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The Effects of the Aerobic Endurance Running Program on the Morphological Characteristics of Adolescent Girls with Different Nutritional Status

Efectos del Programa de Carrera de Resistencia Aeróbica en las Características Morfológicas de las Adolescentes con Diferentes Estados Nutricionales

Milovan Bratic[1]; Andela Dosic[1]; Danijela Zivkovic[1]; Mladen Zivkovic[1]; Ljiljana Bjelakovic[1];
Nikola Stojanovic[1]; Marija Dordevic[2]; Nikola Prvulovic[1] & Sasa Pantelic[1]

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SUMMARY: This study aimed to explore the effects of a single moderate-intensity aerobic endurance running program on the morphological characteristics of normal-weighted and overweighted female adolescents and whether effects differ between individuals of different nutritional statuses. A total of 47 adolescent girls participated in this randomized controlled trial. Before and after 12 weeks of intervention, measurements were obtained for body height, body mass, BMI, triceps, subscapular, abdominal, thigh, and calf skinfolds, and chest, abdominal, thigh, and calf circumference. The total duration of the program was 12 weeks, with a frequency of 2 hours/week (24 sessions). The individual session lasted 60 minutes, and the intensity ranged from 60 % HRmax to 80 %. The findings from the present study suggest that the 12-week aerobic endurance running program induced changes in morphological characteristics of female adolescents. The significant reductions in body mass and BMI were small for normal-weight adolescents (-2,64 % and -3,48 %) and moderate for overweight adolescents (-4,14 % and -4,36 %) following the experimental program. The magnitude of reductions in the skinfold thickness was small for both groups (triceps, subscapular, abdominal, and calf) and moderate for thigh skinfold and a sum of skinfolds in the overweight group. The reductions in the magnitude of all circular measures were small for both groups. It ranged from -1.59 % to -2.59 % for normal-weight and from -2.54 % to -3.92 % for overweight adolescents, respectively. Additionally, the effects of the applied program seem more favorable to overweight than normal-weight adolescents. This study's current findings indicate that the 12-week aerobic endurance running program is effective due to improvements in morphological characteristics, body mass, and BMI of female adolescents. Additionally, this study's findings show that applied aerobic endurance running program proved more effective for overweight adolescents.

KEY WORDS: Aerobic endurance running; Adolescent girls; Morphological characteristics; Nutritional status.

INTRODUCTION

Globally, overnutrition and obesity remain pressing public health problems in the 21st century (World Health Organization, 2004). Much attention from the scientific public is mainly focused on overweight and obesity in the pediatric population because childhood and adolescence represent critical developmental periods for future health. Recent studies indicate the presence of a positive linear trend of overnutrition among adolescents from the USA, Canada, and Europe (Ahluwalia *et al*., 2015).

In Serbia, according to the latest official data from the "Dr. Milan Jovanovic Batut" Institute for Public Health, the prevalence of excessive nutrition among adolescent girls aged 11, 13, and 15 years was determined to be 19 %, 16.2 %, and 15.7 % (Gudelj-Rakic *et al*., 2019).

The period of adolescence is critical for overweight individuals because there is a high probability that they will become obese as adults (Birch & Ventura, 2009). Excess

[1] Faculty of Sport and Physical Education, University of Nis, Carnojevica 10a, Nis, Serbia.
[2] The Academy of Applied Preschool Teaching and Health Studies, Balkanska 18, Krusevac, Serbia.

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body mass leads to chronic non-communicable diseases such as type 2 diabetes and cardiovascular diseases (World Health Organization, 2004) and causes serious health problems, such as high blood pressure and increased blood biochemical parameters (Reinehr *et al*., 2005).

Militello *et al*. (2016) point out that the increase in overnutrition and obesity is due to changes in lifestyle, where physical inactivity (Kohl 3rd *et al*., 2012) and poor diet (World Health Organization, 2004) stand out as the most prominent causes. Notably, 80 % of adolescents aged 13–15 do not meet the recommended physical activity of 60 minutes daily of moderate to high intensity (Finne *et al*., 2011). Moreover, overweight adolescents have poorer functional capacity (McGraw *et al*., 2000).

