Physical education and sport through the centuries
2024, 11(2), 95-108
ISSN 2335-0598
https:// phedss.fsfv-pr.rs

Original research article DOI: 10.5937/spes2402095A

EFFECTS OF CORE TRAINING ON AN UNSTABLE SURFACE ON THE FUNCTIONAL MOBILITY OF ADOLESCENTS

Ashrf Nouri M. Abohllala[1], Nataša Branković[1], Mia I. Stanojević[2], Igor Stanojević[3], Sreten V. Marković[1], Nebojša Trajković[1], Uroš Nikolić[1]

[1]Faculty of Sport and Physical Education, University of Niš, Serbia
[2]Faculty of Sport and Physical Education, University of Novi Sad, Serbia
[3]Academy of Educational Medical Vocational Studies, Aleksinac, Serbia

ABSTRACT

This study determined the effects of core body ball Pilates training on the functional mobility of adolescents. The study included 48 participants who were randomly assigned to either an experimental group (E; n = 24) or a control group (C; n = 24). Participants in the experimental group performed exercises on a Pilates ball twice a week for ten weeks. The control group followed the regular physical education (PE) program. The sample of measurement instruments consisted of seven standard Functional Mobility Screening (FMS) tests. The results indicated that the experimental program led to statistically significant improvements and had medium effects on the results of the Trunk Stability Push-Up ($p< .01$; ES=.41), Rotational Stability ($p< .05$; ES=.35), and Shoulder Mobility tests ($p< .05$; ES=.29). The control group did not show statistically significant improvements in any of the FMS tests ($p> .05$). The results of intergroup differences in functional mobility at the final measurement indicated statistically significantly better results in the experimental group in three of seven FMS tests. Moderate effects of the applied experimental treatment in the Trunk Stability Push-Up (ES=.41), Rotational Stability (ES=.31), and Shoulder Mobility (ES=.35) tests were determined. Effects ranging from small to moderate were observed in the Active Straight-Leg Raise test (ES=.19). In the Deep Squat test, Hurdle Step, and In-Line Lunge tests, the effect size measures were small (ES=.01). The study confirmed the superiority of Pilates on the ball compared to the regular PE program in the adaptation of functional mobility in adolescents.

Key words: Pilates ball training, core muscles, FMS, students

Corresponding author
Nataša Branković
natasa97531@gmail.com

Copyright: © 2025 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

INTRODUCTION

Pilates is a fitness method that uses well-designed and controlled stretching and strength exercises to improve flexibility, strengthen and shape muscles, enhance their tone, body posture, and overall muscle form (Siller, 2003).

Implementing Pilates on unstable surfaces, such as rollers, Pilates balls, or BOSU balls, enhances joint and soft tissue mobility, balance, movement coordination, stability, and core mobility (Ignjatović, 2020). Consequently, this improves the quality of functional movement patterns, which are fundamental to functional mobility.

Functional mobility is characterized by a balanced integration of stability and mobility of specific joints in the human body during the performance of activities in various positions and planes of movement (Forhan & Gill, 2013). The knee joint, lumbar spine, and scapulothoracic joint serve stability functions, while the glenohumeral joint, hip joint, and thoracic region of the spine facilitate mobility (Thompson, Gordon, Pescatello, & American College of Sports Medicine, 2010).

This physiological capability enables individuals to move independently and safely in diverse environments while engaging in a range of functional activities and tasks (Cech & Martin, 2012). Impaired functional mobility is associated with an increased risk of falls, which can consequently lead to a loss of independence and a higher likelihood of hospitalization (Enderlin et al., 2015).

From a functional perspective, a strong core is essential for the efficient performance of daily and athletic activities. Core stability refers to the active component of the body's stabilization system, which consists of the deep (local) muscles of the inner core unit and the superficial (global) muscles of the outer core unit. Through synergistic action, the muscles of the inner and outer core units provide complete stability and mobility of the torso and pelvis, generating powerful and functional movements of the upper and lower extremities (Lawrence, 2011).

Studies generally indicate that Pilates on a fitness ball significantly enhances functional mobility (Baumschabel et al., 2015; Dinc et al., 2017; Lago-Fuentes et al., 2018; Saberian et al., 2019; Šćepanović et al., 2020; Vurgun & Edis, 2021). Generally, the improvement of functional mobility is based on enhancing postural stability and mobility, as well as neuromuscular control of movement, which can be significantly improved even within a relatively short time frame (six weeks) (Liang et al., 2018). Specifically, it has been established that core training on a Pilates ball over a period of 8 to 12 weeks, with a frequency of two to three training sessions per week, markedly improves movement patterns fundamental to human motion.

It is well established that physical activity in children and adolescents offers numerous health benefits, underscoring the importance of their participation in organized physical activities. Movement patterns that form the foundation of functional mobility screening are also integral to various sports and recreational activities, facilitating efficient engagement in physical activity while minimizing the risk of injury (O'Brien et al., 2022).

