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Research article

EFFECTS OF BALL PILATES ON MUSCULAR FITNESS IN FEMALE ADOLESCENTS

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Abstract. *This study determined the effects of ten-week Pilates ball training on muscular fitness in female adolescents. The sample of 48 participants was randomly divided into the experimental (n = 24) and control group (n = 24). The experimental group (age: 15.28 ± 0.48; body height: 164.47 ± 4.59 cm; body weight: 58.72 ± 6.68 kg) performed the Pilates ball program in physical education classes twice a week for ten weeks, while the control group (age: 15.26 ± 0.29, body height: 164.35 ± 4.75 cm; body weight: 58.86 ± 5.99 kg) performed the standard physical education program. Muscular fitness was assessed by flexors, extensors and lateral torso muscles endurance tests, the front plank test, and the single-leg squat test. The results showed that both groups of participants statistically significantly improved muscular fitness between the two measurements (p < 0.01), but numerically greater effects were achieved in the experimental group. The most remarkable effects between the two measurements of the experimental group were registered in the torso flexor and extensor endurance. In the control group, the most significant effects were found in bilateral torso endurance. In addition, significantly greater effects (p <0.01) at the final measurement were determined in the experimental group for the endurance of torso flexors (p <.01) and extensors (p <.05) and in the single-leg squat test when performed with the right leg (p <.01). In bilateral torso endurance assessment tests, more significant effects were registered only at a numerical level in the experimental group. The authors concluded that exercising on an unstable compared to a stable surface is a more efficient training stimulus in transforming torso flexor and extensor muscles and dynamic control of hips and legs.*

Key words: *students, training on unstable surfaces, physical education, torso stabilizers*

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INTRODUCTION

Trunk stabilizer muscle training is increasingly prevalent in practice, considering its numerous benefits in conditioning and physiotherapy. The central body region consists of muscles that support and stabilise the lumbopelvic complex and kinetic chain, and control movement during the production and transfer of force while performing functional movements (Skotnicka, Karpowicz, Sylwia-Bartkowiak, & Strzelczy, 2017). Stabilising the trunk, these muscles significantly affect motor behaviour and efficiency.

According to Willson, Dougherty, Ireland, & Mcclay (2005) stability can be achieved only by the coordinated action of active (muscles), passive (spinal column), and control systems (nervous system). The active system consists of global and local torso muscles, with the former transferring the force and moving the spinal column as a whole. In contrast, local muscles, which are smaller and positioned deeper, cannot produce large force but are significant in proprioception, postural control, and spinal column stability (McGill, 2001). Their development should be planned in the initial stages of torso stability and mobility training in such a way as to maintain the correct position of the spine column during exercise (Cartel, Beam, McMahan, Barr, & Brown, 2006). The harmonious development of all torso stabilizers is essential as disproportion in their development leads to compensatory movements and imbalances in the global chain of stability (Perić, Stojanović, Pavlović-Veselinović, Ilić, & Stojanović, 2015).

Stability is necessary for the performance of functional movements in everyday life, sports and recreation. Increasing stability improves movement and physical fitness and, thus, performance in sports as it enables complete transfer of force from the lower to the upper extremities, and in the opposite direction (Cosio-Lima, Reynolds, Winter, Paolone, & Jones, 2003; Prieske et al., 2016; Sukalinggam, Sukalinggam, Kasim, & Yusof, 2012).

The core muscles are composed of deep, slow muscle fibers that make up the local muscular system and superficial, fast muscle fibers that make up the global muscular system. Deep muscles control and limit excessive pressure forces and rotational forces between the vertebrae and increase intra-abdominal pressure and spinal rigidity to improve intervertebral neuromuscular control. Superficial muscles transfer the load between the upper and lower extremities, provide stability between the pelvis and the spine, and ensure body center stabilization and eccentric control during functional movements (Clark, Lucett, McGill, Montel, & Sutton, 2018).

Scientific literature is dominated by research monitoring the effectiveness of torso stability training on electromyographic activity (EMG), strength, and endurance of the global trunk stabilizers. In contrast, local stabilizers have been studied considerably less. Research indicates that torso stabilizers develop more efficiently, especially in non-athletes, by exercising on an unstable than a stable surface due to increased proprioceptive demands (Carter et al., 2006; McCackey, 2011; Prieske et al., 2016; Sekendiz, Cug, & Korkusuz, 2010; Stanton, Reaburn, & Humphries, 2004; Sukalinggam et al., 2012).

Although there are contradictory findings (Anderson & Behm, 2004), it has been determined that an unstable surface is an additional stimulant that significantly increases EMG activity (Behm, Leonard, Young, Bonsey, & MacKinnon, 2005; Duncan, 2009; Kim, Kim, & Chung, 2014; Lehman, Hoda, & Oliver, 2005; Ostrowski, Carlson, Lawrence, 2017; Petrofski et al., 2007; Vilaca-Alves et al., 2016), so training on a Pilates ball is recommended for improving torso stability. However, some research suggests that EMG activity does not depend on the stability of exercising surfaces (Pirauá et al., 2017; Uribe et al., 2010).

Although the application of props (dumbbells, medicine balls, smaller balls, etc.), as an additional load to unstable surface exercise, can reduce the EMG activity, additional load has been found to generally increase the efficiency of exercise in a dynamic regime without violating the movement pattern (Anderson & Behm, 2004; Baechle & Earle, 1994).

In a number of studies, training on a Pilates ball is implemented along with some other training, primarily technical and tactical, cardiovascular, or load training. Research points to a large diversity in the selection and dosage of training variables. Still, it has generally been determined that the period of 6 to 12 months with a frequency of two to three training sessions a week is sufficient to provoke adaptive changes of torso stabilizer muscles, assuming that the other training variables are optimally dosed. The degree of adaptation primarily depends on the initial fitness of athletes, selection of exercises, frequency and intensity of the training sessions, the length of the recovery phases, and the total duration of the experiment.

The authors have mainly compared the effectiveness of anterior, posterior, and lateral planks on unstable (standard or mini Pilates ball) and stable surfaces (ground or bench) on the strength and endurance of torso stabilizer muscles. They have generally confirmed the superiority of exercise on an unstable compared to a stable surface (McCackey, 2011; Prieske et al., 2016; Sukalinggam et al., 2012). However, a considerably smaller number of studies have found that trunk stability can also be effectively improved by a dynamic regime of exercise using only torso flexion and torso extension exercises on a ball without any endurance exercises.

