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The effects of dietary and physical activity interventions on tinnitus symptoms: An RCT

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ABSTRACT

Objective: Subjective tinnitus is defined as the perception of irregular sound at different frequencies. Although the underlying cause of tinnitus is unclear, increased body weight is known to increase tinnitus symptoms. The present study aimed to determine the effects of dietary and physical activity interventions on tinnitus symptoms.
Methods: Sixty-three obese subjects with tinnitus aged 20 to 65 years were divided into diet + physical activity (P.A.) (n = 15), diet (n = 16), P.A. (n = 15), and control (n = 17) groups. Dietary records, anthropometric measurements, Tinnitus Handicap Inventory (THI), Beck Depression Inventory (BDI), Short-Form Health Survey (SF-36), and Visual Analogue Scale (VAS) of all individuals were recorded and compared at the baseline and at study completion.
Results: Body weight decreased in the diet + P.A. (-5.9 (3.5) kg), diet (-3.4 (0.9) kg), and P.A. (-2.0 (2.1) kg) groups compared to the baseline ($p < 0.05$). There was a more significant decrease in tinnitus frequency, tinnitus severity, and VAS scores in individuals with a weight loss of $\geq$ 5.0% than in those with < 5.0% ($p < 0.05$). A decrease of 1 kg/m^2 in BMI decreased the BDI score by 0.485 units and the THI score by 0.523 units. Step counts were increased in the diet + P.A. (3562.3±739.9) and P.A. (3797.1 ± 1801.1) groups compared to baseline ($p < 0.01$). Each increase of 1000 steps increased the SF-36 score by 1.592 units and decreased the THI score by 0.750 units ($p < 0.05$).
Conclusion: Dietary and physical activity interventions, alone or in combination, alleviated tinnitus symptoms and increased quality of life in individuals with tinnitus. Due to its contribution to obesity prevention and positive effects on tinnitus, organizing dietary and physical activity programs for obese individuals with tinnitus would improve these individuals' quality of life.

1. Introduction

Subjective tinnitus is defined as the perception of irregular sound at different frequencies without any external stimulus. It is an expressed symptom of a pathology in the auditory system, which has serious negative effects on quality of life [1]. Despite several hypotheses about the etiology of subjective tinnitus, no theory has been generally accepted. However, it is thought that various diseases may cause subjective tinnitus. Obesity is one of the diseases believed to cause subjective tinnitus [2,3].

Obesity, a disease with an ever-increasing prevalence, is defined as excessive fat accumulation in the body [4]. In

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recent years, the increase in the prevalence of subjective tinnitus in addition to obesity and the higher prevalence of subjective tinnitus in obese individuals corroborate the hypothesis that these two conditions are associated with each other [5,6].

Besides obesity, physical activity is also associated with tinnitus through its physiological and psychological effects [7]. A limited number of studies have shown that physically active individuals with tinnitus have lower tinnitus severity than sedentary individuals [7,8].

Based on the above-mentioned information, this study aimed to observe the efficacy of dietary and physical activity interventions on tinnitus symptoms.

2. Methods

This randomized controlled trial was conducted at the Ankara University Faculty of Medicine, Ear Noise Throat Department, Audiology and Speech Disorders Center between October 2019 and January 2021. Individuals who were diagnosed with subjective tinnitus and met the inclusion/exclusion criteria were included in the study.

2.1. Inclusion criteria

- Being between the ages of 20 and 65.
- Having a body mass index (BMI) above 30 kg/m^2.
- Being sedentary
- Being a subjective tinnitus patient diagnosed by a specialist for at least six months.
- Volunteer to participate in the study.
- Exclusion criteria
- Being on an ongoing dietary-physical activity program.
- Receiving vitamin-mineral supplements.
- Being pregnant or breastfeeding.
- Having any comorbid diseases such as hypertension, high blood pressure and hyperglycaemia.
- Having any middle ear pathology such as otosclerosis or otitis media.
- Having a history of neuropsychiatric disorders.

Eligible individuals were randomized based on their file numbers (via randomizer.org) and divided into diet + P.A. (n = 15), diet (n = 16), P.A. (n = 15), and control (n=17) groups (Fig. 1). After the individuals were informed, the study was suspended for three days to determine the mean step counts. Ethical approval for the research was obtained from Ankara University Ethics Committee (No: 151003-18). Ethical approval for the research was obtained from Ankara University Ethics Committee (No: 151003-18) and registered under clinicaltrials.gov (identifier no: NCT05265949).

