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Original Article

The influence of endurance and strength training on body composition and physical fitness in female students

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Abstract
Introduction. Physical activity plays a major role in human life. Faced with the threats of a sedentary lifestyle, it becomes a key factor conditioning proper physical, social and mental development of a young body. The benefits of physical activity are obvious. Its optimal level stimulates development, secures motor needs, strengthens heart function, improves muscle and joint flexibility, strengthening the muscles and bones. In the literature on physical activity, the importance of endurance and strength training as well as its positive impact on achieving a higher level of physical fitness is emphasized among people of different ages. In addition, research results indicate clear progress when even applying 4 weeks of training.**Objective.** The aim of the study was to examine the influence of a 6-week endurance and strength training programme on adaptive changes within body composition and physical fitness of young women. **Materials and methods.** The study involved 11 women aged 23-27 (x=24.09±1.30), students of the Cracow University of Economics. The research procedure included measurements of shoulder, chest, waist, hip, thigh and calf circumference, followed by body composition analysis using the TANITA BC-1000 scale. Percentage of body fat, total percentage of body water, muscle mass, basal metabolic rate, metabolic age, bone mass and level of visceral fat were measured. Subsequently, the EUROFIT physical fitness test was conducted. The following tests were selected: balance, agility, jumping, static strength, trunk strength, functional strength of upper limbs and shoulder girdle, and speed as well as endurance. Upon completion of the 6-week study, endurance and strength training consisting of 3 programmes were carried out: full-body, i.e. moderate-intensity exercises, HIIT, i.e. high-intensity interval training, and turbo training, i.e. high-intensity training combining endurance and strength exercises. **Results.** The results of research showed the significant influence of training on the reduction in hip circumference, waist and body fat content of the surveyed women, as well as improvement in their level of physical fitness in terms of postural balance, agility, jumping ability, static force, abdominal muscles and functional strength of the shoulders and shoulder girdle, speed and running endurance. **Conclusion.** The 6-week endurance and strength training reduced circumferences of the examined women and the level of body fat while increasing muscle mass and improved physical fitness. Bearing in mind the positive impact of training on the components of body composition and the level of human physical fitness, it is advisable to intensively promote active ways of spending free time.
Keywords: physical activity, body components, fitness, women

Introduction

It has long been known that technical progress has caused a radical decrease in human physical activity, which is primarily associated with lower levels of muscular strength and cardiovascular endurance(Kudryavtsev et al. 2018).Faced with the threats of a sedentary lifestyle, physical activity becomes a key factor conditioning proper physical, social and mental development of a young body.The benefits of physical activity are obvious. Its optimal level stimulates development, secures motor needs, strengthens heart function, improves muscle and joint flexibility, strengthening the muscles and bones. It has been proven that active people, compared to those inactive, enjoy a better well-being and are less likely to experience mental or physical discomfort.According to the Global Recommendations on Physical Activity for Health (2010), the minimum level of physical activity among adults should include moderate aerobic exercise for at least 150 minutes per week or intense aerobic exercise - at least 75 minutes per week.

The objective of this activity is to increase the overall physical fitness of a person and thus, to improve physical and mental health (Strohle, 2009).To achieve even greater health benefits, it is recommended to increase moderate aerobic physical activity to 300 minutes per week or 150 minutes of intense aerobic exercise per week. It has long been known that regular physical activity causes numerous adaptations within the skeletal, muscular and cardiopulmonary systems. Therefore, deficits associated with this activity should be seen as a negative phenomenon within the context of human health.In undertaking physical activity, the important role of

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motives is emphasized, among which the health factor stands out, especially preferred by the female population (Woll and Bös, 2002; Schuch et al. 2014; Sawicki and Suchý, 2017; Sawicki, 2018). Adaptation through physical exercises is a key principle of kinesiology, which refers to the improvement of health, well-being and physical fitness in human populations of different age groups (Staron et al., 1994).