Despite a large number of studies, the effectiveness of progressive Pilates ball training, programmed by exercises performed in the static and dynamic regime of exercise, has still been insufficiently studied, especially in females without previous training experience. Therefore, this study was based on the assumption that by combining different exercise regimes on an unstable surface that provokes greater muscular activity due to increased postural stability requirements, torso stabilizer endurance would be significantly improved. Furthermore, stronger torso stabilizers would enable a more comprehensive transfer of force to the upper and lower extremities, which would improve sports performance. For these reasons, this longitudinal research determined the effectiveness of a Pilates ball on muscular fitness in young female adolescents.

METHOD

The sample of participants

The study involved 48 first-year students of the "Svetozar Marković" Grammar School in Niš, with an average age of 15.28 ± 0.48 years. All participants included in the experiment were clinically healthy and without previous training experience in sports clubs for the last six months. The only form of organized exercise in which they were involved was regular physical education teaching. The participants were first thoroughly informed about the experimental research goal and concept in written form. Then, if they were interested in participating in the research, they submitted written consent to be included in the research signed by their parents. Parental consent was necessary since the participants were underage. Finally, the participants were told that they could withdraw from the research at any time if they wanted to, for any reason.

The research ensured the anonymity of the participants following the recommendations for clinical research defined by the World Medical Association's Declaration of Helsinki (2013). Statistical data processing included the testing results of only those participants who had fewer than two absences during the experimental period.

The sample of participants was randomly divided into the experimental group (EG) and control group (CG) of 24 participants in each. The basic anthropometric characteristics (average body height [cm], average body weight [kg], and body mass index [kg / m^2]) of the experimental and control group are shown in Table 1.

Table 1 Basic anthropometric characteristics of the experimental and control group of participants (mean values ± standard deviation)

Participants	N	MA	BH	BW	BMI
Experimental group	24	15.28 ± 0.48	164.48 ± 4.59	58.72 ± 6.68	21.78 ± 2.87
Control group	24	15.26 ± 0.29	164.35 ± 4.75	58.87 ± 5.99	21.84 ± 2.39

Legend: N - number of participants; MA - mean age (years); BH - mean body height; BW - mean body weight; BMI - body mass index.

The sample of measuring instruments

The characteristics of the sample were evaluated using the following parameters: body height (cm), body weight (kg), and body mass index (BMI=kg/m2). Body height was measured using the Martin anthropometer (GPM 101GmbH Switzerland) that measures with an accuracy of 0.1 cm. Measurement was performed according to the protocol of the International Biological Program - IBP (Weiner & Lourie, 1969). Body weight and the body mass index were measured using the body structure analyzer (Inbody 720 Tetrapolar; 8-Point Tactile Electrode System - Biospace Co. Ltd). Participants were told in advance not to have breakfast before the measurement.

Muscle fitness was assessed using the following tests:

1. Trunk Flexor Endurance Test
2. Trunk Extensor Endurance Test
3. Trunk Lateral Endurance Test – right side
4. Trunk Lateral Endurance Test – left side
5. The Front (Forearm) Plank Test
6. Single-Leg Squat Test – right leg
7. Single-Leg Squat Test – left leg

Tests for isometric endurance assessment of the flexors, extensors, and lateral trunk muscles were taken from the American Council on Exercise (2015) that recommends McGill's testing protocol. The reliability and validity of these tests were confirmed in the study of Evans, Kathryn, Refshaugea, and Adams (2007) and del Pozo-Cruz, Mocholi, del Pozo-Cruz, Parraca, and Adsuar (2014). In addition, the clinical single-leg squat test was taken from McGovern, Martin, Christoforetti, and Kivlan (2018), and its reliability and validity were confirmed in the study of Crossley, Zhang, Schache, Bryant, and Cowan (2011) and McGovern, Christoforetti, Martin, and Phelps (2019). The reliability and validity of the front plank test, taken from the Thompson, Gordon, Pescatello, and the American College of Sports Medicine (2010), were confirmed in the study of Tong, Wu, and Nie (2014). All the applied tests are timed tests that assess the isometric endurance of muscles. The result of all the tests except for the single-leg squat test is the time of holding the correct static position, expressed in seconds.

The trunk flexor endurance test is a timed test that assesses the muscular endurance of the rectus abdominal muscle, the transverse abdominal muscle, and the oblique abdominal muscles. The examinee sits on the floor with hips and knees bent at a 90-degree angle and shoulders leaning against a board positioned at a 60-degree incline in relation to the floor. The feet should rest on the floor (or be fastened with a belt) along the entire length, and the hips, knees and the second toe should be in line. The examinee should cross his arms over the chest so that palms touch the opposite shoulder. The goal of the test is to hold this position without back support for as long as possible. The test result is the duration of the examinee's holding the proper position, expressed in seconds.

The trunk extensor endurance test involves static, isometric contraction of the trunk extensor muscles that stabilize the spine. The examinee first lies on his stomach on a raised surface (Swedish box), positioning the iliac crest at the edge of the surface on which he lies while supporting the upper part of the body with his hands against the floor. The examiner stabilizes the examinee's legs with his hands or nylon tape. The examinee then crosses his arms over the chest and maintains a position in which the upper part of the body is without support by trunk extensor endurance muscles. The aim of the test is for the examinee to maintain a horizontal position using the strength and endurance of the trunk extensor muscles for as long as possible. When the examinee breaks the horizontal position by bending the trunk downwards, the test is terminated. The test result is the duration of the examinee's holding the proper position, expressed in seconds.

The trunk lateral endurance test assesses the endurance of transverse abdominal muscles, oblique abdominal muscles, the quadratus lumborum muscle, and spinal extensor muscles. The examinee first lies on his side with legs extended, aligning his feet on top of each other or in a tandem position (heel-to-toe), leaning against the floor with forearm bent at the elbow and on the sides of his feet. The upper arm should be extended along the side of the body or across the thorax to the opposite shoulder. The hips should be elevated off the floor, and the body should be in straight alignment (head, neck, trunk, hips, and legs). The goal of the test is to hold this position for as long as possible. The result in this test is the endurance time in the lateral bridge, expressed in seconds. When the examinee breaks the position, the test is terminated. Considering that the test is bilateral, the endurance time in a proper position is measured on both the left and right side of the body.

