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Effects of physical training on body weight, pulmonary function and dietary patterns in adolescents with obesity

Efectos del entrenamiento físico sobre el peso corporal, la función pulmonar y los patrones dietéticos en adolescentes con obesidad

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Abstract. Physical activity offers a powerful tool to address the challenges faced by obese teenagers. By promoting social inclusion, improving physical health, and boosting mental well-being, sports can significantly enhance their overall quality of life. Our research discusses the negative effects of obesity in adolescents and the benefits of a sports program when addressing these issues. The study involved 60 participants (30 males and 30 females) aged 14-16 for a period of eight months. Results showed significant weight loss for most participants: 26 participants lost around 10% of their body weight, another group lost around 8%, and only 4 subjects did not experience significant weight change. The study also observed a 9.5% improvement in motor skills on average. The mean weight loss difference between intervention and control was 9.30%. The study emphasizes the detrimental effects of obesity in adolescents and highlights the effectiveness of physical activity programs in promoting weight loss, enhancing respiratory function and induce healthy eating habits among obese adolescents. It also underscores the positive social and lifestyle benefits associated with regular physical activity.
Keywords: physical activity; obesity; exercise; inclusion; nutrition

Resumen. La actividad física ofrece una herramienta poderosa para abordar los desafíos que enfrentan los adolescentes obesos. Al promover la inclusión social, mejorar la salud física e impulsar el bienestar mental, el deporte puede mejorar significativamente su calidad de vida en general. Nuestra investigación analiza los efectos negativos de la obesidad en adolescentes y los beneficios de un programa deportivo a la hora de abordar estos problemas. El estudio involucró a 60 participantes (30 hombres y 30 mujeres) de entre 14 y 16 años durante un período de ocho meses. Los resultados mostraron una pérdida de peso significativa para la mayoría de los participantes: 26 participantes perdieron alrededor del 10% de su peso corporal, otro grupo perdió alrededor del 8% y solo 4 sujetos no experimentaron un cambio de peso significativo. El estudio también observó una mejora del 9,5% en las habilidades motoras en promedio. La diferencia media de pérdida de peso entre la intervención y el control fue del 9,30%. El estudio enfatiza los efectos perjudiciales de la obesidad en los adolescentes y destaca la efectividad de los programas de actividad física para promover la pérdida de peso, mejorar la función respiratoria e inducir hábitos alimenticios saludables entre los adolescentes obesos. También subraya los beneficios sociales y de estilo de vida positivos asociados con la actividad física regular.
Palabras clave: actividad física; obesidad; ejercicio; inclusión; nutrición

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Introduction

Approximately 25% of adolescents in developed countries are overweight or obese (Fan, & Zhang, 2022; Latino, Tafuri, Saraiello, & Tafuri, 2023). Obesity is now recognized as one of the most pressing public health problems (Montesano, & Mazzeo, 2019), reducing life expectancy and quality of life (Hsu et al., 2021). The World Health Organization, United Nations, and the International Olympic Committee have advocated that physical activity (PA) has an important role to play in reducing the worldwide burden of obesity throughout childhood and adolescence (Hassapidou et al., 2023; Due et al., 2009; Hong et al., 2023; Septiantoko et al., 2024). PA has been recognized as a crucial lifestyle factor that has the potential to affect body weight and body composition, thus playing a significant role in the management and avoidance of excess weight and obesity (Aidar et al., 2022; Cataldi et al., 2019). Regular PA increases cardiovascular health, improves lung function, strengthens bones and muscles, and can lead to management or loss of weight (Farì et al., 2021; Farì et al., 2023, Guerra et al., 2014; La Torre et al., 2023). Therefore, PA, when designed appropriately, has the potential to significantly enhance the physical health of obese adolescents (Latino et al., 2023; Latino & Tafuri, 2023, 2024a,b; Mazzeo et al., 2016; Morsanuto et al., 2023). Additionally, there is strong evidence that PA offers a powerful benefit for obese teenagers in terms of both social inclusion and health (Muscogiuri et al., 2016; Rocca et al., 2016; Silva et al., 2022; Tafuri, & Latino, 2024; Mazzeo, 2016).

Engaging in consistent PA is imperative for the purpose of weight control and the enhancement of overall well-being. PA improves cardiovascular health, muscular strength, and endurance (Montesano et al., 2019; Hale et al., 2021). Participation in PA and sports encourages physical exercise and expenditure, this can help obese teenagers burn calories and improve their weight control efforts. These benefits translate into better overall fitness and a healthier lifestyle. Although obese teenagers may face challenges with respiratory functions during sports activities, these activities still offer considerable benefits (San-Cristobal et al., 2020).

Epidemiological data illustrates that obesity can negatively impact respiratory functions in teenagers (Mazzeo, & Liccardo, 2019; Boulet, 2013). Several studies have frequently linked it to an elevated likelihood of manifesting the signs and symptoms of asthma (Anwar, Kustiyah, & Riyadi, 2023; Reyes-Angel, Kaviany, Rastogi, & Forno, 2022; Sansone, Attanasi, Di Pillo, & Chiarelli, 2020; Zhang et al., 2020). In comparison to non-obese individuals with asthma, obese patients tend to experience more symptoms and increased morbidity. This particular condition represents a significant risk factor for various respiratory complications including an increased need for ventilation, heightened respiratory effort, inefficiency in respiratory muscle function, and reduced respiratory compliance (Loux, Matusik, & Hamzic, 2023). Moreover, studies have shown that PA, including both aerobic and anaerobic exercise, can have a positive impact on respiratory parameters in the obese population (Oudjedi, & Aissa, 2020; Irandoust et al., 2021; Elnaggar, Shendy, & Elfakharany, 2021; Calcaterra et al., 2022). Boulet (2013) explores the connection between obesity and respiratory disorders. While obesity presents challenges for respiratory functions, PA offers a valuable tool for improvement. By choosing appropriate activities, gradually increasing intensity, and maintaining a long-term commitment, obese individuals can experience significant benefits in their breathing and overall health.