2.2. Physical activity

Subjects were given a simple pedometer [OmronHJ-321®pedometer (Omron Medical Turkey)] and instructed to wear it as soon as they woke up the next day and not to take it off except for activities such as sleeping and taking a shower. For three consecutive days following the initial interview, all study subjects were called, and mean step counts were recorded. Individuals in the diet + P.A. and P.A. groups were called again to explain the importance of physical activity and were instructed to take an average of 10,000 steps per day for an active life. The subjects in the diet and control groups received no intervention except for step tracking. All subjects were called every two weeks on different days and the step counts were recorded for 12 weeks.

2.3. Dietary intervention

According to studies, an approximately 12-week period is sufficient for a clinically acceptable weight loss (≈5–10%) [9]. Therefore, subjects in the diet + P.A. and diet groups were included in a 12-week individualized dietary program to achieve sufficient weight loss. Following the recording of the first three-day step counts, the dietary program was initiated. Subjects were monitored by phone calls every two weeks to correct their wrong eating habits and maintain the diet. The dietary energy was calculated by the Schofield equation based on the age and gender of the individual [10]. The dietary program was arranged to consist of 10–20% proteins, 45–60% carbohydrates, and 20–35% fats. The 24-h dietary records of all subjects were collected at the beginning and end of the study, and the data were analyzed using the BeBIS program. The total amount of water that individuals should consume was calculated according to the World Health Organization (WHO) recommendation (total calories*1.0-1.5 ml) and the importance of reaching the targeted water consumption was explained to the individuals [11]. The body water ratio of individuals was measured at the beginning and end of the study with the Tanita BC 601 device (Tarti Medical, Istanbul, Turkey) and the difference was compared.

2.4. Anthropometric measurements

The subjects' body weight, fat percentage, and body water ratio measurements were recorded using the Tanita BC 601 analyzer in the morning on an empty stomach and without shoes. Waist circumference was measured using an inflexible measuring tape [12]. All measurements were repeated at the end of the study.

2.5. Tinnitus tests and scales

Tinnitus frequency and tinnitus severity

Tinnitus frequency (starting from 1000 Hz) was determined using the AC40 (Interacoustics, Assens, Denmark) audiometer by instructing the subject to match the frequency of the given signal with their tinnitus. Then, the subject was asked to match the tinnitus severity in 1 dB increments, starting from a level lower than the hearing threshold. The procedure was completed when the intensity of the given sound was equal to the tinnitus severity [13].

Tinnitus handicap inventory (THI)

The THI consists of 25 items rated on a scale from 0 to 4 points. A higher score indicates a greater handicap from

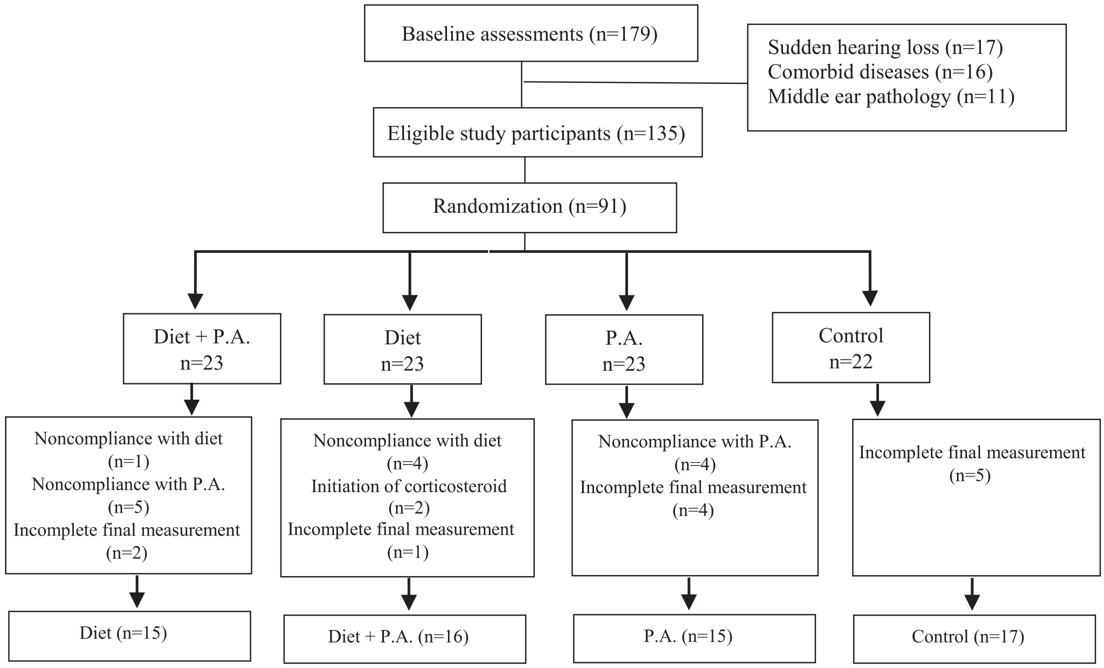

Fig. 1. Flowchart of the study.

tinnitus. The validated Turkish version of the THI was used in this study [14].

