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ORIGINAL RESEARCH

Effect of 12 weeks of zumba combined with halotherapy on body composition, respiratory, and cardiorespiratory parameters in sedentary older adults

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Abstract

This randomized controlled trial aimed to investigate the effects of a 12-week Zumba fitness program combined with halotherapy on body composition, respiratory function, and cardiorespiratory fitness in sedentary older adults, compared with Zumba training alone. Twenty sedentary participants were randomly assigned to either a Zumba + Halotherapy group (Group A, n = 10) or a Zumba-only group (Group B, n = 10). Both groups completed supervised Zumba sessions four times per week for 12 weeks, while Group A additionally received 20 minutes of halotherapy after each session. Body composition (body weight, BMI, body fat percentage), respiratory parameters (maximal inspiratory and expiratory pressure [MIP, MEP], forced vital capacity [FVC], forced expiratory volume in 1 s [FEV_1], peak expiratory flow [PEF], FEV_1/FVC ratio, maximal voluntary ventilation [MVV]), and maximal oxygen uptake (VO_2max) were assessed pre- and post-intervention. Data were analyzed using two-way repeated-measures ANOVA (group × time), with effect sizes reported as partial eta-squared (ηp^2). Significant group × time interactions were observed for body weight, BMI, and body fat percentage, indicating greater improvements in Group A. Regarding respiratory and performance outcomes, significant interactions favored the Zumba + Halotherapy group for MIP, FEV_1, PEF, and VO_2max ($p < 0.05$). No significant group × time interactions were found for FVC, FEV_1/FVC ratio, or MVV ($p > 0.05$). Effect size analyses demonstrated medium-to-large and large effects, particularly for respiratory muscle strength and aerobic capacity. Incorporating halotherapy into a structured Zumba fitness program yields superior improvements in body composition, respiratory muscle strength, and cardiorespiratory fitness compared with Zumba exercise alone. These findings suggest that halotherapy-enhanced aerobic training represents a promising, non-pharmacological intervention for improving physical and respiratory health in sedentary older adults.

Introduction

Sedentary behavior and insufficient physical activity are important risk factors for obesity, cardiovascular disease, impaired physical function, and respiratory dysfunction (Fan et al., 2013). Regular physical activity is therefore essential for maintaining functional capacity and cardiorespiratory health across adulthood, particularly as age-related declines in aerobic capacity and respiratory muscle function become more evident. Dance-based exercise represents an accessible and engaging form of physical activity with physical, psychological, and social benefits (Duberg et al., 2013; Kattenstroth et al., 2013). Among these modalities, Zumba Fitness is a rhythmic, Latin-inspired aerobic exercise program that has been

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associated with improvements in cardiorespiratory fitness, body composition, muscular endurance, and VO_2max (Barene et al., 2014; Barranco-Ruiz & Villa-González, 2020). Evidence from different populations, including women, young adults, and working or physically inactive individuals, further suggests that Zumba may support exercise adherence and psychological well-being through its enjoyable and socially interactive characteristics (Vendramin et al., 2016; Pekel et al., 2020; Donath et al., 2014; Notarnicola et al., 2015; Delextrat et al., 2016; Pawar, 2021; Guerendiain et al., 2019). However, these findings cannot necessarily be generalized to sedentary adults aged 50–60 years, who may have lower baseline fitness and progressive reductions in aerobic capacity, respiratory muscle strength, and pulmonary elasticity.

Halotherapy is a complementary, non-pharmacological intervention involving exposure to micronized dry salt aerosols (Lazarescu et al., 2014). Proposed effects include modulation of airway conditions, mucociliary clearance, and respiratory function through the properties of aerosolized sodium chloride (Munteanu, 2017; Achkar et al., 2015; Vladeva, 2015; Bar-Yoseph et al., 2016; Hoffman, 2021; Kwiatkowska et al., 2021; Barber et al., 2022). Previous studies have reported improvements in pulmonary function parameters, including FEV_1, FVC, and PEF, particularly in populations with respiratory disorders (Vladeva, 2015; Bar-Yoseph et al., 2016; Achkar et al., 2022; Barber et al., 2022). Emerging evidence has also suggested potential effects on respiratory muscle strength, exercise endurance, and recovery in physically inactive populations (Munteanu, 2017; Crisan-Dabija et al., 2021; Hoffman, 2021; Kwiatkowska et al., 2021), while related studies have explored its potential application alongside exercise-based interventions (Barranco-Ruiz et al., 2020; Oleksa et al., 2022).

The rationale for combining Zumba and halotherapy is based on their potentially complementary physiological targets rather than an established synergistic mechanism. Zumba provides a structured aerobic stimulus that primarily challenges cardiorespiratory fitness, muscular endurance, and body composition, whereas halotherapy may influence respiratory function. Exercise training can itself improve respiratory muscle function and cardiorespiratory performance (Kim et al., 2019), while previous investigations have reported potential respiratory effects associated with halotherapy-related interventions (Antonovici et al., 2020; Antonovici et al., 2023). Thus, whether the addition of halotherapy provides benefits beyond those achieved through Zumba exercise alone remains an empirical question. This question may be particularly relevant for sedentary adults aged 50–60 years, in whom reduced habitual physical activity may contribute to lower exercise tolerance and declining respiratory and aerobic function.

Despite evidence supporting Zumba and halotherapy as independent interventions, the effects of their combination in sedentary adults aged 50–60 years remain insufficiently investigated. Therefore, this randomized controlled trial examined whether adding halotherapy to a 12-week Zumba Fitness program would result in greater improvements in body composition, respiratory function, and cardiorespiratory fitness than Zumba exercise alone. The outcomes included body weight, body mass index, body fat percentage, maximal inspiratory and expiratory pressure (MIP and MEP), forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), peak expiratory flow (PEF), FEV_1/FVC, maximal voluntary ventilation (MVV), and maximal oxygen uptake (VO_2max). We hypothesized that the combined intervention would produce greater improvements in these outcomes than Zumba exercise alone.

Methods

Study Design and Participants

A total of 20 sedentary older adult volunteers (56.5 ± 2.93 years) participated in this study. Participants were selected from individuals who had not engaged in any regular physical activity or exercise programs for the past six months. This criterion was essential to assess the impact of a sedentary lifestyle on the study's outcomes. Their baseline physical activity levels were characterized by the absence of regular exercise and a predominantly sedentary lifestyle, including office work or activities involving prolonged sitting. Participants' dietary habits generally reflected a Western dietary pattern, typically high in calories, low in nutritional value, and rich in processed foods. However, no specific dietary control was imposed, as the primary objective was to observe the effects of physical activity and halotherapy. It is important to note that participants' dietary patterns may have had potential implications for overall health, but these were not the focus of the current study. Participants' health

conditions were evaluated through a comprehensive pre-screening process. Eligible individuals were free from physical or cardiovascular conditions, including lower back pain, musculoskeletal disorders, or cardiovascular diseases. All participants were physically healthy and had no history of chronic illnesses. Furthermore, no changes in participants' health status occurred during the study.