The period of early adolescence is crucial for encouraging a physically active life, which is especially important for female adolescents. For both males and females, aerobic exercise causes physiological changes (McCarthy & Roy, 2012; Silva *et al*., 2014; Kenney *et al*., 2015; Zouhal *et al*., 2020). However, several fundamental distinctions impact the alterations' absolute magnitudes. Compared to males, females often have a higher body fat percentage and lower muscle mass. Females often exhibit fewer absolute adaptations than males but relatively similar relative adaptations to an aerobic training program because they typically have lower initial physiological values (McCarthy & Roy, 2012). Moderate intensity is the appropriate training regimen for overweight and obese individuals who usually have low aerobic fitness and provides more adherence to the training plan (Stiegler & Cunliffe, 2006). Moreover, adolescent girls provided several reasons to cease sports and physical activity, like crossing traditional sports boundaries, teasing, and overall body image, which could explain the declining trend in overall participation in sports and physical activity (Slater & Tiggemann, 2010).

The arguments above are essential in choosing an appropriate training program for overweight female adolescents. Physical activity in the form of aerobic activities (running, walking, jumping) can contribute to the improvement and maintenance of body composition parameters (Kenney *et al*., 2015), reducing the thickness of the upper arm and abdomen skinfolds, as well as fat mass in adolescents (Farias *et al*., 2009). Aerobic activities, primarily aerobic endurance, of varying intensity cause desirable results in reducing body fat mass (Zouhal *et al*., 2020), triceps skinfold, BMI, fat mass (FM), and increasing fat-free mass (FFM) (Silva *et al*., 2014).

Therefore, this study aimed to explore the effects of a single moderate-intensity aerobic endurance running program on the morphological characteristics of normal-weighted and overweighted female adolescents and whether such a program could cause more favorable effects for individuals of different nutritional statuses.

MATERIAL AND METHOD

Participants. A total of 47 adolescent girls participated in this randomized controlled trial. The criteria for inclusion in the study were: 1) adolescent girls aged 15 years ± six months; 2) BMI values belong to the group with increased BMI or to the group whose BMI values are within normal limits for the given age according to the classification of Cole *et al*. (2000); 3) do not suffer from chronic diseases; 4) were not involved in an organized form of physical activity for at least six months before the start of the experimental program; 5) both groups had the same regular physical education classes. Criteria for exclusion from the study were adolescent girls with respiratory and cardiovascular diseases, developmental disabilities, adolescent girls in the process of recovery from injury or illness, and adolescent girls who were involved in some organized physical activity six months prior to the start of the study. Participants were also excluded from the study if they were taking any medication. A purpose-designed questionnaire collected criteria for inclusion and exclusion from the study. A detailed overview of the selection of participants is shown in Figure 1. Experimental procedures reported in this study were performed by the ethical standards of the Helsinki Declaration, and the participants and their parents signed an informed consent form. The ethical committee approved the experimental protocols of the Faculty of Sport and Physical Education, University of Nis, Serbia.

Thirty-two subjects completed the experimental program after being randomly assigned to one of two groups: a group with normal BMI values (Normal; n=19); and a group with elevated BMI values (Overweight; n=21) (Fig. 1).

Measurements. The Body Mass Index (BMI) was used to assess nutritional status and categorize the subjects into groups. BMI is calculated as the ratio of body mass (kg) / body height (m^2) (He *et al*., 2000). Anthropometric measurements were performed by trained personnel following the recommendations of Eston & Reilly (2001). They included measurements of body height, body mass, triceps skinfold, subscapular skinfold, abdominal skinfold, thig skinfold and calf skinfold and chest circumference, abdominal circumference, and thigh and calf circumference. Body height was measured with an anthropometer according to Martin (GPM, Switzerland) (measurement accuracy 0.1