Furthermore, it has been established that a high score on the Functional Movement Screen (FMS) positively correlates with higher levels of physical activity and negatively with elevated levels of body fat in children and adolescents (Mitchell et al., 2016), Additionally, Mitchell at al. (2016) also found poorer functional mobility results in older adults compared to younger individuals, but this was observed only in physically inactive and overweight individuals.

This is particularly important for children and adolescents whose predominantly sedentary lifestyle negatively impacts their health status. Participation in organized physical activities improves their physical fitness (aerobic and muscular fitness), cardiometabolic health (lipid levels, glucose, and blood pressure), bone health, and mental health (Hallal et al., 2012). These factors highlight the importance of timely development of fundamental movement FMS patterns in children and adolescents.

Despite the large number of studies examining the effectiveness of Pilates on a ball on the functional mobility of both athletes and non-athletes, there are significant differences in the applied training programs, exercise selection, frequency of training sessions, intensity, and duration of the exercises. In most studies, participants performed Pilates on a ball alongside floor Pilates (Baumschabel et al., 2015; Lago-Fuentes et al., 2018; Liang et al., 2018; Šćepanović et al., 2020), roller exercises (Dinc et al., 2017), regular off-season sports activities, and other activities. For these reasons, the exclusive effectiveness of Pilates on a ball is still insufficiently researched, particularly among young adolescents.

Studies examining this issue have predominantly been conducted on male participants who are older than the participants in our study, as functional mobility declines with age (Mitchell at al., 2016). While these studies are certainly justified, it cannot be overlooked that there is a noticeable lack of similar research conducted on younger populations.

Bagherian et al. (2019) and Vurgun and Edis (2021) examined the effectiveness of training on a Pilates ball on the functional mobility of adolescents. However, unlike our study, the participants in their research were male athletes in late adolescence. The only study involving participants in early adolescence, similar to our study, was conducted by Dinc et al. (2017), though their participants were also male. Like the two previously mentioned studies, their findings confirmed that Pilates ball training effectively improves fundamental movement patterns.

However, no studies have been conducted to investigate the effectiveness of Pilates ball training in participants in the early adolescent phase without prior training experience. The aim of this study is to determine the effects of Pilates ball training, designed to improve core stability and mobility, on the functional mobility of non-athlete female adolescents.

METHOD

The sample of participants

This experimental study included 48 first-grade female high school students, aged 15 to 16 years. All participants were clinically healthy, without any cardiovascular or respiratory diseases, developmental disorders, musculoskeletal injuries, or other conditions that would contraindicate their participation in the study. Aside from regular physical education classes, the participants had not engaged in any additional training activities over the past six months.

Through a randomization method, participants were allocated into an experimental group and a control group. The experimental group (E; n = 24; mean ± SD: 15.28 ± 0.48 years; BMI: 21.43 ± 1.10 kg/m^2) engaged in Pilates ball training during physical education classes, with a specific focus on the strengthening and stretching of core muscles. The control group (K; n = 24; mean ± SD: 15.06 ± 0.29 years; BMI: 20.68 ± 1.54 kg/m^2) followed the physical education curriculum as prescribed by the Institute for the Improvement of Education of the Republic of Serbia.

This study was approved by the Ethics Committee of the Faculty of Sports and Physical Education in Niš. In accordance with the ethical standards and guidelines for clinical research outlined in the Helsinki Declaration of the World Medical Association (2013), the anonymity of the participants was upheld.

Following a comprehensive introduction of the participants to the concept of this longitudinal study and obtaining written consent from the parents for their participation, the participants voluntarily agreed to take part in the study. They were informed that they could withdraw from the study at any time for any reason if they so wished.

The statistical analysis of the data was based on the results of participants who had no more than two absences during the experimental period.

The sample of measuring instruments

At the initial and final assessments, a screening of the quality of seven fundamental movement patterns (Deep Squat, In-Line Lunge, Shoulder Mobility, Rotary Stability, Hurdle Step, Trunk Stability Push-Up and Active Straight-Leg Raise tests) was conducted to evaluate functional mobility. The tests were adapted from Cook et al. (2014a, 2014b).

Functional mobility screening (FMS) is a clinical instrument with a well-defined ranking and evaluation system for the quality of seven movement patterns that form the basis of human motion. These patterns identify functional limitations and asymmetries.

The screening movement patterns comprise fundamental movements necessary for normal functioning and effective athletic participation, while reducing the risk of injury. Additionally, the FMS provides an initial assessment of the musculoskeletal condition of the participants, potential deficits in motor control, and dysfunctions within the kinetic chain, making it highly applicable in both fitness and rehabilitation settings (Cook et al., 2010).

The maximum composite score for all seven tests is 21 points, with a composite score below 14 considered at risk for injury (Bonazza et al., 2017). The minimum number of points in the evaluation system of each test is zero, and the maximum is three. A grade zero indicates that the participant feels pain during performing any part of any test. For each of the seven FMS tests, specific scoring system criteria are defined when it comes to points one and two, but it can be generalized that one point is given to the participant who is not able to perform the movement pattern whereas two points indicate that the participant performs the movement pattern with certain compensations. The participant who performs the movement pattern optimally and without any compensation is rated with three points.