For the study, the sample size was calculated in G Power 3.1.9.2 with an effect size of 0.80 and $\alpha = 0.05$. The sample size calculated was 8 participants per group, which is sufficient to compare two groups: GA (Zumba + Halotherapy) and GB (Zumba only). The effect size of 0.80 used for sample size estimation was based on expected changes in VO_2max, which has been reported to exhibit large intervention effects in exercise-based studies involving sedentary adults (Schaun et al., 2022). The total sample size was 20, with 10 subjects in each group. Initially, 30 participants were included in the study; however, 20 participants were ultimately included in the final analysis due to a 10 dropout rate. Participant loss occurred for various reasons, including personal issues, health problems, and absence from the study. The dropout rate was carefully considered to minimize its impact on the statistical analysis, and the final sample size remained adequate for comparing GA and GB groups. It is important to note that although participants from both genders were included in the study, the sample size calculation was not designed to compare subgroups based on gender (e.g., GA male, GA female, GB male, GB female). This is acknowledged as a limitation of the study. Future research should consider larger sample sizes that allow for gender-based subgroup comparisons to better understand potential gender differences in response to the interventions.

This study is a randomized clinical trial (RCT), designed to evaluate the effects of Zumba exercise combined with halotherapy on various physical and respiratory parameters in sedentary individuals. The study utilized a block randomization method, stratified by gender, to assign participants to one of two study groups: Group A (Zumba + Halotherapy) and Group B (Zumba only). Participants were randomly allocated to their respective groups using a computer-generated random sequence to minimize bias. The randomization procedure was conducted by a researcher not involved in recruitment or assessment to ensure allocation concealment and reduce selection bias. The study adheres to the principles of randomized clinical trial methodology, with baseline and post-intervention assessments to measure changes in body composition, respiratory parameters, and cardiovascular fitness.

Experimental Design

Eligible participants who met all inclusion criteria and provided written informed consent were enrolled by the study researcher responsible for participant recruitment. Following completion of baseline assessments, participants were allocated to either the Zumba + Halotherapy group (n = 10; 56.3 ± 3.3 years, 175.19 ± 6.24 cm) or the Zumba-only group (n = 10; 55.7 ± 2.31 years, 173.09 ± 4.55 cm) using computer-generated block randomization stratified by sex. Both groups participated in 30-minute Zumba fitness sessions four days per week for 12 weeks. However, Zumba + Halotherapy group received a 20-minute halotherapy session immediately following their Zumba fitness exercise sessions. The allocation sequence was generated in advance by a researcher who was not involved in participant recruitment or outcome assessment. [The block size was fixed at 10]. To maintain allocation concealment, individual assignments were placed in sequentially numbered, opaque, sealed envelopes prepared before participant allocation. After baseline assessments had been completed, the researcher responsible for allocation opened the next envelope and assigned the participant to the corresponding intervention group. Thus, the allocation sequence was inaccessible to the researcher responsible for enrollment and baseline assessment until the participant had completed the baseline evaluation. The randomization and allocation procedures were designed to minimize selection bias and maintain comparable group allocation. The same researcher who generated the allocation sequence did not participate in participant recruitment or outcome assessment. Measurements of body composition (body weight, body mass index, body fat percentage), respiratory parameters (MIP, MEP, FVC, FEV1, PEF, FEV1/FVC%, MVV), and VO2max were conducted for both groups before and after the intervention (on the first day of the first week and the last day of the twelfth week, respectively). All physiological and performance assessments (including VO_2max, MIP, MEP, and spirometric measurements) were conducted by the same experienced assessor, who was blinded to group allocation throughout the pre- and post-intervention testing sessions. The primary outcome

of this exploratory randomized controlled trial was the change in maximal oxygen uptake (VO_2max) following the 12-week intervention. All other body composition and respiratory parameters were considered secondary outcomes. All measurements were carried out under identical environmental conditions (temperature 22–24°C, relative humidity 45%–55%) and supervised by the same research team to ensure consistency. The experimental flow is presented in Figure 1.

Halochamber (Saline Aerosol) Procedure

Respirable particles account for the majority (approximately 80%) of the aerosol environment dispersed in the air, with this fraction consisting of particles measuring between 1 and 5 μm in diameter. This particle size range allows the aerosol to effectively reach all sections of the respiratory tract. During the dry aerosol generation process, the intense mechanical treatment applied to salt crystals increases the surface energy of the particles and imparts a negative electric charge to them. These physicochemical properties of dry salt aerosol form the basis of halotherapy's therapeutic mechanism, which is characterized by a multi-component therapeutic effect at extremely low doses. In the treatment room, the concentration of fine sodium chloride aerosol is maintained between 1 and 10 mg/m³, classified into different therapeutic modes: Mode 1: 1.0 mg/m³; Mode 2: 1.0-3.0 mg/m³; Mode 3: 3.0-5.0 mg/m³; Mode 4: 7.0-10.0 mg/m³ (Crisan-Dabija et al., 2021; Metel et al., 2023).

The halocomplex with a controllable microclimate generally consists of a single equipped room. The main treatment room is designed for participants to sit in comfortable chairs. The halogenerator ensures the supply of dry, fine-grained aerosol composed predominantly of respirable particles (less than 5 microns), with the respirable fraction exceeding 80%. Currently, the Dry Salt Air HaloCompact-01 halogenerator, produced by "Halomed" UAB Savanorui, Vilnius, Lithuania, is used to equip halo-complexes. During the intervention, the dry sodium chloride aerosol concentration was maintained within a therapeutic range of 3–5 mg/m³, corresponding to Mode 3 halotherapy, which has been reported in previous clinical and experimental studies as a safe and effective concentration for respiratory support and airway clearance.