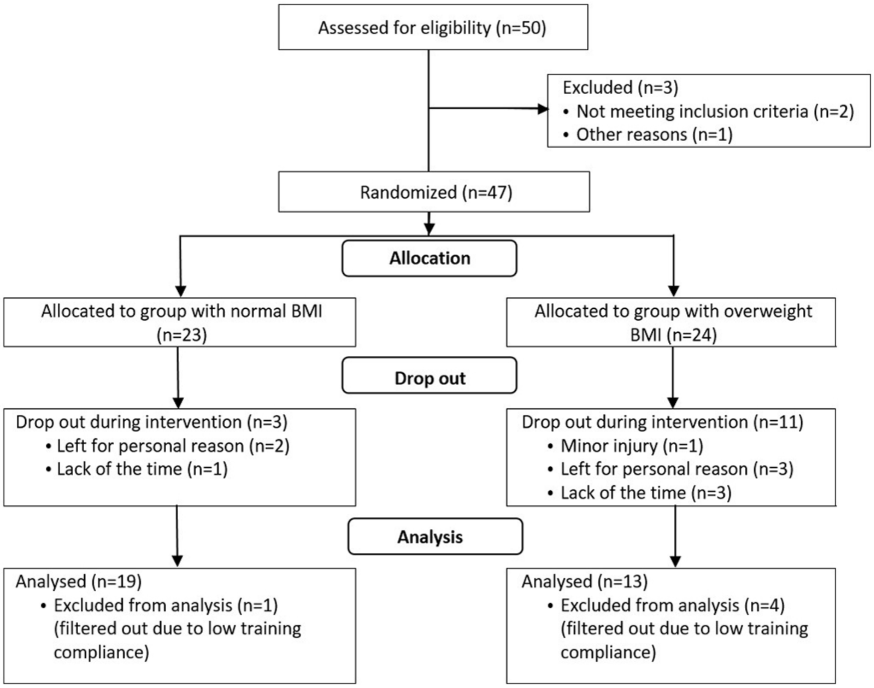

Fig. 1. Flow chart diagram of subjects included in the study, randomization, and analysis.

cm), body mass to the nearest 0.1 kg using a portable electronic digital scale (Tanita UM-72 Made in Japan), and subcutaneous adipose tissue with a John Bull caliper (CMS instruments, London, UK) to the nearest 0.2 mm. Subcutaneous adiposity was calculated as the sum of all measured skinfolds (triceps, subscapular, abdominal, thigh, and calf). The circumferences were measured with a flexible tape with a measurement accuracy of 0.1 mm.

Experimental program. All sessions were supervised by trained instructors familiar with running training methods and trained to perform practical training. The experimental program was designed following the principles recommended by the American College of Sports Medicine and the WHO (Riebe *et al*., 2018; Chaput *et al*., 2020). A more detailed description of the experimental program is shown in Table I.

The total duration of the program was 12 weeks, with a frequency of 2 hours/week (total number of sessions = 24). The duration of the individual session was 60 minutes, and the intensity ranged from 60 % HRmax at the beginning to 80 % HRmax at the end of the experimental program. One session was divided into an introductory-preparatory part (of 20 min), the central part (of 30 min), and the final part (of 10 min). Each training session began with a 10-minute low-intensity warm-up period (introductory-preparatory part) consisting of a combination of walking and jogging or running ABC pre-exercises, followed by 10-minute stretching for larger muscle groups. The central part of the session consisted of continuous or interval running sessions lasting 30 minutes. The final part of the training consisted of 10-minute loosening and stretching exercises (Table I). The intensity in each session was determined based on the maximum heart rate (HRmax), which was calculated based on the form: 220 - age. Heart rate was monitored during all sessions using heart rate monitors (PC-15; Sigma Elektro, Gmbh & Co, Germany) to control the intensity.