The single-leg squat test is a functional test for the hips and lower legs, containing balance, mobility, and strength elements. It is deemed that the quality of performing this test reflects neuromuscular control during walking. Hip abduction during walking can be observed in persons who underperform in this test (Alexander, Crossley, & Schache, 2009). The test is used to assess lower body strength, particularly the hip flexor and knee extensor, gluteal muscle groups, and hip stabilizers. The examinee should first stand on one leg while the other leg is lifted off the ground in front of the body so that the hip is flexed to approximately 45° and the knee of the non-stance leg flexed to approximately 90°. The arms should be extended in front of the body freely or with hands clasped. From this position, the examinee should squat down so that the flexion in the knee joint is approximately 60° and then return to the starting position. Clinical observation usually involves knee and hip stability assessment. During the test, the knees, feet, and hips should remain in line. The examinee should perform five successive repetitions on each leg, where each squat is worth 15 points with a maximum score of 75 points. In the case of compensatory movements (torso rotation, turning the hips inwards or outwards, or the movements of the knee inwards), the test is interrupted.

The front plank test evaluates the endurance of the trunk stabilizer muscles, especially the endurance of the stabilizers of the back of the trunk that keep the spine in neutral alignment during this test. The test is performed so that the examinee lies down on his stomach and assumes the front plank position leaning against the floor only by his forearms and toes. In doing so, the hips should be at shoulders level, and elbows bent at an angle of 90° and positioned directly below the shoulders. In addition, the body should be fully extended from the shoulders to the heel without raising or lowering the hips beyond shoulder level. The test result is the examinee's holding time in the correct position, expressed in seconds.

Procedures

The research was conducted in the "Svetozar Markovic" Grammar School in Niš in the second semester of the 2018/2019 school year. The experimental program of the Pilates ball lasted for ten weeks and was carried out in physical education classes, twice a week for 45 minutes (a total of 20 classes). The classes had a standard, four-part structure that included introductory, preparatory, main, and final parts (Table 2).

Before the beginning and at the end of the experimental period, appropriate initial and final measurements of parameters for assessing the sample characteristics and muscle fitness tests were performed to determine the variability of the results from the initial to the final condition in the experimental and control groups. The parameters for assessing the sample characteristics were measured on the first day of measurement in the appropriate premises of the Faculty of Sports and Physical Education in Niš. On the second and third day of measurement, the muscular fitness variables were measured in the gym of the "Svetozar Marković" Grammar School in Niš.

Measurements were taken by previously trained measurers, PhD students of the Faculty of Sport and Physical Education, and Physical Education teachers. All the measurers received instructions for measurement and testing in advance. The same group of measurers conducted both the initial and final measurements at approximately the same time of day and with the same measuring instruments according to standardized measurement protocols. During the measurement, the participants were barefoot and minimally dressed. Testing was conducted under identical conditions for all participants. After the initial measurement, the participants were randomly divided into an experimental and a control group.

The contents of the introductory, preparatory and final phases of the physical education classes were the same for both groups (Table 2). In the introductory phase of the class (3-5 minutes), simple and familiar movements with an already formed dynamic stereotype were applied to ensure the dynamics of exercise and thus the necessary physiological impact on the body. The means of the introductory part of the class were "natural forms of movement" (walking, brisk walking, running, jumping, etc.), various figures and other stylistic movements, and various elementary games, which enabled the physiological warm up of the student's body with their dynamic content. In the preparatory phase of the class (8 minutes), complexes of shaping exercises in pairs and with props (with a hoop, ball, and jump rope) were performed, with the aim of a complete preparation of the muscles, tendons, and ligaments for the upcoming activities in the main phase of the class. In the main phase, which lasted for 30 minutes, the experimental group carried out the experimental program of Pilates ball exercises for trunk muscle stabilizer development. In contrast, the control group followed the physical education curriculum contents prescribed by the Institute for the Advancement of Education and Upbringing. In the final phase of the class (3-4 minutes), both groups of participants did stretching exercises.

Table 2 The structure and content of the classes of the experimental and control program

Phase of the class	Experimental group	Control group
Introductory	Physiological warming (3-5 min)	Physiological warming (3-5 min)
Preparatory	Shaping exercises (8-10 min)	Shaping exercises (8-10 min)
Main	Pilates on the ball (25-30 min)	Volleyball, athletics and gymnastics program (25-30 min)
Final	Static stretching exercises (5 min)	Static stretching exercises (5 min)

The experimental Pilates ball program was designed according to the guidelines of Clark et al. (2018). By optimal development of neuromuscular efficiency and gradual increasing of proprioceptive requirements during the training period, the necessary conditions for efficient development of muscle stability of the global and local stabilization system were created. In the basic phase of neural adaptation, which lasted for three weeks, the emphasis was on performing the basic movements necessary for establishing motor control and getting used to an unstable exercise surface. During three weeks, participants performed exercises to develop static stability of the body core front, side, and back, and the flexion, extension, and trunk rotation exercises necessary to improve the functional training outcomes. The movements were one-dimensional and performed with minimal spinal column and pelvis movement to improve neuromuscular efficiency and intervertebral stability. The emphasis was more on the quality than quantity of the exercises, so the exercises were done at a slow pace. During exercise, the participants tried to maintain stability and optimal neuromuscular control which enables coordinated movement.

In the developmental phase of accumulation characterized by increased neural requirements, the participants did significantly more complex and more intensive exercises for improving core muscle dynamic stability (trunk core stabilization during limb movements) and lateral and rotational flexion and trunk extension exercises to improve muscle strength and balance. The spinal column eccentric and concentric movements were done more dynamically and with a full range of motion.

The last, advanced phase of specialization was characterized by structurally more complex and energetically more demanding multi-dimensional movements that include a larger number of components in one movement. It was conducted to increase force production of the trunk stabilizer muscles for the sake of improving dynamic core stability. Trunk lateral and rotational flexion and extension exercises were done faster than the exercises in the previous phase, but not too fast so that the coordination of movements would not be disturbed.

Exercise progression is achieved by reducing the support surface, increasing proprioceptive requirements, changing the number of repetitions and sets, and, in the case of time-limited exercises, increasing exercise time. Furthermore, the applied exercises evenly engaged the front and back muscle groups of the body, which enabled the harmonious development of the muscles and prevented injuries due to possible imbalances. Along with the improvement of neuromuscular coordination and stability of the spinal column and lumbopelvic region, the participants also improved functional efficiency, so they performed the functional movement patterns without excessive spinal movements during flexion, extension, lateral flexion, and trunk rotation exercises.