Minick et al. (2010) confirmed the excellent inter-rater reliability of FMS tests. Moderate to good “inter-rater” and “intra-rater” reliability of the FMS was confirmed by the studies of Onate et al. (2012) and Teyhen et al. (2012). Although the FMS has a high face and content validity, the criterion (congruent) validity is relatively low (Warren et al., 2018).

Procedures

The ball Pilates training program (Table 1) was implemented over 10 weeks during regular physical education (PE) classes. The foundation of the program consisted of exercises aimed at improving core stability and mobility, which the participants performed twice a week for a duration of 45 minutes.

The training was preceded by a ten-minute physiological warm-up consisting of low to moderate intensity running and dynamic stretching exercises. At the end of the training, a five-minute “cool-down” was conducted, consisting of static stretching exercises with a particular emphasis on stretching the core muscles. The experimental program (Table 1) was implemented in three phases (The Phase of Neural Adaptation, The Developmental Phase of Accumulation and The Advanced Phase of Specialization) according to the recommendations taken from Clark et al. (2018).

Physical education and sport through the centuries
2024, 11(2), 95-108
ISSN 2335-0598

Table 1. *The ball Pilates training program*

Phase 1 / Week 1 /Pace: Slow				Phase 1 / Week 2 /Pace: Slow			
Exercises	S	R	Time (s)	Exercises	S	R	Time (s)
Balanced Sitting	1	/	:60	Balanced Sitting	1	/	:60
Ball Prone Bridge	2	/	:60	Ball Prone Bridge	3	/	:45
Ball Side Bridge	2	/	:60 es	Ball Side Bridge	3	/	:45 es
Ball Supine Bridge	2	/	:60	Ball Supine Bridge	3	/	:45
Ball Forward Bend	3	10	/	Ball Reverse Crunch	3	10	/
Ball Trunk Hyperextension	3	10	/	Ball Reverse Hyperextension	3	10	/
Ball Supine Hip Rotation	2	8	/	Ball Supine Hip Rotation	3	8	/

Phase 1 / Week 3/Pace: Slow				Phase 2/ Week 4/Pace: slow to moderate			
Exercises	S S	R	Time (s)	Exercises	S	R	Time (s)
Balanced Sitting	2	/	:45	Balanced Sitting – one leg off	1	/	:60
Ball Prone Bridge	3	/	60	Single-Leg Ball Prone Bridge	2	/	:35 el
Ball Side Bridge	3	/	:60 es	Ball Side Bridge - upper leg up	2	/	:30 es
Ball Supine Bridge	33 3	/	:60 es	Ball Supine Bridge- one leg up	2	/	:30 el
Ball Forward Bend	2	10	/	Ball V-Pass	3	10	/
Ball Reverse Crunch	2	10	/	Ball Lateral Crunch	2	8 es	/
Ball Trunk Hyperextension	2	10	/	Ball Diagonal Crunch	2	8 es	/
Ball Reverse Hyperextension	2	10	/	Superman on a Ball Exercise	2	8	/
Ball Supine Hip Rotation	3	8-10	/	Ball Single-leg Hip Rotation	1	10 el	/

Phase 2 Week 5 /Pace: slow to moderate				Phase 2 Week 6 /Pace: moderate			
Exercises	S	R	Time (s)	Exercises	S	R	Time (s)
Balanced Sitting – one leg off	2	/	:40 el	Balanced Sitting – one leg off	3	/	:30
Ball Single Leg Prone Bridge	2	/	:40 el	Ball Single Leg Prone Bridge	3	/	:30
Ball Side Bridge - upper leg up	2	/	:40 es	Ball Side Bridge - upper leg up	3	/	:30 es
Ball Supine Bridge - one leg up	2	/	:40 el	Ball Supine Bridge - one leg up	3	/	:30 el
Ball Pike	1	6	/	Ball Pike	1	10	/
Ball Lateral Crunch	2	10 es	/	Ball Lateral Crunch	3	8 es	/
Ball Diagonal Crunch	2	10 es	/	Ball Diagonal Crunch	3	8 es	/
Superman on a Ball Exercise	2	10	/	Superman on a Ball Exercise	2	12	/
Ball Single-leg Hip Rotation	2	7 el	/	Ball Single-leg Hip Rotation	2	10 el	/

Phase 2/ Week 7/Pace: moderate				Phase 3 / Week 8 /Pace: As fast as can be controlled			
Exercises	S	R	Time (s)	Exercises	S	R	Time (s)
Balanced Sitting – one leg off	3	/	:35	Ball 4-point Kneeling	2	/	:30
Ball Single Leg Prone Bridge	2	/	:50 el	Ball Forearm Plank	3	/	:30
Ball Side Bridge - upper leg up	2 es	/	:50 el	Ball Side Plank – elbow on ball	3 es	/	:30 es
Ball Supine Bridge - one leg up	2	/	:50 el	Ball Supine Bridge - one leg up	3	/	:35 el
Ball Pike	2	6	/	Ball Pike	2	8	/
Ball Lateral Crunch	3	10 es	/	Ball Lateral Crunch	3	12 es	/
Ball Diagonal Crunch	3	10 es	/	Ball Diagonal Crunch	3	12 es	/
Superman on a Ball Exercise	3	10	/	Superman on a Ball Exercise	3	10	/
Ball Single-leg Hip Rotation	3	8 el	/	Ball Single-leg Hip Rotation	3	10 el	/