Statistical analyses. Descriptive data are presented as mean ± standard deviation. The normality of the data was assessed with the Kolmogorov-Smirnov test. Multivariate analysis of variance (MANOVA) and univariate analysis of variance (ANOVA) was performed to explore differences between groups at initial and final time points. The significant within-subject differences after the experimental program for both groups were determined using repeated-measures ANOVA. The magnitude of within-subject effects was determined using the Cohen Effect size (ES) (Cohen, 2013). Effect size criteria were as follows: <0.2 trivial effects, 0.2–0.6 small effects, 0.6–1.2 moderate effects, 1.2–2.0 large effects, and >2.0 very large effects (Hopkins *et al*., 2009). In order to determine the effects of the experimental program, a univariate analysis of covariance (ANCOVA) (General Linear Model) was used. Pretest measurements were used as the covariate to control for any differences between groups at the final measurement. Data were processed using Statistical Package for Social Sciences SPSS (v18.0, SPSS Inc., Chicago, IL, USA). Statistical significance was set at $p < .05$.

RESULTS

The results showed significant differences between groups in body mass, BMI, subscapular skinfold, and the sum of skinfolds at initial measurement (Table I), where overweight individuals presented higher values than normal-weight individuals. At the final measurement, significant differences between groups are evident in body mass,BMI, and subscapular skinfold, where overweight individuals obtained higher values than normal-weight individuals.

Results presented in Figure 1 showed significant experimental intervention improvements in all tested variables within both groups (normal-weight and overweight adolescents) (p<.001). The magnitude of improvements is expressed as effect size (small to moderate) and percentage (range: from -1.59 to -12.79).

In order to inspect the meaningful difference between groups at the final measurement and control for between-group differences at the initial measurement, it was necessary to analyze covariance. The multivariate analysis of covariance revealed a statistically significant difference between the groups at the final measurement. The low value of Wilks' Lambda (0.12) and Rao's approximation (6.23) with the significant finding (.005) indicates a difference between groups in overall benefits induced by an applied experimental program regarding morphological characteristics (Table II).

At the univariate level, it is evident that the initial values as a covariate contributed to the overall positive effects of the aerobic endurance running program on thigh skinfold (adjusted mean: 51,05 vs. 51,56), skinfold sum (adjusted mean: 86,01 vs. 91,68), and chest circumference (adjusted mean: 81,69 vs. 83,12), in favor of overweight adolescents (Fig. 2). No statistically significant differences were found in the remaining skinfold and circular measures, BMI, and body mass; however, it is noticeable that the adjusted means are numerically lower for the overweight adolescent girls in body mass (56,07 vs. 56,69), triceps (14,34 vs. 14,74), subscapular (11,62 vs. 12,70), abdominal (16,65 vs. 17,60), thigh (26,12 vs. 28,63), calf (17,28 vs. 18,01) skinfolds, skinfold sum (86,01 vs. 91,68), and chest (81,69 vs. 83,12), and thigh (51,05 vs. 51,65) circumference. Normal-weight adolescents presented lower values only in BMI (21,31 vs. 21,83), abdominal (65,06 vs. 65,49), and calf (34,97 vs. 35,13) circumference. Therefore, the twelve-week aerobic endurance running program caused significant positive effects for both groups; however, it proved more effective for overweight adolescents.

DISCUSSION

The findings from the present study suggest that the 12-week aerobic endurance running program induced favorable changes in morphological characteristics of female adolescents. The significant reductions in body mass and BMI were small for normal-weight adolescents (-2,64 % and -3,48 %) and moderate for overweight adolescents (-4,14 % and -4,36 %) following the experimental program. In a recent review, Zouhal *et al*. (2020) argue that many aerobic exercise interventions could cause a significant reduction in body weight, BMI, and overall body fat in adolescents following at least 12 weeks of aerobic treatment.

Table I. Weekly training plan.

	Number of sessions	Type of activity	Duration / Number of intervals / Rest between interval	Intensity (% HRmax)
Weeks 0-4	1 & 5	continuous	20 min	60 %
	2 & 6	interval	2x10 min / 5 min	
	3 & 7	interval	6 x 100m / 3 min	
	4 & 8	continuous	30 min	
Weeks 5-8	9 & 13	continuous	30 min	70 %
	10 & 14	interval	3 x 10 min / 5 min	
	11 & 15	interval	3 x 300m / 3 min	
	12 & 16	continuous	30 min	
Weeks 9-12	9 & 13	continuous	30 min	80 %
	10 & 14	interval	3 x 10 min / 5 min	
	11 & 15	interval	2 x 600m / 10 min	
	12 & 16	continuous	30 min	

Legend: HRmax - maximum heart rate

Table II. Descriptive statistics, pre and post-differences between normal-weight and overweight female adolescents.

