IJMA

International Journal of Medical Arts

VOLUME 6, ISSUE 6, JUNE 2024

P- ISSN: 2636-4174
E- ISSN: 2682-3780

Available online at Journal Website
https://ijma.journals.ekb.eg/
Main Subject [Physical Therapy]

Original Article

Effect of Resistance Training on Physical Performance in Underweight Females

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Article information

Received: 09-05-2024

Accepted: 14-06-2024

DOI: 10.21608/IJMA.2024.288279.1966.

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Citation: Abd AL-aal EMR, Obaya HE, Ghaleb HAM. Effect of Resistance Training on Physical Performance in Underweight Females. IJMA 2024 June; 6 [6]: 4566-4572. doi: 10.21608/IJMA. 2024.288279.1966.

ABSTRACT

Background: Underweight persons have problems in increasing muscle size, body weight and also fitness levels. Resistance training [RT] has remarkable effect in increasing muscle size [hypertrophy].

Aim of the work: To determine the effect of resistance training on muscle strength, physical performance and psychological state in underweight females.

Patients and Methods: Sixty underweight females were recruited in this study. They were selected from the clinical nutrition department, Kafr Al Zayat general hospital. They aged from 20 to 30 years old with a BMI between 16 to 18.4 kg/m². They randomly distributed into two equal groups; Group A [Study group] [Resistance training group]: 30 female subjects received strengthening training exercises in the form of upper body exercises [push-up, dips, bridges and planks] and lower body exercises [squats and lungs], in addition to high caloric diet, and group B [Diet group] received only high caloric diet. BMI, muscle mass, muscle strength measurements, physical performance and Rosenberg self-esteem scale were assessed pre and post the study.

Results: There was a significant increase in all variables that represent BMI [2.92%], skeletal muscle mass [10,46 %], muscle strength measures for upper limb [shoulder abduction, elbow flexion, elbow extension [15.21% , 55.16% , 26.50 % respectively] and for lower limb [planter flexion, ankle dorsiflexion, knee extension [13.51%, 15.53%, 43.34% respectively], six minute walk test [6.90%], one minute sit-up test [43.99%] and Rosenberg self-esteem scale [37.05%] in resistance training group [A] than diet group [B] but there was no significant difference between all these variables in between groups pre-treatment [p>0.05].

Conclusion: Resisted training has significant optimistic effects on muscle bulk, muscle strength and improving physical performance and psychological state for underweight females. Therefore, it is recommended as a basic program for underweight females.

Keywords: Underweight; Physical performance; Resistance training.

INTRODUCTION

Young women who are thin, consume little food, and are inactive are just as likely to develop diabetes as obese individuals. Measures of body mass index [BMI] indicate that extreme obesity [BMI>35 kg/m2] and underweight [BMI<18.5 kg/m2] are linked to a markedly increased risk of negative health outcomes. The prevalence of underweight women in the 20–29 age group reached 29.0% in 2010, but it remained high at 20.7% in 2019, according to the National Health and Nutrition Examination Survey report. Thus, investigating the causes of young women's thinness and how they relate to potential health risks and preventative actions is an urgent need [1].

Globally, malnutrition costs billions of dollars annually due to missed chances for economic expansion and underinvestment in human capital as a result of avoidable deaths in both adults and children [2]. Compared to women of normal weight, underweight women [UW] are more likely to display worse psychological wellbeing. It has also been discovered that low self-esteem, excessive stress levels, and body dissatisfaction are related. Furthermore, thinness in young women is also associated with inadequate nutritional intake and inactivity [1].

When prescribed and monitored properly, resistance training [RT] is a safe and efficient means of enhancing physical performance markers in healthy children and adults. Children and adolescents who receive RT may have improvements in their muscle strength and motor skills, such as their ability to jump [3]. Resistance training is the application of physical activities intended to increase muscular strength and stamina. Lifting weights is frequently connected to it. A range of training methods, including bodyweight exercises, isometrics, and plyometrics, can also be included [4].

