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# Impact of resistance exercise and diet on physical activity, sleep, and fatigue in obese individuals: a randomized controlled trial

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## Abstract

**Background** Obesity is a global health challenge linked to reduced physical activity, poor sleep, and increased fatigue. While diet is central to weight management, resistance training may offer additional benefits, but its combined impact on sleep and activity patterns in individuals with obesity remains unclear. This study aimed to compare the effects of a 12-week resistance training program combined with calorie-restricted dietary intervention (Diet + RT) versus diet alone on self-reported physical activity levels, sleep quality, fatigue, body weight, and waist circumference in individuals with obesity.

**Methods** In this randomized controlled trial, 40 individuals with obesity were assigned to either a calorie-restricted Diet group or a Diet + RT group for 12 weeks. The exercise program targeted major muscle groups at moderate intensity, performed three times per week under professional supervision. Outcomes included the International Physical Activity Questionnaire (IPAQ), Pittsburgh Sleep Quality Index (PSQI), Fatigue Severity Scale (FSS), body weight, and waist circumference, measured at baseline, mid-intervention, and post-intervention. Data were analyzed using repeated-measures ANOVA and chi-square tests.

**Results** Groups were comparable at baseline (all  $p > 0.05$ ). Significant time  $\times$  group interactions were found for body weight ( $F = 25.83$ ), waist circumference ( $F = 27.38$ ), sleep quality ( $F = 22.19$ ), and fatigue severity ( $F = 53.94$ ) (all  $p < 0.001$ ), favoring the combined intervention. Self-reported physical activity levels, measured via the IPAQ, also differed significantly between groups at baseline ( $\chi^2 = 8.44$ ), mid-intervention ( $\chi^2 = 16.41$ ), and post-intervention ( $\chi^2 = 14.40$ ) (all  $p < 0.01$ ).

**Conclusions** Diet + RT yields superior improvements in self-reported physical activity, sleep quality, body weight, fatigue, and waist circumference compared to diet alone in individuals with obesity.

**Trial registration** The protocol is registered with <http://clinicaltrials.gov/> (15/August/2023, Clinical Trial, NCT06004427).

**Keywords** Fatigue, Obesity, Physical activity, Resistance exercise, Sleep quality, Weight management

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## Background

Obesity has become one of the most pressing global public health challenges, affecting individuals across all age groups and socioeconomic backgrounds. According to the World Health Organization [1], more than 1.9 billion adults worldwide are overweight, and over 650 million are classified as obese. The increasing prevalence of obesity is not only a risk factor for metabolic diseases such as type 2 diabetes, hypertension, and cardiovascular disorders [2] but also contributes to reduced physical fitness [3], impaired quality of life [4], and disrupted sleep patterns [5]. The urgency to identify effective, evidence-based interventions for managing obesity comorbidities is paramount.

Among the most widely recommended strategies in obesity management, diet and physical activity remain central to improving long-term outcomes [6]. While dietary modifications can lead to short-term reductions in body weight, sustained improvements in health and behavior often require the addition of structured exercise programs [7]. Resistance training (RT), in particular, is increasingly incorporated into obesity interventions due to its potential to enhance overall physical function and improve body composition [8].

Notably, physical activity levels have been closely associated with sleep quality and perceived fatigue, especially among individuals with obesity [9, 10]. Poor sleep is recognized as both a cause and consequence of excess weight, influencing appetite regulation, metabolic health, and physical activity behavior [5, 9]. Inadequate sleep can increase fatigue and sedentary time, thereby further limiting energy balance and overall well-being.

While the relationship between physical activity and sleep quality is evident, the type of exercise modality used is also critical. Although aerobic exercise has been more extensively studied in relation to sleep, findings consistently demonstrate that regular aerobic exercise is associated with improvements in sleep quality, sleep latency, and total sleep time in both healthy and clinical populations [10]. However, the specific effects of RT on sleep outcomes remain underexplored. Recent studies suggest that RT may also yield meaningful improvements in sleep parameters, including sleep efficiency and reduced sleep disturbances, particularly in individuals with overweight or obesity [11]. However, these preliminary findings have yet to be confirmed through rigorous, controlled studies. Given the growing interest in non-pharmacological interventions to address poor sleep among this population, examining the unique contributions of RT warrants further attention.

