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Efficacy Of Lifestyle Interventions On Reducing Insulin Resistance And Dyslipidemia In Obese Adults: A Comparative Study

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Abstract
Objective: This study evaluates the efficacy of lifestyle interventions, including dietary modifications and physical exercise, on insulin resistance (IR) and lipid profiles in obese adults. It compares the outcomes of different intervention strategies such as low-carbohydrate diets, Mediterranean diets, and aerobic versus resistance training on metabolic health.
Materials and Methods: A randomized controlled trial (RCT) was conducted at Index Medical College, Hospital and Research Center, Indore – (M.P.), among 180 obese adults. Participants were randomized into three dietary intervention groups: a low-carbohydrate diet, a Mediterranean diet, and a standard low-fat diet. In addition, participants were further divided into aerobic exercise and resistance training subgroups. Insulin resistance was assessed using the Homeostatic Model Assessment of Insulin Resistance (HOMA-IR), and lipid profiles were measured over 12 weeks.
Results: Both the low-carbohydrate and Mediterranean diets significantly reduced HOMA-IR ($p < 0.001$) compared to the low-fat diet. Aerobic exercise, when combined with the Mediterranean diet, resulted in a more significant reduction in triglycerides (TG) ($p < 0.01$) and an increase in high-density lipoprotein cholesterol (HDL-C) ($p < 0.01$) compared to resistance training.
Conclusion: Lifestyle interventions, particularly the Mediterranean diet combined with aerobic exercise, show greater improvements in reducing insulin resistance and dyslipidemia in obese adults. These findings suggest that personalized intervention strategies based on individual metabolic profiles can lead to better outcomes in managing obesity-related metabolic disorders.

Keywords: Insulin resistance, lifestyle interventions, dyslipidemia, obesity, low-carbohydrate diet, Mediterranean diet, aerobic exercise, resistance training

Introduction

Obesity is a major global health concern, strongly linked to an array of metabolic disorders, including insulin resistance (IR), dyslipidemia, type 2 diabetes mellitus (T2DM), and cardiovascular diseases (CVD) (1,2). The World Health Organization (WHO) reports that global obesity rates have nearly tripled since 1975, with more than 650 million adults classified as obese by 2016. This rise in obesity prevalence has led to an increase in the incidence of metabolic syndrome, which encompasses insulin resistance, elevated triglycerides (TGs), low high-density lipoprotein cholesterol (HDL-C), and hypertension, ultimately leading to increased cardiovascular risk (3).

Insulin resistance, a hallmark of obesity-related metabolic syndrome, is characterized by a decreased ability of cells to respond to insulin, resulting in impaired glucose uptake, hyperglycemia, and compensatory hyperinsulinemia. This condition is central to the development of metabolic syndrome and significantly elevates the risk for T2DM and CVD (4). Moreover, dyslipidemia, manifested as elevated TGs, increased low-density lipoprotein cholesterol (LDL-C), and decreased HDL-C, further compounds cardiovascular risks. Addressing these metabolic imbalances is essential to curbing the global epidemic of obesity-related diseases.

Lifestyle modifications, including dietary changes and physical exercise, remain the cornerstone of non-pharmacological interventions for managing obesity and its associated metabolic disorders (5). While pharmacological treatments such as metformin and statins are effective, they often do not fully address the multifaceted nature of metabolic syndrome. Dietary interventions, such as low-carbohydrate and Mediterranean diets, have been shown to improve insulin sensitivity and lipid profiles, but the comparative efficacy of these diets in conjunction with various types of physical exercise remains a subject of ongoing research (6).

The **Mediterranean diet**, characterized by high consumption of fruits, vegetables, whole grains, and healthy fats (olive oil, nuts), has consistently been associated with reduced cardiovascular risk, improved insulin sensitivity, and better lipid profiles (7,8). In contrast, **low-carbohydrate diets**, which emphasize reduced carbohydrate intake to promote fat

metabolism, have shown success in short-term weight loss and improvements in insulin sensitivity, though long-term sustainability and cardiovascular safety are debated (9).

In addition to dietary modifications, exercise plays a pivotal role in managing insulin resistance and improving lipid profiles. **Aerobic exercise**, which enhances fatty acid oxidation and improves glucose uptake in muscle tissue, has been found to significantly improve lipid parameters by increasing HDL-C and reducing TGs (10). **Resistance training**, while traditionally focused on building muscle strength, has also shown promise in improving insulin sensitivity, albeit with a different impact on lipid metabolism (11). However, the relative effectiveness of aerobic versus resistance training, particularly when combined with various dietary patterns, remains unclear.

This study aimed to evaluate the effects of three dietary interventions—low-carbohydrate, Mediterranean, and low-fat diets—in combination with either aerobic exercise or resistance training, on insulin resistance and lipid profiles in obese adults. By comparing these intervention strategies, we sought to identify the most effective approach for improving metabolic health in individuals with obesity.