Table 3 Experimental program

Phase 1 / Week 1 /Pace: Slow				Phase 1 / Week 2 /Pace: Slow			
Exercises	S	REP	Time (s)	Exercises	S	REP	Time (s)
Balanced Sitting – one leg up	1	/	:60 el	Balanced Sitting – one leg up	1	/	:60 el
Ball Prone Bridge	1	/	:60	Ball Prone Bridge	2	/	:45
Ball Side Bridge	1 es	/	:45 es	Ball Side Bridge	2 es	/	:30 es
Ball Supine Bridge	1	/	:60	Ball Supine Bridge	2	/	:45
Ball Crunch	3	8	/	Ball Crunch	3	8-10	/
Ball Trunk Hyperextension	3	8	/	Ball Trunk Hyperextension	3	8-10	/
Ball Trunk Rotation	1	8 es	/	Ball Trunk Rotation	1	8-10 es	/
Phase 1 / Week 3/Pace: Slow				Phase 2/ Week 4/Pace: Medium			
Exercises	S	REP	Time (s)	Exercises	S	REP	Time (s)
Balanced Sitting – one leg up	1	/	:60 el	Kneeling on a Ball -4F	1	/	:15
Kneeling on a Ball -4F	1	/	10	Plank - forearms on ball	1	/	:20
Ball Prone Bridge	2	/	:60	Ball Side Bridge - upper leg up	2 es	/	:35 es
Ball Side Bridge	2 es	/	:35 es	Ball Supine Bridge- one leg up	1	/	:35 el
Ball Supine Bridge	2	/	:60	Ball V-Pass	2	10	/
Ball Crunch	3	10	/	Ball Diagonal Crunch	2	8 es	/
Leg Raise – ball between feet	1	10	/	Ball Side Crunch	2	8 es	/
Ball Trunk Hyperextension	3	10	/	Ball Trunk Hyperextension	2	10	/
Ball Trunk Rotation	1	10 es	/	Ball Reverse Hyperextension	1	12	
/	/	/	/	Ball Hips Rotation	1	10 es	/
Phase 2 Week 5 /Pace: Medium				Phase 2 Week 6 /Pace: Medium			
Exercises	S	REP	Time (s)	Exercises	S	REP	Time (s)
Kneeling on a Ball -4F	1	/	:15-20	Kneeling on a Ball -4F	1	/	:20
Plank - forearms on ball	1	/	:25	Plank - forearms on ball	1	/	:30
Ball Side Bridge - upper leg up	2 es	/	:40 es	Ball Side Bridge - upper leg up	2 es	/	:45es
Ball Supine Bridge - one leg up	1	/	:40 el	Ball Supine Bridge - one leg up	1	/	:50 el
Ball V-Pass	2	10-12	/	Ball V-Pass	2	12	/
Ball Diagonal Crunch	2	8-10 es	/	Ball Diagonal Crunch	2	10 es	/
Ball Side Crunch	2	8-10 es	/	Ball Side Crunch	2	10 es	/
Ball Trunk Hyperextension	2	10-12	/	Ball Trunk Hyperextension	2	10	/
Ball Reverse Hyperextension	1	12-15	/	Ball Reverse Hyperextension	2	10	/
Ball Hip Rotation	1	12 es	/	Ball Hip Rotation	2	8 es	/
Phase 2/ Week 7/Pace: Medium				Phase 3 / Week 8 /Pace: As fast as can be controlled			
Exercises	S	REP	Time (s)	Exercises	S	REP	Time (s)
Kneeling on a Ball -4F	1	/	:25	Kneeling on a Ball -2F	1	/	:15
Ball Forearm Plank	2	/	:17	Ball Forearm Plank	2	/	:20
Ball Side Bridge - upper leg up	2 es		:50 es	Ball Side Bridge - upper leg up	2 es	/	:55 es
Ball Supine Bridge - one leg up	1	/	:55/:60 el	Ball Supine Bridge - one leg up	2	/	:60 el
Ball V-Pass	2	12-15	/	Ball V-Pass	3	12	/
Ball Diagonal Crunch	3	8 es	/	Pike on the ball	1	8	/
Ball Side Crunch	8	8 es	/	Ball Diagonal Crunch	3	8-10 es	/
Ball Trunk Hyperextension	2	10-12	/	Ball Side Crunch	3	8-10 es	/
Ball Reverse Hyperextension	2	10-12	/	Supermen on a Ball	3	10-12	/
Ball Hip Rotation	2	10 es	/	Ball Hip Rotation	3	8 es	/
Phase 3 / Week 9 /Pace: As fast as can be controlled				Phase 3/ Week 10 /Pace: As fast as can be controlled			
Exercises	S	REP	Time (s)	Exercises	S	REP	Time (s)
Kneeling on a Ball -2F	1	/	:20	Kneeling on a Ball -2F	1	/	:25
Ball Forearm Plank	2	/	:25	Ball Forearm Plank	2	/	:30
Ball Side Bridge - upper leg up	2 es	/	:60 es	Ball Side Bridge - upper leg up	3 es	/	:45 es
Ball Supine Bridge - one leg up	3	/	:45 el	Ball Supine Bridge - one leg up	3	/	:50 el
Ball V-Pass	3	12-15	/	Ball V-Pass	3	15	/
Pike	2	8	/	Pike	3	8	/
Supermen	3	12	/	Supermen	3	15	/
Ball Hip Rotation	3	8-10 es	/	Ball Hip Rotation	3	10 es	/
Ball Diagonal Crunch	3	10 es	/	Ball Diagonal Crunch	3	10-12 es	/
Ball Side Crunch	3	10 es	/	Ball Side Crunch	3	10-12 es	/

Legend: el - with each leg; es - on both sides; 4F - four points of support;
2F - two points of support; REP - the number of repetitions; S -the number of sets.

The participants of the control group chose volleyball as a sports game of the students' choice (Table 4).