Given the bidirectional relationship between physical activity, sleep, and fatigue, there is a need for integrative interventions that target these factors simultaneously. This study uniquely integrates supervised RT with dietary

intervention to comprehensively evaluate its effects on self-reported physical activity levels (excluding the supervised sessions), sleep quality, fatigue, body weight, and waist circumference in individuals with obesity. By addressing these interconnected outcomes, the study seeks to contribute to more comprehensive, patient-centered obesity management strategies.

## Methods

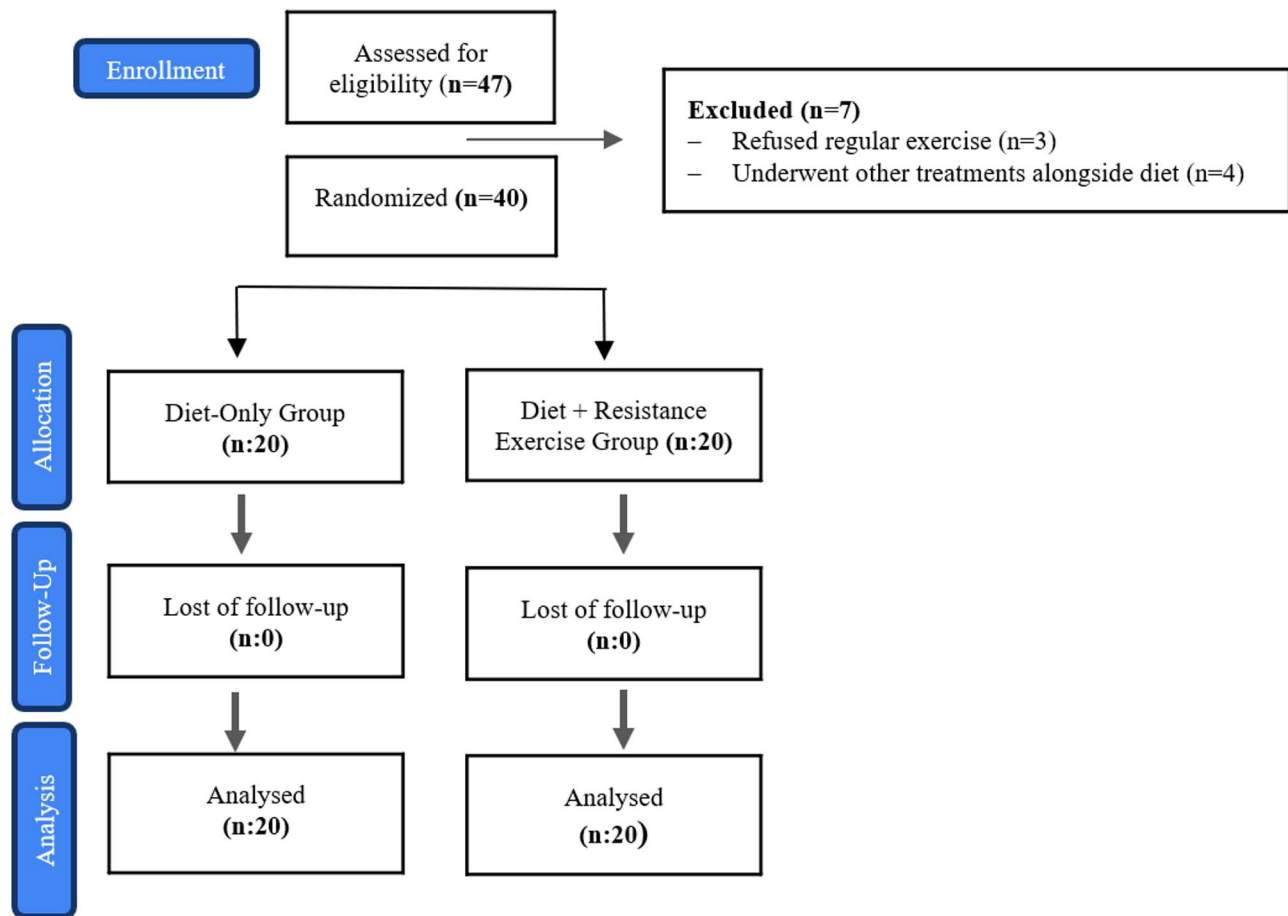
### Study design and participants

This study was conducted as a single-blind, randomized controlled trial (RCT) to evaluate the effects of a Diet + RT compared to diet alone on self-reported physical activity levels, sleep quality, fatigue, body weight, and waist circumference in individuals with obesity. The protocol is registered with <http://clinicaltrials.gov/15/August/2023>, Clinical Trial, NCT06004427). The 12-week intervention included assessments at Baseline (T0), Mid-Intervention (T1, Week 6), and Post-Intervention (T2, Week 12). Participants were recruited from a community health center between September and December 2023. The study adhered to the CONSORT 2010 guidelines [12], and received ethical approval from the Üsküdar University Non-Interventional Research Ethics Committee (Approval No: 61351342/December 2022). Written informed consent was obtained from all participants prior to enrollment. The study flowchart detailing the enrollment, allocation, and follow-up processes is presented in Fig. 1.

### Eligibility criteria

Individuals aged 18 years and older with a Body Mass Index (BMI) of 30 kg/m<sup>2</sup> or higher [1] who voluntarily agreed to participate and signed informed consent were included. Participants were excluded if they had participated in a calorie-restricted diet program or experienced  $\geq 10\%$  weight change in the last six months; used excessive vitamin or mineral supplements ( $> 500\%$  of the recommended daily intake); had diagnosed Type 1 or Type 2 diabetes, uncontrolled thyroid disorders, or other endocrine dysfunctions; suffered from respiratory conditions such as severe asthma or COPD that would prevent indirect calorimetry assessments; had musculoskeletal, cardiovascular, or chronic pain conditions that limited exercise participation; were pregnant or lactating; or had psychiatric conditions (e.g., severe depression, eating disorders, or cognitive impairment) that might impair adherence. Individuals unwilling to track dietary intake, physical activity, or attend counseling were also excluded [13].