Phase 3 / Week 9 /Pace: As fast as can be controlled				Phase 3/ Week 10 /Pace: As fast as can be controlled			
Exercises	S	R	Time (s)	Exercises	S	R	Time (s)
Ball 4-point Kneeling	2	/	:45	Ball 4-point Kneeling	1	/	:25
Ball Forearm Plank	3	/	:45	Ball Forearm Plank	2	/	:30
Ball Side Plank – elbow on ball	3 es	/	:45 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 Pike	2	10	/	Ball V-Pass	3	15	/
Ball Lateral Crunch	3	15 es	/	Pike	3	8	/
Ball Diagonal Crunch	3	15	/	Superman on a Ball Exercise	3	15	/
Superman on a Ball Exercise	3	12 es	/	Ball Hip Rotation	3	10 es	/
Dumbbell Russian Twist	3	10 es	/	Ball Diagonal Crunch	3	10-12 es	/
Ball Single-leg Hip Rotation	3	12 es	/	Ball Side Crunch	3	15 es	/

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

The participants in the control group attended PE classes following a classical structure, which included an introductory, preparatory, main, and concluding phase. Physiological warming up in the introductory phase was achieved through light jogging or, less frequently, by engaging in elementary games. The preparatory phase included various complexes of shaping exercises in pairs, using balls or hoops. During the main phase of the class, part of the program content of the regular physical education curriculum was implemented, which included instructional units in volleyball, athletics, gymnastics, aerobics, and conditioning training (strength exercises with dumbbells and medicine balls, as well as agility and dexterity polygons). In the concluding phase of the class, the participants performed static stretching exercises for all major muscle groups.

Statistical data processing

For the statistical data analysis, the software package IBM SPSS Statistics for Windows, version 23.0 (SPSS, Inc., UN: Chicago, IL, USA) was used. To describe the sub-samples of the experimental and control groups, basic descriptive parameters of the sample characteristics and functional mobility were calculated at the initial and final measurements. The normality of the distribution of the results was calculated by the Shapiro-Wilk test. After testing the assumptions of normality, it was determined that it is necessary to use nonparametric tests to assess functional mobility. Therefore, to determine differences in functional mobility between the groups of participants at the initial and final measurements, the Mann-Whitney U test was conducted.

To determine differences within the experimental group and within the control group between the initial and final measurements, the Wilcoxon signed-rank test was applied. To assess the effect size, the value of r was used, which is interpreted according to Fritz et al. (2011) as follows: if the value of r is greater than 0.5, it indicates a large effect; if r is around 0.3, it indicates a medium effect; and a small effect is indicated when r is 0.1. Statistical significance was set at $p < .05$.

RESULTS

Table 2. *Intergroup Differences in Functional Mobility at Initial Measurement*

Test	Group	M	SD	Z	p	r
DS	E	2.17	0.56	-0.564	.573	.08
	C	2.22	0.68			
ILL	E	2.20	0.58	-0.942	.346	.14
	C	2.16	0.41			
SM	E	2.49	0.55	-0.353	.724	.05
	C	2.45	0.63			
RS	E	1.80	0.46	-0.235	.795	.04
	C	1.74	0.51			
ASLR	E	2.34	0.61	-0.191	.848	.03
	C	2.38	0.55			
TSPU	E	2.40	0.58	-0.337	.791	.05
	C	2.43	0.39			
HS-R	E	2.41	0.49	-0.292	.770	.04
	C	2.40	0.50			

Legend: DS - Deep Squat test; ILL - In-Line Lunge test; SM - Shoulder Mobility test; RS - Rotational Stability Test; ASLR - Active Straight Leg Raise test; TSPU - Trunk Stability Push-Up test; HS - Hurdle Step test; E - experimental group; C - control group; M - arithmetic mean; SD - standard deviation; Z - the value of the Mann Whitney U coefficient; p - coefficient of significance of Z - statistics; r - Rosenthal's measure of the effect size.

Table 2 shows the intergroup differences in the parameters of functional mobility at the initial measurement. The statistical significance of the Z-statistics coefficients indicates that no statistically significant differences were found in the individual variables of functional mobility between the experimental and control groups (p > .05).