According to Garber et al. (2011), adaptation processes may lead to morphological (e.g. muscle mass, bone mass, fat mass, water content) as well as functional changes in the body (physical fitness) depending on the type and scope of physical load, age, sex and external conditions, while the level of physical fitness depends on the frequency, intensity, duration and type of physical activity (Thum et al., 2017). There are many different types of motor interventions that can be used in kinesiology to achieve desired adaptive effects. The main ones include endurance aerobic training which helps improve cardiovascular fitness (Höltke, 2003; Schjerve et al., 2008).In fitness training, anaerobic exercises that can increase muscle strength and reduce body mass are also of great importance (Campbell et al., 1994; Jozsi et al., 1999). Krüger (2011) emphasizes that there is an interaction between endurance and strength training. Without sufficient muscle strength, optimal endurance training is not possible. In addition to aerobic endurance, it is therefore advisable to train the strength of muscles that are particularly subjected to stress during endurance training.Many experts in the field of sports and physical education emphasize the great impact of intensive functional training on the process of developing strength, endurance, flexibility and coordination by performing a multitude of exercises involving various muscle groups and joints, their effects influencing people of different ages and of both sexes (Greenlee et al. 2017; Phillips et al. 2017).Tomschi et al. (2018) highlight the greater impact of mixed training (aerobic-anaerobic) on the overall level of muscle strength and cardiovascular endurance, while Weiss (2010) and Cassemiro et al. (2017) prefer traditional training aimed at achieving significant effects in e.g. strength or endurance, especially among those involved in competitive sports.

According to Hennig (2020) and Thiel (2018), the most effective training programme is a set of exercises performed at high or maximum intensity in a relatively short time (30-60 seconds), combined with specified periods for rest. The most important forms of this type of training include HIIT (High-Intensity Interval Training), which aims to burn fat, improve body endurance and strengthen muscles.Depending on the degree of endurance and strength training, the duration of each session should be from 15 to 20 minutes or longer. It should also be underlined that the minimum duration of the entire training programme is 4 weeks at a frequency of 2-3 times a week and all parts of the body should be involved in the training. For optimal results, endurance and strength training is applied over a period of several weeks. In their research, Furman et al. (2018) show that after a 16-week cycle of exercises aimed at improving functional fitness of the body as well as endurance and muscle strength of participants, significant progress was achieved. A similar view is also expressed by Froböse (2014),who emphasizes the reasonability of implementing endurance and strength training without using external loads for people from different age groups. In addition to water, the main components of the body are fat, muscle and bone mass. They form the so-called base of physical features, which plays the most important role in maintaining and increasing the level of activity and physical as well as sport-related fitness (Seiler, 2010; Stöggl and Sperlich, 2015; Rybakova et al., 2020).

Achieving a high level of physical fitness is possible due to a mutual relationship between the quality of body composition elements and the specificity of sport and physical activity (Branco et al., 2015; Rybakova et al., 2020).Generally, it may be stated that research devoted to physiological adaptation of the body of young people (especially of women) as a result of functional training of both athletes and people who are not involved in competitive sport, is not very vast, and therefore, should be conducted on a larger scale.The aim of this work is to determine the influence of 6-week endurance and strength training on adaptive changes regarding the body composition and physical fitness of young women. The study on body composition included: the amount of fat, total water, muscle mass, basal metabolic rate, metabolic age, bone mass, level of visceral fat, while the analysed elements of physical fitness were strength of the trunk muscles, explosive strength of the lower limbs, strength endurance of the upper limbs and shoulder girdle, cardio-respiratory endurance, body balance and agility.
Carrying out this objective required obtaining answers to the following research questions:
1. Does 6-week endurance and strength training change the anthropometric parameters of the examined women?
2. Does 6-week endurance and strength training change the body composition of the examined women?
3. Does 6-week endurance and strength training improve the physical fitness of the examined women?

Materials & Methods

Participants

The study involved 11 women aged 23-27 (x=24.09±1.30), students of the Cracow University of Economics. The first tests were conducted on 12 Jan. 2019 at a sports hall. First, body composition analysis and anthropometric measurements were performed. Then, the examined women took part in the EUROFIT physical fitness test (Tittlbach and Bös, 2002). Subjects participating in the experiment for 6 weeks (15 Jan. 2019–24 Feb. 2019) were subjected to endurance and strength training. After the training cycle, on 5 Mar. 2019, repeated measurements and tests were carried out to assess changes in the body composition components and physical fitness of the studied women.