All inclusion and exclusion criteria, besides body weight and waist circumference, were assessed through self-reporting and structured interviews. No objective



**Fig. 1** Flowchart of the study

medical assessments were performed before participant enrollment.

### Randomization and blinding

Participants were randomly assigned in a 1:1 ratio to either the Diet group ( $n=20$ ) or the Diet+RT group ( $n=20$ ). Randomization was computer-generated using Random.org.

This was a single-blind study in which all outcome assessments were performed by a single physiotherapist who was not involved in the intervention and was blinded to group allocation. Participants were assigned anonymized codes, and standardized assessment forms were used to ensure objectivity. Participants and interventionists were aware of their assignments due to the nature of the intervention.

### Interventions

#### Diet intervention

All participants followed a calorie-restricted diet designed by a registered dietitian, aiming for an individualized daily energy deficit of approximately 500–750 kcal. This approach was based on current clinical practice

guidelines from Obesity Canada [14, 15] and the European Federation of the Associations of Dietitians [16].

Basal metabolic rate (BMR) was calculated using the Mifflin-St Jeor equation, which is recognized for its accuracy in estimating resting energy expenditure in both obese and non-obese individuals [17, 18]. Total daily energy expenditure was then estimated by multiplying the BMR by an activity factor corresponding to each participant's reported physical activity level [19]. The registered dietitian adjusted the energy deficit for each participant according to BMI classification and clinical presentation to support gradual weight loss.

The target was a weekly weight loss of 0.5–1.0 kg, consistent with recommendations by the World Health Organization [1]. Macronutrient distribution was structured as follows:

- 45–50% carbohydrates.
- 15–20% protein.
- 30–35% fat.

Meal plans were individualized and revised every 6 weeks. To monitor adherence, participants were

instructed to complete self-reported 3-day dietary logs (including one weekend day), and follow-up support was provided through biweekly phone calls. Additionally, weight and waist circumference measurements were recorded to support and verify compliance.

