Together, these effects increase adherence to caloric deficits and increase fat loss over standard diets.

In addition, protein is important in maintaining lean body mass, particularly during weight loss. Preservation of this is important because RMR is driven primarily by lean mass. High protein diets that maintain RMR prevent the metabolic slowdown often seen with caloric restriction (Moon & Koh, 2020). These effects are further complemented by physical activity. Aerobic exercise as well as resistance training is associated with mitochondrial function and lipid metabolism improvement and muscle protein synthesis stimulation leading to increased muscle mass and strength. These activities were likely to have synergistically increased the improvements seen in glucose metabolism, lipid profiles, and body composition in this study. Also, exercise is correlated with reductions in systemic inflammation, as indicated by declines in markers such as C-reactive protein, which may assist in explaining the improved metabolic results (Kanthajan et al., 2024).

Implications for Individual Health and Fat Loss

The implications of this study are important not only for clinical practice but also for public health. Robust reductions in fat mass and waist circumference suggest that the HPD+PA intervention may be especially effective for individuals with central obesity, a strong risk factor for metabolic syndrome and cardiovascular disease. Also, the fasting glucose levels and lipid changes suggest that this intervention may lower the risk for type 2 diabetes and atherosclerosis.

Promising for those interested in sustainable weight loss are the high rates of adherence in this study. The intervention is feasible because its practical components (easily accessible protein sources and structured exercise routines) apply to a wide variety of populations. In addition, the gender-specific benefits of the intervention suggest that dietary and exercise recommendations may be even more effective when tailored to individual characteristics. This study is in a broader context of integrated methods of obesity management. Obesity is a multifaceted disease and is associated with multiple comorbidities, and therefore healthcare providers and policymakers should target first interventions that include structured physical activity in combination with nutrition modification.

Limitations and Strengths

While the evidence of efficacy demonstrated herein is robust, some limitations of this study must be

recognized. Its 12-week duration is not long enough to be able to evaluate the long-term sustainability and eeffectivenessof the intervention. The observed benefits need to be evaluated over time in future studies with longer follow-up periods.

Also, while validated, self-reported dietary intake relies on reporting bias. Further validation of the findings would be strengthened by objective measures of dietary adherence such as biomarkers. The generalizability of the results is limited to populations with more advanced disease states because individuals with severe metabolic disorders are excluded.

However, the study has its strengths. High internal validity is ensured by using the randomized controlled design, and by using the dual-energy X-ray absorptiometry (DXA) to measure body composition with accuracy and reliability. The study's applicability to different populations is further enhanced by the inclusion of both male and female participants and subgroup analysis of gender-specific responses. In addition, the high adherence rates and complete monitoring of dietary and physical activity behaviors indicate the feasibility of the intervention in real-world settings.

Conclusions

The synergistic effects of high-protein diets and structured physical activity in promoting significant fat loss, improving metabolic health and adherence are underscored in this study. The intervention group showed significant decreases in body weight, fat mass, waist circumference, glucose regulation, and lipid profiles over 12 weeks. Personalized approaches are further stressed by the ability to appropriately respond to gender-specific variations. Such combined interventions may be effective in combating obesity and associated disorders, the findings suggest. However longer-term studies are needed to confirm sustainability and broader implications for integrating such strategies for improving public health outcomes.

References

Bird, S. R., & Hawley, J. A. (2017). Update on the effects of physical activity on insulin sensitivity in humans. *BMJ open sport & exercise medicine*, *2*(1), e000143. https://doi.org/10.1136/bmjsem-2016-000143

Boutari, C., & Mantzoros, C. S. (2022). A 2022 update on the epidemiology of obesity and a call to action: as its twin COVID-19 pandemic appears to be receding, the obesity and dysmetabolism pandemic continues to rage on. *Metabolism: clinical and experimental*, *133*, 155217. https://doi.org/10.1016/j.metabol.2022.155217

Chen, C. N., Hsu, K. J., Chien, K. Y., & Chen, J. J. (2021). Effects of Combined High-Protein Diet and Exercise Intervention on Cardiometabolic Health in Middle-Aged Obese Adults: A Randomized Controlled Trial. *Frontiers in cardiovascular medicine*, *8*, 705282. https://doi.org/10.3389/fcvm.2021.705282

Esteve-Ibáñez, H., Drehmer, E., da Silva, V. S., Souza, I., Silva, D. A. S., & Vieira, F. (2025). Relationship of Body Composition and Somatotype with Physical Activity Level and Nutrition Knowledge in Elite and Non-Elite Orienteering Athletes. *Nutrients*, *17*(4), 714. https://doi.org/10.3390/nu17040714

Gorini, S., Camajani, E., Feraco, A., Armani, A., Karav, S., Filardi, T., Aulisa, G., Cava, E., Strollo, R., Padua, E., Caprio, M., & Lombardo, M. (2025). Exploring Gender Differences in the Effects of Diet and Physical Activity on Metabolic Parameters. *Nutrients*, *17*(2), 354. https://doi.org/10.3390/nu17020354