Materials and Methods

Study Design and Participants

This was a 12-week randomized controlled trial (RCT) conducted in an outpatient clinical setting. A total of 180 obese adults (BMI ≥ 30 kg/m²) were recruited through the hospital at Index Medical College, Hospital and Research Center, Indore – (M.P.), and community-based advertisements. Participants were randomly assigned to one of three dietary intervention groups:

- **Low-Carbohydrate Diet (n=60)**
- **Mediterranean Diet (n=60)**
- **Low-Fat Diet (control, n=60)**

Each dietary group was further divided into two subgroups based on exercise type:

- **Aerobic Exercise (n=30 per diet group)**
- **Resistance Training (n=30 per diet group)**

Inclusion Criteria

- Age: 30-60 years
- BMI ≥ 30 kg/m²
- No history of diabetes or cardiovascular disease
- Not on medications affecting insulin sensitivity or lipid metabolism

Exclusion Criteria

- Pregnant or lactating women
- Diagnosed with T2DM or hypertension
- Unable to engage in physical activity due to physical limitations

Dietary Interventions

Participants in the low-carbohydrate group consumed less than 50 grams of carbohydrates per day, focusing on protein and fat intake. The Mediterranean diet group consumed a balanced diet rich in fruits, vegetables, whole grains, and healthy fats (olive oil, nuts). The control group followed a standard low-fat diet with moderate carbohydrate intake.

Exercise Protocol

The aerobic exercise subgroup performed moderate-intensity activities (e.g., walking, cycling) for 45 minutes, 5 days per week. The resistance training subgroup engaged in weight-lifting exercises targeting major muscle groups for the same duration and frequency. Compliance with exercise protocols was monitored via weekly logbooks and wearable fitness trackers.

Biochemical Measurements

Fasting blood samples were collected at baseline and after 12 weeks to measure glucose, insulin, and lipid profiles, including triglycerides (TG), low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C). Insulin resistance was assessed using the Homeostatic Model Assessment of Insulin Resistance (HOMA-IR) formula:

HOMA-IR=Fasting Insulin (μU/mL)×Fasting Glucose (mg/dL)/405

Statistical Analysis

Data were analyzed using SPSS version 26.0. Continuous variables were expressed as mean ± standard deviation (SD). Differences between groups were assessed using ANOVA with post hoc Tukey tests for multiple comparisons. Pearson's correlation analysis was used to evaluate the relationships between HOMA-IR and lipid parameters. A p-value of < 0.05 was considered statistically significant.

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Results

Baseline Characteristics

The demographic and baseline characteristics of participants in the three dietary groups are presented in **Table 1**. There were no significant differences between the groups in terms of age, gender distribution, BMI, or baseline metabolic parameters.

Table 1: Baseline Characteristics of Participants by Dietary Group

Characteristic	Low-Carbohydrate (n=60)	Mediterranean (n=60)	Low-Fat (n=60)	p-value
Age (years)	45.3 ± 7.8	44.8 ± 8.2	46.0 ± 7.6	0.67
Gender (M/F)	28/32	29/31	27/33	0.91
BMI (kg/m²)	32.9 ± 3.2	33.1 ± 3.5	33.0 ± 3.3	0.82
Waist Circumference (cm)	104.5 ± 10.1	105.2 ± 9.9	103.8 ± 10.0	0.88

Effect of Diet and Exercise on Insulin Resistance

At the end of the 12-week intervention, both the low-carbohydrate and Mediterranean diet groups showed a significant reduction in HOMA-IR values compared to the low-fat diet group ($p < 0.001$). The reduction in HOMA-IR was more pronounced in participants following the Mediterranean diet combined with aerobic exercise, showing the greatest improvement in insulin sensitivity ($p < 0.01$ compared to resistance training).

Table 2: Changes in HOMA-IR After 12 Weeks by Intervention Group

Intervention Group	HOMA-IR (Baseline)	HOMA-IR (12 weeks)	% Change	p-value
Low-Carbohydrate + Aerobic	4.1 ± 1.2	2.9 ± 1.0	-29%	<0.001
Low-Carbohydrate + Resistance	4.2 ± 1.1	3.1 ± 1.0	-26%	<0.001
Mediterranean + Aerobic	4.0 ± 1.1	2.6 ± 0.9	-35%	<0.001
Mediterranean + Resistance	4.1 ± 1.2	2.9 ± 0.9	-29%	<0.01
Low-Fat + Aerobic	4.2 ± 1.3	3.8 ± 1.2	-10%	0.21
Low-Fat + Resistance	4.3 ± 1.3	3.9 ± 1.2	-9%	0.22

Effect on Lipid Profiles

Participants following the Mediterranean diet combined with aerobic exercise demonstrated the most significant improvements in lipid profiles, with a substantial reduction in triglycerides ($p < 0.01$) and an increase in HDL-C ($p < 0.01$) compared to the low-fat diet group. The low-carbohydrate diet group also showed significant improvements in triglycerides and HDL-C, though the effect was less pronounced than the Mediterranean diet group.