Methods

Anthropometric measurements and fitness tests

The research began with anthropometric measurements. The circumference of the arm, trunk, waist, hips, thighs and calves was measured. A tailor tape measure was used for this purpose. The measurements were performed as follows: the height of the subjects was measured using a tape measure. Body composition analysis was conducted using the TANITA BC-1000 scale. Total body mass, body fat and total water content percentages, muscle mass, basal metabolic rate, metabolic age, bone mass and level of visceral fat were measured. The subjects were informed about the measurement methods.

The research used the method of direct observation - the EUROFIT physical fitness test. The following elements were selected: balance test (standing on one foot on a balancing board), agility test (Sit and Reach test), jumping test (standing long jump), static force test (compression of dynamometer using hand), measurement of trunk strength (number of sit-ups performed in 30 seconds), functional strength test of upper limbs and shoulder girdle (hangingon bar with both hands on grips and elbows flexed at 90 degree angle), running speed test (covering 5-metre sections 10 times) and running resistance test (multi-grade shuttle run). Before performing individual tests, the subjects were informed about the method of their performance and measurement.

Experiment

The aim of the experiment was to investigate how endurance and strength training, consisting of 3 training programmes by Marta Hennig (www.codzienniefit.pl), affect changes in circumferences and body composition as well as the physical fitness of the examined women. The experiment included 11 women aged 23-27.

During the first stage of the experiment, the subjects were acquainted with the main principles of training and exercise techniques. The following stage consisted of anthropometric measurements and body composition analysis. The EUROFIT fitness test was then carried out to determine the level of physical fitness. Details of the experiment are described in the 'Methods' section. The study participants underwent 3 training programmes:

• "Full-body", i.e. moderate-intensity exercises aimed at strengthening the whole body, burning fat and improving fitness,

• "HIIT", which is a high-intensity interval type of training, the aim of which was to increase metabolism, burn fat and build fitness,

• "Turbo training", which is a high-intensity training type, combining cardio and strength exercises, enabling fat burning, building fitness and strengthening muscles.

Each training programme was recorded in the form of a video by its author. Subjects exercised at home using the device chosen to recreate the training.

The training programme lasted 6 weeks. The subjects exercised every other day. During the week, they performed 3 or 4 training units. The "Full-body" programme lasted 48 minutes, HIIT - 30.5 minutes, and Turbo training - 53 minutes. Each of them included a warm-up (10 minutes) and cool-down (4 minutes). The training plan is shown in Table 1.

Table 1. Plan of the 6-week endurance-strength training programme

Day of week/week	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
week 1		Full-body		HIIT		Turbo	
week 2	Full-body		HIIT		Turbo		Full-body
week 3		HIIT		Turbo		Full-body	
week 4	HIIT		Turbo		Full-body		HIIT
week 5		Turbo		Full-body		HIIT	
week 6	Turbo		Full-body		HIIT		Turbo

During the week, the subjects spent 131.5 to 179.5 minutes on exercise. Throughout the training period, each programme was performed 7 times. The total volume of training was 15.34 hours.

HIIT TRAINING:

Interval training, the main part lasting about 20 minutes. Consists of 4 series, 4 exercises each. Each exercise is performed for 20 seconds, twice in a row. After each exercise, there is a 10-second interval, and between sets - 60 seconds (for walking in place).

1st series – squat and walk, lunges, squat jumps, jumping lunges

2nd series – push-ups, burpees, push-ups with shoulder tap, burpees with rotation

3rd series – mountain climber (slow), hand-to-toe, mountain climber (fast), hand-to-toe

4th series – plank leg jumping jacks (slow), side plank right, plank leg jumping jacks (fast), side plank left

TURBO TRAINING:

Training consists of 4 blocks. In the 1st block, 3 sets are performed, and in the 2nd, the remaining 2 sets. The 1st, 3rd and 4th block contain 4 exercises and the 2nd - 3 exercises. Each exercise lasts 40 s, between blocks there is a 40-s interval (intended for walking in place). The main part lasts about 43 minutes.