### **Resistance exercise intervention**

Participants in the Diet + RT group engaged in a 12-week, supervised, progressive resistance training program based on the American College of Sports Medicine (ACSM) guidelines for obesity management [20, 21]. The program included:

- **Frequency and Timing:** Resistance training sessions were conducted three times per week, between 4:00 p.m. and 6:00 p.m.
- **Duration:** 45–60 min per session.
- **Exercise Type:** Free-weight and machine-based resistance exercises targeting major muscle groups, including squats, lunges, leg press, bench press, rows, and core exercises.
- **Intensity:** Moderate-to-high (60–80% of one-repetition maximum [1-RM]), a range supported by evidence to effectively improve muscle strength and fat-free mass in individuals with obesity [22].
- **Volume:** 2–3 sets of 8–12 repetitions per exercise.
- **Rest Intervals:** Participants rested for 60–90 s between sets and 90–120 s between different exercises.
- **Progression:** Loads were increased every 6 weeks, based on reassessment of 1-RM values and participant performance, in line with principles of progressive overload [23].
- **Safety and Adaptation:** Modifications were implemented as needed to ensure joint safety and accommodate physical limitations commonly observed in individuals with obesity.
- **Compliance Monitoring:** Compliance was monitored through attendance tracking and periodic 1-RM reassessments to ensure that training intensity (60–80% of 1-RM) was maintained; heart rate was recorded for safety monitoring.
- **Supervision:** All sessions were supervised by a licensed physiotherapist with expertise in obesity rehabilitation and resistance training.

### **Outcome measures**

Data were collected at Baseline (T0), Mid-Intervention (T1, Week 6), and Post-Intervention (T2, Week 12) using validated instruments.

### **Primary outcomes**

1. **Physical Activity Levels:** Physical activity levels were assessed using the International Physical Activity Questionnaire (IPAQ-Short Form), which assesses activity in occupational, transport, household and leisure time domains. The questionnaire measures the frequency (days per week), duration (minutes per day), and intensity (light, moderate, vigorous) of activities performed over the past seven days. Physical activity is reported in Metabolic Equivalent of Task (MET) minutes per week, with participants classified as inactive if less than 600 MET-min/week, minimally active if between 600 and 3000 MET-min/week, and vigorously active if more than 3000 MET-min/week [24, 25]. This tool was chosen because of its widespread use in obesity-related physical activity research and its validated use in diverse populations [26].
2. **Sleep Quality:** Sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI), a widely validated tool for assessing subjective sleep quality and disturbance over the past month. The PSQI consists of 19 self-rated items grouped into seven components: sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, sleep medication use, and daytime dysfunction. Each component is scored from 0 to 3, and the total score ranges from 0 to 21. A PSQI total score greater than 5 indicates poor sleep quality [27, 28]. This scale was chosen because of its ability to comprehensively assess different aspects of sleep and its frequent use in studies investigating sleep disturbance in obesity [10].
3. **Fatigue Severity:** Fatigue severity was measured using the Fatigue Severity Scale (FSS), which assesses the impact of fatigue on daily activities. Obesity has been associated with increased fatigue and reduced energy levels, making this tool particularly relevant [29]. The FSS consists of nine statements relating to the perception of fatigue and its impact on physical and social activities. Each item is rated on a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). The final score is calculated as the mean of all item scores, with scores of 5 or more indicating clinically significant fatigue [30, 31]. The scale was chosen because of its established validity in measuring fatigue in various health conditions, including obesity-related fatigue [32].

### **Secondary outcomes**

4. **Waist Circumference:** Waist circumference was measured as an indicator of central obesity

and metabolic risk according to standardized anthropometric guidelines. Measurements were taken at the midpoint between the lowest rib and the iliac crest using a flexible, non-stretchy tape measure. A waist circumference of 88 cm or more for women and 102 cm or more for men was classified as abdominal obesity based on WHO criteria [1]. This measure was chosen because of its strong association with obesity-related health risks, including metabolic syndrome and cardiovascular disease [33, 34].

- 5. Body Weight and BMI:** Body weight and body mass index (BMI) were assessed using a calibrated bioimpedance scale (Tanita, Japan) to monitor weight changes throughout the study. BMI was calculated as weight in kilograms divided by height in meters squared ( $\text{kg}/\text{m}^2$ ). According to the WHO classification, a BMI between 18.5 and 24.9  $\text{kg}/\text{m}^2$  was considered normal weight, between 25.0 and 29.9  $\text{kg}/\text{m}^2$  was considered overweight, and 30.0  $\text{kg}/\text{m}^2$  or more was considered obese. These measurements were used as standard indicators of body composition and overall weight status in obesity management [34].