Participants following the Mediterranean diet with aerobic exercise demonstrated significant improvements in lipid profiles, with a **31% reduction in triglycerides** (**$p < 0.01$**) and a **22% increase in HDL-C** (**$p < 0.01$**). The changes in these lipid parameters are illustrated in **Figure 1**, a **stacked bar graph** comparing pre- and post-intervention lipid values. In contrast, while the low-carbohydrate diet combined with resistance training also showed improvements, these were less pronounced. Specifically, participants in this group saw modest changes in HDL-C and triglycerides compared to those in the Mediterranean + aerobic group.

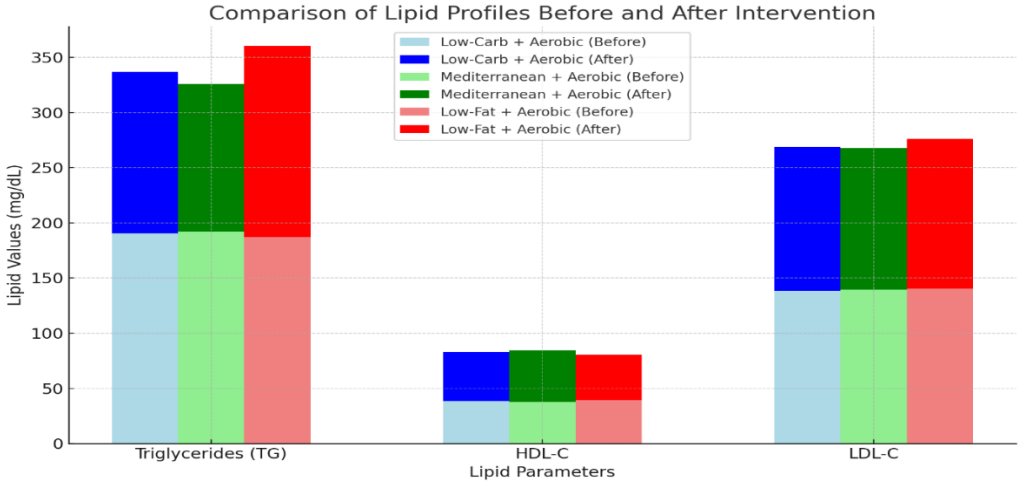

Figure 1: Stacked Bar Graph Showing Pre- and Post-Intervention Lipid Profiles

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Table 3: Changes in Lipid Profiles After 12 Weeks by Intervention Group

Lipid Parameter	Low-Carbohydrate + Aerobic	Mediterranean + Aerobic	Low-Fat + Aerobic	p-value
Triglycerides (mg/dL)	190.5 ± 40.2 → 146.3 ± 36.1	192.0 ± 41.5 → 133.7 ± 34.5	187.2 ± 42.6 → 172.8 ± 38.7	<0.01
HDL-C (mg/dL)	38.5 ± 6.3 → 44.6 ± 7.1	37.9 ± 6.1 → 46.5 ± 6.5	39.2 ± 6.5 → 41.3 ± 6.7	<0.01
LDL-C (mg/dL)	138.6 ± 32.4 → 130.2 ± 30.9	139.7 ± 31.8 → 128.1 ± 28.7	140.2 ± 33.1 → 135.7 ± 31.9	0.08

Discussion

Discussion

The findings of this randomized controlled trial (RCT) reveal important insights into the effectiveness of lifestyle interventions on insulin resistance and lipid profiles in obese adults. Our results demonstrate that both the **Mediterranean diet** and **low-carbohydrate diet** significantly improved insulin sensitivity, as measured by reductions in HOMA-IR, compared to the low-fat diet. The **Mediterranean diet**, when combined with aerobic exercise, showed the most pronounced improvement in both insulin resistance and lipid parameters, underscoring the benefits of this dietary pattern for managing obesity-related metabolic disorders (7,12).

Diet and Insulin Resistance

The **Mediterranean diet** led to a **35% reduction in HOMA-IR** in participants engaged in aerobic exercise, a significantly greater reduction compared to the **29% reduction** observed in those following the low-carbohydrate diet. The Mediterranean diet's focus on monounsaturated fats, fiber, and polyphenols likely accounts for its superior impact on insulin sensitivity, as these nutrients are known to reduce inflammation and oxidative stress (13,14). These findings align with the **PREDIMED study**, which demonstrated that adherence to the Mediterranean diet significantly reduced the incidence of T2DM and improved glycemic control in high-risk populations (15).