	Initial				Final			
	Normal (*n*=19)	Overweight (*n*=13)	F	Sig	Normal (*n*=19)	Overweight	F	Sig
Body height [cm]	164,11±4,91	158,69±5,10	-	-	164,33±5,37	159,06±5,05	-	-
Body mass [kg]	54,26±5,04	62,52±3,03	**27,81**	**.000****	52,83±4,88	59,93±3,04	**21,69**	**.000****
BMI [kg/m^2]	20,12±1,32	24,79±0,99	**117,25**	**.000****	19,42±1,18	23,71±0,88	**124,15**	**.000****
Skinfold [mm]								
triceps	15,41±3,32	16,83±5,91	0,75	NS	14,12±3,48	14,95±5,13	0,30	NS
subscapular	11,55±3,98	15,80±4,70	**7,60**	**.009****	10,35±3,64	13,97±3,95	**7,130**	**.012***
abdominal	17,63±6,15	21,69±7,48	2,82	NS	15,89±5,79	18,94±6,49	1,32	NS
thigh	28,82±5,95	31,34±6,54	1,27	NS	27,40±6,01	28,11±5,76	0,01	NS
calf	18,69±5,43	19,91±4,21	0,45	NS	17,64±5,15	18,03±3,94	0,01	NS
Sum Skinfold	92,11±12,97	105,57±13,69	**7,94**	**.008****	85,41±12,40	92,28±12,13	2,41	NS
Circumference [cm]								
chest	85,35±6,66	83,06±6,37	0,94	NS	83,86±6,35	80,95±6,01	1,68	NS
abdominial	66,53±6,90	68,63±5,44	0,84	NS	64,61±6,60	65,94±5,54	0,35	NS
thigh	53,19±4,14	52,39±5,41	0,22	NS	52,24±3,80	50,58±5,10	1,26	NS
calf	35,17±1,86	36,71±3,11	3,05	NS	34,61±1,83	35,49±2,84	1,14	NS
	Wilks= 0,18	F= 8,19	p= **.000****		Wilks= 0,16	F= 9,07	p= **.000****	

NS - not significante. Sig - the level of significance, **p< .01, +p< .05.

The magnitude of reductions in the skinfold thickness was small for both groups (triceps, subscapular, abdominal, and calf) and moderate for thigh skinfold and a sum of skinfolds in the overweight group. It ranged from -4.93 % to -10.39 % for normal-weight and from -9.44 to -12.73 for overweight adolescents, respectively. These results are comparable to similar research on skinfold thickness reduction following aerobic training in female adolescents (Farias *et al*., 2009; Silva *et al*., 2014).

Both groups experienced small to moderate reductions in all circular measurements (chest, abdomen, thigh, and calf). The improvements ranged from -1.59 % to -2.59 % for normal-weight and from -2.54 to -3.92 for overweight adolescents, respectively. Farias *et al*. (2009) argue that small reductions or even increments in circular measures (arm, thigh, and calf) are possible due to muscle stimuli induced by specific training. Aerobic endurance running training in this study primarily targeted lower limbs; therefore, it is plausible that it evoked significant reductions in the circumference of those areas, mainly due to a decrease in adipose tissue.

The modality, frequency, intensity, and duration of exercise might vary depending on the study's design. Fat contributes as the primary source of energy during physical activity at low to moderate intensities (Stiegler & Cunliffe, 2006). The three main metabolic changes are an elevation in lactate threshold, an increase in maximum oxygen uptake, and an increased dependence on fat as energy with a subsequent reduction in the usage of carbohydrates during exercise. These modifications increase fatty acid oxidation for energy and glycogen storage, which is essential for maintaining sustained aerobic activity (McCarthy & Roy, 2012). The general recommendation for the overall efficiency of aerobic training is 3-4 weekly for at least 30 minutes per session (Zouhal *et al*., 2020). However, our study proved that two weekly training sessions for 60 minutes were sufficient to induce improvements in morphological characteristics, albeit small to moderate.