Table 4 Control group program

Week	Class	Teaching units
I	1.	Volleyball: bouncing the ball with fingers and a spike in a jump and with a change of direction
	2.	Volleyball: side "fleet" serve (swinging serve) and reception serve
II	3.	Volleyball: "jump fleet" serve (jump fleet) and serve reception
	4.	Volleyball: spiking and blocking the ball (double and triple block: blocks of two and three students)
III	5.	Athletics: throwing a 4 kg ball, one of the rational techniques
	6.	Athletics: improvement of the short distance running technique: 100 m; relay 4 x 100 m.
III	7.	Athletics: improvement of the middle distance running technique: 800 m.
	8.	Athletics: cross country: spring: 800 m.
IV	9.	Strength exercises without and with small weights - up to 4 kg
	10.	Strength exercises without and with small weights - up to 4 kg
V	11.	Gymnastics (ground exercises): scales by bending and squatting and joining, reflecting one leg forward roll
	12.	Gymnastics (ground exercises): position on the fists, endurance, reel forward
VI	13.	Gymnastics (ground exercises): two connected star jumps to the right and left
	14.	Gymnastics (ground exercises): vault: squat on and vault with legs spread (for advanced level: amanar)
VII	15.	Gymnastics (composition on a high beam): jump, swings, turns, handstand balance, walking up with hop steps, scale, frontal and lateral dismounts
	16.	Gymnastics (composition on a high beam): jump, swings, turns, handstand balance, walking up with hop steps, scale, frontal and lateral dismounts
VIII	17.	Polygon of dexterity and agility
	18.	Polygon of dexterity and agility
IX	19.	Aerobics
	20.	Aerobics
X	21.	Exercises in corrective gymnastics
	22.	Exercises in corrective gymnastics

Methods of data processing

For all anthropometric measures and muscle fitness tests, basic descriptive parameters of measures of central tendency and variability of results at the initial and final measurement were calculated. As data collected in the research are sourced from the interval measurement scale, the following descriptive measures were calculated: arithmetic mean (Mean), minimum (Min) and maximum (Max) value of results, standard deviation (St.dev.), indicators of asymmetry (Skewness) and flatness (Kurtosis) of the results distribution, and significance of the Shapiro-Wilk normality test (Shapiro-Wilk coefficient).

The Shapiro-Wilk normality test was used following previous research findings, confirming that this test is more reliable in assessing the normality of distribution when research is conducted on small samples of participants.

Considering that the groups of participants did not differ statistically significantly in muscular fitness at the initial measurement, the Multivariate Analysis of Variance

(MANOVA) was calculated to determine multivariate differences between the experimental and control groups in muscular fitness at both the initial and final measurement. At the univariate level, intergroup differences in muscle fitness at the initial and final measurements were determined by the t-test for independent samples.

Statistical significance ($p \leq .05$) of Wilks' lambda criterion was calculated to determine a multivariant statistical significance of intergroup differences. Before conducting the MANOVA analysis, it was checked whether the following criteria (assumptions) for applying the specified statistical technique were met: multivariant normality, absence of outliers, homogeneity of variance, linearity, and multicollinearity.

The one-way repeated measures MANOVA was applied to establish differences in muscular fitness at the multivariate level within the experimental and control groups between the initial and final measurements. The differences between the two measurements within the experimental and control groups were determined by the t-test for dependent samples at the univariate level. Partial eta-squared (η^2p) was used to estimate the effect size. Effect size values are classified into several categories (Ferguson, 2009): if $0 \leq \eta2p < 0.05$ then there is no effect; if $0.05 \leq \eta2p < 0.26$ then the effect is small; if $0.26 \leq \eta2p < 0.64$ then the effect is medium; if $0.64 \leq \eta2p$ then the effect is large.

Statistical data processing was performed in the SPSS version 23.0 statistical data processing package.

RESULTS

Table 4 shows the results of the Multivariate Analysis of Variance of the muscle fitness data of the experimental and control groups at the initial measurement. The results indicate that the experimental and control group at the multivariate level did not differ statistically significantly in muscle fitness at the initial measurement ($p > 0.05$).

Table 4 Multivariate differences in muscular fitness between the experimental and control group at the initial measurement

Wilks' lambda	F	Effect-df	Error-df	p	η^2p
0.716	2.266	7	40	.053	.084

Legend: Wilks' lambda - the value of the Wilks' test coefficient for the equality of group centroids; F - the value of the F-test coefficient, which is an approximation of the Wilks' lambda value; Effect df and Error df - degrees of freedom; p - coefficient of significance of F-statistics; η^2p - partial squared eta (measure of effect size).

Multivariate differences in muscular fitness between the initial and final measurements of the experimental group, determined by the one-way repeated measures MANOVA, are shown in Table 5. The results indicated that statistically significant differences in muscular fitness ($p < 0.01$) between the initial and final measurements of the experimental group were determined and that the size of the effect was large ($\eta^2p = .990$).

Results of the t-test for dependent samples (Table 6) indicate that statistically significant differences in muscular fitness were also determined at the univariate level at repeated measurements in the experimental group ($p < 0.01$) and that a great effect size ($\eta^2p \geq 0.64$) can be observed in all muscular fitness tests. The most significant effects were determined in improving the endurance of the trunk flexor muscles ($\eta^2p = .961$) and endurance of the lateral trunk muscles on the left side ($\eta^2p = .940$).

Table 5 Multivariate differences in muscular fitness of the experimental group between the initial and final measurements

Wilks' lambda	F	Effect-df	Error-df	p	$\eta^2 p$
0.010	244.549	7	17	.000**	.990

Legend: Wilks' lambda - the value of the Wilks' test coefficient for the equality of group centroids; F - the value of the F-test coefficient, which is an approximation of the Wilks' lambda value; Effect df and Error df - degrees of freedom; p - coefficient of significance of F-statistics; $\eta^2 p$ - partial squared eta (measure of effect size). ** - statistical significance at the level of .01.

The results of the one-way repeated measures MANOVA (Table 7) indicate that at the multivariate level between the initial and final measurements of the control group, there are statistically significant differences in muscular fitness ($p < 0.01$) and that the effect size is large ($\eta^2 p = .969$).

The results of the t-test for dependent samples (Table 8) indicate that at the univariate level between the two measurements, statistically significant changes were found in all muscular fitness variables. The average values of the results of muscular fitness tests are significantly higher at the final than at the initial measurement. The value of the partial eta squared coefficient points to large effects ($\eta^2 p \geq 0.64$) in five of the seven muscular fitness tests: 1. the trunk lateral endurance test - left side ($\eta^2 p = .907$); 2. the trunk extensor endurance test ($\eta^2 p = .797$); 3. the trunk lateral endurance test - right side ($\eta^2 p = .772$); 4. the single-leg squat test - left leg ($\eta^2 p = .689$); and 5. the trunk flexor endurance test ($\eta^2 p = .639$). Medium effect size was determined in the front plank test ($\eta^2 p = .595$) and the single-leg squat test - right leg ($\eta^2 p = .490$).