#### Sample size calculation

Sample size estimation was performed using G\*Power (version 3.1.9.7). Based on the results of a recent meta-analysis by Khalafi et al. [35], which reported a moderate standardized mean difference (SMD=0.33; corresponding to  $f=0.31$ ) between combined exercise and diet interventions versus diet alone in individuals with overweight or obesity, we adopted the same effect size for our calculation.

Moreover, previous randomized controlled trials [36, 37] and observational studies [38] assessing the effects of exercise and diet interventions on outcomes such as fatigue, sleep quality, and physical activity in individuals with obesity have reported comparable or greater effect sizes (e.g.,  $f=0.21$  to  $f=0.54$ ), supporting the appropriateness of assuming a medium effect size for power analysis in the present study.

Using  $\alpha=0.05$  and power  $(1-\beta)=0.80$ , the minimum required sample size was 12 participants per group. To account for potential attrition, we included 20 participants per group in the current trial.

#### Statistical analysis

Data analysis was conducted using SPSS 25.0 (IBM, USA). Descriptive statistics, presented as mean  $\pm$  standard deviation (SD), were used to summarize participant characteristics. Chi-square ( $\chi^2$ ) tests were applied to compare categorical variables between groups. Repeated Measures ANOVA was used to assess both within-group and between-group differences over time at Baseline

(T0), Mid-Intervention (T1, Week 6), and Post-Intervention (T2, Week 12). Additionally, paired t-tests were performed to evaluate pre-post changes within each group. A  $p$ -value  $<0.05$  was considered indicative of statistical significance. To minimize potential bias, an intention-to-treat (ITT) analysis was implemented, and missing data were handled using multiple imputation techniques.

#### Results

A total of 40 participants were recruited and randomly allocated to the Diet + RT group ( $n=20$ ) and the Diet group ( $n=20$ ). There were no drop-outs during the 12-week intervention period and all participants completed the study, resulting in a 100% retention rate (see Fig. 1). Compliance with the supervised exercise sessions was high, with a mean attendance rate of 92.5% in the Diet + RT group.

Independent samples t-tests and chi-square tests were used to assess baseline comparability. No statistically significant differences were found between the groups in terms of age (Diet + RT:  $47.3 \pm 4.5$  years; Diet:  $46.8 \pm 3.7$  years;  $p=0.79$ ), gender distribution ( $p=1.00$ ), or BMI classification ( $p=0.56$ ) (Table 1).

#### Anthropometric, sleep, and fatigue outcomes

Changes in body weight, waist circumference, sleep quality (PSQI), and fatigue severity (FSS) were assessed at baseline, mid-intervention, and post-intervention (T0, T1, T2). Statistically significant time  $\times$  group interactions were observed for all outcomes (Table 2), indicating greater improvements in the Diet + RT group compared to the Diet group.

For body weight, a significant time  $\times$  group interaction was found ( $F=25.83$ ,  $p<0.001$ ), favoring the Diet + RT group. Waist circumference also showed a significant interaction effect ( $F=27.38$ ,  $p<0.001$ ), with greater reductions in the Diet + RT group over time.

Sleep quality scores demonstrated a significant time  $\times$  group interaction ( $F=22.19$ ,  $p<0.001$ ), indicating more pronounced improvements in the Diet + RT group. Similarly, fatigue severity decreased significantly more in the Diet + RT group, as reflected by a significant interaction effect ( $F=53.94$ ,  $p<0.001$ ).

#### Self-reported physical activity levels

Self-reported physical activity levels, assessed using the IPAQ, were compared between the two groups at baseline, mid-intervention, and post-intervention using the chi-square test. Statistically significant differences were observed between the groups at all three time points (Table 3).