Obesity has a profound negative impact on pulmonary function and significantly reduces exercise capacity in individuals (López Siguero et al., 2023). With a little planning and effort, obese teenagers can find safe and effective ways to improve their respiratory functions and overall health through PA.

Several observational and correlational studies have addressed the relationship between PA, adolescent obesity, and dietary patterns. The findings of these studies consistently indicate that a number of dietary practices are linked to a higher body mass index (BMI) (Ding et al., 2022; Guevara, Urchaga, Cabaco, & Moral-García, 2020; Manzano-Sánchez, et al., 2022; Monteiro et al., 2020). For instance, the consumption of sugar-sweetened beverages, total sugar, fast food, energy-dense foods, and high-fat diets are associated with an increased BMI. Conversely, lower BMI levels are linked to the intake of fruits, vegetables, and nuts, suggesting a potential connection to teenage obesity (Jokomarsono, Probandari, & Wiboworini, 2022; Sigala, & Stanhope, 2021). Additionally, observational research has identified other factors contributing to childhood obesity, such as skipping breakfast, snacking while watching television, and the consumption of fresh fruit juice (Firnanda, Nuzil, Salsabila, & Khoiriyah, 2023) although the association between this consumption and weight status remains inconclusive across many studies. Participation in organized sports has shown the promise of reducing the prevalence of obesity among adolescents, doubtless due to the promotion of PA and healthy dietary choices. Nevertheless, a recent systematic review has cast doubts upon the direct link between youth sports involvement and weight status (Lee, Pope, & Gao, 2018). While sports participants tend to be more physically active and have a higher fruit and vegetable intake, they also consume more fast food, sugar-sweetened beverages, and overall calories compared to non-participants.

Recent clinical guidelines advocate a holistic strategy when addressing overweight and obesity, emphasizing behavior modification techniques to facilitate changes in dietary habits leading to reduced calorie consumption and increased PA (van Sluijs et al., 2021). This recommendation is underpinned by consistent evidence indicating that the integration of PA with dietary adjustments yields more significant weight reduction compared to dietary modifications in isolation (Hargreaves et al., 2022). Although the most effective approach to weight loss entails a comprehensive strategy encompassing behavior modification, dietary adjustments, and PA, many interventions do not incorporate all these components (Migueles et al., 2023). Indeed, most interventions tend to prioritize increasing PA as the primary method for promoting weight loss.

Both dietary and PA have been highlighted as suitable interventions for combating obesity. Children and adolescent who are physically active are less prone to developing risk factors for chronic diseases compared to their inactive peers, reducing the likelihood of obesity and increasing the chances of maintaining an active lifestyle into adulthood. Additionally, decreasing sedentary behaviors like excessive television watching can lead to positive changes in BMI (Nicholson et al., 2024). Establishing habitual PA from a young age is crucial for impacting mortality and longevity. These findings have significant implications for preventive medicine (Denova-Gutierrez et al., 2023). However, it is evident that changes in environmental factors are necessary to effectively boost habitual PA levels in children and adolescents. Therefore, this paper's novelty lies in its focus on promoting an active lifestyle among adolescents through a combination of physical activity and dietary modifications to combat the rising rates of obesity. Consequently, the objective of this study was to investigate an intervention combining PA with dietary modifications in order to reduce body weight. The secondary aim was to explore how PA could affect respiratory functions and induce healthy eating habits among obese adolescents aged between 14 and 16 years for a period of eight months.

Materials and Methods

Study design

The research consisted in a randomized controlled study whose aim was to investigate the potential of a PA program to improve respiratory functions, reduce body weight, and induce healthy eating habits among obese adolescents. The intervention program involved 8-months of additional PA extracurricular training for the intervention group, and only curricular physical education for the control group.

As for the randomization protocol, a simple randomization method with a random number table was used and an electronic tool for generating numerical sequences was employed for this purpose. Subsequently, it was established that subjects corresponding to "even" digits would fall into the experimental group (EG), while all those corresponding to "odd" digits would make up the control group (CG).

Participants

The study includes 60 participants recruited from a local high school located in the south of Italy (30 males and 30 females), with an age span of 14 to 16 years and exhibiting a weight range between 65 kg to 80 kg. The study required that the participants undergo three session of additional extracurricular training per week.

The activity was carried out in an indoor stadium and contributed to the enhancement of coordinative abilities, specifically focusing on oculo-manual and oculo-podalic coordination, spatio-temporal organization, rhythm, and the capacity for group work (Salam et al., 2020) through team sports.