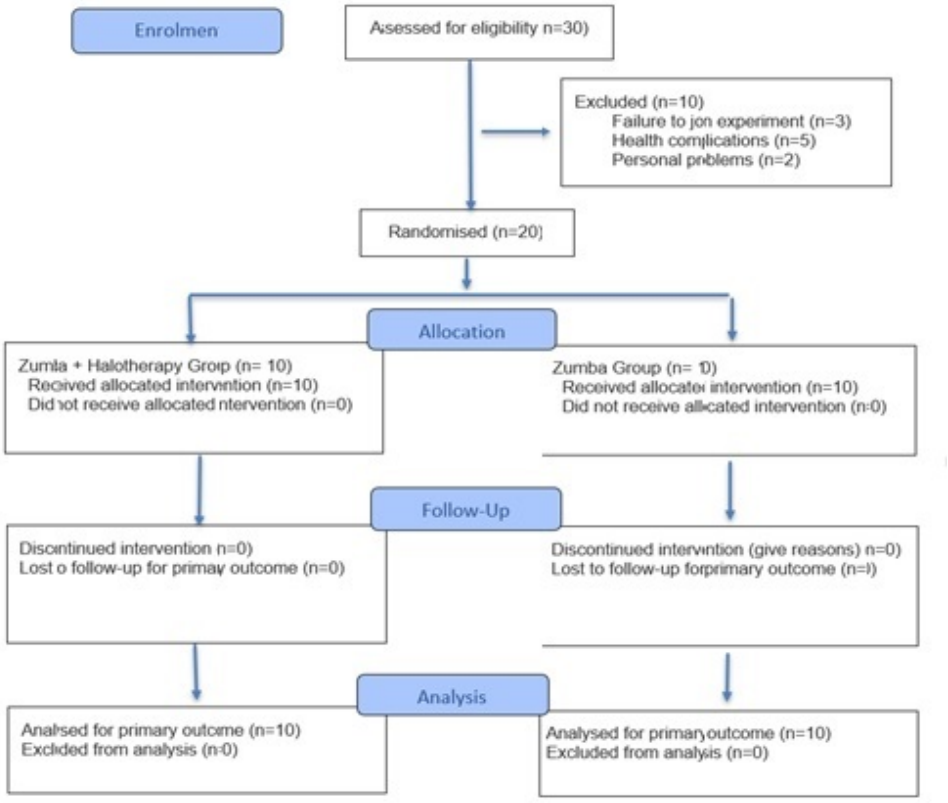

Figure 1. Experimental design.

This concentration range allows adequate deposition of respirable salt particles throughout the respiratory tract while minimizing the risk of airway irritation. In the treatment room, a sensor is installed to continuously monitor the aerosol mass concentration upper detection and monitoring capacity (20 mg/m³) to maintain the prescribed treatment modes. This value refers to the upper detection and monitoring capacity of the aerosol concentration sensor installed in the halotherapy chamber, which continuously monitors aerosol mass concentration to ensure stable and controlled environmental conditions. Throughout all halotherapy sessions, the aerosol concentration remained within the predefined therapeutic range. The halogenerator's microprocessor processes the feedback signals from the sensor and automatically adjusts the salt aerosol parameters in various areas of the room. The microprocessor block also controls the lighting and ventilation systems between treatment sessions. In the treatment room, sensors maintain the microclimate with temperatures ranging from 20 to 24°C and humidity levels between 40 and 60% (20 mg/m³). The process and microclimate parameters are controlled through computer assistance. The procedure was conducted four days a week, with 20-minute sessions, over a 12-week period, totaling 48 sessions. The duration of the procedure and aerosol parameters were prescribed by the specialist doctor based on factors such as the pathology, clinical condition, and overall health status of the participants, as shown in Table 1 and Figure 2 (Cugusi et al., 2019; Ljubojevis et al., 2023).

During the application, participants sat in their designated chairs and calmly inhaled the air. The sessions were conducted with relaxing music and a slideshow. Halotherapy was provided as a treatment following the Zumba sessions. At the end of the halotherapy sessions, feedback was received indicating that all participants felt better, their sleep quality had improved, there were no signs of fatigue or weakness, and their nervous systems were stabilized (Figure 1).

Table 1
Concentration of dry sodium chloride aerosol and halotherapy duration.

Variables	Age Range	FEV_1 (% Pr.)	Concentration (mg/m³)	Halotherapy Duration (days)
Group A (Zumba + Halotherapy	50-60	>60 <60	16-20	12 weeks/48 sessions

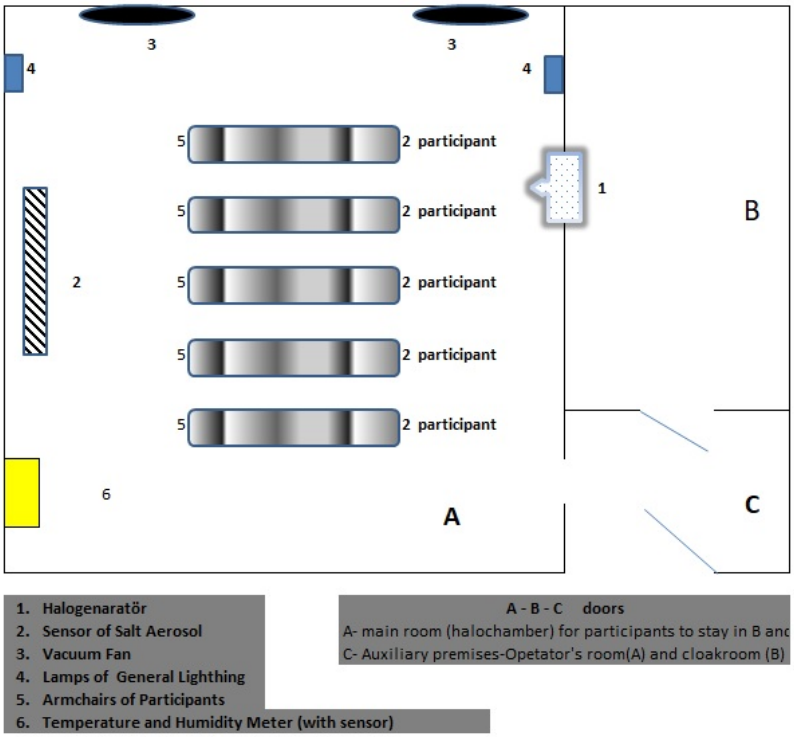

Figure 2. Sample plan of a controlled halocomplex.

Warm-Up Exercise

During the warm-up phase, participants engaged in 10 minutes of low-intensity treadmill walking (RPE, 7-9 km/h). This was followed by stretching exercises targeting the lower and upper extremity muscles (hamstrings, hip adductors, hip abductors, tibialis anterior, gastrocnemius, and soleus), lasting about 10 minutes. Participants' heart rates were monitored throughout the warm-up using Polar watches from the resting to the post-warm-up phases. During this period, careful attention was given to ensure no signs of intense physical fatigue, chest pain, dizziness, presyncope, tachycardia, or hypotension.