Resistance training at a low-to-moderate intensity may also help to avoid arterial stiffness. Apart from these overall health benefits, RT also offers certain benefits particular to gender. Studies on RT in women show that during leg training, exercise-induced femoral artery dilatation was higher in women than in males. The 2020 guidelines of the World Health Organization who have incorporated RT. This emphasizes the need for a more thorough examination of women's training results connected to RT [5]. Therefore, the study focuses on improving muscle mass and improve physical performance and psychological state for underweight female patients.

PATIENTS AND METHODS

Subjects: The present study included 60 underweight females between November 2023 and February 2024. They were selected from the Clinical Nutrition Department, Kafr Al Zayat General Hospital.

The study protocol was approved by the Ethical Committee of the Faculty of Physical Therapy, Cairo University, Egypt at 2023 [No.P. T.REC/012/004793]. Before enrolling into the trial, the investigators ensured that informed written permission was acquired from each participant.

The inclusion criteria were as follows: females aged from 20 to 30 years old with a BMI between 16 and 18.4 kg/m².

Subjects were excluded if they had hearing impairment or mental disorder, orthopedic disorders, moderate and severe anemia [hemoglobin level is below 8.0 g/dl], thyroid dysfunction, hypotension [100/60] or uncontrolled hypertension [150/105], dyspnea at rest, recent pulmonary embolism, auto immune diseases and neuromuscular disease [muscular dystrophy, myasthenia gravis, myopathy, multiple sclerosis and peripheral neuropathy.

Randomization: Fifty-two underweight females were randomly selected and distributed into two groups using computer generation. The sample size was calculated using the G*Power statistical software [version 3.1.9.2; Franz Faul, Universitat Kiel, Germany] [6] and revealed that the required sample size for this study was 26 subjects per group. The calculation was made with $\alpha = 0.05$, power = 80%, and effect size = 0.8.

Evaluation procedures: Before and after 8 weeks of training, all participants were evaluated using the following measures: muscle strength, which was assessed by the Hand Held Dynamometer [HHD] as the main outcome, and physical performance, which was assessed by the six-minute walk test and the 1-minute sit-up test, as secondary outcomes. Additionally, the participants' psychological state was assessed using the Rosenberg self-esteem scale.

Treatment protocols

Sixty underweight females were selected randomly and distributed in two groups of equal size:

Group A [Resistance training group]: 30 females received strength training in addition to a high-calorie diet. The treatment frequency was

three sessions per week, and the entire program duration was 8 weeks. The treatment program consisted of three parts. The first part involved a 5 to 10-minute warm-up, which included stretching major muscle groups of the upper and lower body. The second part, the main part, was divided into exercises for the upper body, including push-ups, dips, bridges, and planks, and exercises for the lower body, including squats and lunges. The training protocols for push-ups, dips, squats, and lunges consisted of two sets of eight repetitions in the first week, three sets of 8 repetitions during weeks 2-3, and three sets of 12 repetitions during weeks 4-8. The format and relative intensity of the training protocols for bridge and plank exercises involved maintaining the correct position for the maximum possible time. The third part, the cooling down phase, involved 5 to 10 minutes of stretching major muscle groups of the upper and lower body. The duration of the sessions was 30 to 45 minutes for the first 4 weeks and 45 to 60 minutes for the last 4 weeks [7].

Group B [High caloric diet group]: 30 females received only a high-calorie diet. Count the number of calories each person in the group consumes on an average day, add these calories together for all 3 days, and then divide that total by three. This will give you the average daily caloric intake for each of them. To gain 1 pound weekly, increase the average daily caloric intake by 500, or by 1,000 to gain 2 pounds weekly [8]. They were re-assessed every week to ten days to check if there were any problems facing them.