1st BLOCK – split lunges, squat jumps, cross lunges, side step jumps

2nd BLOCK – split lunges and hand-to-toe, skaters, lying hip raises

3rd BLOCK– plank leg jumping jacks, triceps push-ups, burpees, shoulder tap and plank

4th BLOCK – diagonal crunches, sit-ups, march mountain climbers, plank hip rotation

FULL-BODY TRAINING:

Training consists of 4 blocks. There are 3 exercises and 2 series in each block. Exercises are performed alternately after 40 and 20 seconds. The blocks are divided by a 40-second interval. The main part lasts approximately 35 minutes.

1st BLOCK – 2 series, sumo squat with leg lift, squat jumps, sprint in place
2nd BLOCK – 2 series, sumo squat, sumo squat and plank, skaters
3rd BLOCK – 2 series, plank with leg lift, push-ups, side plank leg raise
4th BLOCK – 2 series, plank to downward dog, full-body crunch, side-lying leg lift

Statistical analysis

All research results were subjected to statistical analysis. The basic parameters of descriptive statistics were calculated, i.e. the arithmetic mean, standard deviation, coefficient of variation (Sheskin, 1997). The compatibility of variable distribution with normal distribution was checked using the Shapiro-Wilk test. The differences between the tested parameters were evaluated using the Student's *t*-test for dependent samples (Rea and Parker, 2014). Differences at the level of $p<0.05$ were considered statistically significant.

Results

The first part of the study consisted of anthropometric measurements. Body height, mass and circumferences were measured. All data are shown in Table 2. Body mass decreased slightly (by 0.30%). All body circumferences also experienced reduction. The greatest improvement could be seen in the waist (circumference reduction by 1.77%) and hips (by 1.18%). These changes turned out to be statistically significant (waist: $p=0.03$, hips: $p=0.02$). No statistically significant differences were noted for the calves, thighs, arms or chest.

Table 2. Percentage differences (%) in the level of anthropometric parameters for the subjects (n=11) before beginning the experiment (Test 1) and after its completion (Test 2)

Parameter	Test 1			Test 2			Percentage difference (%) between Tests 1 and 2
	X	SD	CV	X	SD	CV	
Age (years)	24.00	1.30	5.40	24.00	1.30	5.40	-
Height (cm)	164.36	3.38	2.06	164.36	3.38	2.06	-
Total body mass (kg)	63.57	14.9	23.43	63.38	14.95	23.59	0.30 NS
Right arm circumference (cm)	27.36	4.53	16.57	26.90	4.19	15.56	1.68 NS
Left arm circumference (cm)	27.27	4.64	17.01	26.91	4.31	16.02	1.32 NS
Chest circumference (cm)	90.86	8.76	9.64	90.23	7.83	8.67	0.69 NS
Waist circumference (cm)	72.18	9.90	13.73	70.9	9.13	12.87	**1.77 ***
Hip circumference (cm)	96.41	13.32	13.82	95.27	13.18	13.84	**1.18 ***
Right thigh circumference cm)	57.05	7.96	13.96	56.41	7.58	13.44	1.12 NS
Left thigh circumference (cm)	56.86	8.22	14.46	56.14	7.82	13.92	1.27 NS
Right calf circumference (cm)	35.68	3.44	9.63	35.41	3.48	9.82	0.76 NS
Left calf circumference (cm)	35.91	3.42	9.52	35.6	3.39	9.52	0.86 NS

The second part of the study involved body composition analysis. The following were measured: body fat, total water content, muscle mass, basal metabolic rate, metabolic age, bone mass and visceral fat level. Statistically significant changes ($p<0.05$) were noted with regard to body fat and total water content. The average amount of body fat decreased by 3.67% and the total amount of water by 3.27%. Detailed data are presented in Table 3.