Table 6 Univariate differences in muscular fitness of the experimental group between the initial and final measurements

Variable	Measurement	M	S	t	p	$\eta^2 p$
TFET	I F	98.58 136.75	19.30 23.34	-23.903	.000**	.961
TEET	I F	91.54 121.08	21.28 24.09	-17.768	.000**	.932
TLET-R	I F	52.71 66.17	15.83 16.50	-13.975	.000**	.895
TLET-L	I F	48.29 64.17	14.58 15.25	-18.969	.000**	.940
TFPT	I F	65.21 100.25	18.30 25.38	-18.170	.000**	.935
SLST-R	I F	35 63.13	17.51 13.25	-15.000	.000**	.907
SLST-L	I F	25 49.79	16.94 18.68	-7.103	.000**	.687

Legend: TFET - trunk flexor endurance; TEET - trunk extensor endurance; TLET-R - trunk lateral endurance - right side; TLET-L - trunk lateral endurance - left side; TFPT - endurance in the Front Plank Test; SLST-R - single-leg squat - right leg; SLST-L - single-leg squat- left leg; I - initial measurement; F – final measurement; M - arithmetic mean; S - standard deviation; t - value of the t-test coefficient; p - coefficient of significance of t-statistics; $\eta^2 p$ - partial squared eta (measure of effect size). ** - statistical significance at the level of .01.

Table 7 Multivariate differences in muscular fitness of the control group between the initial and final measurements

Wilks' lambda	F	Effect-df	Error-df	p	η^2_p
0.031	76.311	7	17	.000**	.969

Legend: Wilks' lambda - the value of the Wilks' test coefficient for the equality of group centroids; F - the value of the F-test coefficient, which is an approximation of the Wilks' lambda value; Effect df and Error df - degrees of freedom; p - coefficient of significance of F-statistics; η^2p - partial squared eta (measure of effect size). ** - statistical significance at the level of .01.

Table 8 Univariate differences in muscular fitness of the control group between the initial and final measurements

Variable	Measurement	M	S	t	p	η^2_p
TFET	I F	93.63 107.13	11.30 11.84	-6.387	.000**	.639
TEET	I F	94.54 107.50	16.62 15.94	-9.491	.000**	.797
TLET-R	I F	53.29 59.17	10.56 11.01	-8.825	.000**	.772
TLET-L	I F	50.79 58.17	9.64 10.46	-14.990	.000**	.907
TFPT	I F	68.79 75.42	21.10 22.01	-7.137	.000**	.595
SLST-R	I F	31.25 43.75	13.93 17.08	-5.816	.000**	.490
SLST-L	I F	27.50 40.00	15.74 15.74	-4.703	.000**	.689

Legend: TFET - trunk flexor endurance; TEET - trunk extensor endurance; TLET-R - trunk lateral endurance - right side; TLET-L - trunk lateral endurance - left side; TFPT - endurance in the Front Plank Test; SLST-R - single-leg squat - right leg; SLST-L - single-leg squat- left leg; I - initial measurement; F – final measurement; M - arithmetic mean; S - standard deviation; t - value of the t-test coefficient; p - coefficient of significance of t-statistics; η^2p - partial squared eta (measure of effect size). ** - statistical significance at the level of .01.

Table 9 indicates the results of the MANOVA analysis of muscular fitness between the experimental and control group of participants at the final measurement. The results indicate that the experimental and control group at the multivariate level differed statistically significantly in muscular fitness at the final measurement ($p < 0.01$).

The results of the t-test for independent samples at the final measurement (Table 10) indicate that statistically significant intergroup differences were determined at the univariate level in four of the seven tests for assessing muscular fitness: the trunk flexor endurance test ($t = 5.545$, $p < .01$), front plank test ($t_{tfpt} = 3.621$, $p < .01$), single-leg squat test - right leg ($t = 4.390$, $p < .01$), and the trunk extensor endurance test ($t = 2.304$, $p < .05$).

Table 9 Multivariate differences in muscular fitness between the experimental and control group at the final measurement

Wilks' lambda	F	Effect-df	Error-df	p	η2p
0.404	8.427	7	40	.000**	.596

Legend: Wilks' lambda - the value of the Wilks' test coefficient for the equality of group centroids; F - the value of the F-test coefficient, which is an approximation of the Wilks' lambda value; Effect df and Error df - degrees of freedom; p - coefficient of significance of F-statistics; η^2p - partial squared eta (measure of effect size). ** - statistical significance at the level of .01.

Table 10 Univariate differences in muscular fitness between the experimental and control group at the final measurement

Variable	Group	M	S	t	p	η^2p
TFET	E K	136.75 107.13	23.34 11.84	5.545	$.000^{**}$	.401
TEET	E K	121.08 107.50	24.09 15.94	2.304	$.026^{*}$	.103
TLET-R	E K	66.17 59.17	16.50 11.01	1.729	.091	.061
TLET-L	E K	64.17 58.17	15.25 10.46	1.589	.119	.052
TFPT	E K	100.25 75.42	25.38 22.01	3.621	$.001^{**}$	.222
SLST-R	E K	63.13 43.75	13.25 17.08	4.390	$.000^{**}$	.295
SLST-L	E K	49.79 40.00	18.68 15.74	1.964	.056	.077

Legend: TFET - trunk flexor endurance; TEET - trunk extensor endurance; TLET-R - trunk lateral endurance - right side; TLET-L - trunk lateral endurance - left side; TFPT - endurance in the Front Plank Test; SLST-R - single-leg squat - right leg; SLST-L - single-leg squat- left leg; I - initial measurement; F – final measurement; M - arithmetic mean; S - standard deviation; t - value of the t-test coefficient; p - coefficient of significance of t-statistics; η^2p - partial squared eta (measure of effect size). ** - statistical significance at the level of .01.

Comparing the average results of the muscular fitness of the experimental and control group shows that the experimental group achieved better results than the control group at the final measurement. Data on partial eta squared indicate medium effects in the trunk flexor endurance test (η^2p = .401) and single-leg squat test - right leg (η^2p = .295), and small effects in the front plank test (η^2p = .222) and trunk extensor endurance test (η^2p = .103). In the single-leg squat test, when performed on the right leg, and trunk lateral endurance tests on both sides of the trunk, the differences determined in favor of the experimental group were only at the numerical level.

DISCUSSION

This research determined the effectiveness of a ten-week experimental Pilates ball program, conducted in regular physical education teaching, and the standard physical education program on transformational processes of muscular fitness in adolescents. The research draft had the character of a draft with equivalent groups since the groups of participants did not differ statistically significantly in muscular fitness before the experiment.