Statistical Analysis: The statistical analysis was conducted by using statistical SPSS Package program version 25 for Windows [SPSS, Inc., Chicago, IL]. Shapiro-Wilk test was used to assess the normality of the data distribution, Levene's test for testing the homogeneity of variance revealed that there was no significant difference [P>0.05]. Independent [unpaired] t-test used to compare between resistance training group and diet group at pre and post treatment for general characteristics of underweight females. Mixed design 2 x 2 MANOVA-test used to compare the tested major dependent variables of interest [body measurements, physical performance, muscle strength, and psychological state] at different two groups [resistance training group vs. diet group] and measuring durations [pre-treatment vs. post-treatment]. Bonferroni correction test [Post hoc-test] to compare between pairwise within and between groups of the tested dependent variables. All statistical analyses were significant at level of probability [$P \leq 0.05$].

RESULTS

Table [1] displayed the demographic characteristics of both groups [A and B]. The groups exhibited no statistically significant difference in age, weight, height, and BMI [P> 0.05].

The underweight females who received the strengthening training and healthy high-caloric diet program showed greater improvements in weight [2.94%], BMI [2.92%], and skeletal muscle [10.46%] compared to underweight females who received only a healthy high-caloric diet program [1.89%, 1.57%, and 1.53%, respectively]. Moreover, the significant increase in mean values of skeletal muscle at post-treatment [43.83 ±3.81] was more favorable in the underweight females in the strengthening group than those in the diet group [39.81 ±3.47] [Table 2].

The underweight females who received the strengthening training and healthy high-caloric diet program also showed greater improvements in shoulder abduction [15.21%], elbow flexion [55.16%], elbow extension [26.50%], plantar flexion [13.51%], ankle dorsiflexors flexion [15.53%], and knee extension [43.34%] compared to underweight females who received only a healthy high-caloric diet program [2.45%, 20.37%, 0.64%, 0.78%, 2.11%, and 0.40%, respectively] [Table 3].

Finally, the underweight females who received the strengthening training and healthy high-caloric diet program demonstrated greater improvements in the 6MWT [6.90%], one-minute sit-up test [44%], and Rosenberg self-esteem scale [37.05%] compared to underweight females who received only a healthy high-caloric diet program [2.1%, 2.9%, and 16.6%, respectively] [Table 4].

Table [1]: Clinical general characteristics for underweight females in both groups

Items	Groups [Mean ±SD]		P value
	Strengthening group [n=30]	Diet group [n=30]	
Age [year]	25.22 ±3.49	25.09 ±3.07	0.887
Weight [kg]	48.04 ±2.64	48.67 ±2.84	0.312
Height [cm]	164.20 ±3.27	165.18 ±3.63	0.411
BMI [kg/m^2]	17.80 ±0.72	17.84 ±0.52	0.827

Data are expressed as mean ±standard deviation; P-value > 0.05: non-significant

Table [2]: Within and between groups comparison for weight, BMI and skeletal muscles

Variables	Items	Groups [Mean ±SD]		Change	P-value [2]
		Strengthening group [n=30]	Diet group [n=30]		
Weight [kg]	Pre-treatment	48.04 ±2.64	48.67 ±2.84	0.63	0.399
	Post-treatment	49.45 ±2.63	49.59 ±2.61	0.14	0.845
	Change [MD]	1.41	0.92		
	95% CI	-0.07 – 2.88	-0.55 – 2.39		
	Improvement %	2.94%	1.89%		
	P-value [1]	0.062	0.220		
BMI [kg/m^2]	Pre-treatment	17.80 ±0.72	17.84 ±0.52	0.04	0.827
	Post-treatment	18.32 ±0.73	18.12 ±0.52	0.20	0.248
	Change [MD]	0.52	0.28		
	95% CI	0.17 – 0.87	-0.06 – 0.62		
	Improvement %	2.92%	1.57%		
	P-value [1]	**0.004***	0.113		
Skeletal muscle [%]	Pre-treatment	39.68 ±4.46	39.21 ±3.16	0.46	0.656
	Post-treatment	43.83 ±3.81	39.81 ±3.47	4.02	**0.0001***
	Change [MD]	4.15	0.60		
	95% CI	2.08 – 6.21	-1.47 – 2.66		
	Improvement %	10.46%	1.53%		
	P-value [1]	**0.0001***	0.571		