The study flowchart is depicted in Figure 1. The criteria for inclusion consisted of: (i) individuals aged between 14 and 16 upon enrollment; (ii) diagnosed with obesity; (iii) the absence of cardiovascular, neuromuscular, orthopedic, or neurologic disorders; (iv) the ability to follow measurement instructions. Criteria for exclusion comprised: (i) display of symptoms necessitating exclusion as decided by a healthcare professional; (ii) interference of any medical event affecting test results and leading to participant exclusion; (iii) unable to avoid physical activity beyond than those indicated by the protocol. Initial guidance was provided to participants and their parents via email before their participation in the study. Subsequently, a second electronic communication was sent to instruct them to attend a briefing session during which the trial objectives were highlighted, and written consent for participation in the research was obtained. After meeting the inclusion criteria, participants were required to complete consent forms before commencing the study. These forms outlined the study objectives, selection criteria, procedures, potential advantages and disadvantages, available options, measures for confidentiality, withdrawal procedures, and a disclaimer concerning injuries. An a priori power analysis was conducted using G*Power (version 3.1.9.6), indicating that a sample size of 54 would provide adequate statistical power (α=0.05, 1-β= 0.80) to detect a moderate effect size (f= 0.25 or 0.4) with a correlation coefficient of p=0.80, a 95% power level, and α=0.05, employing a within-between mixed design. In order to counteract experimental attrition due to participant dropout, 60 individuals were recruited. The confidentiality of all participants was ensured by the researchers. The study was conducted between September 2023 and May 2024, in accordance with the guidelines of the Helsinki Declaration and its subsequent amendments. The study protocol was reviewed and approved by the Department of Medical Science, Exercise and Wellbeing – University of Naples “Parthenope” (DiSMMeB Prot. N. 88592/2024).

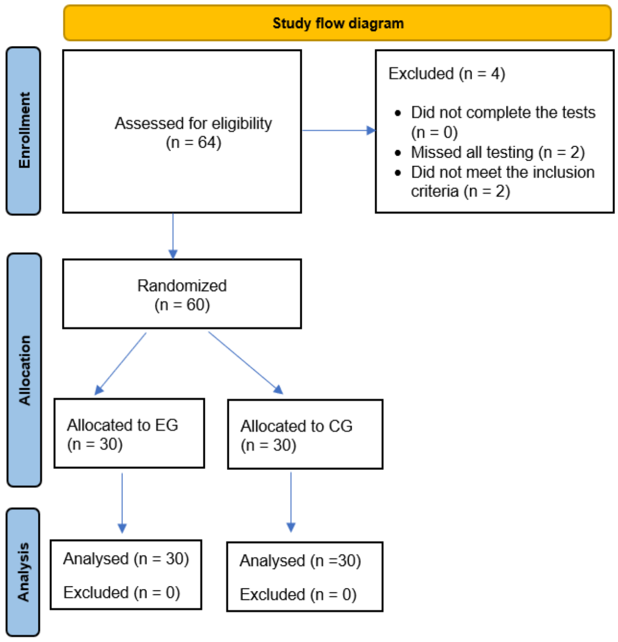

Figure 1. Study Flow diagram.

Procedures

All measurements were conducted across two sessions. The testing sessions occurred with a 72-hour gap between the commencement of the program and the baseline evaluation. During the initial session, respondents completed a survey in which they provided demographic information such as age, gender, medical background, smoking routines, and other variables. Subsequently, students engaged in the assessment tests to analyze respiratory function, body weight, motor skills, and healthy eating habits both at baseline and post-intervention stages. The students underwent individual assessments and performed each examination in a consistent sequence, at the same time of day, and under comparable experimental conditions. All assessments and physical activity regimens were outlined, monitored, and executed by two proficient fitness instructors.

Measures

Motor Tests

The assessment of physical fitness involved four evaluative tests:

1. The standing long jump test, aimed at assessing the horizontal explosiveness of the lower body (Eurofit, 1993).
2. The push-up test, implemented to evaluate strength and endurance of the upper body (Rozenek et al., 2022).
3. The sit and reach test, used to measure the flexibility of the hamstring muscles and lower back (Mayorga-Vega et al., 2014).

These particular assessments were selected due to their ease of administration, minimal time requirement, and basic equipment needs (Krishnan et al., 2017). They are deemed highly suitable for educational settings, and were conducted before and after the intervention programs.

The amount of body fat and the gauge the risk of developing chronic conditions are validated by a number of reference indices, such as BMI, which are derived from predetermined mathematical expressions, where BMI = weight (in kilograms) / height (in square meters). A conventional protocol was adhered to, and standardized tools were employed to conduct the anthropometric assessments (Weiner, & Lourie, 1981). The measurements of height and weight were carried out within a designated space to guarantee privacy. Prior to stepping on the scale, individuals were requested to remove any personal items (such as coats, wallets, watches, etc.) and to take off their shoes. Each measurement was repeated thrice, with verification consistently conducted by the same proficient researcher to mitigate the risk of errors. The average of measurements was considered the most accurate and was recorded. The participants' weight was determined using a portable medical floor scale with a precision of 0.1 kg (Charder's MS6121R, Charder Electronic Co., Taiwan). To ascertain height, a wall-mounted digital stadiometer was employed, measuring to the nearest 0.1 cm (Charder's HM200D, Charder Electronic Co., Taiwan). Subsequently, the measurements of height and weight were employed in the computation of the BMI (kg/m2) (Cole et al., 2000). The BMI values were then converted to percentiles, and the International BMI Cutoff Points were referenced to categorize the students as either overweight or non-overweight (Harmouche-Karaki et al., 2020). BMI evaluation was performed before and after the intervention programs.

Spirometry is a frequently employed pulmonary function test (PFT) employed to quantify the volume of air exhaled forcefully after a deep inhalation. The spirometry assessments conducted covered Forced Expiratory Volume in 1 Second (FEV1), Forced Expiratory Volume in 1 Second % Predicted (FEV1%), Peak Inspiratory Flow (PIF), Peak Expiratory Flow (PEF), and Forced Vital Capacity (FVC). All three were assessed utilizing a portable electronic spirometer (Vyntus Spiro, Vyaire Medical GmbH, Hoechberg, Germany) specifically developed for physiological evaluations. The assessments were carried out in a controlled laboratory environment. Participants adhered to the experimental protocol and any apprehensions were duly addressed. Following the guidelines of the American Thoracic Society (Graham et al., 2019), participants executed forced inhalation and exhalation maneuvers while seated, with their nasal passages obstructed. Through the spirometer's mouthpiece tube, each participant executed a maximal inhalation followed by a vigorous exhalation until complete air expulsion. Each participant participated in a minimum of three trials, with the top one endeavors selected for further scrutiny. Verbal encouragement was employed to stimulate optimal inhalation and exhalation efforts from the participants. The procedure culminated with the individual executing a maximal inhalation.