At baseline, a significant difference in physical activity levels was identified between the groups ( $\chi^2 = 8.44$ ,  $p=0.004$ ). At mid-intervention, this difference remained

**Table 1** Baseline demographic and BMI characteristics of participants by intervention group

Characteristics	Diet + Resistance Exercise (n = 20)	Diet-Only (n = 20)	p-value
<b>Age (years)</b>	47.3 ± 4.5	46.8 ± 3.7	0.79
<b>Gender</b>			1.00
Female, n (%)	13 (65.0%)	14 (70.0%)	
Male, n (%)	7 (35.0%)	6 (30.0%)	
<b>Body Mass Index (BMI, kg/m<sup>2</sup>)</b>			0.56
Class 1 (moderate), n (%)	6 (30.0%)	7 (35.0%)	
Class 2 (severe), n (%)	12 (60.0%)	9 (45.0%)	
Class 3 (morbid), n (%)	2 (10.0%)	4 (20.0%)	

Continuous variables are presented as mean ± standard deviation (SD)

Categorical variables are expressed as frequencies and percentages (n, %)

The chi-square test was used to compare categorical variables between the two groups (e.g., gender and BMI classification)

An independent samples t-test was used to compare continuous variables (e.g., age)

A p-value of less than 0.05 was considered statistically significant

**Table 2** Effects of exercise combined with diet vs. diet alone on anthropometric measures, sleep quality, and fatigue severity over time

Measurement	Test Time	Diet + Resistance Exercise (n = 20)	Diet-Only (n = 20)	Time Effect (F, p)	Time × Group Interaction (F, p)
Weight (kg)	Baseline (T0)	105.03 ± 8.30	105.25 ± 9.75	F = 174.29, p < 0.001	F = 25.83, p < 0.001
	Mid-Intervention (T1)	100.18 ± 5.52	103.35 ± 7.55		
	Post-Intervention (T2)	96.21 ± 7.08	102.04 ± 6.93		
Waist circumference (cm)	Baseline (T0)	101.05 ± 6.86	100.20 ± 7.87	F = 143.68, p < 0.001	F = 27.38, p < 0.001
	Mid-Intervention (T1)	97.70 ± 7.12	98.90 ± 8.12		
	Post-Intervention (T2)	94.55 ± 7.33	97.65 ± 8.08		
Sleep Quality (PSQI)	Baseline (T0)	16.55 ± 1.72	16.70 ± 1.96	F = 46.06, p < 0.001	F = 22.19, p < 0.001
	Mid-Intervention (T1)	14.70 ± 1.85	16.30 ± 2.00		
	Post-Intervention (T2)	13.08 ± 1.16	16.08 ± 1.62		
Fatigue Severity (FSS)	Baseline (T0)	5.16 ± 0.59	5.41 ± 0.74	F = 188.16, p < 0.001	F = 53.94, p < 0.001
	Mid-Intervention (T1)	4.58 ± 0.48	5.19 ± 0.71		
	Post-Intervention (T2)	4.04 ± 0.40	5.07 ± 0.74		

Continuous variables are presented as mean ± standard deviation (SD)

Repeated measures ANOVA (F-test) was used to assess the time effect and the time × group interaction

Statistical significance was set at p < 0.05

**Table 3** Group-based comparison of physical activity levels (IPAQ categories) at baseline, week 6, and week 12

Group	Activity Level	Baseline (T0)	Mid-Intervention (T1)	Post-Intervention (T2)
Diet + Resistance Exercise (n = 20)	Inactive	3 (15.0%)	0 (0.0%)	0 (0.0%)
	Minimally Active	17 (85.0%)	0 (0.0%)	0 (0.0%)
	Vigorously Active	0 (0.0%)	20 (100.0%)	20 (100.0%)
Diet-Only (n = 20)	Inactive	13 (65.0%)	13 (65.0%)	12 (60.0%)
	Minimally Active	7 (35.0%)	7 (35.0%)	8 (40.0%)
	Vigorously Active	0 (0.0%)	0 (0.0%)	0 (0.0%)
$\chi^2$ (p-value)		<b>8.44 (p = 0.004)</b>	<b>16.41 (p &lt; 0.001)</b>	<b>14.40 (p &lt; 0.001)</b>

Frequency (f) and percentage (%) values are presented for each physical activity level within groups across the three time points

Group distributions were compared at each time point using the chi-square ( $\chi^2$ ) test

Statistical significance was defined as p < 0.05

statistically significant ( $\chi^2 = 16.41$ ,  $p < 0.001$ ), and the trend persisted post-intervention ( $\chi^2 = 14.40$ ,  $p < 0.001$ ).