Table 3. Percentage differences (%) in the level of body composition parameters of the subjects (n=11) before beginning the experiment (Test 1) and after its completion (Test 2)

Parameter	Test 1			Test 2			Percentage difference (%) between Tests 1 and 2
	X	SD	CV	X	SD	CV	
Body fat (%)	26.44	10.04	37.99	25.47	9.76	38.32	**3.67 ***
Total water content (%)	51.64	6.37	12.33	52.33	6.15	11.74	**3.27 ***
Muscle mass (kg)	43.16	3.96	9.18	43.59	4.49	10.29	0.97 NS
Basal metabolic rate (kcal)	1401	144.99	10.35	1410.73	157.74	11.18	0.69 NS
Metabolic age (years)	23.27	11.84	50.88	22.18	11.30	50.96	4.68 NS
Bone mass (kg)	2.31	0.20	8.76	2.34	0.25	10.7	1.30 NS
Level of visceral fat	2.73	2.41	88.44	2.45	2.16	88.07	10.26 NS

*Comments: significant differences: *p<0.05; ** p<0.01; ***p<0.001; NS – non-significant differences*

The variability of anthropometric measurements and body composition is mainly influenced by diet and training. The experiment did not include monitoring or changing eating habits of the studied women. Therefore, the results obtained in the second test are not greatly significant.

The final stage of the research was the EUROFIT physical fitness test. It included the following elements: balance, agility, jumping, static strength,trunk strength and functional strength, running speed test and multi-grade shuttle run tests. As exhibited in the analysis, each change turned out to be statistically significant (p<0.05). All results are given listed in Table 4. The obtained average results in postural balance improved to the greatest extent (by 108.19%, p=0.005). However, many factors, such as concentration, could have influenced the results obtained in both tests. As a result of training, functional strength significantly improved. The average results for the hanging on bar test were better in the second test by 54.57% (p=0.01). This was similar in the case of agility. The subjects improved their results in Sit and Reach test by an average of 44.62% (p=0.003). Smaller percentage differences were observed in relation to the remaining samples. The number of sit-ups improved by 14.72% (p=0.007), and in the case of the endurance shuttle run, the results improved by 13.21% (p=0.002). In the examined women, static force (dynamometer grip) increased by 7.66%, while explosive force (standing long jump), by 6.41%. The results for the 10 x 5 m shuttle run improved by 3.72% (p=0.003).

Table 4. Percentage differences (%) in the level of physical fitness of subjects (n=11) before beginning the experiment (Test 1) and after its completion (Test 2)

EUROFIT trial	Test 1			Test 2			Percentage difference (%) between Tests 1 and 2
	X	SD	CV	X	SD	CV	
Postural balance (s)	21.37	13.5	63.16	44.49	20.98	47.16	**108.19****
Sit and Reach (cm)	8.36	3.98	47.61	12.09	2.74	22.64	**44.62** **
Standing long jump (cm)	160.45	22.45	13.99	170.73	20.92	12.26	**6.41** ***
Dynamometer grip	31.07	4.49	14.44	33.45	4.49	13.42	**7.66** *
Sit-ups	21.27	3.32	15.60	24.45	2.84	11.62	**14.72** **
Hanging on bar (s)	6.45	7.08	109.63	9.97	10.1	101.25	**54.57** **
10 x 5m shuttle run (s)	21.22	1.92	9.04	20.43	1.97	9.62	**3.72** **
Endurance shuttle run	5.30	1.35	25.38	6.00	1.56	26.12	**13.21** **

*Comments: significant differences: *p<0.05; ** p<0.01; ***p<0.001; NS – non-significant differences.*

Discussion

In view of the threats caused by a sedentary lifestyle, it seems that physical activity plays a key pro-health role. It helps prevent obesity, strengthens bones, the heart as well as joints, reducing the risk of cardiovascular disease. Physical activity can assume the form of health or fitness training, which allows to increase physical and mental performance, while improving the body's vital processes.

The essence of such training is caring for the musculoskeletal and the cardiovascular systems. In this study, the objective was to determine how 6 weeks of endurance and strength training affect the body of young women. In the research, it was shown that the training resulted in changes to anthropometric parameters of the examined women by reducing the mass and circumference of the measured parts of the body.