In order to evaluate the students' dietary patterns, a brief validated questionnaire was employed (Persson et al., 2019). The Food Frequency Questionnaire (FFQ) was originally designed as a quick screening tool to provide an overall view of an individual's dietary pattern and to identify poor dietary patterns with a focus on risk factors for cardiovascular diseases (Becker et al., 2004). It comprises questions regarding the frequency of consumption of different food groups based on indicators from the NNR of a healthy dietary pattern (Cole, & Lobstein, 2012). The FFQ was completed on the day of the general examination. Categories ranging from 'never' or 'less than once a month' to '6+ per day' are used and participants have to choose one of these options.

Participants were required to specify the quantity of (i) vegetables (excluding potatoes, chips, and fried potatoes) and (ii) fruit (excluding fruit juice) they typically consumed on a daily basis, encompassing various forms such as fresh, dried, frozen, and canned. A serving of vegetables was operationally defined as ½ cup of cooked vegetables or 1 cup of salad vegetables, whereas a serving of fruit was described as 1 medium piece, 2 small pieces, or 1 cup of diced fruit (Jakicic, & Davis, 2011). Adherence to national dietary guidelines was determined based on whether students reported consuming four or more servings of vegetables and three or more servings of fruit each day (Trudeau, & Shephard, 2008). To evaluate the intake of sugar-sweetened beverages, students were asked about their regular consumption of soft drinks (e.g., Coke, lemonade), cordials, or sports drinks (e.g., Gatorade) on a daily or weekly basis. Students were divided into groups based on daily consumption of sugar-sweetened beverages. Assessment of high-fat food consumption was conducted by questioning students on the frequency with which they consumed items like burgers, pizza, chicken, or chips from popular fast-food chains. Students were categorized according to their weekly consumption of high-fat foods. These specific questions were chosen due to the need to differentiate between various levels of intake among students in the study sample (Martin et al., 2018).

Additional training

The structure of this PA program for obese adolescents was designed to include three training sessions weekly (Table 1). The initial phase (first phase 15 days) involved a focus on education: Interviews were conducted regarding dietary behaviors conducive to good health and the significance of PA among adolescents solely the intervention sessions aimed at opposing daily habits were implemented. Over the ensuing months, the entire set of three sessions was executed, leading to a rise in the length of sessions (from an average of 30-45 minutes to 55-70 minutes) as well as the level of exertion during the activities. We have observed the benefits of low-intensity aerobic exercise, particularly during the warm-up phase of a workout session.

It's important to gradually increase heart rate and blood flow at the beginning of a workout. This prepares your body for more strenuous activity and helps prevent injuries (Warm-up with Low Intensity Exercise). Benefits of Low-

Intensity Aerobic Training are:

- *Increased Fat Burning:* Exercise mobilizes fat stores, and low-intensity exercise can be effective for using fat as fuel.
- *Boosted Basal Metabolism:* Engaging in consistent aerobic physical activity has the potential to marginally increase one's basal metabolic rate, representing the amount of energy expended by the body while at rest.
- *Improved Daily Activity Endurance:* Low-intensity exercise can improve your stamina for everyday activities.
- *Enhanced Recovery:* Exercise helps your body repair and rebuild itself after exertion. Low-intensity exercise can promote recovery from higher intensity workouts.
- *Better Blood Flow:* Exercise improves circulation, delivering oxygen and nutrients throughout your body, including the brain and muscles.
- *Blood Pressure and Heart Rate Regulation:* Regular exercise can help regulate blood pressure and heart rate, both at rest and during activity.

Table 1.
Training session.

Time (min.)	exercise
10	Slow ride
8	joint mobilization exercises
3	respiratory gym exercises
8	exercises with small tools
4	Exercises with weights (1,2,3,4,5 Kilos)
6	strengthening abdominal and dorsal muscles
10	games with a ball
3	stretching
8	Slow ride
10-15	Optional exercises for coordination and strengthening with a ball

Work in Progress: This suggests the program is designed to gradually increase difficulty or complexity over time. Participants might start with simpler exercises and progress to more challenging ones as their fitness improves. While alternating paths refers to incorporating different types of exercises in the program.

Coordinative Exercises: These exercises focus on improving balance, agility, and coordination. Examples include jumping drills, catching and throwing exercises, or obstacle courses.

Conditional Exercises: These exercises target improving physical fitness components such as cardiovascular endurance, muscular strength, and power. Examples include jogging, bodyweight exercises, or resistance training with weights. The program focused on basic skills for common team sports like basketball, football (soccer), volleyball, and handball.

The circuit training approach with a focus on specific skills and gradual progression appears to be an effective way to improve coordination, agility, and team game skills in obese adolescents.

The activity was predominantly conducted with natural weights such as balloons, cones, rods, carpets, elastic bands and circles. It was only in the fifth month that medicinal flasks, weighted anklets, and various other small implements were incorporated. Additionally, there were designated sessions focused on unrestricted play activities. Incorporating free play sessions demonstrates a well-rounded approach to the sports program. It addresses not only physical skills but also those social and mental aspects important for an overall well-being in obese adolescents.