Training Programme

The exercise intervention consisted of a 12-week supervised Zumba-based aerobic training program designed for sedentary adults aged 50–60 years. Training sessions were conducted 3–4 days per week on non-consecutive days in an indoor exercise facility and were supervised by a qualified exercise specialist. Session duration ranged from 40 to 50 minutes, progressing gradually across the intervention period.

Session Structure: Each training session was structured into three standardized phases: warm-up, main Zumba workout, and cool-down.

Warm-up (10 minutes): The warm-up phase lasted 10 minutes and consisted of low-intensity rhythmic movements synchronized with slow-tempo music. Exercises included marching in place, step-touch movements, arm swings, shoulder rolls, and dynamic mobility exercises for the upper and lower extremities. The primary objectives of the warm-up were to gradually increase heart rate, enhance joint mobility, and prepare participants for the aerobic component of the session.

Main Zumba Workout (20–30 minutes): The main exercise phase consisted of low- to moderate-impact Zumba choreography incorporating basic Latin dance movements (e.g., salsa, merengue, cumbia-inspired steps). Exercise intensity, session duration, and weekly frequency were progressively increased throughout the intervention, in accordance with the principle of progressive overload.

Weeks 1–4 (Adaptation phase): Participants exercised 3 days per week for total session duration of 40 minutes, with the main workout performed at 50–55% of estimated HRmax corresponding to RPE 8–9 on the Borg 6–20 scale. Choreography emphasized simple, repetitive movements performed at a slow tempo, with limited coordination and balance demands.

Weeks 5–8 (Cardiorespiratory adaptation and development phase): Training frequency increased to 3–4 days per week, and session duration progressed to 40–45 minutes. Exercise intensity was maintained between 55–65% HRmax (RPE 9–10). Movement complexity, lower-body involvement, and multi-directional patterns were gradually introduced to enhance aerobic capacity and neuromuscular coordination.

Weeks 9–12 (Development and peak load phase): Participants trained 4 days per week, with session duration increased to 50 minutes. Exercise intensity reached ~70% HRmax, corresponding to RPE 10–12. The choreography involved higher coordination demands, longer continuous dance sequences, and improved movement continuity, while maintaining low-impact execution to ensure safety. Heart rate was monitored periodically during sessions using heart rate monitors, and perceived exertion was assessed to ensure adherence to the prescribed intensity range.

Cool-down (10 minutes): The cool-down phase consisted of 10 minutes of gradually decreasing movement intensity followed by static stretching exercises targeting major muscle groups, including the quadriceps, hamstrings, calves, hip flexors, lower back, shoulders, and chest. Each stretch was held for 15–30 seconds to promote recovery and reduce post-exercise muscle stiffness.

Intensity Prescription and Maximum Heart Rate (HRmax) Estimation: Estimated using the age-predicted formula: HRmax = 220 − age (years). Exercise intensity was prescribed as a percentage of HRmax and verified using the Borg Rating of Perceived Exertion (RPE) scale (6–20) to account for individual variability in cardiovascular responses.

Safety and Monitoring Procedures: Before enrollment, all participants underwent health screening and were instructed to report any cardiovascular, musculoskeletal, or metabolic conditions. Throughout the intervention: Participants exercised at a self-selected, pain-free intensity within the prescribed target zone. Sessions were discontinued if participants experienced dizziness, chest pain, excessive dyspnea, or musculoskeletal discomfort. Adequate hydration breaks were provided as needed. Attendance and adverse events were recorded throughout the study period. No exercise-related adverse events were

reported during the intervention. The suitability criterion for the training was calculated as the percentage of sessions attended relative to the total number of sessions scheduled. Participants who attended at least 80% of the sessions were deemed to have complied with the training protocol.

Assessments

Body compositions measurements

Height Measurements—Participants were measured in an anatomical position, barefoot, with equal body weight distribution on both feet. The distance between the top of the head and the foot sole was measured in meters using an electronic measurement device, and the measurements were recorded to an accuracy of 0.1 mm (Seca, Germany) (Miller et al., 2016). Older adults whose heights were measured were included in the body composition analysis. The participants' body weight (kg), body mass index (BMI, kg/m^2), and bioelectrical impedance analysis (BIA) were conducted using the Inbody 270 Body Composition Analyzer. BIA is an analysis method based on electrical conductivity differences (Lukaski, 2003).

Respiratory parameter measurement

The peak expiratory flow rate (PEFmax), forced expiratory volume in one second (FEV1), FEV1/FVC ratio (Tiffenau index), maximal voluntary ventilation (MVV), and forced vital capacity (FVC) values were analyzed using the MGF Diagnostics CPFS/D USB spirometer (Saint Paul, Minnesota, United States). Individuals with an FEV1/FVC ratio <70%, any chronic or acute illness, use of medications that could affect lung function, or a history of upper respiratory tract infection were excluded from the study. Lung function measurements were performed with the participant in a seated position (Çelikel et al., 2025). During the tests, subjects wore a nose clip to prevent air leakage and were instructed to seal their lips tightly around the mouthpiece (ATS, 2002).

Maximum inspiratory (MIP) and expiratory (MEP) pressure measurements

MIP and MEP measurements were performed using a portable handheld oral respiratory pressure measurement device (MicroRPM, CareFusion Micro Medical, Kent, United Kingdom) in accordance with the guidelines of the American Thoracic Society and the European Respiratory Society (ATS, 2002). After appropriate filters and holders were placed, the nasal airway was closed with a clip. Inspiratory and expiratory manoeuvres were performed in a sitting position; MIP and MEP measurements commenced with residual volume and total lung capacity, respectively, and continued for at least 1 second (Bostancı et al., 2021). Three measurements were taken in each participant during all measurement sessions. The intraclass correlation coefficient (ICC) was calculated as 0.862 for MIP and 0.844 for MEP.

Cardiorespiratory fitness

The maximal oxygen uptake (VO_2max) test was initiated with a speed of 6 km/h-1 on a motorized treadmill (H/P/Cosmos, Pulsar med 3p- Sports & Medical, Nussdorf-Traunstein, Germany). The treadmill speed was increased by 1 km/h-1 every 3 minutes until subjects were physically exhausted and unable to continue the test. The treadmill grade was set at 0.5 degrees throughout the test.

Table 2
Training programme.