Beck depression inventory (BDI)

The BDI consists of 21 items in total that are rated on a scale from 0 to 3 points. A higher total score indicates a greater level of depression. The validated Turkish version of the BDI was used in this study [15].

Short form 36 (SF-36)

The SF- 36 consists of 36 items assessing general health status that are rated on a scale from 0 to 100 points. A higher score represents better health status and a lower score indicates impairment in health. The validated Turkish version of the SF-36 was used in this study [16].

Visual analogue scale (VAS)

On the visual analog scale, the subjects were asked to mark the tinnitus severity and the level of annoyance due to tinnitus on two separate 10-cm lines. As the measurement result advances from 0 to 10, the tinnitus severity and annoyance increase.

Statistical analysis

The sample size was calculated using the G-power program and the study was completed with a 95% power ($\alpha = 0.05$ and effect size = 0.90). The results were assessed using the SPSS (Statistical Package for Social Science, version 22.0; IBM, US) software. Number (n) and percentage (%) were used for categorical data and mean ± standard deviation or median (interquartile range-IQR) values for descriptive data. The Mann-Whitney U test was used to compare the two groups that were not normally distributed. For within-group variances, the Paired t-test was used when the data were normally distributed and the Wilcoxon Rank test when the data were not normally distributed. For between-group variances (number of groups > 2), in turn, the One-way ANOVA and the Kruskal-Wallis analysis were used when the data were normally and not normally distributed, respectively. The post-hoc test results were expressed as letters in groups with differences. The direction and degree of this relationship were examined by multiple linear regression analysis for normally distributed data and interpreted by including age and sex in the model. For all analyses, the results were analyzed based on a 95% confidence interval and a $p < 0.05$ significance level.

3. Results

A total of 63 subjects participated in the study and more than half of the subjects in each group were women. The mean age was 41.7±9.5 years in the diet + P.A. group, 46.0 ± 11.3 years in the diet group, 47.6 ± 11.0 years in the P.A. group, and 43.1±8.1 years in the control group. The majority of the subjects were high school graduates and non-smokers. In total, 13.3% of the diet + P.A. group, 18.7% of the diet group, 20.0% of the P.A. group and 17.6% of the control group had hearing loss. Dizziness was recorded only in the diet (12.5%) and P.A. (6.6%) groups. The time from the onset of tinnitus was 4.6 ± 0.6 years in the diet + P.A. group, 4.3 ± 0.5 years in the diet group, 4.2 ± 0.3 years in the P.A. group, and 4.1 ± 0.8 years in the control group. In terms of tinnitus localization, the most reported site was unilateral (left) in all groups (>50.0%). There was a high incidence of ringing among the subjects in all groups as the tinnitus sound characteristic (Table 1).

Table 1. General characteristics of participants.

	Diet + P.A.	Diet	P.A.	Control
Gender (female %)	53.3	75.0	66.6	76.5
Age (years)	41.7±9.5	46.0±11.3	47.6±11.0	43.1±8.1
Nonsmoker (%)	84.7	87.5	86.7	94.1
Education (%)				
Primary school	20.2	25.0	13.3	15.4
Secondary-high school	53.3	54.3	60.0	53.9
University +	26.5	20.7	27.7	30.7
Hearing loss (%)	13.3	18.7	20.0	17.6
Dizziness (%)	-	12.5	6.6	-
Tinnitus duration (years)	4.6±0.6	4.3±0.5	4.2±0.3	4.1±0.8
Tinnitus localization (%)				
Unilateral (right)	13.3	25.0	26.6	29.4
Unilateral (left)	66.7	56.3	53.4	58.9
Bilateral	13.3	18.7	20.0	11.7
Tinnitus sound type (%)				
Ringing	66.7	81.2	66.7	64.7
Whistling	13.3	12.5	13.3	17.6
Hissing	13.3	-	13.3	5.8

Data were presented as mean ± standard deviation or percentage.