The effects of the applied program seem more favorable to overweight than normal-weight adolescents. A possible explanation for this outcome could refer to a homeostatic mechanism, where excess body fat elevates the resting metabolic rate and increases the energy cost of physical activity (Kenney *et al*., 2015). It is plausible that overweight adolescents benefited more from the applied experimental program than normal-weight adolescents based on these physiological responses. However, weight loss depends on many factors such as energy intake, appetite, and energy expenditure (resting metabolic rate, thermic effect of activity, and thermic effect of a meal). Although we suggested to our participants to maintain their dietary and daily life activities habits, unfortunately, we could not track any alterations from a behavioral standpoint. Therefore, any decisive conclusion on this matter would be highly speculative.

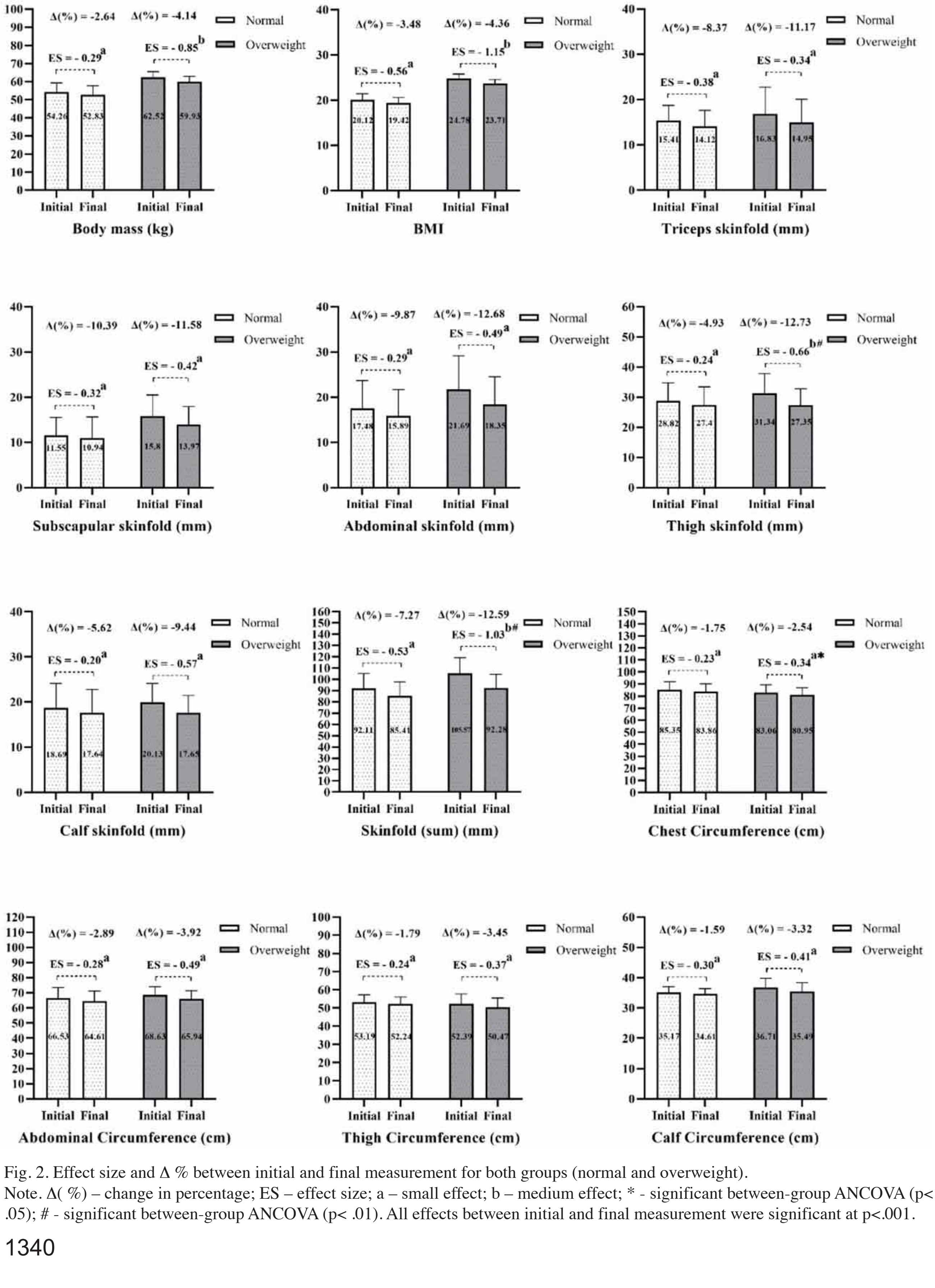

Fig. 2. Effect size and Δ % between initial and final measurement for both groups (normal and overweight).
Note. Δ(%) – change in percentage; ES – effect size; a – small effect; b – medium effect; * - significant between-group ANCOVA (p< .05); # - significant between-group ANCOVA (p< .01). All effects between initial and final measurement were significant at p<.001.

Our results show that even without dietary management, a specified physical aerobic endurance program can encourage favorable alterations in morphological characteristics. The justification for such an approach is that any alterations in food intake management could mask the eventual positive effects induced by the experimental program. Consequently, evaluating the experimental program outcomes is not entirely feasible if specific dietary recommendations are implemented, which could impact the variables of interest. Therefore, a 12-week aerobic endurance program for normal-weighted and overweighted adolescents in a progressive fashion (60 %-80 %) proved effective and ultimately improved tested parameters. Owens *et al*. (1999) emphasize that an exercise intensity of around 70–75 percent of maximum HR for this age group produces a reasonably high energy expenditure and beneficial changes in body composition. We should note that training intensity, apart from the initial four preparatory weeks, progressed throughout two blocks of four weeks (70 % and 80 %), which approximately meet the recommendations in the above study.