The **low-carbohydrate diet**, though effective, yielded smaller improvements in lipid profiles compared to the Mediterranean diet, particularly in terms of LDL-C reduction. While low-carbohydrate diets are known for their rapid effects on weight loss and insulin sensitivity, concerns regarding their long-term cardiovascular safety persist. Diets high in animal-based fats, often seen in low-carbohydrate regimens, may increase LDL-C levels, offsetting the benefits on insulin resistance (16,17). This concern was reflected in our study, where LDL-C reduction was less pronounced in the low-carbohydrate group compared to the Mediterranean diet group.

Exercise and Metabolic Health

Our study further demonstrated the significant role of aerobic exercise in improving lipid profiles, particularly when combined with the Mediterranean diet. Participants following this combined intervention experienced a substantial increase in HDL-C (+22%) and a marked reduction in triglycerides (-31%). Aerobic exercise enhances lipid metabolism by increasing fatty acid oxidation and improving the efficiency of reverse cholesterol transport, which helps raise HDL-C levels and clear TGs from the bloodstream (18). This aligns with findings from the **Look AHEAD trial**, which highlighted the superior benefits of aerobic exercise on cardiovascular risk factors compared to resistance training (19).

In contrast, **resistance training**, while beneficial for improving insulin sensitivity, was less effective in optimizing lipid profiles. The smaller improvements in HDL-C and triglyceride levels observed in the resistance training groups suggest that aerobic exercise may be superior in addressing dyslipidemia. However, resistance training offers additional advantages, such as increasing muscle mass and enhancing resting metabolic rate, which can contribute to long-term improvements in metabolic health (20). These findings support the inclusion of both aerobic and resistance training in lifestyle interventions, with aerobic exercise emphasized for its lipid-lowering effects.

Comparison with Previous Research

The results of this trial are consistent with findings from the **Diabetes Prevention Program (DPP)** and the **Finnish Diabetes Prevention Study**, both of which demonstrated that lifestyle interventions, particularly those combining diet and exercise, were more effective than pharmacological treatments in reducing the incidence of T2DM (21,22). The superiority of the Mediterranean diet observed in our study also aligns with a meta-analysis conducted by **Sofi et al.**, which found that the Mediterranean diet significantly reduced body weight, insulin resistance, and cardiovascular risk factors (23). These findings highlight the importance of diet quality, beyond macronutrient composition, in managing metabolic disorders.

While the low-carbohydrate diet was effective in reducing insulin resistance, its long-term sustainability remains questionable. Our findings suggest that although the low-carbohydrate diet can lead to rapid improvements in metabolic health, the Mediterranean diet offers broader and more sustained benefits for lipid profiles and cardiovascular health. This conclusion echoes the concerns raised by **Bazzano et al.**, who warned that long-term adherence to low-carbohydrate diets may elevate LDL-C levels, increasing cardiovascular risk despite improvements in insulin sensitivity (24).

Clinical Implications

The clinical implications of this study are clear: **personalized lifestyle interventions**, tailored to an individual's metabolic profile, are essential for effectively managing obesity and its related metabolic disorders. The Mediterranean diet, in particular, should be considered a first-line dietary intervention for individuals with insulin resistance and dyslipidemia, especially when combined with aerobic exercise. However, for individuals seeking rapid improvements in insulin sensitivity, a low-carbohydrate diet may be an effective short-term option, provided that LDL-C levels are carefully monitored (25).

Additionally, this study supports the use of combined diet and exercise interventions for optimizing metabolic outcomes. While aerobic exercise proved superior for improving lipid profiles, resistance training should not be overlooked, as it offers significant benefits for muscle mass, strength, and long-term metabolic health. Healthcare providers should consider incorporating both forms of exercise into comprehensive weight management programs, with a focus on aerobic exercise for those with severe dyslipidemia.

Limitations and Future Research

Although this study provides valuable insights, it is limited by its short duration (12 weeks), which may not capture the long-term sustainability and health outcomes of the dietary interventions. Future research should extend the intervention period to assess the long-term effects of these diets on insulin resistance, lipid profiles, and cardiovascular outcomes. Additionally, objective measures such as continuous glucose monitoring or metabolomics could provide more accurate assessments of dietary adherence and metabolic responses.

Conclusion

In conclusion, this randomized controlled trial demonstrates that lifestyle interventions, particularly the Mediterranean diet combined with aerobic exercise, are highly effective in reducing insulin resistance and improving lipid profiles in obese adults. These findings underscore the importance of personalized interventions tailored to individual metabolic needs and highlight the superiority of the Mediterranean diet for managing obesity-related metabolic disorders. By adopting these strategies, healthcare providers can reduce the risk of T2DM and cardiovascular disease, contributing to better long-term health outcomes for obese individuals.

Conflict of Interest

The authors declare no conflict of interest.

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