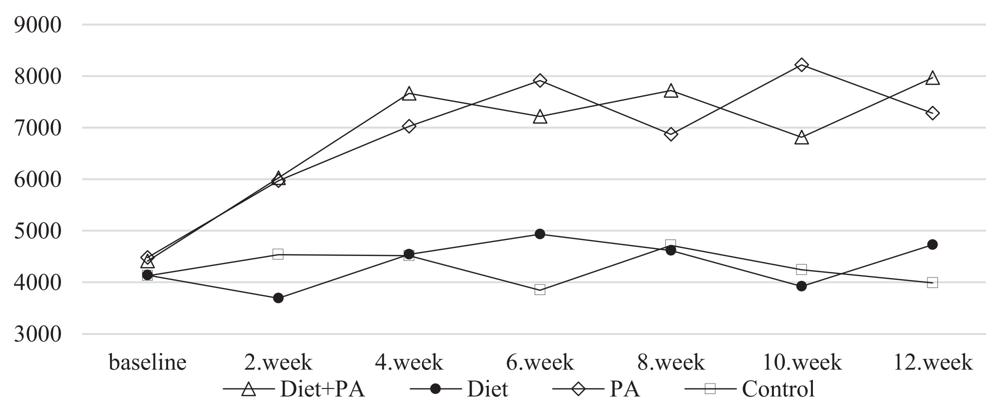

Fig. 2. Changes in the number of steps by groups.

By week 12, the body weight was significantly decreased in the diet + P.A. (-5.9 (3.5) kg, $p < 0.01$), diet (-3.4 (0.9) kg, $p < 0.01$), and P.A. groups (-2.0 (2.1) kg, $p < 0.05$). BMI, waist circumference, neck circumference, and total body fat were also decreased in the intervention groups, with the most significant reductions in the diet + P.A. group ($p < 0.05$). Body water percentage increased in the diet + P.A. and diet groups ($p < 0.05$) (Table 2). When step counts were evaluated, a significant increase was observed in the diet + P.A. (3562.3±739.9 $p<0.01$) and P.A. groups (3797.1±1801.1 $p<0.01$) compared to baseline (Fig. 2).

Considering the change in tinnitus frequency, there was a significant decrease compared to baseline in the diet + P.A. (-2.1 ± 0.1 Hz), diet (-1.4 ± 0.6 Hz), P.A. (-1.8 ± 0.5 Hz), and control groups (-1.4 ± 0.4 Hz) ($p < 0.05$). The tinnitus severity, VAS (annoyance), THI, and BDI scores also decreased in all groups compared to baseline, with the most significant changes in the diet + P.A. group ($p < 0.05$). The VAS (severity) score, on the other hand, decreased in all groups except for the control group compared to baseline. The SF-36 score increased in the diet + P.A., diet, and P.A. groups compared to baseline ($p < 0.05$) (Table 3).

There was a more significant change in tinnitus frequency (-2.0 (1.0)), tinnitus severity (-14.0 (13.0)), VAS severity (-2.0 (1.1)), VAS annoyance (-2.5 (1.8)), SF-36 (10.0 (6.0)) and BDI (-3.5 (2.0)) scores in subjects with a weight loss of ≥ 5.0% than in those with < 5.0% ($p < 0.05$) (Table 4).

The changes in VAS scores were positively correlated with the changes in BMI, waist circumference, total body fat, and neck circumference and negatively correlated with the change in body water percentage. The step count was negatively correlated with the VAS severity score ($p < 0.05$) (Table 5).

A decrease of 1 kg/m^2 in BMI decreased the BDI score by 0.485 (Cl: 0.143–0.827, $p = 0.006$) units and the THI score by 0.523 (Cl: 0.221–0.956, $p = 0.015$) units. Each 1000-step increase increased the SF-36 score by 1.592 (CI: -3.532–1.413, $p = 0.035$) units and decreased the THI score by 0.750 (Cl: 0.221–0.956, $p = 0.001$) units (Fig. 3b).

The total energy intake decreased significantly compared to baseline in the diet + P.A. (-278.3 ± 117.8 kcal) and diet groups (-205.7 ± 177.2 kcal). The carbohydrate, protein, SFA and PUFA intakes also decreased in the diet + P.A. and diet groups ($p < 0.05$). The fat intake, on the other hand,

Table 2. Changes in anthropometric measurements and step counts.