It is noteworthy that energy expenditure during exercise does not give us the whole picture. According to (Kenney *et al*., 2015), the metabolic rate remains temporarily increased following exercise. Returning the metabolic rate to its pre-exercise level can require several minutes following light training and up to several hours following a more intense training regime. Therefore, the effects of the applied program in this study could be altered even after training sessions.

Our study demonstrates that 120 minutes of aerobic endurance training per week could significantly improve morphological characteristics. Some evidence supports a dose-response relationship between the amount of aerobic activity performed and the amount of weight loss. As a result, these data suggest a connection between the quantity of aerobic exercise and overall weight reduction (Stiegler & Cunliffe, 2006). The ACSM recommends moderate-intensity physical exercise for 150 to 250 minutes per week to avoid weight gain. However, that exercise volume results in moderate weight reduction, and higher physical activity levels (>250 minutes per week) are required for more substantial weight loss (Kenney *et al*., 2015). Although the standard recommendation is at least 150 minutes per week, a well-designed program with proper load management and control during a training session can influence small to moderate improvements in morphological characteristics, as our study has shown.

Importantly, unfit individuals may not be able to, or be motivated to exercise intensely or frequently without developing unfavorable attitudes, which may be driven by overall exhaustion. We argue that exercise intensity that is achievable by most individuals and signifies a productive activity or accomplishment is moderate. To support previous findings, the adherence magnitude in our study was 82,6 % for normal-weight and 54.1 % for overweight adolescents, respectively. Therefore, introducing a more vigorous or frequent training session could increase overweight adolescents' dropout rate.

Nonetheless, the strength of this study is in the effectiveness and simplicity of the applied program. With the aid of cost-friendly heart monitor devices, it is easy to follow and modify depending on the participants' abilities. This aerobic endurance running program can be applied almost anywhere, without adequate facilities and additional equipment. Monitoring the program's effects is possible by measuring skinfolds which proved reliable in adolescent girls (Rodriguez *et al*., 2005).