Table 3. *Changes in Functional Mobility: Initial vs. Final Measurements (Experimental and Control Group)*

Test	Meas.	M	SD	Z	p	r
DS	I (EG)	2.17	0.56	-1.732	0.083	.25
	F (EG)	2.30	0.51			
	I (CG)	2.22	0.68	-0.728	.481	.015
	F (CG)	2.24	0.59			
ILL	I (EG)	2.20	0.58	-1.000	0.317	.14
	F (EG)	2.26	0.51			
	I (CG)	2.16	0.41	-0.190	.849	.004
	F (CG)	2.20	0.50			
SM	I (EG)	2.49	0.55	-2.000	0.046*	.29
	F (EG)	2.65	0.50			
	I (CG)	2.45	0.63	-0.190	.797	.005
	F (CG)	2.48	0.65			
RS	I (EG)	1.80	0.46	-2.449	0.014*	.35
	F (EG)	1.96	0.62			
	I (CG)	1.74	0.41	-0.192	.870	.005
	F (CG)	1.79	0.48			
ASLR	I (EG)	2.34	0.61	-1.633	0.102	.24
	F (EG)	2.45	0.50			
	I (CG)	2.38	0.55	-0.192	.850	.003
	F (CG)	2.40	0.58			
TSPU	I (EG)	2.40	0.58	-2.828	0.005**	.41
	F (EG)	2.64	0.44			
	I (CG)	2.43	0.39	-0.130	.875	.002
	F (CG)	2.45	0.46			
HS	I (EG)	2.41	0.50	-0.942	0.346	.14
	F (EG)	2.46	0.44			
	I (CG)	2.37	0.51	-0.309	.760	.005
	F (CG)	2.40	0.48			

Legend: EG – experimental group; CG – control group; DS - Deep Squat test; ILL - In-Line Lunge test; SM - Shoulder Mobility test; RS - Rotational Stability Test; ASLR - Active Straight Leg Raise test; TSPU - Trunk Stability Push-Up test; HS - Hurdle Step test; I - initial measurement; F - final measurement; Meas - measurement; M - arithmetic mean; SD - standard deviation; Z - the value of the Wilcoxon signed rank test; p - coefficient of significance of Z - statistics; r - Rosenthal's measure of the effect size; ** - statistical significance at the level of .01; * - statistical significance at the level of .05.

The results of the Wilcoxon signed-rank test (Table 3) indicate significant changes in the experimental group from the initial to the final measurement in the Trunk Stability Push-Up test (p < .01), Rotational Stability test (p < .05) and Shoulder Mobility test (p < .05). In other functional mobility tests, the observed changes were only at the numerical level (p> .05). According to Fritz et al. (2011), medium effects in the experimental group were identified in the Trunk Stability Push-Up (r=.41), Rotational Stability (r= .35) and Shoulder Mobility (r= .29) tests. In the Active Straight-Leg Raise test (r= .24) and the Deep Squat test (r= .25), the effect size was found to range from small to medium. Small effects were observed in the Hurdle Step (r= .14) and In-Line Lunge tests (r= .14).

The Wilcoxon signed-rank test (Table 3) indicates that the control group did not exhibit statistically significant changes in any of the functional mobility tests when comparing final and initial measurements (p > .05). The effect sizes calculated across all functional mobility assessments in the control group suggest trivial effects, which, as delineated by Fritz et al. (2011), remain below the recommended minimum effect size threshold (r < 0.1).

Table 4. *Intergroup Differences in Functional Mobility at Final Measurement*

Test	Group	M	SD	Z	p	r
DS	E	2.30	0.51	-0.626	.531	.01
	C	2.24	0.59			
ILL	E	2.26	0.51	-0.717	.473	.01
	C	2.20	0.50			
SM	E	2.65	0.50	-2.449	.014*	.35
	C	2.48	0.65			
RS	E	1.96	0.62	-2.121	.034*	.31
	C	1.79	0.48			
ASLR	E	2.45	0.50	-1.324	.180	.19
	C	2.40	0.58			
TSPU	E	2.64	0.44	-2.828	.005**	.41
	C	2.45	0.46			
HS-R	E	2.48	0.48	-0.628	.530	.01
	C	2.42	0.51			

Legend: DS - Deep Squat test; ILL - In-Line Lunge test; SM - Shoulder Mobility test; RS - Rotational Stability test; ASLR - Active Straight Leg Raise test; TSPU - Trunk Stability Push-Up test; HS - Hurdle Step test; E - experimental group; C - control group; M - arithmetic mean; SD - standard deviation; Z - the value of the Mann Whitney U coefficient; p - coefficient of significance of Z - statistics; r - Rosenthal's measure of the effect size.**- statistical significance at the level of .01; * - statistical significance at the level of .05.

The results of the Mann-Whitney U test (Table 4) indicate that statistically significant intergroup differences at the final measurement were found in the Trunk Stability Push-Up (p < .01), Shoulder Mobility (p < .05) and Rotational Stability tests (p < .05). In the remaining functional mobility tests (Deep Squat, In-Line Lunge and Active Straight-Leg Raise tests), the identified intergroup differences were not statistically significant (p > .05).

According to Fritz et al. (2011), effect size measures indicate medium effects in the Trunk Stability Push-Up, Shoulder Mobility and Rotational Stability tests. In all other functional mobility tests, the observed effects were small (r = 0.1).