## Discussion

This RCT demonstrates that concurrently implementing Diet + RT significantly enhances self-reported physical activity levels, sleep quality, and fatigue outcomes in obese adults compared to diet alone. The consistency and strength of these improvements underscore the multifaceted benefits of incorporating structured physical training into obesity management programs.

Participants in the Diet + RT group experienced a substantial increase in physical activity levels and were more likely to reach vigorous activity thresholds by the 6th and 12th week of the intervention. This shift aligns with structured RT protocols recommended by ACSM, which have been shown to enhance self-efficacy and behavioral activation in sedentary populations [22, 23]. The supervised nature of the intervention likely contributed to improved motivation and adherence [39], supporting the feasibility of resistance-based programs in individuals with obesity. However, the use of a self-reported tool (IPAQ) may introduce bias, and the lack of objective physical activity measures (e.g., accelerometry) limits the interpretability of these findings. Notably, previous studies have yielded mixed results; for instance, Hintze et al. [40] found no significant change in physical activity behavior following a long-term resistance program in postmenopausal women, suggesting that factors such as age, baseline fitness, and hormonal status may influence intervention outcomes.

Improvements in sleep quality observed in the Diet + RT group are also in agreement with previous meta-analyses demonstrating that structured exercise interventions, including RT, lead to significant reductions in sleep disturbances among individuals with obesity [10]. Possible mechanisms include reductions in systemic inflammation, improvements in circadian rhythm regulation, and enhanced mood and anxiety control—all of which are influenced by physical activity. The limited improvements in the Diet group underscore the role of exercise in complementing nutritional strategies to optimize sleep health.

Although the Diet + RT group showed significant improvements in PSQI scores, their mean post-intervention score (13.08) remained above the clinical cut-off of 5, indicating persistent—though improved—poor sleep quality [27]. This finding suggests that, although sleep quality improved, disturbances persisted to some extent. Such partial improvement may reflect the relatively short duration of the intervention and highlights the need for longer-term or more intensive exercise protocols to achieve clinically normalized sleep outcomes in this population.

Fatigue severity, as measured by the FSS, showed a significant and clinically meaningful reduction in the Diet + RT group, with post-intervention scores falling below the clinical threshold of 5 (mean =  $4.04 \pm 0.40$ ). This transition from clinically significant to subclinical fatigue levels suggests that RT may effectively alleviate perceived fatigue in individuals with obesity. Proposed mechanisms include increased muscle mass, improved metabolic efficiency, and enhanced mitochondrial function, which collectively reduce the physical demands of daily activities [29]. Furthermore, the concurrent improvements in sleep quality observed in this group may have contributed to reduced daytime fatigue, underscoring the interconnected nature of sleep and energy regulation.

However, not all studies report similar benefits. For example, Hintze et al. [40] found no significant reduction in fatigue following a year-long RT program in overweight women, highlighting possible interindividual differences in responsiveness to exercise. These inconsistencies point to the importance of tailoring interventions based on individual characteristics and suggest that combining RT with other modalities—such as aerobic activity or behavioral strategies—may be necessary to optimize fatigue outcomes in certain populations.

Anthropometric improvements, particularly reductions in waist circumference, were also more pronounced in the Diet + RT group. This aligns with prior evidence showing that RT leads to preferential reductions in visceral fat and waist circumference, even in the absence of dramatic weight loss [22]. These changes carry significant clinical implications, given the association between abdominal obesity and increased cardiometabolic risk [34]. Nonetheless, the absence of significant BMI reduction in either group suggests that improvements in body composition may not always be reflected in overall weight changes, a finding echoed in other studies [41].

This study has several notable strengths. It was designed as a RCT and achieved full retention of participants over the 12-week period, which helps to reduce the risk of bias and supports the reliability of the findings. In addition, by comparing a Diet + RT with diet alone, the trial allowed for a clearer understanding of the specific contribution of RT. This design is also relevant to practice, as it reflects how lifestyle interventions are often implemented in real-world obesity management.