The control group continued with curricular physical education lessons. They started with a full body warm-up, proceeded with a series of primary drills aimed at enhancing athletic abilities and intended to enhance overall physical well-being, and concluded with a cooldown regimen. The warm-up routine encompassed activities such as stationary marching, wide toe touches, leg and arm swings, rotations of the shoulders and hips, push-ups, lunges, walking jacks, jumping jacks, hip rotations, and bodyweight squats. As for the main drills, they encompassed a range of sports and pursuits including volleyball, badminton, and table tennis, both individual and paired activities, collective drills, bodyweight movements, exercises utilizing small training equipment, joint flexibility drills, and pilates routines. The cooldown segment included a diverse array of stationary stretching exercises comprising stretches for the glutes, standing quadriceps, lateral torso, shoulders, triceps, lower back, abdomen, and the child's pose. This phase was deemed crucial for muscle relaxation and the enhancement of joint flexibility.

Materials and resources

The materials and resources used in the PA program for obese adolescents include:

- An indoor Stadium, providing a controlled environment for year-round exercise, regardless of weather conditions
- Small tools (Clavette, supports, circles, sticks, elastic bands), these could be cones or markers used for creating boundaries, setting up agility drills, or marking pathways.
- Basketball and soccer balls, used to introduce basic skills and drills for these popular team sports.
- 1,2,3,5 kg medicinal balls, these weighted balls can be used for throwing, catching, core exercises, and building strength.
- 1.2 and 3 kg weights, free weights can be used for strength training exercises targeting various muscle groups
- Ballasted anklets of 1,2,3, Kgs, weighted ankle cuffs can add resistance to exercises for improved leg strength and power.

Testing Equipment

1. Detection Grids: These are agility ladders used for footwork drills and to improve coordination.
2. Spirometer: This device measures lung capacity and is used to assess respiratory function.

Statistical Analysis

Statistical procedures were carried out utilizing IBM SPSS version 25.0 (IBM, Armonk, NY, USA). Descriptive statistics are presented as mean ± standard deviation. Normality assumptions were validated through the Shapiro-Wilk test, while the Levene test was used to evaluate homogeneity of variances. An independent sample t-test was utilized to examine group differences at baseline. A two-way ANOVA (group (experimental/control) × time (pre/post-intervention)) with repeated measures on the time dimension was employed to explore the effect of the exercise program on dependent variables. Whenever 'Group x Time' interactions showed significance, paired t-tests were carried out to detect notable differences. The extent of the significant 'Time x Group' interaction was assessed using the partial eta squared (η^2p) value, with delineations of small ($\eta^2p < 0.06$), medium ($0.06 \leq \eta^2p < 0.14$), and large ($\eta^2p \geq 0.14$) (Norouzian, & Plonsky, 2018). Moreover, Cohen's d was utilized to determine effect sizes for pairwise comparisons, with categorizations of small ($0.20 \leq d < 0.50$), moderate ($0.50 \leq d < 0.79$), and large ($d \geq 0.80$) (Cohen, 1992). Statistical significance was indicated by a threshold of $p < 0.05$.

Results

All participants received the designated treatment conditions as allocated, with no instances of reported injuries observed over the course of the experiment. The individuals involved in the study demonstrated uniformity in terms of age, gender, and anthropometric characteristics. Statistical analysis indicated no significant differences ($p > 0.05$). Participant characteristics are shown in table 2. The results of all outcome measures can be found in Table 3.

Table 2.
Characteristics of participants

Variable	EG (n = 30) Mean ± SD	CG (n = 30) Mean ± SD
Age (y)	15.00 ± 0.78	14.93 ± 0.86
Height (cm)	169.26 ± 5.17	167.50 ± 5.21
Weight (kg)	66.66 ± 6.47	66.80 ± 8.28
Body mass index (kg.m^{-2})	95.04 ± 3.82	95.24 ± 3.08
Sex, n (%)		
Male	13 (43.33)	16 (53.33)
Female	17 (56.67)	14 (46.67)

Table 3.
Changes in respiratory function, motor skills and BMI after exercise program.

	Experimental Group (n = 30)			Control Group (n = 30)		
	Baseline	Post-test	Δ	Baseline	Post-test	Δ
Standing long jump	1.51 (0.06)	1.55 (0.05)†*	0.03 (0.02)	1.48 (0.05)	1.49 (0.06)	0.00 (0.02)
Push ups	6.26 (1.83)	13.46 (3.44)†*	7.20 (2.51)	5.70 (1.36)	5.70 (2.11)	0.06 (2.06)
Sit and reach	4.93 (2.30)	9.36 (3.07)†*	4.43 (1.69)	5.70 (1.29)	4.70 (0.91)	-1.00 (1.28)
FFQ	20.16 (1.72)	24.63 (2.41)†*	4.46 (0.81)	19.83 (2.35)	18.33 (2.69)	-1.50 (2.17)
FEV 1	1.87 (0.16)	2.13 (0.35)†*	0.25 (0.23)	1.86 (8.04)	1.83 (0.09)	-0.02 (0.04)
FEV 1 (%)	86.37 (0.65)	88.78 (2.09)†*	2.45 (1.70)	86.20 (0.98)	85.77 (1.90)	-0.43 (0.97)
PIF	128.94 (1.46)	136.90 (2.17)†*	7.96 (2.23)	127.96 (2.04)	128.20 (2.09)	0.23 (0.39)
PEF	2.61 (0.20)	2.92 (0.20)†*	0.30 (0.31)	2.47 (0.26)	2.52 (0.32)	0.04 (0.10)
FVC	3.95 (0.66)	5.23 (0.15)†*	1.28 (0.72)	4.10 (0.62)	4.12 (0.56)	0.02 (0.31)
Weight (kg)	66.66 ± 6.47	64.13 (6.07)	-2.53 (1.61)	66.80 ± 8.28	65.93 (8.05)	-0.86 (1.63)
BMI	95.04 (3.82)	86.12 (5.86)†*	-3.91 (2.59)	95.24 (3.08)	94.00 (3.14)	-0.20 (0.84)

Note: values are presented as mean (± SD); Δ: pre- to post-training changes; †Significant 'Group x Time' interaction: significant effect of the intervention (p< 0.001). *Significantly different from pre-test (p< 0.001); Ω BMI percentile indicates the relative position of the child's BMI number among children of the same sex and age. FFQ: Food Frequency Questionnaire; FEV1: forced expiratory volume in 1 second; FEV1 (%): Forced Expiratory Volume in 1 Second % Predicted; PIF: Peak Inspiratory Flow; PEF: Peak Expiratory Flow; FVC: Forced Vital Capacity.