DISCUSSION

At the end of the experimental period, the experimental group achieved significant improvements in the Trunk Stability Push-Up, Rotational Stability and Shoulder Mobility tests. The effectiveness in performing these tests largely depends on core stability and mobility, which the training program undoubtedly enhanced. Additionally, it is assumed that the observed adaptive changes resulted from the unstable exercise surface. Training on the ball has been found to provoke a more complex interaction between passive and active subsystems, enabling the maintenance of intervertebral neutral zones within physiological limits (Ignjatović, 2020).

The effects observed in the Trunk Stability Push-Up test ranged from medium to large effects. This indicates that the experimental program significantly improved asymmetric trunk stability in the transverse and sagittal planes (Cook et al., 2014b).

In the Shoulder Mobility and Rotational Stability tests, the effect sizes were medium. Teyhen et al. (2012) emphasize that the result in the Shoulder Mobility test is largely conditioned by the mobility of the thoracic spine and shoulder girdle, involving a range of movements such as flexion and extension, abduction and external rotation, and adduction and internal rotation. Exercises for spine flexion and extension were the dominant part of the program, while other exercises aimed at improving shoulder mobility were not applied sufficiently. It is assumed that the medium effect sizes in this test were also influenced by the core strengthening exercises, which formed the basis of the program and facilitated the transfer of force impulses from the core to the upper extremities.

In the Deep Squat, In-Line Lunge, Hurdle Step, and Active Straight Leg Raise tests, only numerical improvements were observed with small effect sizes. In addition to core stability and mobility, which the training program effectively enhanced, the performance of these tests largely depends on the stability and mobility of the hips, knees, and ankles (Cook et al., 2014a; Cook et al., 2014b). For achieving maximum scores in these tests, Foran (2012) suggests that the training program should include not only core strengthening exercises but also exercises for developing flexibility, balance, and coordination. Clearly, the training program did not improve these abilities to a sufficient degree.

In the existing literature that has studied this issue (Baumschabel et al., 2015; Dink et al., 2017; Lago-Fuentes et al., 2018; Saberian et al., 2019; Šćepanović et al., 2020; Vurgun & Edis, 2021) there is considerable variability in the applied training stimuli, the participants' previous training experience, and consequently, their initial fitness level. For these reasons, comparing the results of this study with those of other studies may not be entirely objective.

The training program in the study conducted by Skotnicka et al. (2017) included not only Pilates ball exercises to increase core stability and mobility but also appropriate corrective exercises on the floor to improve the functional mobility of the lower extremities. Additionally, in their study, as well as in those conducted by Bagherian et al. (2019).), Lago-Fuentes et al. (2018), Saberian-Amirkolaei et al. (2019), and Vurgun and Edis (2020), the participants were athletes who, alongside the training program, engaged in numerous training activities that increased the training volume and contributed to the observed effects.

A higher training volume in the study conducted by Baumschabel et al. (2015) was achieved through a greater frequency of training sessions (five times per week) compared to our study, where training sessions were conducted only twice a week.

Consequently, their study observed significant effects of Pilates ball exercises on all functional mobility tests. Additionally, their study showed that Pilates on the ball was more effective than Pilates on the floor in improving the functional mobility of non-athlete females.

In the study conducted by Dinc et al. (2017), the training program included exercises on the Pilates ball and roller, and the training sessions were longer (60 minutes) compared to our study (45 minutes). In their study, unlike ours, significant effects were observed in the Deep Squat, Hurdle Step, In-Line Lunge and Trunk Stability Push-Up tests. However, unlike our study, no statistically significant effects were found in the other FMS tests. Given that their study involved young soccer players, rather than non-athletes as in our study, it is assumed that more intense training stimuli were required to achieve the desired training effects.

The combination of Pilates exercises on the ball and Pilates on the floor, implemented in the studies conducted by Liang et al. (2018) and Šćepanović et al. (2020), also resulted in greater training effects than in our study. In their studies, significant effects were observed in all FMS variables.

The results of the final measurement compared to the initial measurement in the control group (Table 6) showed that the standard physical education program had no statistically significant effects in any variable of functional mobility. The effects observed in all FMS variables were, according to Coolican (2009), trivial, below the threshold of the recommended minimum effect size. It is assumed that the minimal numerical improvements observed in all functional mobility tests were a result of the experience gained during the initial measurement.

Unlike other studies in which the control group performed Pilates on the floor (Baumschabel et al., 2015; Lago-Fuentes et al., 2018), programs at the Faculty of Sport and Physical Education (Skotnicka et al., 2017; Šćepanović et al., 2020), warm-up and stretching exercises (Liang et al., 2018), or regular sports activities, in our study, the control group only engaged in part of the standard physical education curriculum.

At the conclusion of the experiment, a comparison of the effectiveness between the experimental and standard physical education programs revealed the effects of the Pilates ball program.

The final measurement confirmed the superiority of the experimental program over the standard program of the control group in tests whose effectiveness predominantly depends on core stability and shoulder girdle mobility. Specifically, the experimental and control groups differed statistically significantly in favor of better results in the experimental group in the following tests: Trunk Stability Push-Up, Shoulder Mobility and Rotational Stability.