Each of the parameters decreased, but only with respect to the waist circumference (1.77% circumference reduction) and hips (1.18%) were the noted changes statistically significant (p<0.05). Rýzková et al. (2017), examining the influence of HIIT training together with aqua-fitness training on the body composition and physical fitness of female students, obtained similar results regarding waist circumference and the ratio of waist to hip circumference (WHR).The impact of 6-week endurance and strength training on the body composition of the studied women, by reducing the percentage of body fat and increasing muscle mass, has also been confirmed.

The average amount of body fat experienced a statistically significant decrease of 3.67% (p<0.05), while muscle mass slightly increased by 0.97% compared to the first test. The research results obtained by Campbell et al. (1994) and Colado et al. (2012) also confirm the positive effect of strength training, mainly on the reduction of body fat and increase in muscle tissue among seniors. In their research, Jozsi et al. (1999) emphasize the effects of strength training on weight reduction and an increase in the level of muscle strength among women and men both at a young and older age, while Rýzková et al. (2017) noted a significant decrease in body fat among students examined in their studyThe results obtained in this study indicate that 6-week endurance and strength training programme improved the physical fitness of the examined women, primarily in terms of trunk muscle, lower limb explosive, upper limb and shoulder girdle endurance strength, as well as cardiopulmonary endurance.

Each trial was performed better in the 2nd test than in the 1st one, however, the greatest improvement was noted in terms of body balance (improvement by 108.19%), strength endurance of upper limbs and shoulder girdle (improvement by 54.57%) and agility (improvement by 44.62%).

In their studies, Staron et al. (1994) and Gießing (2006) noticed a significant increase in muscle strength of the examined women and men already at the early phase of strength training, while the results of the research by Rýzkova et al (2017) show improvement in body balance and agility. Additionally, Mayorga-Vega et al. (2016) and Guijarro-Romero et al. (2020) noted that the students studied by them achieved a much higher level of physical fitness after completing fitness training.

Fitness is an extremely rapidly developing form of physical activity (Troisien, 2009). All fitness clubs offer numerous classes, such as: step, TBC, ABT, stretching, Fit Ball, aqua-aerobics, body balance, fat burning. Therefore, depending on the specific training goal, an appropriate class can be chosen. The advantage of fitness training is the possibility of exercising outside gyms, e.g. at home.

There are plenty of sources available where ready-made workouts can be found: books, DVDs, websites, and social networks. Many fitness instructors and personal trainers share their knowledge via the Internet by publishing numerous materials.

The conducted experiment shows that even a small dose of planned physical activity leads to significant changes in the body of young women. Combining this with other elements of a healthy lifestyle (e.g. diet), may result in the multiplication of benefits.

Conclusions

The conducted research allowed to formulate the following conclusions:

1. The 6-week endurance and strength training programmed induced changes in anthropometric parameters of the examined women, reducing circumferences (waist, hips, shoulders, thighs, calves, chest).
2. The 6-week endurance and strength training programmed caused changes in body composition of the examined women, reducing the level of body fat while increasing muscle mass and water content.
3. The 6-week endurance and strength training programmed improved physical fitness of the examined women regarding all of the tested components, i.e. in terms of strength of the trunk muscles, explosive strength of the lower limbs, endurance strength of the upper limbs and shoulder girdle, as well as cardiovascular endurance, agility and balance.

In the overall conclusion, it may be stated that the application of endurance and strength training in this work had visible impact on body composition parameters and the level of physical fitness of the examined women. It should be emphasized that in the era of the dominance of passive forms of spending free time and the associated decline in the level of physical fitness, it is very important to encourage young people to undertake physical activity, which has invaluable health benefits. It seems that in the coming years, more and more women will choose a healthy lifestyle in which physical activity is a main linker. The form of implementation of this activity will be health training or one of the newly created forms of fitness training. This study included young women in whom adaptive changes were noted under the influence of the 6-week endurance and strength training programmed, therefore, it would be advisable to carry out further research of this type among representatives of other age groups and among both sexes, also implementing longer training periods than 6 weeks.

Conflict of Interests: The authors have no conflict of interest to declare.

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