During the experimental period, both groups of female participants statistically significantly improved muscular fitness, but larger effects were achieved in the experimental group. Based on the size of the partial eta squared coefficient between the initial and final measurements of muscular fitness of the experimental group, it is evident that it has to do with large effects of the applied experimental program at both the multivariate (η^2p = .990) and univariate level (η^2p (ttfet) = .961; η^2p (tteet) = .932; η^2p (ttlet-r) = .895; η^2p (ttlet-l) = .940; η^2p (ttfpt) = .935; η^2p (tslst-r) = .907; η^2p (tslst-l) = .687) in all muscular fitness tests. The greatest effects between the two measurements of the experimental group were registered in endurance of the trunk flexors (η^2p = .961), trunk extensors (η^2p = .932), and trunk lateral stabilizers on the left side (η^2p =

.940), while the smallest effect was found in the endurance of lateral trunk muscles on the right side (η^2p = .687). The large effects between the two measurements in the bilateral single-leg squat test suggest that exercising on an unstable surface, along with improving the endurance of the trunk stabilizers, especially the trunk extensors, also improved lower body strength and the hip stabilizer muscle strength and endurance.

A significant improvement of muscular fitness was also registered in the control group of participants between the initial and final measurement (Λ= 0.031, F(7,17) = 76.311, p < 0.01). Great effect size, though numerically a little smaller than in the experimental group, was registered at both the multivariate (η^2_p = .969) and univariate level (η^2p (ttfet) = .639; η^2p (tteet) = .797; η^2p (ttlet-r) = .772; η^2p (ttlet-l) = .907; η^2p (ttfpt) = .595; η^2p (tslst-r) = .490; η^2p (tslst-l) = .689). The standard physical education program most effectively influenced the lateral endurance muscles of the left (η^2p = .907) and right side of the trunk (η^2p = .772), while the lowest impact was registered in the front plank test (η^2p = .595).

The average muscular fitness results of both groups of participants in most tests at the initial and final measurement were within the reference values for age and gender, taken from the research done by Dejanović, Cambridge, and McGill (2014). The mean values of the results of the front Plank test in both groups were within the normative values (60-120 s) both at the initial (TFPTi = 65.21 s in the experimental group; TFPTi = 68.79 s in the control group) and the final measurement (TFPTf = 100.25 s in the experimental group; TFPTf = 75.42 s in the control group), with slightly higher numerical values registered in the control group at the initial measurement and in the experimental group at the final measurement, indicating a greater influence of the experimental program compared to the control group program. Namely, the Plank exercise, which was an integral part of the experimental group's program, and which engages the front of the body's core muscles and specifically activates the oblique abdominal muscles and lateral trunk stabilizers (Aggarwal, Kumar, & Kumar, 2010), has definitely contributed to the significant development of torso flexors. The measure of the effect size indicates a medium effect in the trunk flexor endurance test (η^2_p= .401) and the single-leg squat test – right leg (η^2_p= .295), and a lesser effect in the Plank Test (η^2_p= .222) and the trunk extensor endurance test (η^2_p= .103).

By comparison with norms for age and gender, it can be noticed that the average results of the trunk flexor and extensor endurance tests at the initial (TFETi = 98.58, TEETi = 91.54, in the experimental group; TFETi = 93.63, TEETi = 94.54, in the control group) and final measurement (TFETf = 136.75, TEETf = 121.08, in the experimental group; TFETf = 107.13; TEETf = 107.50 in the control group) were also within the reference values for girls aged 15 (TFET = 161.4 ± 78.2; TEET = 171.6 ± 62.8; in the control group) and 16 (TFET = 135.5 ± 69.8; TEET = 147.7 ± 66.3).

The same was observed in tests for assessing bilateral trunk endurance, in which, according to the mentioned authors, in both groups of participants at the initial (TLET-Ri = 52.71, TLET-Li = 48.29, in the experimental group; TLET-Ri = 53.29, TLET-Li = 50.79 in the control group) and at the final measurement (TLET-Rf = 66.17, TLET-Rf = 64.17, in the experimental group; TLET-Rf = 59.17; TLET-Rf = 59.17; TLET-Lf = 58.17 in the control group) the average value were also within the normative values for 15-year-old (TLET-R = 68.2 ± 27.4; TLET -L = 70.2 ± 31.5) and 16-year-old girls (TLET-R = 55.2 ± 29.5; TLET-L = 55.7 ± 26.4). According to Dejanovic et al. (2014), the reference values of the trunk lateral endurance test performed on the left side of the body are numerically slightly higher over the norms for test performed on the right side.

Considering the fact that, at the initial measurement, the control group had numerically better results than the experimental group in all muscular fitness tests, except in the trunk flexor endurance test and single-leg squat test when performed on the right leg, in which the experimental group of participants had numerically better results, it is evident that the Pilates ball program is generally more effective than the control group's program in the transformation of muscular fitness.

The results of this research are consistent with the results of numerous previous studies that researched the effectiveness of Pilates ball exercise on muscular fitness (Carter et al., 2006; McCackey, 2011; Prachi et al., 2019; Prieske et al., 2016; Sekendiz et al., 2010; Stanton et al., 2004; Sukalinggam et al., 2012). These results generally indicated that similar effects were achieved in participants of both genders, although numerically better results were registered in male compared to female participants (Prieske et al., 2016; Stanton et al., 2004). Stanton et al. (2004) determined significant improvements in all trunk stabilizer endurance tests in a sample of fifteen-year-old athletes who performed only 12 training sessions during the six-month experimental period. The applied exercises were of similar intensity and duration as in this study. Exercise progression during the experimental period in their study was achieved only by increasing the number of repetitions and the number of sets of exercises and not by increasing the number of exercises or intensity of the exercises.

Sekendiz (2010) found that a 12-week stabilization training on a Pilates ball with a frequency of three training sessions per week was an effective training stimulant for improving strength and endurance of trunk flexors and extensors in female non-athletes. Regarding the longer duration of the experimental period and the higher frequency of training sessions than in this study, the obtained results were expected.

Similar improvements in the trunk flexor and extensor strength and endurance in non-athlete students of both genders were found by Sukalinggam et al. (2012) after six weeks of Pilates ball training, with a frequency of three training sessions per week. Participants did only dynamic trunk flexion and extension exercises, not isometric endurance exercises representing a more intense training stimulus. More significant changes were found in female participants probably because they had poorer results at the initial measurement. A study by McCackey (2011) and Prachi et al. (2019) shows that training effects similar to those from this study can be achieved in a much shorter experimental period if the program is implemented with a high frequency. However, Cosio-Lima et al. (2003) did not find significant improvements in non-athlete female students in any stabilization endurance test ($p>0.05$) after five weeks of high-frequency training (5 times a week), but only registered significant improvements in the EMG activity of trunk flexors ($p=0.04$) and extensors ($p=0.01$). In general, more significant improvements in trunk stabilizer endurance have been observed in athletes (Carter et al., 2006; Prieske et al., 2016; Stanton et al. 2004), so it can be assumed that sports activity engages trunk stabilizers to the same or greater extent as specific exercises for its development.