	Diet+ P.A. (n=15)		Diet (n=16)		P.A. (n=15)		Control (n=17)		Intergroup p value
	Baseline	Change (Δ)	Baseline	Change (Δ)	Baseline	Change (Δ)	Baseline	Change(Δ)	
Body weight (kg)	89.3 (33.2)	-5.9 (3.5)$^{**}_{a}$	80.4 (12.1)	-3.4 (0.9)$^{**}_{a.b}$	89.6 (32.4)	-2.0 (2.1)$^{*}_{b}$	86.9 (19.8)	0.3 (0.6)$_{c}$	0.001
BMI (kg/m^2)	33.5±2.8	-2.3±0.9$^{**}_{a}$	32.8±2.4	-1.49±0.9$^{**}_{a}$	33.1±4.5	-1.1±0.5*	33.0±2.4	-0.1±0.7$_{b}$	0.001
WC (cm)	111.0 (17.0)	-5.0 (2.0)$^{**}_{a}$	106.0 (20.5)	-3.0 (-0.9)$^{*}_{a}$	101.0 (23.5)	-2.0 (1.0)*	106.0 (17.5)	0.0 (0.0)$_{b}$	0.001
Neck circumference (cm)	39.9±2.9	-1.5±0.6$^{**}_{a}$	38.5±4.3	-1.0±0.9$^{**}_{a.b}$	39.6±3.7	-0.8±0.4$^{*}_{b}$	41.7±3.8	0.0±0.4$_{c}$	0.001
Total body fat (%)	35.6±7.4	-1.5±2.1*	38.2±6.0	-1.1±2.0*	34.2±5.5	-1.4±.5*	36.9±7.4	-0.1±1.1	0.026
Body water ratio (%)	46.4±4.9	2.5±1.7**	45.0±3.7	1.4±2.2*	45.3±5.3	0.5±1.1	49.3±3.4	-0.8±0.7	0.076
Step count	4409.6±504.9	3562.3±739.9$^{**}_{a}$	4134.3±1390.1	593.7±1629.9$_{b}$	4480.7±596.7	3797.1±1801.1$^{**}_{a}$	4126.4±1162.0	-141.1±1477.9$_{b}$	0.001

Data were presented as mean±standard deviation or median (IQR). BMI: Body mass index; WC: Waist circumference. Within-group changes were presented as *p< 0.05 and **p< 0.01. Intergroup post-hoc changes were indicated by the letters (a,b,c). Different letters on the same line show statistical significance.

Table 3. Changes in tinnitus characteristics and scale scores.

	Diet + P.A. (n=15)		Diet (n=16)		P.A. (n=15)		Control (n=17)		Intergroup p value
	Baseline	Change (Δ)	Baseline	Change (Δ)	Baseline	Change (Δ)	Baseline	Change (Δ)	
Tinnitus frequency (Hz)	6.1±1.9	-2.1±0.1$^{**}_{a}$	6.2±1.8	-1.4±0.6$^{*}_{b}$	8.8±3.1	-1.8±0.5$^{*}_{b}$	6.8±2.5	-1.1±0.4$^{*}_{c}$	0.001
Tinnitus severity (dB)	43.0±13.8	-16.2±11.9$^{**}_{a}$	42.1±12.1	-12.5±11.2$^{*}_{b}$	51.3±18.5	-12.6±12.5$^{*}_{b}$	55.0±21.6	-8.2±7.2$^{*}_{c}$	0.001
VAS (severity)	5.6±1.7	-2.5±1.1$^{**}_{a}$	6.8±1.5	-1.9±0.6$^{*}_{b}$	5.7±1.1	-1.9±0.9$^{*}_{b}$	6.5±1.7	-0.9±0.7$_{c}$	0.001
VAS (annoyance)	6.1±2.2	-2.7±1.0$^{**}_{a}$	6.3±1.5	-2.7±.7$^{**}_{a}$	5.6±1.1	-2.1±.8$^{**}_{b}$	6.6±1.7	-1.6±0.9$^{*}_{c}$	0.001
SF-36	55.0±13.9	12.3±5.6$^{**}_{a}$	51.3±13.4	8.8±3.4$^{*}_{b}$	52.4±12.7	8.5±4.7$^{*}_{b}$	53.7±13.1	4.1±4.8$_{c}$	0.001
THI	34.8±15.9	-13.3±2.6$^{**}_{b}$	43.7±19.8	-9.1±4.5$^{*}_{b}$	37.8±11.9	-8.6±3.8$^{*}_{b}$	35.1±16.2	-5.1±0.9$^{*}_{b}$	0.01
BDI	10.6 ±4.45	-4.5±2.4$^{**}_{a}$	11.9±3.4	-3.5±1.0$^{**}_{b}$	8.5±5.5	-3.3±0.8$^{**}_{b}$	9.8±5.4	-2.3±1.7$^{*}_{c}$	0.001

VAS: Visual analog scale; SF-36: Quality of life questionnaire; BDI: Beck depression inventory; THI: Tinnitus handicap inventory. Data were presented as mean±standard deviation. Within-group changes were presented as *p< 0.05 and **p< 0.01. Intergroup post-hoc changes were indicated by the letters (a,b,c). Different letters on the same line show statistical significance.