Week	Frequency (day/week)	Time (min)	Density (HRmax % / RPE)	Content	Notes
1	3	30	50–55 % / RPE 7–8	Basic Zumba steps, slow tempo	Adaptation
2	3	30	50–55 % / RPE 7–8	Rhythmic walking, simple choreography	Adaptation
3	3	40	55–60 % / RPE 7–8	Latin rhythms, coordination	Progressive increase
4	3	40	55–60 % / RPE 8–9	Balance + Zumba	Progressive increase
5	3	40	60–65 % / RPE 8–9	Medium-tempo choreography	Cardiorespiratory adaptation
6	4	45	60–65 % / RPE 8–9	Lower-body focused	Cardiorespiratory adaptation
7	4	45	65–70 % / RPE 8-9	Multi-directional movements	Development
8	4	45	65–70 %/ RPE 9–10	Endurance-focused	Development
9	4	50	70 / % RPE 9–10	High coordination	Development
10	4	50	70 / % RPE 9–10	Continuity	Development
11	4	50	70–75 % / RPE 9–10	Complex choreography	Peak load
12	4	50	70–75 % / RPE 9–10	Complex choreography	Peak load

A gas analyzer system (MetaLyzer 3B analyzer, Cortex Biophysik GmbH, Germany) was used to measure oxygen uptake (VO2) and was calibrated before each test according to the manufacturer's instructions. The highest 60-s VO2 value during the test was considered the VO_2 max. The last completed 3-minute velocity of the treadmill test was identified as the maximal testing velocity (Vmax). The details of the VO_2max test were previously described elsewhere (Nummela et al., 2016).

Psychometric Properties: The VO_2max test, which is based on heart rate, oxygen uptake, and carbon dioxide production measurements, provides high accuracy. The test is considered reliable due to the gas analysis system's calibration before each test.

Measurement Errors: Measurement errors were minimized by ensuring that the equipment was calibrated correctly and that participants were in suitable physical conditions before the test.

Reference Values: In the literature, minimal detectable changes in VO2max are typically considered to be around 10%, and increases in VO_2 max are regarded as reliable indicators of improvements in cardiovascular fitness (Nummela et al., 2016). All measurements in this study were performed using reliable and valid instruments, and measurement errors were minimized through appropriate precautions. The reference values from the literature were applied to interpret clinically significant changes, ensuring that the results meaningfully reflected physiological alterations in participants (Lukaski, 2003; Miller et al., 2016; Cugusi et al., 2019; Ljubojevic et al., 2019; Çelikel et al., 2025).

Statistical Analysis

Statistical analyses were performed using SPSS software (Version 27.0 for Windows, Chicago, IL, USA) with a statistical significance level set at 0.05. The Shapiro-Wilk normality test was applied to determine the homogeneity of the sample. To analyse the differences between measurements across trials, repeated measures two-way analysis of variance and Bonferroni correction were used. Additionally, the effect size in pairwise group comparisons was calculated using partial eta-squared (ηp^2). The interpretation of the ηp^2 parameter is as follows: small values, such as 0.01, indicate a small effect size; medium values, such as 0.06, indicate a medium effect; and large values, such as 0.14, indicate a strong effect (Richardson, 2011). The intraclass correlation coefficient (ICC) was calculated to assess the repeatability of measurements obtained from the same observer. The interpretation of the results is as follows: scores between 0.50 and 0.75 are considered moderate, scores between 0.75 and 0.90 are considered good, and scores of 0.90 and above are considered excellent (Koo et al., 2016).

Results

Table 3 presents the pre-test and post-test values (mean ± standard deviation) for body weight, body mass index (BMI), and body fat percentage in the Zumba + Halotherapy (Group A) and Zumba only (Group B) groups during the 12-week intervention period. Group × time interactions were analyzed using two-way repeated measures ANOVA. According to the analysis results, a significant group × time interaction was detected for body weight (F (1-18) = 13.279, p = 0.002, ηp^2 = 0.425). Similarly, a statistically significant interaction was observed for the BMI parameter (F (1-18) = 5.350, p = 0.033, ηp^2 = 0.229). A strong group × time interaction was detected in body fat percentage (F (1-18) = 24.678, p = 0.001, ηp^2 = 0.578). Effect size values indicate that the Zumba program combined with halotherapy has a medium to high effect on body composition parameters.

Table 3
Comparative analysis of body composition changes across groups and time: Group A (Zumba + Halotherapy) vs. Group B (Zumba).

Parameters	Groups	Pre Test	95 CI		Post Test	95 CI		Group x Time Interaction		
		Mean ± SD	L.B.	U.B.	Mean ± SD	L.B.	U.B.	F	p	ηp^2
Body Weight (kg)	Zumba + Halotherapy	88.18 ± 5.02	85.07	91.29	83.51 ± 4.58	80.67	86.35	13.279	0.002*	0.425
	Zumba	81.32 ± 2.90	79.52	83.12	79.31 ± 2.11	78.04	80.62			
BMI (kg/m2)	Zumba + Halotherapy	23.67±0.86	23.14	24.2	21.86 ± 0.93	21.28	22.44	5.350	0.033*	0.229
	Zumba	23.57±0.74	23.11	24.03	22.71 ± 0.76	22.24	23.18			
Body Fat (%)	Zumba + Halotherapy	24.94 ± 1.86	23.79	26.09	20.83 ± 0.66	20.42	21.24	24.678	0.001*	0.578
	Zumba	26.56 ± 0.88	26.01	27.11	25.56 ± 0.68	25.14	25.98			

**p<0.05; ηp2: small > 0.01, medium ≥ 0.06, large ≥ 0.14*

Table 4
Comparative analysis of performance and physiological parameters between groups across time: Group A (Zumba + Halotherapy) vs. Group B (Zumba).

Parameters	Groups	Pre Test	95 CI		Post Test	95 CI		Group x Time Interaction		
		Mean ± SD	L.B.	U.B.	Mean ± SD	L.B.	U.B.	F	p	ηp^2
MIP (cmH2O)	Zumba+Halotherapy	76.46 ± 2.22	75.08	77.84	93.0 ± 5.55	89.66	96.54	24.510	0.001*	0.577
	Zumba	78.33 ± 0.94	77.75	78.91	86.05 ± 2.50	84.5	87.6			
MEP (cmH2O)	Zumba+Halotherapy	75.7 ± 6.04	71.96	79.44	87.50 ± 5.38	84.17	90.83	13.426	0.002*	0.427
	Zumba	72.8 ± 5.33	69.5	76.10	77.0 ± 5.58	73.54	80.46			
FVC (L)	Zumba+Halotherapy	4.48 ± 0.28	4.31	4.65	5.27 ± 0.28	5.10	5.44	4.557	0.047*	0.202
	Zumba	4.10 ± 0.17	3.99	4.21	4.65 ± 0.26	4.49	4.81			
FEV1 (L)	Zumba+Halotherapy	3.75 ± 0.14	3.66	3.84	4.09 ± 0.14	4.02	4.18	0.042	0.840	0.002
	Zumba	3.35 ± 0.20	3.23	3.78	3.67 ± 0.18	3.56	3.78			
PEFmax (L)	Zumba+Halotherapy	7.68 ± 0.20	7.56	7.80	8.80 ± 0.36	8.58	9.02	12.647	0.002*	0.413
	Zumba	7.85 ± 0.17	7.74	7.96	8.41 ± 0.24	8.26	8.56			
FEV1/FVC (%)	Zumba+Halotherapy	79.61 ± 2.10	78.31	80.91	84.84 ± 0.46	84.55	85.13	2.834	0.110	0.136
	Zumba	79.24 ± 1.63	78.51	80.25	82.64 ± 1.83	81.51	83.77			
MVV (L)	Zumba+Halotherapy	110.38 ± 1.15	109.67	111.09	114.59 ± 0.99	113.98	115.2	0.475	0.500	0.026
	Zumba	100.12 ± 1.27	99.33	100.91	110.98 ± 1.47	110.07	111.89			
Max VO2 (ml/kg/min.)	Zumba+Halotherapy	25.26 ± 1.22	24.2	26.02	32.26 ± 1.61	31.26	33.26	67.145	0.001*	0.789
	Zumba	24.56 ± 1.42	23.68	25.44	25.58 ± 1.48	24.66	26.5			