The observed medium effect sizes in these tests can be attributed to the applied experimental program, which was specifically targeted at strengthening and stretching the core region of the body. A strong core improves the control of spinal muscles during the execution of movement patterns that are fundamental to these tests.

However, the intergroup differences were not statistically significant in the Deep Squat, In-Line Lunge, Active Straight Leg Raise, and Hurdle Step tests. The experimental program had small effects in these tests. Such results can be attributed to the design of the training program. Specifically, the applied training stimuli did not include specific exercises to enhance the flexibility of the hamstrings, gastrocnemius, and soleus muscles, nor did they include targeted exercises for enhancing the mobility and stability of the hip, knee, and ankle joints.

CONCLUSION

Overall, the findings of this study confirmed the superiority of the applied Pilates ball stability and mobility exercise program over the standard physical education curriculum in enhancing the functional mobility of young adolescent girls. After the ten-week period, significant improvements and medium effects were observed in the experimental group's results in the Rotational Stability, Shoulder Mobility, and Trunk Stability Push-Up tests. In the other FMS tests, the observed improvements were merely numerical, and the effects were trivial. The standard physical education program did not induce significant changes in any of the FMS tests. At the final measurement, small effects of the applied experimental program were observed in the Deep Squat, Hurdle Step, and In-Line Lunge tests. The effect size in the Active Straight Leg Raise test ranged from small to medium effects, while medium effects were found in the Trunk Stability Push-Up, Rotational Stability, and Shoulder Mobility tests. It can be concluded that stabilization endurance exercises, in conjunction with dynamic core exercises on the Pilates ball, represent an appropriate training stimulus for improving functional mobility in tests where effectiveness is predominantly influenced by core stability and the mobility of the shoulder girdle muscles.

REFERENCES

1. Bagherian, S., Ghasempoor, K., Rahnama, N., & Wikstrom, E. A. (2019). The effect of core stability training on functional movement patterns in college athletes. *Journal of Sport Rehabilitation, 28*(5), 444-449. https://doi.org/10.1123/jsr.2017-0107
2. Baumschabel, M., Kiseljak, D., & Filipović, V. (2015). The impact of Pilates on spine flexibility. *Physiotherapia Croatica, 13*(1), 34-37.
3. Bonazza, N. A., Smuin, D., Onks, C. A., Silvis, M. L., & Dhawan, A. (2017). Reliability, validity, and injury predictive value of the functional movement screen: A systematic review and meta-analysis. *The American Journal of Sports Medicine, 45*(3), 725-732. https://doi.org/10.1177/0363546516641937
4. Cech, D. J., & Martin, S. (2012). *Functional movement development across the life span* (3rd ed.). Philadelphia, PA: Saunders/Elsevier.
5. Clark, M. A., Lucett, S. C., McGill, E., Montel, I., & Sutton, B. (2018). *NASM essentials of personal fitness training* (6th ed.). Burlington, MA: Jones & Bartlett Learning.
6. Coolican, H. (2009). *Research methods and statistics in psychology (5th ed.).* Retrieved from https://doi.org/10.4324/9780203769669
7. Cook, G., Burton, L., Hoogenboom, B. J., & Voight, M. L. (2014a). Functional movement screening: The use of fundamental movements as an assessment of function - Part 1. *International Journal of Sports Physical Therapy, 9*(3), 396-409.