A few shortcomings of the present study should be noted: 1) the reduction in the number of participants who completed the experimental program; 2) the absence of nonexercise activity tracking methods; 3) no implementation of energy intake recall instruments; 4) and no assessment of muscle mass alterations. However, we should note that inventories based on energy intake recall could be misleading and provide erroneous findings. Moreover, regarding fat-free mass, Stiegler & Cunliffe (2006) argue that aerobic endurance exercise has the advantage of causing fat mass reductions with little to no impact on fat-free mass. In addition, this study did not implement sophisticated equipment to track muscle mass changes.

To conclude, this study's current findings indicate that the 12-week aerobic endurance running program without dietary management is effective due to improvements in the morphological characteristics of female adolescents. Additionally, this study's findings show that applied aerobic endurance running program proved more effective for overweight adolescents. Apart from a few shortcomings, this study has conclusively demonstrated the effectiveness of exercise training in promoting small to moderate alterations in tested variables. Importantly, we should note that although the overall weekly training volume was less than recommended (minimum 150 min), the program proved effective. As a result, we advise healthcare and sports professionals dealing with this demographic, to promote exercise regimens with the prescribed volume and intensity in the current study. Finally, future research should track any alterations in nonexercised daily activities and energy intake to derive valuable information regarding the overall effectiveness of aerobic endurance training.

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RESUMEN: Este estudio tuvo como objetivo explorar los efectos de un programa único de carrera de resistencia aeróbica de intensidad moderada sobre las características morfológicas de mujeres adolescentes con peso normal y con sobrepeso y si los efectos difieren entre individuos con diferentes estados nutricionales. Un total de 47 niñas adolescentes participaron en este ensayo controlado aleatorio. Antes y después de 12 semanas de intervención, se obtuvieron mediciones de altura corporal, masa corporal, IMC, tríceps, pliegues cutáneos subescapular, abdominal, muslo y pantorrilla, y circunferencia torácica, abdominal, muslo y pantorrilla. La duración total del programa fue de12 semanas, con una frecuencia de 2 horas/semana (24 sesiones). La sesión individual tuvo una duración de 60 minutos y la intensidad osciló entre el 60 % y el 80 % de la FCmáx. Los hallazgos del presente estudio sugieren que el programa de carrera de resistencia aeróbica de 12 semanas indujo cambios en las características morfológicas de las adolescentes. Las reducciones significativas en la masa corporal y el IMC fueron menores para los adolescentes con peso normal (-2,64 % y -3,48 %) y moderadas para los adolescentes con sobrepeso (-4,14 % y -4,36 %) después del programa experimental. La magnitud de las reducciones en el grosor del pliegue cutáneo fue pequeña para ambos grupos (tríceps, subescapular, abdominal y pantorrilla) y moderada para el pliegue cutáneo del muslo y la suma de los pliegues cutáneos en el grupo con sobrepeso. Las reducciones en la magnitud de todas las medidas circulares fueron pequeñas para ambos grupos. Osciló entre -1,59 % y -2,59 % para normopeso y entre -2,54 % y -3,92 % para adolescentes con sobrepeso, respectivamente. Además, los efectos del programa aplicado parecen más favorables para los adolescentes con sobrepeso que para aquellos de peso normal. Los hallazgos actuales de este estudio indican que el programa de carreras de resistencia aeróbica de 12 semanas es eficaz, debido a las mejoras en las características morfológicas, la masa corporal y el IMC de las adolescentes. Además, los hallazgos de este estudio muestran que el programa de carrera de resistencia aeróbica aplicada demostró ser más efectivo para los adolescentes con sobrepeso.

PALABRAS CLAVE: Carrera de resistencia aeróbica; Niñas adolescentes; Características morfológicas; Estado nutricional.

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Correspoding author:
Nikola Stojanovic, Ph.D.
The University of Nis
Faculty of Sport and Physical Education
Carnojevica 10a
Nis 18000
REPUBLIC OF SERBIA

E-mail: nikola987_nish@hotmail.com