On the other hand, Prieske et al. (2016), in a sample of young athletes who did training for the development of core stability two to three times a week for nine weeks, found significant effects only in strengthening the trunk extensors but not the trunk flexors, even though the training program also included specific exercises for its strengthening. Such results probably occurred because the average values of the trunk flexor results at the initial measurement were significantly better than the average values of the trunk extensors, so more intensive stimuli were needed for its development. In addition, the mentioned author found similar effects in improving the endurance of the trunk extensors in the group of participants who exercised on the ground, so the conclusion that an unstable exercise surface produces greater training effects is called into question.

Effects of the experimental program

At the final measurement, the Multivariate Analysis of Variance (Λ= 0.404, F (7,40) = 8.427, $p < 0.01$, η^2_p = .596) determined statistically significant intergroup differences at the multivariate level. The results of the t-test for independent samples have shown that groups of female participants differed statistically significantly at the univariate level, but only in four of the seven muscular fitness tests. Statistically significantly larger effects at the final measurement were found in the experimental group in the single-leg squat test performed with the right leg and all the tests for assessing body core muscular endurance except in tests for assessing lateral trunk stabilizer endurance in which higher effects were registered only at the numerical level. The level of statistical significance of intergroup differences in the trunk flexor endurance test (ttfet = 5.545, p <.01), plank test (ttfpt = 3.621, p <.01) and the single-leg squat test when performed by the right leg (tslst-r = 4.390, p <.01) was.01, while the determined level of intergroup differences in the trunk extensor endurance test was at the .05 level of significance (tteet = 2.304, p <.05). In other muscle fitness tests, numerical but not statistically significant intergroup differences were registered at the final measurement in favor of the experimental group. Compared to the control group, the experimental group achieved numerically better results in both tests for assessing trunk lateral endurance and in the single-leg squat test when performed with the left leg.

In general, a more efficient training response to exercise on an unstable surface was expected given the concept of the experimental program, which contained specific exercises for the development of torso stabilizers. In addition to dynamic exercises, the experimental program contained exercises of isometric contractions of torso stabilizer muscles in conditions of increased postural requirements for maintaining stability during exercising on an unstable surface, also activating local and deep stabilizers, in addition to global ones (Carter et al., 2006). Although training in unstable conditions produces less force, training on an unstable surface obviously provides an additional load on trunk stabilizers to maintain balance in unstable conditions, which contributes to their strengthening. Furthermore, greater adaptations of synergists and trunk stabilizer muscles in the experimental group are obviously a consequence of the unstable exercise surface that provokes a more complex interaction of passive (joints and spinal ligaments) and active (neural and muscular) subsystems that keep the intervertebral neutral zones within physiological limits.

CONCLUSION

Exercise on an unstable surface improves the neuromuscular adaptations to training stimuli, so the use of Pilates balls is often an integral part of the training process. This research determined the effectiveness of the Pilates ball on the muscular fitness of female adolescents. Comparing the effectiveness of a ten-week Pilates ball program and the standard physical education program found that both programs significantly improved participants' muscular fitness during the experimental period, with numerically greater effects recorded in all muscular fitness tests in the experimental group. Pilates on a ball most effectively influenced the endurance of torso flexors and extensors, while the most significant effect of the standard physical education program, although numerically smaller than in the experimental group, was noticed in improved bilateral torso muscular endurance. Significantly greater effects of the experimental program at the final measurement were found in the single-leg squat test when performed with the right leg and all the tests for assessing the endurance of torso stabilizer muscles, except in the tests for assessing lateral torso stabilizer endurance in which higher experimental group effects were registered only at the numerical level. Accordingly, the authors conclude that a ten-week Pilates ball program is more efficient than the standard physical education program in transforming the muscular fitness of female adolescents, so its implementation in the physical education curriculum can be recommended.

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EFEKTI PILATESA NA LOPTI NA MIŠIĆNI FITNES ADOLESCENTKINJA

Ovom studijom su utvrđivani efekti desetonedeljnog treninga na pilates lopti na mišićni fitnes adolescentkinja. Uzorak od 48 ispitanica je nasumično bio podeljen na eksperimentalnu ($n = 24$) i kontrolnu grupu ($n = 24$). Eksperimentalna grupa (uzrast: 15.28 ± 0.48; visina tela: 164.48 cm; težina tela: 69.2 ± 6.3 kg) je dva puta nedeljno tokom 10 nedelja na časovima fizičkog vaspitanja sprovodila program pilatesa na lopti dok je kontrolna grupa (uzrast: 15.28 ± 0.48; visina tela: 164.35 cm; težina tela: 58.86 kg) sprovodila standardni program fizičkog vaspitanja. Mišićni fitnes je bio procenjen testovima za procenu izdržljivosti fleksora, ekstenzora i lateralnih mišića trupa, testom prednji plank i testom čučanj na jednoj nozi. Rezultati su pokazali da su između dva merenja obe grupe ispitanica statistički značajno poboljšale mišićni fitnes ($p < 0.01$) ali su numerički veći efekti postignuti u eksperimentalnoj grupi. Najveći efekti između dva merenja eksperimentalne grupe registrovani su u izdržljivosti fleksora i ekstenzora trupa. U kontrolnoj grupi najveći efekti su utvrđeni u bilateralnoj izdržljivosti trupa. Značajno veći efekti ($p < 0.01$) na finalnom merenju utvrđeni su kod eksperimentalne grupe u izdržljivosti fleksora ($p < .01$) i ekstenzora trupa ($p < .05$) i u testu čučanj na jednoj nozi izvođenom desnom nogom ($p < .01$). U testovima za procenu bilateralne izdržljivosti trupa, veći efekti kod eksperimentalne grupe su registrovani samo na numeričkom nivou. Autori zaključuju da vežbanje na nestabilnoj u odnosu na stabilnu površinu predstavlja efikasniji trenažni stimulans u transformaciji mišića fleksora i ekstenzora trupa i dinamičkoj kontroli kukova i nogu.

Ključne reči: *učenici, trening na nestabilnoj površini, fizičko vaspitanje, stabilizatori trupa*