**p<0.05; ηp2: small > 0.01, medium ≥ 0.06, large ≥ 0.1.*

Table 4 presents the pre-test and post-test mean ± standard deviation values for the MIP, MEP, FVC, FEV_1, PEF, FEV_1/FVC ratio, MVV, and VO_2max parameters in the Zumba + Halotherapy (Group A) and Zumba only (Group B) groups over the 12-week intervention period. Group × time interactions were analyzed using two-way repeated measures ANOVA. The analysis results showed a strong group × time interaction for MIP (F (1-18) = 24.510, p = 0.001, ηp^2 = 0.577) and MEP (F (1-18) =13.426, p= 0.002, ηp^2 = 0.427). Statistically significant group × time interactions were also detected in FEV_1 (F (1-18) = 4.557, p = 0.047, ηp^2 = 0.202) and PEF (F (1-18) = 12.647, p = 0.002, ηp^2 = 0.413) parameters also showed statistically significant group × time interactions. Furthermore, a significant interaction with a very large effect size was observed in VO_2max values (F (1-18) = 67.145, p = 0.001, ηp^2 = 0.789). In contrast, no significant group × time interactions were detected for FVC (F (1-18) = 0.042, p = 0.840, ηp^2 = 0.002), FEV_1/FVC ratio (F (1-18) = 2.834, p = 0.110, ηp^2 = 0.136), and MVV (F (1-18) = 0.475, p = 0.500, ηp^2 = 0.026) parameters. Effect size values indicate that the Zumba program combined with halotherapy produces a high level of physiological effect, particularly on respiratory muscle strength and aerobic capacity.

Discussion

The present randomized controlled trial examined whether adding halotherapy to a 12-week Zumba Fitness program produced greater changes in body composition, respiratory function, and cardiorespiratory fitness than Zumba exercise alone in sedentary adults aged 50–60 years. The principal finding was that the combined intervention resulted in greater improvements in body weight, BMI, body fat percentage, MIP, MEP, FEV_1, PEF, and VO_2max, whereas no between-group differential changes were observed for FVC, FEV_1/FVC, or MVV. The pattern of findings is therefore not consistent with a generalized improvement across all pulmonary outcomes; rather, the additional benefit associated with halotherapy appeared to be concentrated in respiratory muscle strength, selected expiratory flow measures, and aerobic capacity.

The greater reductions in body weight, BMI, and body fat percentage in the Zumba + halotherapy group indicate that the combined intervention was associated with more favorable changes in body composition than Zumba alone. Because both groups performed the same structured Zumba program, the between-group differences cannot reasonably be attributed to the aerobic exercise stimulus alone. Nevertheless, the present design does not allow us to determine whether halotherapy directly influenced energy metabolism or whether the additional changes resulted indirectly from differences in

exercise tolerance, training response, or other unmeasured behavioral factors.

Previous work has established that Zumba-based exercise can improve body composition and cardiorespiratory fitness (Barene et al., 2014; Barranco-Ruiz & Villa-González, 2020). The present findings are consistent with this literature but suggest that the addition of halotherapy may have been associated with a greater magnitude of change in body composition. Importantly, however, evidence supporting a direct metabolic effect of halotherapy remains limited. Therefore, the observed body-composition differences should be interpreted as an additional association observed when halotherapy was added to Zumba rather than as evidence that halotherapy independently increases energy expenditure or fat oxidation.

The most pronounced respiratory findings were observed for MIP and MEP, with significant group × time interactions and relatively large effect sizes. These results suggest that participants receiving halotherapy in addition to Zumba experienced greater improvements in respiratory muscle strength than those undertaking Zumba alone. This interpretation is biologically plausible because respiratory muscles, like other skeletal muscles, can adapt to repeated physical training stimuli (Kim et al., 2019). Previous studies have also reported improvements in respiratory function and physical performance following interventions involving aerobic exercise or saline aerosol exposure (Antonovici et al., 2020; Antonovici et al., 2023).

The present findings are also broadly comparable with observations reported by Christopher et al. (2015), Kim et al. (2019), Antonovici et al. (2021), and Antonovici et al. (2023), who described improvements in respiratory function, respiratory muscle performance, or functional capacity following respiratory-oriented interventions. However, comparisons should be made cautiously because these studies differed in participant characteristics, intervention protocols, and outcome measures. In particular, the present participants were sedentary adults without clinically diagnosed respiratory disease, whereas some previous investigations involved populations with respiratory impairment. Thus, the current results extend, rather than directly replicate, the existing evidence.

Significant improvements were also observed in FEV_1 and PEF, whereas FVC, FEV_1/FVC, and MVV did not demonstrate significant group × time interactions. This differential response is important because it suggests that the intervention did not produce uniform changes across pulmonary function. The improvement in FEV_1 and PEF may indicate greater changes in expiratory flow or airway-related function, whereas the absence of a significant FVC response suggests that substantial changes in lung volume cannot be inferred from the present data. Similarly, the lack of a significant FEV_1/FVC interaction does not support a conclusion that the intervention altered the overall ratio between expiratory volume and vital capacity. These findings are therefore more consistent with selective changes in respiratory performance than with generalized structural modification of pulmonary function.