Despite the strengths of this RCT, several limitations should be acknowledged. First, the intervention duration was limited to 12 weeks, which may not have been sufficient to observe clinically normalized outcomes in certain domains, such as sleep quality. Prior findings indicate that RT may require longer durations to induce significant body composition changes, particularly in individuals with obesity [20]. Second, the study did not include a follow-up phase beyond the 12-week intervention

period. Therefore, the long-term sustainability of the observed improvements remains unknown. Future studies should incorporate extended follow-up assessments to determine whether intervention effects are maintained over time. Third, the current study employed a single-mode RT protocol based on free weights and machines. However, evidence suggests that the effects of RT may vary substantially depending on the modality used. For instance, resistance bands have been shown to be more effective in reducing body fat, whereas bodyweight exercises may lead to greater improvements in skeletal muscle mass [22]. Future studies should compare different resistance modalities within a similar framework to determine optimal exercise prescriptions for individuals with obesity. Fourth, although participants were asked to complete dietary logs and adherence was supported through follow-up, actual daily caloric intake was not objectively quantified or analyzed. As a result, the relationship between the prescribed energy deficit and observed weight loss could not be fully evaluated. Future research should incorporate validated dietary assessment tools and report energy intake data to better understand the impact of nutritional interventions. Fifth, although a bioimpedance scale was used for weight measurements, body composition data (e.g., fat mass and lean mass) were not extracted or analyzed. Therefore, we were unable to determine whether weight changes reflected fat loss, muscle gain, or both. Future studies should include body composition assessments to better evaluate the clinical significance of weight-related outcomes. Sixth, all inclusion and exclusion criteria—except for anthropometric measurements—were based solely on self-reported data and structured interviews. No clinical or laboratory assessments (e.g., blood pressure, lipid profile, or glucose levels) were performed prior to enrollment. This reliance on self-declaration may introduce potential bias or misclassification, particularly due to recall or social desirability bias, which are well-documented limitations of self-reported health data [42]. Future studies should consider incorporating objective clinical or laboratory measures to validate self-reported health information and improve diagnostic accuracy.

## Conclusion

This RCT demonstrated that integrating a structured RT program with calorie-restricted dietary intervention resulted in significantly greater improvements in self-reported physical activity levels, sleep quality, fatigue severity, body weight, and waist circumference compared to diet alone among individuals with obesity. Despite the modest sample size, the consistency and magnitude of these effects—particularly the transition from clinically significant to subclinical fatigue and the reduction in central adiposity—highlight the clinical relevance of

RT as a complementary strategy in obesity management. These findings reinforce the value of incorporating RT into multidisciplinary interventions targeting both physical and psychosocial outcomes. To strengthen the evidence base and inform clinical guidelines, future research should include larger, more diverse populations, longer intervention periods, and extended follow-up to assess the sustainability and generalizability of these benefits. Additionally, the potential additive or synergistic effects of combining RT with aerobic exercise—widely recommended in obesity guidelines—should be explored to further enhance intervention efficacy.

## Abbreviations

ACSM	American College of Sports Medicine
BMI	Body Mass Index
BMR	Basal Metabolic Rate
Diet + RT	Resistance Training Program Combined with Calorie-Restricted Dietary Intervention
FSS	Fatigue Severity Scale
IPAQ	Physical Activity Questionnaire
MET	Metabolic Equivalent of Task
PSQI	Pittsburgh Sleep Quality Index
RCT	Randomized Controlled Trial
RT	Resistance Training
WHO	World Health Organization

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## Author contributions

Conceptualization and Study Design: ALC, ÖŞ; Manuscript Writing and Draft Preparation: EES, BB, ÖŞ; Data Collection and Acquisition: ALC, BB; Data Analysis and Interpretation: ÖŞ, EES; Critical Revision and Review of the Manuscript: EES, BB, ÖŞ, ALC. All authors read and approved the final manuscript.

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## Data availability

Data sets generated during the current study are available from the corresponding author upon reasonable request.

## Declarations

### Ethics approval and consent to participate

All study procedures were conducted in line with the rules and principles of the Declaration of Helsinki and approved by the Üsküdar University Non-Interventional Research Ethics Committee (decision no:61351342/December 2022). Informed consent was obtained from all participants also, patients were verbally informed about the study before giving written informed consent.

### Consent for publication

Not applicable.

### Competing interests

The authors declare no competing interests.

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