Data are reported as mean ± standard deviation [SD]; MD: Mean difference; CI: confidence interval *: Significant [P<0.05]; P-value[1]: probability value within each group; P-value[2]: probability value between both groups, pre- and post-treatment

Table [3]: Within and between groups comparison for muscle strength measurements

Variables	Items	Groups [Mean ±SD]		Change	P-value [2]
		Strengthening group [n=30]	Diet group [n=30]		
Shoulder abduction [kg]	Pre-treatment	17.36 ±1.09	17.57 ±0.89	0.21	0.469
	Post-treatment	20.00 ±1.17	18.00 ±0.93	2.00	**0.0001***
	Change [MD]	2.64	0.43		
	95% CI	2.07 – 3.20	-0.13 – 0.99		
	Improvement %	15.21%	2.45%		
	P-value [1]	**0.0001***	0.135		
Elbow flexion [kg]	Pre-treatment	20.45 ±3.84	22.53 ±4.53	2.08	0.684
	Post-treatment	31.73 ±3.90	27.12 ±2.39	461	**0.012***
	Change [MD]	11.28	4.59		
	95% CI	2.14 – 20.39	-4.53 – 13.71		
	Improvement %	55.16%	20.37%		
	P-value [1]	**0.0001***	**0.016***		
Elbow extension [kg]	Pre-treatment	17.28 ±2.63	18.71 ±2.17	1.43	0.062
	Post-treatment	21.86 ±2.08	18.83 ±2.18	3.03	**0.0001***
	Change [MD]	4.58	0.12		
	95% CI	3.36 – 5.79	-1.09 – 1.32		
	Improvement %	26.50%	0.64%		
	P-value [1]	**0.0001***	0.851		
Planter flexion [kg]	Pre-treatment	26.80 ±4.09	26.91 ±4.77	0.11	0.928
	Post-treatment	30.42 ±4.01	27.12 ±4.76	3.30	**0.008***
	Change [MD]	3.62	0.21		
	95% CI	1.19 – 6.06	-2.22 – 2.64		
	Improvement %	13.51%	0.78%		
	P-value [1]	**0.004***	0.864		
Ankle dorsiflexors flexion [kg]	Pre-treatment	18.22 ±2.20	19.00 ±2.18	0.78	0.264
	Post-treatment	21.05 ±3.13	19.40 ±2.32	1.65	**0.020***
	Change [MD]	2.83	0.40		
	95% CI	1.45 – 4.19	-0.97 – 1.77		
	Improvement %	15.53%	2.11%		
	P-value [1]	**0.0001***	0.561		
Knee extension [kg]	Pre-treatment	18.62 ±2.15	20.06 ±2.44	1.44	0.052
	Post-treatment	26.69 ±2.34	20.14 ±3.42	6.55	**0.0001***
	Change [MD]	8.07	0.08		
	95% CI	6.61 – 9.51	-1.37 – 1.52		
	Improvement %	43.34%	0.40%		
	P-value [1]	**0.0001***	0.921		

Data are reported as mean ± standard deviation [SD]; MD: Mean difference; CI: confidence interval; * Significant [P<0.05]; P-value[1]: probability value within each group; P-value[2]: probability value between both groups at pre- and post-treatment

Table [4]: Within and between groups comparison for physical performance and psychological state measurements