8. Cook, G., Burton, L., Hoogenboom, B. J., & Voight, M. L. (2014b). Functional movement screening: The use of fundamental movements as an assessment of function - Part 2. *International Journal of Sports Physical Therapy, 9*(4), 549-563.
9. Cook, G., Burton, L., Kiesel, K., Rose, G., & Bryant, M.F. (2010). *Movement, functional movement sistems: Screening, assessment and corrective strategies.* California: On Target Publications.
10. Dinc, E., Kilins, B. E., Bulat, M., Erten, Y. T., & Bayraktar, B. (2017). Effects of special exercise programs on functional movement screen scores and injury prevention in preprofessional young football players. *Jornal of Exercise Rehabilitation, 13*(5), 535-540. DOI: 10.12965/jer.1735068.534
11. Enderlin, C, Rooker, J., Ball, S., Hippensteel, D., Alderman, J., Fisher, S.J., ... Jordan, K. (2015). Summary of factors contributing to falls in older adults and nursing implications. *Geriatric Nursing, 36*(5), 397-406. http://doi.org/10.1016/j.gerinurse.2015.08.006
12. Foran, B. (2012). *High-performance fitness training*. Zagreb: Gopal.
13. Forhan, M., & Gill, S. V. (2013). Obesity, functional mobility and quality of life. *Best Practice & Research Clinical Endocrinology & Metabolism, 27*(2), 129-137. https://doi.org/10.1016/j.beem.2013.01.003
14. Fritz, C. O., Morris, P. E., & Richler, J. J. (2011). Effect size estimates: current use, calculations, and interpretation. *Journal of Experimental Psychology*, *141*(1), 2-18. https://doi.org/10.1037/a0024338
15. Hallal, P. C., Andersen, L. B., Bull, F. C., Guthold, R., Haskell, W., Ekelund, U., & Lancet Physical Activity Series Working Group (2012). Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet, 380*(9838), 247–257. https://doi.org/10.1016/S0140-6736(12)60646-1
16. Ignjatović, A. (2020). *Vežbanje na nestabilnim podlogama – primena u treningu, nastavi, rekreaciji i rehabilitaciji [Exercise on unstable surfaces - application in training, teaching, recreation and rehabilitation]*. Jagodina: Fakultet pedagoških nauka.
17. Lago-Fuentes, C., Rey, E., Padrón-Cabo, A., Sal de Rellán-Guerra, A., Fragueiro-Rodríguez, A., & García-Núñez, J. (2018). Effects of core strength training using stable and unstable surfaces on physical fitness and functional performance in professional female futsal players. *Journal of Human Kinetics, 65,* 213-224. https://doi.org/10.2478/hukin-2018-0029
18. Lawrence, M. (2011). *The complete guide to core stability* (3rd ed.). London: A&C Black.
19. Liang, L. C., Wang, Y. T., & Lee, A. J. (2018). The effects of core stability training on the functional movement screen and postural stability in collegiate students. *International Society of Biomechanics in Sports, 36*(1), 750-753. https://commons.nmu.edu/isbs/vol36/iss1/177
20. Minick, K. I., Kiesel, K. B., Burton, L., Taylor, A., Plisky, P., & Butler, R. J. (2010). Interrater reliability of the functional movement screen. *Journal of Strength and Conditioning Research, 24*(2), 479-486. https://doi.org/10.1519/JSC.0b013e3181c09c04
21. Mitchell, U. H., Johnson, A. W., Vehrs, P. R., Feland, J. B., & Hilton, S. C. (2016). Performance on the functional movement screen in older active adults. *Journal of Sport and Health Science, 5*(1), 119-125. https://doi.org/10.1016/j.jshs.2015.04.006
22. O'Brien, W., Khodaverdi, Z., Bolger, L., Tarantino, G., Philpott, C., & Neville, R. D. (2022). The Assessment of Functional Movement in Children and Adolescents: A Systematic Review and Meta-Analysis. *Sports Medicine*, *52*(1), 37–53. https://doi.org/10.1007/s40279-021-01529-3

23. Onate, J. A., Dewey, T., Kollock, R. O., Thomas, K. S., Van Lunen, B. L., DeMaio, M., & Ringleb, S. I. (2012). Real-time intersession and interrater reliability of the functional movement screen. *Journal of Strength and Conditioning Research, 26*(2), 408-415. https://doi.org/10.1519/JSC.0b013e318220e6fa
24. Saberian, A., Balouchy, R., & Sheikhhoseini, R. (2019). The effect of eight-week Swiss ball training on the integration of functional movements and balance of teenage badminton players. *Journal of Rehabilitation Sciences & Research, 6*(4), 153-159. doi: 10.30476/jrsr.2019.81534.1002
25. Siller, B. (2003). *The Pilates body: The ultimate at-home guide to strengthening, lengthening and toning your body- without machines.* New York: The Amazon book.
26. Skotnicka, M., Karpowicz, K., Sylwia-Bartkowiak, W., & Strzelczy, R. (2017). The impact of the corrective and stability exercises program on the quality of basic movement patterns among dance students. *Trends in Sport Sciences, 1*(24), 31-38.
27. Teyhen, D. S., Shaffer, S. W., Lorenson, C. L., Halfpap, J. P., Donofry, D. F., Walker, M. J., ... & Childs, J. D. (2012). The functional movement screen: A reliability study. *Journal of Orthopaedic & Sports Physical Therapy, 42,* 530-540. https://doi.org/10.2519/jospt.2012.3838
28. Thompson, W. R., Gordon, N. F., Pescatello, L. S., & American College of Sports Medicine. (2010). *ACSM's Guidelines for exercise testing and prescription.* (8th ed). Baltimore (MD): Lippincott Williams & Wilkins.
29. Šćepanović, T., Protić-Gava, B., Sporiš, G., Rupčić, T., Miljković, Z., Liapikos, K., ... Trajković, N. (2020). Short-term core strengthening program improves functional movement score in untrained college students. *The International Journal of Environmental Research and Public Health, 17,* 8669-8677. https://doi.org/10.3390/ijerph17228669
30. Vurgun, H. & Edis, C. (2020). Only Swiss ball core exercises can improve of functional movement screen score and core muscle endurance? *International Journal of Applied Exercise Physiology, 9*(10), 181-187.
31. Warren, M., Lininger, M. R., Chimera, N. J., & Smith, C. A. (2018). Utility of FMS to understand injury incidence in sports: current perspectives. *Open Access Journal of Sports Medicine, 9,* 171-182. https://doi.org/10.2147/OAJSM.S149139
32. World Medical Association (2013). World medical association declaration of helsinki: Ethical principles for medical research involving human subjects. *JAMA*, *310*(20), 2191-2194. https://doi.org/10.1001/jama.2013.281053

Received on 03.12.2024.
Accepted on 16.12.2024.