The findings can be compared with Rashleigh et al. (2014), who reported improvements in several respiratory parameters following halotherapy-related interventions, including FVC, FEV_1, oxygen saturation, and arterial blood-gas variables. The fact that FVC did not change differentially in the present study may reflect differences in population and intervention exposure. Rashleigh et al. examined respiratory outcomes in a different clinical context, whereas the current study involved relatively healthy sedentary adults and combined halotherapy with regular aerobic exercise. Similarly, Metel et al. (2022) reported beneficial functional effects following a substantially more intensive speleotherapy and exercise program in older adults with chronic respiratory disease. Their protocol involved considerably greater exposure to the intervention than the 20-minute post-exercise halotherapy sessions used in the present study, which may partly explain differences in the magnitude and pattern of pulmonary responses.

Wise and Brown (2005) also reported favorable changes in physical activity and quality-of-life-related outcomes in individuals receiving respiratory-oriented interventions. Although these findings provide supportive contextual evidence, the different clinical characteristics and outcome domains prevent direct equivalence with the present results. Taken together, the available literature suggests that respiratory-oriented interventions may influence selected functional outcomes, but the specific pulmonary parameters responding to treatment appear to depend on participant characteristics, intervention dose, and the exercise context.

VO_2max demonstrated the largest group × time effect among the measured outcomes. This finding indicates that the addition of halotherapy was associated with a substantially greater improvement in maximal aerobic capacity than Zumba alone. The result is consistent with the established capacity of aerobic exercise to improve cardiorespiratory fitness and with previous evidence that Zumba can increase VO_2max (Barene et al., 2014; Barranco-Ruiz & Villa-González, 2020). The present findings additionally suggest that the respiratory component of the combined intervention may have contributed to the observed between-group difference.

Several mechanisms could potentially explain this observation, although none was directly measured in the present study. Exercise training can improve respiratory muscle function and contribute to more effective ventilatory responses during exercise (Kim et al., 2019; Antonovici et al., 2020; Antonovici et al., 2023). Halotherapy has also been proposed to influence respiratory function through exposure to saline aerosols (Metel et al., 2022; Rashleigh et al., 2014). It is therefore possible that changes in respiratory function contributed to improved exercise tolerance and, consequently, to greater aerobic adaptation. However, because ventilation, airway resistance, oxygen kinetics, or training intensity during the intervention were not directly assessed, the present data cannot establish this pathway. Accordingly, the observed improvement in VO_2max should be interpreted as an outcome associated with the combined intervention rather than as evidence of a confirmed respiratory mechanism.

The findings of Metel et al. (2022) provide some support for this interpretation, as their combined speleotherapy and exercise intervention produced improvements in functional outcomes in older adults with chronic respiratory disease. However, the substantially different intervention dose and clinical characteristics of their participants limit direct comparison. Likewise, Rashleigh et al. (2014) reported improvements in respiratory outcomes following halotherapy, but their findings primarily concerned pulmonary and gas-exchange variables rather than VO_2max. The current study therefore contributes preliminary evidence that a respiratory-oriented complementary intervention may be associated with additional improvements in aerobic capacity when integrated with structured aerobic exercise.

An important consideration is whether the present findings justify describing the interaction between Zumba and halotherapy as synergistic. The data demonstrate greater improvements in several outcomes in the combined group, but they do not establish a mechanistic synergy between the two interventions. In particular, no direct measurements of airway inflammation, mucociliary clearance, oxygen delivery, respiratory efficiency, or metabolic responses were obtained. The findings should therefore be interpreted as evidence of an additional or complementary effect associated with adding halotherapy to Zumba rather than proof of a specific synergistic mechanism.

This distinction is particularly relevant because previous literature has proposed several physiological mechanisms for halotherapy, including mucolytic, anti-inflammatory, and respiratory effects (Metel et al., 2022; Rashleigh et al., 2014). While these mechanisms may provide plausible explanations for some of the present findings, they remain mechanistic hypotheses in the context of this study. The absence of significant changes in FVC, FEV_1/FVC, and MVV further argues against interpreting the intervention as producing a uniform improvement in pulmonary function. Instead, the response pattern suggests that respiratory muscle strength and selected dynamic flow measures may be more responsive than static or global ventilatory measures.

The present results also complement the evidence that aerobic exercise itself can stimulate respiratory muscle adaptations and improve cardiorespiratory performance (Kim et al., 2019; Antonovici et al., 2020; Antonovici et al., 2023). Thus, the additional improvements observed in the combined group may reflect the coexistence of exercise-induced adaptations and the potential contribution of the halotherapy exposure. Whether these effects are additive, interactive, or mediated by changes in exercise tolerance cannot be determined from the present data and should be investigated using studies incorporating direct physiological measurements.

From a practical perspective, the present findings suggest that a short halotherapy exposure added to a structured Zumba program may be associated with additional improvements in selected respiratory and cardiorespiratory outcomes in sedentary adults aged 50–60 years. This is potentially relevant because this population may benefit from exercise modalities that are both physically effective and acceptable for sustained

participation. However, the findings should not be interpreted as evidence that halotherapy should replace established exercise or pulmonary rehabilitation approaches. Rather, the present results provide preliminary support for investigating halotherapy as a complementary component of exercise-based interventions.

The results should also be considered in relation to the broader literature. Previous studies have reported beneficial respiratory and functional effects of halotherapy or speleotherapy, particularly in populations with respiratory disorders (Wise & Brown, 2005; Rashleigh et al., 2014; Metel et al., 2022). The current study differs by examining sedentary adults without established respiratory disease and by integrating halotherapy with a standardized aerobic exercise program. This difference in population may explain why the present study demonstrated pronounced effects for respiratory muscle strength and VO_2max but not for all pulmonary function measures.

Overall, the present findings provide preliminary evidence that adding halotherapy to a 12-week Zumba program may enhance selected adaptations in body composition, respiratory muscle strength, expiratory flow, and maximal aerobic capacity compared with Zumba alone. However, the results should be regarded as hypothesis-generating, particularly given the small sample size and the absence of direct mechanistic measurements. Future adequately powered trials should determine whether the observed benefits are reproducible and should incorporate measures of ventilatory efficiency, respiratory muscle activation, airway function, and exercise intensity to clarify the mechanisms underlying the additional response to combined Zumba and halotherapy.