Motor test

A two-factor repeated measures ANOVA found a significant 'Time x Group' interaction for the Standing long jump test ($F_{1,58} = 9.69$, $p < 0.001$, $\eta^2_p = 0.78$, large effect size), Push ups test ($F_{1,58} = 148.94$, $p < 0.001$, $\eta^2_p = 0.72$, large effect size), and Sit and reach test ($F_{1,58} = 195.50$, $p < 0.001$, $\eta^2_p = 0.77$, large effect size). The post-hoc analysis revealed a significant improvement in the score for Standing long jump test ($t = 7.20$, $p < 0.001$, $d = 1.31$, large effect size), Push ups test ($t = 15.70$, $p < 0.001$, $d = 2.86$, large effect size), and Sit and reach test ($t = 14.32$, $p < 0.001$, $d = 2.61$, large effect size) in the intervention group. No significant changes were found for the control group ($p > 0.05$).

Spirometry test

A two-factor repeated measures ANOVA found a significant 'Time x Group' interaction for the FEV 1 ($F_{1,30} = 43.48$, $p < 0.001$, $\eta^2_p = 0.82$, large effect size), FEV 1 (%) ($F_{1,58} = 72.01$, $p < 0.001$, $\eta^2_p = 0.81$, large effect size); PIF test ($F_{1,58} = 346.03$, $p < 0.001$, $\eta^2_p = 0.85$, large effect size), PEF test ($F_{1,58} = 19.69$, $p < 0.001$, $\eta^2_p = 0.83$, large effect size), and FVC test ($F_{1,58} = 75.95$, $p < 0.001$, $\eta^2_p = 0.86$, large effect size), . The post-hoc analysis revealed a significant improvement in the score for FEV 1 ($t = 4.07$, $p < 0.001$, $d = 0.82$, large effect size), FEV 1 (%) ($t = 4.21$, $p < 0.001$, $d = 0.84$, large effect size), PIF ($t = 19.47$, $p < 0.001$, $d = 3.55$, large effect size), PEF ($t = 5.53$, $p <$

0.001, $d = 1.01$, large effect size), and FVC ($t = 9.65$, $p < 0.001$, $d = 1.76$, large effect size) in the intervention group. No significant changes were found for the control group ($p > 0.05$).

BMI

A two-factor repeated measures ANOVA found a significant 'Time x Group' interaction for the BMI ($F_{1,58} = 54.53$, $p < 0.001$, $\eta^2_p = 0.88$, large effect size). The post-hoc analysis revealed a significant improvement in the score for this variable ($t = -8.26$, $p < 0.001$, $d = -1.50$, large effect size) in the intervention group. No significant changes were found for the control group ($p > 0.05$).

FFQ

A two-factor repeated measures ANOVA found a significant 'Time x Group' interaction for the FFQ ($F_{1,58} = 197.33$, $p < 0.001$, $\eta^2_p = 0.77$, large effect size). The post-hoc analysis revealed a significant improvement in the score for this variable ($t = 3.46$, $p < 0.001$, $d = 0.83$, large effect size) in the intervention group. No significant changes were found for the control group ($p > 0.05$).

Discussion

The main purpose of this study was to investigate the potential of a combined nutritional and PA program to reduce body weight. While, the second objective was to explore how PA could affects respiratory functions and induce healthy eating habits among obese adolescents aged between 14 and 16 years over a period of eight months.

The study demonstrates that PA programs can work as an effective intervention for weight loss and overall health benefits. A significant weight reduction has been demonstrated, essentially the average weight loss among participants was -4.44% after eight months of participation with a mean weight loss difference between intervention and control of 9.30%.

While the majority of participants experienced weight loss, the amount varied. 24 participants lost 10% or more of their body weight, while 4 lost 8%. Only 2 participants did not show significant weight changes (Table 3, Figure 2). Males experienced a more favorable weight reduction compared to females. All participants in the intervention program reported positive effects, including improvements in appearance, physical function, and breathing control. This finding aligns with an extensive body of prior literature indicating a positive correlation between increased levels of PA and an improvement in weight status (Mulyanti et al., 2024; Wassenaar et al., 2019; Khan, & Hillman, 2014). It also supports both national and international directives advocating for organized PA and sports as strategies to address the issue of physical inactivity (Webster et al., 2015).

Individuals engaging in over 210 minutes of organized PA weekly were observed to have a higher probability of adhering to national recommendations for fruit and vegetable intake, with an even greater likelihood linked to increased levels of participation.