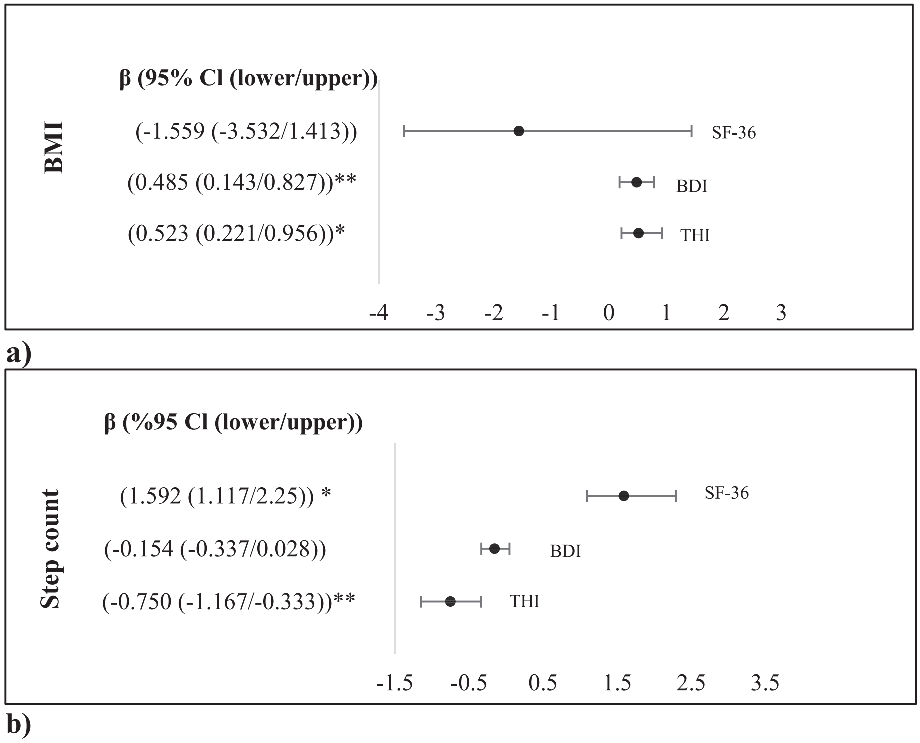

Fig. 3. a) The effect of the change in BMI on the changes in the SF-36, BDI, and THI scores b) The effect of the change in step counts on the changes in the SF-36, BDI, and THI scores. Adjusted for age and sex by multiple linear regression analysis. Step count changes were calculated over 1000 unit. SF-36: Quality of life questionnaire; BDI: Beck depression inventory; THI: Tinnitus handicap inventory. *$p < 0.05$. **$p < 0.01$.

Table 4. Changes in tinnitus characteristics and scale scores according to the degree of weight loss.

	<5% Weight loss (n=39)	≥5% Weight loss (n=24)	p
Tinnitus frequency (Hz)	-1.0 (1.0)	-2.0 (1.0)	0.001
Tinnitus severity (dB)	-9.0 (11.5)	-14.0 (13.0)	0.001
VAS (severity)	-1.0 (1.0)	-2.0 (1.1)	0.001
VAS (annoyance)	-2.0 (1.0)	-2.5 (1.8)	0.003
THI	-9.0 (8.0)	-10.0 (6.0)	0.287
SF-36	7.0 (5.0)	10.0 (6.0)	0.026
BDI	-3.0 (1.5)	-3.5 (2.0)	0.038

VAS: Visual analog scale; SF-36: Quality of life questionnaire; BDI: Beck depression inventory; THI: Tinnitus handicap inventory.Data were presented as median (IQR).

decreased in the diet + P.A. and diet groups but increased in the P.A. group ($p < 0.05$) (Table 6).

4. Discussion

Obesity, which can affect all body organs and systems, has been frequently associated with tinnitus in recent years. Among the reasons is that the increased free fatty acids in obesity changes the pH balance of the inner ear and causes cochlear vascular injury [17]. Another reason is that the prevalence of tinnitus in obese individuals is higher than in those with normal weight [5]. The study by Gallus et al. found the prevalence of tinnitus in obese individuals to be 2.14 times higher than in those with normal weight [6]. In another study conducted with 14,178 individuals in the USA, it was found that the gradual increase in BMI increased the prevalence of tinnitus [17]. Accordingly, a reduction in body weight is expected to reduce tinnitus symptoms. Because, after weight loss in obese individuals, the oxidative response and free radicals in the circulatory system decrease [18]. Decreased oxidative response is also known to reduce tinnitus symptoms [19]. In the present study, BMI decreased significantly in the diet + P.A. (-2.3 ± 0.9 kg/m^2), diet (-1.49 ± 0.9

Table 5. Correlation between changes in VAS scores and anthropometric measurements.