Variables	Items	Groups [Mean ±SD]		Change	P-value [2]
		Strengthening group [n=30]	Diet group [n=30]		
Six-minute walk test [m]	Pre-treatment	327.94 ±25.09	332.32 ±26.89	4.38	0.663
	Post-treatment	350.57 ±54.59	339.24 ±29.93	11.33	**0.0001***
	Change [MD]	22.63	6.92		
	95% CI	2.73 – 42.53	-12.98 – 26.81		
	Improvement %	6.90%	2.08%		
	P-value [1]	**0.0001***	0.492		
One minute sit up test [repetition]	Pre-treatment	18.80 ±3.07	17.23 ±2.50	1.57	0.058
	Post-treatment	27.07 ±3.60	16.73 ±2.52	10.34	**0.0001***
	Change [MD]	8.27	0.50		
	95% CI	6.64 – 9.89	-1.12 – 2.12		
	Improvement %	43.99%	2.90%		
	P-value [1]	**0.0001***	0.544		
Rosenberg self-esteem scale [points]	Pre-treatment	19.81 ±6.97	19.50 ±6.90	0.30	0.870
	Post-treatment	27.15 ±6.66	22.73 ±6.54	4.42	**0.021***
	Change [MD]	7.34	3.23		
	95% CI	3.61 – 11.07	-0.49 – 6.95		
	Improvement %	37.05%	16.56%		
	P-value [1]	**0.0001***	0.089		

Data are reported as mean ± standard deviation [SD]; MD: Mean difference; CI: confidence interval; * Significant [P<0.05]; P-value[1]: probability value within each group; P-value[2]: probability value between both groups at pre- and post-treatment

DISCUSSION

Resistance training can be used as a potential method to balance the decline in muscle mass, strength, and body dissatisfaction, as developments in muscle mass have been noticed alongside psychological improvements in women of middle age after engaging in RT [9].

This study was conducted to explore the effects of RT on physical performance, muscle strength, and psychological state in underweight females. This was achieved by assessing BMI, muscle mass, muscle strength, physical performance, and self-esteem after 8 weeks of RT in addition to a healthy, high-calorie diet program.

This is one of the few studies to assess a rehabilitation program that may be quite demanding for the treatment of underweight complications and its effects on daily physical activity. After the rehabilitation program involving resistance training, muscle strength, physical performance, and self-esteem were improved. Participant satisfaction was high, and no adverse effects were reported. The results of the present study revealed a significant increase in BMI of the strengthening group by 2.92% post-treatment.

Resistance training increases body mass by elevating the basal metabolic rate, which in turn enhances the ability to intake food and increase muscle mass, both of which contribute to an increase in body weight.

The results of the present study are consistent with **Sjjapong *et al.*** [7], who found that after eight weeks of resistance training and a high-calorie diet, the subjects experienced weight gains of 1.06% and 0.88% respectively, following the high-calorie diet only. This aligns with the findings of **Skattebo *et al.*** [10], who reported that after ten weeks of resistance training, qualified young female cross-country skiers experienced an increase in body mass of about 2.5±1.2%.

The results of the present study revealed a significant increase in skeletal muscle of 10.46% after treatment in the strengthening group. This finding is in line with the conclusion drawn by **Legerlotz *et al.*** [11], who determined that RT with upper and lower body exercises combined with a high protein diet resulted in increased body weight and improved body composition.

Furthermore, when comparing the two groups post-treatment, a significant difference in skeletal muscle was found, favoring underweight females who received the strengthening training and a healthy high-calorie diet program over underweight females in the healthy high-calorie diet group.

Moreover, a study by **Ormsbee *et al.*** [12] found that RT improved muscular growth and strength by increasing the synthesis of muscle proteins. High-calorie diets rich in protein and amino acids have been shown to enhance the physiological benefits of resistance training, including increased muscular strength, hypertrophy,

and improvements in body composition, while also inhibiting exercise-induced proteolysis.

Additionally, the present study aligns with the findings of **Liu *et al.*** [13], who reported that resistance band intensity is adequate to activate muscles and encourage muscle fiber thickening. Furthermore, self-weight training engages multiple muscle groups simultaneously, providing a more comprehensive approach to muscle building compared to isolated muscle stimulation.