Elevated engagement in organized sports and similar activities, coupled with reduced sedentary behaviors and screen time among young individuals, can facilitate the development of healthier dietary patterns (Logan et al., 2020; Bjørnarå et al., 2021; Mardiyah et al., 2024). More precisely, involvement in extracurricular sports-related activities was linked to an increase in the consumption of food items considered to be non-obesogenic, such as fruits, vegetables, and dairy products. Findings regarding intake of sugar-sweetened beverages were inconclusive. The total duration spent on screens and watching TV was connected to a higher consumption of obesogenic foods like fast food and sugary beverages, along with a decrease in the consumption of non-obesogenic options like fruits and vegetables (Kanellopoulou et al., 2021). Consuming fried foods and poor-quality dietary choices was more prevalent during TV viewing sessions, particularly as the duration of viewing increased. Increased daily screen device usage was associated with a higher intake of obesogenic foods and a lower consumption of fruits and vegetables. In numerous studies, sedentary behaviors were correlated with lower-quality dietary selections, while engaging in homework was linked positively to healthier eating habits (Toomey et al., 2022). In essence, reducing sedentary activities outside of school hours, particularly screen time, and dedicating more time to participating in sports were associated with more healthful eating habits (Must, & Tybor, 2005). This is consistent with the findings of a systematic review (Nelson et al., 2011); however, unlike this review, our study did not identify a correlation between engaging in sports activities and the propensity to regularly indulge in sugar-sweetened beverages. Our findings indicated that individuals who had a habit of consuming sugar-sweetened beverages showed significantly higher rates of sports participation compared to those who did not consume them regularly. The absence of this connection could be attributed to the widespread prevalence of sugar-sweetened beverage consumption in the population, making it challenging to distinguish between individuals who partake in these unhealthy options on a consistent basis and those who do not (Grace, Herbert, Elliott, & Sculthorpe, 2016; Kurniawan et al., 2024).

Engaging in regular PA is a cornerstone of effective weight management strategies (Hackett, 2020). Sport programs offer structured and enjoyable ways for obese teenagers to consistently engage in physical exercise, which is crucial for burning calories and reducing body fat (Prasertsri, & Padkao, 2021). This structured exercise not only aids in weight loss but also promotes muscle strengthening and enhances bone density, which are essential for overall physical health (Branco et al., 2021).

The long-term benefits of incorporating sports into the lives of obese teenagers cannot be overstated. Establishing a routine of PA during adolescence increases the likelihood of maintaining an active lifestyle into adulthood (Greco et al., 2019; Johnson et al., 2023).

Furthermore, the habits and discipline learned through sports can encourage a lifetime of healthy living. This includes not only PA but also healthier eating habits, contributing to the overall quality of life.

Moreover, regular PA helps burn calories and create an energy deficit, which contributes to weight loss or maintenance. Therefore, a healthy diet is an essential component when addressing adolescent obesity. It should include plenty of fruits, vegetables, and whole grains. These foods are rich in nutrients and fiber, which promote satiety and overall health. Lean protein sources help build and repair tissues, supporting growth and development. The intake of processed foods, sugary drinks, and unhealthy fats should be limited since these foods are high in calories and low in nutrients, contributing to weight gain and health problems (PriyAdArShini et al., 2021; Latino et al., 2021).

Addressing adolescent obesity requires a comprehensive approach that combines PA and a healthy diet. These interventions can effectively reduce excess weight, improve physical and mental health, and enhance overall well-being. By promoting healthy lifestyle habits among adolescents, we can empower them to achieve their full potential and lead fulfilling lives.

Studies have shown that males tend to lose weight more effectively than females through PA and dietary changes and in fact in our study, males experienced a more favorable weight reduction compared to females.

Furthermore, regular PA can significantly improve respiratory functions in obese adolescents. Exercise strengthens the respiratory muscles, increases lung capacity, and improves oxygen utilization (Pleasants et al., 2024). In the present investigation, a comparison of pre- and post-training values of ventilatory parameters indicated a significant improvement in Peak Inspiratory Flow (PIF), Peak Expiratory Flow (PEF), and Forced Vital Capacity (FVC) within the experimental group ($p<0.05$). On the contrary, the control group did not show any enhancements in lung parameters after the training program ($p>=0.05$) (Table 3). Additionally, following the 8-month intervention program, PIF exhibited a significantly higher value ($p= 0.04$) in the experimental group compared to the control group (Table 3). This difference is likely due to the fact that PA triggers more pronounced ventilatory responses, thereby facilitating improved and sustained ventilation to meet gas exchange demands during PA and subsequent training adaptations. Prior research has suggested that PA focused on enhancing motor skills can increase maximal respiratory function in inactive individuals (Latino, Greco, Fischetti, & Cataldi, 2019; Wang et al., 2023) while also boosting inspiratory muscle strength in active, healthy individuals (Svartengren et al., 2020). Moreover, strength training has been observed to induce unique changes in the respiratory system, characterized by increased diaphragm mass and respiratory muscle strength in children and adolescents (Smith et al., 2014). This effect is likely a result of strength exercises like jump squats and burpees, which stimulate the respiratory muscles by engaging them in maintaining spinal stability (Breda et al., 2021). Several previous studies have reported similar findings, demonstrating improvements in PIF following respiratory exercises and muscle strength training (Washburn et al., 2014). PIF represents the maximum flow rate achieved during maximal inhalation and serves as an indicator of the inspiratory muscles' maximum contraction capacity (Curioni, & Lourenço, 2005). The PA program employed throughout this study included deep inhalations and inspiratory hiccups, exercises aimed at strengthening the inspiratory muscles, while activities such as planks and push-ups targeted enhancing expiratory muscle strength.

It can be inferred that an elevation in BMI results in a reduction in FEV1 and FVC values. This indicates that obesity in adolescent males impacts pulmonary functions. This period is crucial for identifying pulmonary impairment in order to implement interventions aimed at reducing obesity in adolescents and preventing future adult obesity (Hagan et al., 1986). It is advisable to encourage children to engage in more outdoor physical activities and ensure adequate sleep of at least 8–9 hours per day. It is essential to be cautious of consuming high-calorie diets, junk food, and to limit screen time including TV, mobile games, and video games (Wing et al., 1998).