Hijová E. (2024). Postbiotics as Metabolites and Their Biotherapeutic Potential. *International journal of molecular sciences*, *25*(10), 5441. https://doi.org/10.3390/ijms25105441

Kanthajan, T., Pandey, M., AlQassab, O., Sreenivasan, C., Parikh, A., Francis, A. J., & Nwosu, M. (2024). The Impact of Exercise on C-reactive Protein Levels in Hypertensive Patients: A Systematic Review. *Cureus*, *16*(9), e68821. https://doi.org/10.7759/cureus.68821

Koliaki, C., Dalamaga, M., & Liatis, S. (2023). Update on the Obesity Epidemic: After the Sudden Rise, Is the Upward Trajectory Beginning to Flatten?. *Current obesity reports*, *12*(4), 514–527. https://doi.org/10.1007/s13679-023-00527-y

Leidy, H. J., Clifton, P. M., Astrup, A., Wycherley, T. P., Westerterp-Plantenga, M. S., Luscombe-Marsh, N. D., Woods, S. C., & Mattes, R. D. (2015). The role of protein in weight loss and maintenance. *The American journal of clinical nutrition*, *101*(6), 1320S–1329S. https://doi.org/10.3945/ajcn.114.084038

Moon, J., & Koh, G. (2020). Clinical Evidence and Mechanisms of High-Protein Diet-Induced Weight Loss. *Journal of obesity & metabolic syndrome*, *29*(3), 166–173. https://doi.org/10.7570/jomes20028

Mujica-Johnson, F. N., Concha López, R., Peralta Ferroni, M., & Burgos Henríquez, S. (2024). Gender Perspective in Physical Education Teacher and School Training. Critical analysis in terms of the Chilean context (Gender perspective in Physical Education, teacher training and schooling. Critical analysis based on the chilean context). *Challenges, 55*, 339–345. https://doi.org/10.47197/retos.v55.103535

Oppert, J. M., Bellicha, A., van Baak, M. A., Battista, F., Beaulieu, K., Blundell, J. E., Carraça, E. V., Encantado, J., Ermolao, A., Pramono, A., Farpour-Lambert, N., Woodward, E., Dicker, D., & Busetto, L. (2021). Exercise training in the management of overweight and obesity in adults: Synthesis of the evidence and recommendations from the European Association for the Study of Obesity Physical Activity Working Group. *Obesity reviews : an official journal of the International Association for the Study of Obesity*, *22 Suppl 4*(Suppl 4), e13273. https://doi.org/10.1111/obr.13273

Pranoto, N. W., Anugrah, S., Fitriady, G., Setyawan, H., Adrian Geantă, V., Sibomana, A., & Ndayisenga, J. (2024). The effectiveness of diet and exercise in the management of obesity. *Retos: Nuevas Perspectivas de Educación Física, Deporte y Recreación*, *58*. http://dx.doi.org/10.47197/retos.v58.105295

Romano, B. C., de Araújo, I. M., Ribeiro, M. S. P., Parreiras E Silva, L. T., Dick-de-Paula, I., Fukada, S. Y., Porto, F. M., Jorgetti, V., de Assis Pereira, F., Elias, L. L. K., & de Paula, F. J. A. (2024). Low-calorie and high-protein diet has diverse impacts on the muscle, bone, and bone marrow adipose tissues. *JBMR plus*, *9*(1), ziae150. https://doi.org/10.1093/jbmrpl/ziae150

Springmann, M., Clark, M., Mason-D'Croz, D., Wiebe, K., Bodirsky, B. L., Lassaletta, L., de Vries, W., Vermeulen, S. J., Herrero, M., Carlson, K. M., Jonell, M., Troell, M., DeClerck, F., Gordon, L. J., Zurayk, R., Scarborough, P., Rayner, M., Loken, B., Fanzo, J., Godfray, H. C. J., … Willett, W. (2018). Options for keeping the food system within environmental limits. *Nature*, *562*(7728), 519–525. https://doi.org/10.1038/s41586-018-0594-0

Westerterp-Plantenga, M. S., Lemmens, S. G., & Westerterp, K. R. (2012). Dietary protein - its role in satiety, energetics, weight loss and health. *The British journal of nutrition*, *108 Suppl 2*, S105–S112. https://doi.org/10.1017/S0007114512002589

Willis, L. H., Slentz, C. A., Bateman, L. A., Shields, A. T., Piner, L. W., Bales, C. W., Houmard, J. A., & Kraus, W. E. (2012). Effects of aerobic and/or resistance training on body mass and fat mass in overweight or obese adults. *Journal of applied physiology (Bethesda, Md. : 1985)*, *113*(12), 1831–1837. https://doi.org/10.1152/japplphysiol.01370.2011