Limitations

This study has certain limitations. The relatively small sample size may limit the statistical power and generalizability of the findings; therefore, future studies are recommended to include larger sample sizes. Additionally, the selection of participants based on specific inclusion criteria may restrict the generalization of the results to different age groups, fitness levels, or individuals with pre-existing health conditions. An important limitation of this study is the lack of control over potential confounding variables. Factors such as dietary regulation, hydration status, sleep patterns, and circadian variations were not controlled due to resource constraints. These variables have the potential to influence body composition, respiratory function, and overall physical performance. Future research should account for these confounding factors to isolate the specific effects of halotherapy and Zumba exercise interventions. Implementing these controls would enhance the internal validity of the findings and provide a clearer understanding of the intervention's specific effects. On the other hand, the study provides valuable insights into the short-term effects of halotherapy and Zumba exercise. However, one of the study's key limitations is the absence of long-term follow-up assessments. Although the current study demonstrated positive outcomes during the 12-week intervention period, the lack of follow-up evaluations prevents drawing definitive conclusions regarding the sustainability of these effects. A further limitation of the present study is the absence of a sham or placebo-controlled halotherapy condition. Due to the distinctive environmental characteristics of halotherapy chambers (e.g., air salinity, sensory perception, and ambient conditions), blinding of participants was not feasible. Consequently, placebo and expectancy effects cannot be completely excluded, particularly for effort-dependent outcomes such as respiratory muscle strength and maximal oxygen uptake. Future randomized controlled trials should incorporate sham halotherapy environments or alternative control conditions to better isolate the specific physiological effects of dry salt aerosol exposure. A further limitation of this study is the absence of participant and assessor blinding. Due to the nature of the exercise and halotherapy interventions, blinding of participants was not feasible. In addition, outcome assessors were aware of group allocation, which may have introduced expectancy or motivational bias, particularly in effort-dependent measures such as VO_2max and maximal respiratory pressures. Although standardized testing protocols were used for all assessments, the potential influence of expectancy effects cannot be entirely excluded. Future randomized controlled trials should incorporate blinded assessors to further strengthen internal validity. A key limitation of the present study is the relatively small sample size, which may have limited the statistical power to detect smaller between-group differences, particularly across multiple secondary outcomes. Although the study was powered based on expected changes in VO_2max, the possibility of

type I error inflation due to multiple comparisons cannot be excluded. Therefore, the findings should be interpreted as exploratory and hypothesis-generating rather than confirmatory. Larger, adequately powered randomized controlled trials are warranted to confirm these preliminary findings and to further elucidate the independent and combined effects of Zumba exercise and halotherapy. Additionally, future research should aim to control for potential confounding variables such as lifestyle changes, exercise habits, and environmental factors. This approach would enhance the internal validity of the findings, allowing for a clearer understanding of the intervention's specific effects.

Conclusions

The present randomized controlled trial provides novel evidence demonstrating that the integration of halotherapy into a structured Zumba fitness program elicits superior adaptations in body composition, respiratory function, and cardiorespiratory fitness in sedentary older adults compared with Zumba exercise alone. By incorporating both aerobic training and a complementary respiratory-focused intervention, this study offers a comprehensive, non-pharmacological approach to addressing the multifactorial consequences of sedentary behavior. The principal findings indicate that the Zumba + Halotherapy intervention resulted in significantly greater reductions in body weight, body mass index, and body fat percentage, as supported by moderate-to-large group × time interaction effects. These changes suggest that halotherapy may enhance metabolic and physiological responses to aerobic exercise, potentially by improving respiratory efficiency and oxygen availability during training sessions. Importantly, the magnitude of the observed effect sizes underscores the clinical relevance of these body composition improvements rather than merely their statistical significance. From a respiratory perspective, the most pronounced adaptations were observed in maximal inspiratory pressure, forced expiratory volume in one second, and peak expiratory flow, with large effect sizes indicating substantial improvements in respiratory muscle strength and airway function. In contrast, the absence of significant group × time interactions for forced vital capacity, FEV_1/FVC ratio, and maximal voluntary ventilation suggests that halotherapy may preferentially influence dynamic respiratory parameters and inspiratory muscle performance rather than static lung volumes. This selective adaptation pattern provides important mechanistic insight into how halotherapy may complement aerobic exercise. Cardiorespiratory fitness, as reflected by maximal oxygen uptake, exhibited the largest effect size among all measured outcomes, highlighting the synergistic potential of combining halotherapy with aerobic dance-based exercise. Enhanced VO_2max likely reflects improved integration between pulmonary function, respiratory muscle performance, and cardiovascular capacity, enabling participants to tolerate higher exercise workloads with reduced ventilatory strain. Collectively, these findings support the hypothesis that halotherapy augments the physiological benefits of Zumba exercise by optimizing respiratory conditions during and after training, thereby facilitating more effective adaptations in both respiratory and systemic performance domains. The observed improvements extend beyond conventional aerobic exercise outcomes and emphasize the added value of incorporating targeted respiratory interventions into exercise programs for sedentary populations. In conclusion, the combination of halotherapy with Zumba fitness represents an innovative and effective strategy for improving body composition, respiratory muscle strength, and aerobic capacity in sedentary older adults. This integrative approach may have practical implications for exercise prescription, rehabilitation, and health promotion programs aiming to mitigate the adverse effects of sedentary behavior and declining respiratory function.

Practical Implications

The present findings indicate that adding halotherapy to a structured aerobic exercise program such as Zumba may enhance clinically relevant adaptations in respiratory muscle strength and cardiorespiratory fitness in sedentary older adults. The pronounced improvements observed in maximal inspiratory pressure and VO_2max suggest that this combined intervention may improve exercise tolerance and ventilatory efficiency beyond aerobic exercise alone. From a clinical practice perspective, short-duration halotherapy sessions implemented immediately after aerobic exercise may serve as a feasible, non-pharmacological adjunct to conventional exercise-based interventions aimed at improving respiratory function. This approach may be particularly relevant for older adults with low baseline respiratory muscle strength or those who experience exercise-related ventilatory

discomfort. In applied settings, including community health programs and preventive rehabilitation, the combination of Zumba and halotherapy offers an accessible and well-tolerated strategy that simultaneously targets aerobic capacity and respiratory performance. However, given the limited effects observed on static lung volumes, this intervention should be considered complementary rather than substitutive to established pulmonary rehabilitation protocols. Overall, integrating respiratory-supportive modalities with aerobic exercise may represent a practical strategy to optimize functional outcomes and support long-term physical activity participation in sedentary aging populations.

Trial registration

Chinese Clinical Trial Registry (NCT07193108), registered on 12 September 2025.

Authors' Contribution

Study Design: MS, RZ, CY, ASA; Data Collection: MS, ASA; Statistical Analysis: RZ, CY; Manuscript Preparation: MS, RZ, CY, ASA.

Ethical Approval

The study protocol was reviewed and approved by the Health Sciences Ethics Committee of Çankırı Karatekin University (Approval No: 2026/29) and it was carried out in accordance with the Code of Ethics of the World Medical Association also known as a declaration of Helsinki.

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Conflict of Interest

The authors hereby declare that there was no conflict of interest in conducting this research.

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