In accordance with the muscle strength of the upper limb, the results of the study showed a significant increase in shoulder abduction, elbow flexion, and elbow extension by 15.21%, 55.16%, and 26.50% respectively in the strengthening group [A]. This improvement in muscle strength in the strengthening group was attributed to the fact that resistance exercise increased muscle fiber synthesis, which in turn allowed the muscles to work more effectively without limitations, leading to an increase in muscle strength. Additionally, the high caloric diet provided an increased level of protein and carbohydrates, supplying the muscles with the necessary energy for exercises, thereby improving muscle capability for physical mobility and increasing muscle strength.

Furthermore, in relation to the strength of the muscles of the lower limb, the results of this study indicated a significant increase in ankle plantar flexion, ankle dorsiflexion, and knee extension by 13.51%, 15.53%, and 43.34% respectively in the strengthening group.

Mazzwtti *et al.* [14] found that long-term training, typically more than six weeks for previously trained subjects, has been shown to increase the force production capacity of intact muscle by increasing the cross-sectional area of individual muscle fibers as a result of fiber hypertrophy.

Although it has been shown that prescribed RT improves muscle strength, power, and speed measurements, these findings were derived from studies that included intervention periods ranging from 4 to 12 weeks [15, 16].

The results of the current study were supported by **Harries*et al.*** [17], who reported that, instead of muscle growth, enhanced neuromuscular activation and coordination following RT are typically responsible for increases in strength and power in both underweight pre-adolescents and adolescents.

According to the results of the physical performance measurements, the present study showed a significant increase in the 6MWT and the 1-minute sit-up test by 6.90% and 43.99% respectively in the strengthening group.

To our knowledge, this study was one of the first and limited studies to directly examine muscle strength of different body parts and its impact on physical performance in underweight women.

The outcomes of the study are in agreement with **Foroncewicz *et al.*** [18], who indicated that measurements of exercise capacity were a primary element to assess patients after any rehabilitation program. Although the 6MWT and 1-minute sit-up test delivered information about functional capacity, therapy response, and prognosis after that specific program. The increase in muscle mass and strength of quadriceps and abdominal muscles allowed each woman to perform the 1-minute sit-up test very easily and quickly, which indicated an improvement in physical and functional performance after participating in the resistance training in addition to a healthy high-caloric diet.

The results of our study showed a significant increase in the Rosenberg Self-Esteem Scale score [RSES] by 37.05% in the strengthening group. This increase in the RSES score might be a result of improvements in body composition, body shape, muscle strength, and the ability to perform activities of daily living. All of these improvements should ultimately enhance the psychological aspects by increasing self-esteem.

Our results are in agreement with **Sajjapong *et al.*** [7], who stated that changes in muscle mass and body weight improved simultaneously with the self-esteem score for body image.

In line with the findings of **Velez *et al.*** [19], who found that teenagers who participated in RT for 12 weeks saw improvements in their self-esteem scores for body image from the pre-test to the post-test, while the control group showed no change.

There are several limitations to consider. The physical status of underweight females might affect the treatment program, as well as the differences in motivation between them. Additionally, the ability of underweight females involved to follow the instructions of the treatment program is a factor.

Conclusion: It was concluded that underweight females experienced a reduction in physical performance, muscle strength, and psychological and emotional well-being. Resistance training exercises, especially push-ups, dips, bridges, planks, squats, and lunges, are recommended for underweight females, along with a high-calorie diet. Therefore, resistance training exercises appear to be an effective way to rehabilitate underweight females, increasing physical performance, muscle strength, overall fitness, and psychological well-being.

Conflicts of interest: None.

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IJMA

International Journal of Medical Arts

VOLUME 6, ISSUE 6, JUNE 2024

P- ISSN: 2636-4174
E- ISSN: 2682-3780