	VAS (severity)		VAS (annoyance)	
	r	p	r	p
BMI (kg/m^2)	0.600	0.001	0.506	0.001
WC	0.271	0.034	0.289	0.024
Total body fat (%)	0.557	0.001	0.459	0.001
Neck circumference (cm)	0.476	0.001	0.411	0.001
Body water ratio (%)	-0.369	0.003	-0.393	0.002
Step count	-0.315	0.013	-0.143	0.271

BMI: Body mass index; WC: Waist circumference.

Table 6. Changes in total energy and macro-nutrient intakes.

	Diet + P.A. (n=15)		Diet (n=16)		P.A. (n=15)		Control (n=17)		Intergroup p value
	Baseline	Change (Δ)	Baseline	Change (Δ)	Baseline	Change (Δ)	Baseline	Change (Δ)	
Total energy (kcal)	1870.9±123.8	$-278.3\pm117.8^{**}_{a}$	1833.4±158.3	$-205.7\pm177.2^{**}_{a}$	1773.9±151.9	$70.0\pm23.3_{b}$	1952.5±95.9	$-74.6\pm19.9_{c}$	0.001
Carbohydrate (g)	204.5 (63.5)	$-25.7\ (22.2)^{**}_{a}$	180.5 (58.2)	$-21.3\ (19.7)^{**}_{a}$	164.9 (52.6)	$9.1\ (5.2)_{b}$	249.3 (29.0)	$-7.6\ (7.5)_{b}$	0.001
Protein (g)	58.4±13.3	$-4.3\pm10.8^{*}_{a}$	64.2±6.3	-5.9±7.7b*	57.0±7.0	$3.9\pm7.5_{c}$	62.9±11.4	$-3.2\pm5.6_{a}$	0.020
Fat (g)	83.5 (14.3)	$-14.0\ (22.7)^{**}_{a}$	91.4 (22.8)	$-12.1\ (16.3)^{**}_{a}$	80.7 (23.5)	$7.2\ (9.5)^{*}_{c}$	86.9 (11.2)	$-2.0\ (6.3)_{b}$	0.001
SFA (g)	27.1 (7.1)	$-5.0\ (7.5)^{*}_{a}$	28.2 (15.0)	$-2.3\ (6.6)_{a}$	24.7 (11.7)	$2.1\ (8.2)_{b}$	29.1 (5.4)	$-1.2\ (1.6)_{b}$	0.001
MUFA (g)	26.9 (5.7)	1.3 (7.5)	26.8 (16.4)	-1.4 (9.9)	23.3 (15.9)	2.9 (5.4)	27.2 (5.0)	2.0 (2.5)	0.190
PUFA (g)	24.5 (3.4)	$-10.6\ (6.0)^{**}_{a}$	30.1 (8.7)	$-8.9\ (10.6)^{**}_{a}$	$23.1\ (7.9)_{b}$	2.1 (4.9)	24.7 (7.0)	$-2.0\ (3.9)_{b}$	0.009

SFA: Saturated fatty acids; MUFA: Mono-unsaturated fatty acids; PUFA: Poly-unsaturated fatty acids. Data were presented as mean±standard deviation or median (IQR). Within-group changes were presented as $^{*}p < 0.05$ and $^{**}p < 0.01$. Intergroup post-hoc changes were indicated by the letters (a,b,c). Different letters on the same line show statistical significance.

kg/m^2), and P.A. (-1.1 ± 0.5 kg/m^2) groups at the end of the 12 weeks ($p < 0.05$) (Table 2). The tinnitus frequency, tinnitus severity, VAS, and THI scores were also significantly lower in the diet + P.A., diet, and P.A. groups compared to the control group ($p < 0.05$) (Table 3). The comparison of results according to the rate of reduction in body weight revealed a greater decrease in tinnitus frequency, tinnitus severity, and VAS scores in subjects with a weight loss of ≥ 5.0% than in those with < 5.0% ($p < 0.05$) (Table 4).