Overall, the study emphasizes the multifaceted benefits of PA in safeguarding health, promoting well-being, and restoring lost functionality. It highlights the importance of movement as a cornerstone of a healthy lifestyle. The study's findings highlight the importance of individualizing weight loss goals and strategies. The positive subjective experiences reported by participants suggest that sports programs can promote both physical and mental health benefits for obese adolescents (Jakicic et al., 2015).

A consistent body of evidence supports the notion that combining PA with dietary adjustments leads to more significant weight loss compared to relying solely on dietary modifications. Washburn et al. (2014) conducted a systematic review affirming that weight loss is notably higher when PA is paired with dietary changes, as opposed to dietary modifications alone (resulting in a median weight loss of 8.8% of initial body weight versus 6.9%). This finding was further corroborated by an earlier review indicating a 20% greater weight loss with the combined approach compared to dietary modifications alone (Baigi et al., 2022). Moreover, research suggests that this substantial difference in weight loss outcomes between PA combined with dietary modifications and dietary changes alone remains consistent even with shorter intervention durations lasting from 12 to 24 weeks (Pagliara et al., 2021). A recent study investigating a 4-week comprehensive behavioral weight loss intervention involving 282 adolescents [mean age, 12.89 ± 2.28 y; 53.5% male; mean height, 162.41 ± 10.94 cm; mean Body Weight, 81.65 ± 19.44 kg; mean Waist Circumference., 97.4 ± 11.4 cm] utilized an objective evaluation of PA and sedentary behaviors (Yang et al., 2022). The study revealed that children and adolescents can benefit from diet- and exercise-based interventions in improvement of body weight, waist circumference, and BMI. These findings offer valuable insights into the specific patterns and intensities of PA that should be emphasized within comprehensive weight loss programs integrating behavioral and dietary modifications. Although PA can enhance weight loss beyond what is achievable through dietary modifications alone, its effectiveness in further promoting weight loss appears to hinge on the level of dietary adjustments made and the extent of caloric intake. A literature review by Donnelly et al. (1994) indicated that the impact of PA on weight loss diminishes when dietary restrictions are severe (resulting in energy intake below the amount required to meet resting energy expenditure). For instance, studies on very-low-calorie diets (≤800 kcal per day) have demonstrated that incorporating endurance or resistance exercise does not augment weight or fat loss compared to the outcomes from severe dietary restrictions alone (Van De Kolk et al., 2019). Nevertheless, enhancements in cardiorespiratory and musculoskeletal fitness have been observed in response to either endurance or resistance training, respectively, even in conjunction with strict dietary limitations (Hopkins et al., 2022). The ongoing inquiry presents evidence that supports a positive correlation between sport programs and weight status; however, certain constraints within the study require further examination (Confroy et al., 2021). Specifically, the main limitation involves the physical tests used to evaluate the participants' fitness starting level at baseline and after training. These tests were chosen in order to obtain a complete evaluation of the participants and because they are easier to undertake, take little time and require simple equipment. However, in order to accomplish the purpose of this study, several tests should have been conducted to assess endurance performance, muscle strength, balance, coordination, and dexterity. Another limitation regarded the limited sample size of 60 participants was a result of challenges in recruiting participants. Additionally, the inability to control the dietary and sleep patterns of the participants poses a significant limitation. Moreover, the unequal distribution of genders among the participants within the research groups may hinder the study's applicability to a broader population (Latino, Cataldi, & Fischetti, 2021, Corvino et al., 2020; Messina et al., 2016). Limitations include the reliance on self-report measures of participation in PA, screen time and eating habits. The study also failed to investigate socio-emotional factors associated with PA, indicating another area of limitation. Hence, future research should investigate similar variables across a more diverse and extensive sample. Despite these limitations, the results obtained could offer valuable insights for future research endeavors. As a result, the study's effectiveness was bolstered by a systematic approach that produced immediately applicable positive results for daily training regimens.

Conclusions

The debate around the best interventions for combating obesity in teenagers often centers on diet and lifestyle changes. Among these, sport programs are frequently advocated for their multifaceted benefits. While some argue that dietary adjustments alone can suffice, a compelling case exists for the significant role of sport programs in improving the health of obese teenagers. Sport programs offer a comprehensive approach to tackling obesity in teenagers, addressing not just physical health, but also dietary eating habits and pulmonary function. Encouraging obese teenagers to participate in sports can lead to lasting positive changes in their health and quality of life.

While dietary changes and other lifestyle adjustments are crucial when addressing teenage obesity, sport programs offer a uniquely comprehensive array of benefits that address physical, and long-term health dimensions. The potential for sport programs to instill lifelong healthy habits and prevent chronic diseases underscores their importance.

In conclusion, the proposed program may suppose a useful tool to improve pulmonary function, reduce the burden and prevalence of adolescent obesity and its associated comorbidities. Therefore, it is imperative that policymakers, educators, and healthcare providers recognize and support the integration of sport programs into the lives of adolescents to ensure their healthy development and long-term health.

Author Contributions

Conceptualization, F.M. and F.L.; methodology, F.M. and F.L.; software, F.T.; validation, F.M., F.L. and F.T.; formal analysis, E.S. K.A. and N.S.; investigation, F.M., F.L. and F.T; data curation, F.M; writing—original draft preparation, F.M. and F.L.; writing—review and editing, F.L.; funding acquisition, D.T. All authors have read and agreed to the published version of the manuscript.

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Informed Consent Statement

Written informed consent has been obtained from the patient(s) to publish this paper.

Conflicts of Interest

The authors declare no conflict of interest.

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