Although it is used frequently due to its ease of measurement, BMI does not reflect body fat distribution [20]. Body fat percentage, which better reflects fat distribution, has recently been associated with tinnitus [21]. A study with 171,722 people using UK biobank data found that increased body fat was associated with the presence of tinnitus ($p < 0.01$) [20]. In the present study, the reductions in WC and total body fat were positively correlated with a decrease in VAS severity ($r = 0.271$, $p = 0.034$; $r = 0.5557$, $p=0.001$) and VAS annoyance scores ($r = 0.289$, $p = 0.024$; $r = 0.459$, $p = 0.001$, respectively) (Table 5).

It is thought that in addition to body fat percentage, increased neck circumference may cause tinnitus due to mechanical pressure and inflammatory response. Because locally increased adipose tissue around the neck could increase tinnitus by applying pressure to the veins [22]. In addition, the increase in lipid peroxidation and free fatty acids in the circulatory system due to the increase in adipose tissue also triggers tinnitus by causing inner ear damage [23]. However, there are quite limited studies on the subject in the literature [24–26]. The study by Martines et al. identified a significantly higher rate of subjects with high neck circumference (43.48%) among those with tinnitus than in the control group (14.86%) ($p < 0.01$) (26). In the present study, the tinnitus severity and tinnitus frequency also decreased after the reduction in neck circumference in the diet + P.A., diet, and P.A. groups. A reduction in neck circumference ($r = 0.476$, $p = 0.001$) was positively correlated with a decrease in VAS annoyance ($r = 0.411$, $p=0.001$) score (Table 5).

Decreased body water percentage increases tinnitus symptoms. Therefore, it is recommended that water consumption should be increased in individuals with tinnitus [27]. Lee et al. associated decreased water consumption with increased tinnitus symptoms ($p < 0.05$) [28]. In the present study, the body water percentage of the subjects increased compared to baseline in the diet + P.A. (2.5 ± 1.7%) and diet groups (1.4 ± 2.2%). The change in body water percentage was negatively correlated with the change in tinnitus severity and VAS scores ($p < 0.05$) (Table 5).

Psychiatric disorders are among the most common comorbidities that reduce the quality of life in individuals with tinnitus [29]. Physical activity is often recommended for individuals with tinnitus because of its positive impacts on emotional state and tinnitus [30]. Studies have shown that individuals with tinnitus have lower levels of physical activity and higher rates of anxiety and depression than those without tinnitus [31–33]. In the present study, the step counts of the subjects increased compared to baseline in the diet + P.A. (3562.3 ± 739.9) and P.A. (3797.1 ± 1801.1) groups ($p < 0.01$) (Fig. 2). Each 1000-step increase increased the SF-36 score by 1.592 units and decreased the THI score by 0.750 units ($p < 0.05$). A decrease of 1 kg/m^2 in BMI decreased the BDI score by 0.485 units and the THI score by 0.523 units (Fig. 3a). The changes in the SF-36 and BDI scores were more significant in subjects with a weight loss of ≥ 5.0% than in those with < 5.0% ($p<0.05$) (Table 4). This is probably because, in addition to tinnitus, obesity is also highly associated with quality of life, emotional state, and depression [34]. Therefore, as a result of the increase in the degree of weight loss (>5.0%), the change in SF-36 and BDI scores was found to be higher than that of THI.

High blood glucose and hyperlipidemia may cause atrophy in the vascular system, resulting in tinnitus or perception of a louder sound heard in tinnitus [35]. Studies have shown that a diet rich in carbohydrate and fat increases the risk and symptoms of tinnitus [36,37]. In the present study, total carbohydrate and fat intakes of the subjects significantly decreased compared to baseline in the diet + P.A. and diet groups ($p < 0.01$) (Table 6). In parallel with this finding, the tinnitus symptoms of the subjects also decreased ($p < 0.05$) (Table 3).

This study has some limitations. The data could not be supported by blood results. In addition, mostly first and second-degree obese individuals were included in the study. This is an inevitable outcome as the presence of comorbidities increases with increasing obesity degree and individuals with comorbidities were not included in the study. Despite these limitations, the detailed observation of the efficacy of dietary and

P.A. interventions in each group separately and the support of the findings with anthropometric measurements enhanced the strength of the research.

In conclusion, dietary and physical activity interventions alleviated tinnitus symptoms and increased quality of life in individuals with tinnitus. Due to its contribution to obesity prevention and protective effects on tinnitus, it is important to organize appropriate dietary and physical activity programs for obese individuals with tinnitus. It is of great importance to refer obese individuals with tinnitus to diet clinics for effective weight loss.

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Declaration of Competing Interest

The authors declare that they have no conflicts of interest.

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