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EFFECTS OF BALL PILATES ON BODY COMPOSITION, FUNCTIONAL MOBILITY AND MUSCULAR FITNESS IN ADOLESCENTS

DOCTORAL DISSERTATION

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УНИВЕРЗИТЕТ У НИШУ

ФАКУЛТЕТ СПОРТА И ФИЗИЧКОГ ВАСПИТАЊА

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ЕФЕКТИ ПИЛАТЕСА НА ЛОПТИ НА ТЕЛЕСНУ КОМПОЗИЦИЈУ, ФУНКЦИОНАЛНУ ПОКРЕТЉИВОСТ И МИШИЋНИ ФИТНЕС АДОЛЕСЦЕНАТА

ДОКТОРСКА ДИСЕРТАЦИЈА

NIŠ, 2024

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Data on Doctoral Dissertation

Doctoral Supervisor:	Nataša Branković, PhD, full professor, University of Niš, Faculty of Sports and Physical Education
Title:	The Effects of Ball Pilates on Body Composition, Functional Mobility, and Muscular Fitness of Adolescents

Abstract:

This doctoral dissertation was conducted with the aim of determining the effects of the ball Pilates on body composition, functional mobility, and muscular fitness in female adolescents. A sample of 48 participants was randomly divided into an experimental group (E; n = 24; mean ± SD: 15.28 ± 0.48 years; BMI: 21.43 ± 1.10 kg/m^2) and a control group (K; n = 24; mean ± SD: 15.06 ± 0.29 years; BMI: 20.68 ± 1.54 kg/m^2). The experimental group performed the ball Pilates program twice a week for ten weeks, while the control group followed the standard Physical Education program. The experimental program consisted of stabilization endurance exercises and dynamic exercises on a Pilates ball focusing on strengthening trunk stabilizer muscles. The sample of measuring instruments included three parameters for assessing body composition (skeletal muscle mass - kg, body fat mass - kg and body fat percentage -%), seven standard functional mobility tests that are integral parts of the essential movement patterns screening (FMS), and five tests for assessing muscular fitness (tests for the flexor, extensor, and lateral trunk muscles' isometric endurance assessment, the Front Plank Test and the clinical, bilateral the Single-Leg Squat test). The results showed that the experimental program statistically significantly influenced the improvement of muscular fitness, particularly the trunk stabilizer muscles endurance, where large effects were observed. Additionally, significant improvements and moderate effects in all body composition parameters and three functional mobility tests (in the Trunk Stability Push-Up test, and the bilateral Rotational Stability and Sholder Mobility tests) were found in the experimental group. In the control group, significant improvements and minor effects were found only in muscular fitness, while the improvements found in body composition and functional mobility were only at a numerical level. The results of intergroup differences in body composition, muscular fitness and three functional mobility tests (Trunk Stability Push-Up, Rotational

Stability and Sholder Mobility tests) at the final measurement indicated statistically significantly better results in the experimental group. Large effects of the applied experimental treatment were observed in all trunk stabilization endurance tests. Medium effects were found in all body composition parameters, the Trunk Stability Push-Up test, and the bilateral In-Line Lunge and Active Straight Leg Raise tests. Effects ranging from small to medium were observed in the Active Straight Leg Raise and Single-Leg Squat tests. In the Deep Squat test and the bilateral In-Line Lunge and Hurdle Step tests, the effect sizes were small. The study confirmed the superiority of training on a Pilates ball over the regular physical education program in improving the body composition, muscular fitness and those tests of functional mobility, the effectiveness of which is dominantly dependent on core stability and the mobility of the shoulder girdle muscles.

Scientific Field:	Physical Education and Sport
Scientific Discipline:	Scientific disciplines in Sport and Physical Education
Key Words:	Pilates training, skeletal muscle mass, body fat mass, trunk stabilizer endurance, FMS, skeletal muscle mass, body fat mass, students
UDC:	009; 001.891
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Подаци о докторској дисертацији

Ментор:	др Наташа Бранковић, редовни професор, Универзитет у Нишу, Факултет спорта и физичког васпитања
Наслов:	Ефекти пилатеса на лопти на телесну композицију, функционалну покретљивост и мишићни фитнес адолесцената

Резиме:

Ова докторска дисертација је спроведена са циљем утврђивања ефектата пилатеса на лопти на телесну композицију, функционалну покретљивост и мишићни фитнес адолесценткиња. Узорак од 48 испитаница је насумично био подељен на једну експерименталну (Е; n = 24; mean ± SD: 15.28 ± 0.48 година; BMI: 21.43 ± 1.10 kg/m^2) и једну контролну групу (К; n = 24; mean ± SD: 15.06 ± 0.29 година; BMI: 20.68 ± 1.54 kg/m^2). Експериментална група је два пута недељно током десет недеља спроводила програм пилатеса на лопти док је контролна група спроводила стандардни програм физичког васпитања. Експериментални програм се састојао од вежби стабилизационе издржљивости и динамичких вежби на пилатес лопти са акцентом на јачање мишића стабилизатора трупа. Узорак мерних инструмената је био сачињен од три параметра за процену телесне композиције (скелетно-мишићна маса - kg, масна маса тела - kg и масна маса тела -%), седам стандардних тестова функционалне покретљивости који су саставни део скрининга базичних образаца покрета (FMS), и пет тестова за процену мишићног фитнеса (тестови за процену изометријске издржљивости флексора, екстензора и латералних мишића трупа, тест предњи планк и клинички билатерални тест чучањ на једној нози). Резултати су показали да је експериментални програм статистички значајно утицао на побољшање мишићног фитнеса, посебно на издржљивост мишића стабилизатора трупа где су утврђени велики ефекти. Осим тога, код експерименталне групе су утврђена значајна побољшања и средњи ефекти у свим параметрима телесне композиције и три теста функционалане покретљивости (тест стабилност трупа у склеку и билатерални тестови ротациона стабилност и покретљивост рамена) Код контролне групе, значајна побољшања и мали ефекти су утврђени само у мишићном фитнесу док су у телесној композицији и функционалној покретљивости утврђена побољшања била само на нумеричком нивоу. Резултати међугрупних разлика у телесној композицији, мишићном фитнесу и три теста функционалне покретљивости (стабилност трупа у склеку, ротациона стабилност и покретљивост рамена) на финалном мерењу су указали на статистички значајно боље резултате код експерименталне групе. Утврђени су велики ефекти примењеног експерименталног третмана у свим тестовима стабилизационе издржљивости трупа. Средњи ефекти су утврђени у свим параметрима телесне композиције, тесту стабилност трупа у склеку и билатералним тестовима ротациона стабилност и покретљивост рамена. Ефекти у распону малих до средњих утврђени су у тесту активно предножење и тесту чучањ на једној нози. У тесту дубоки чучањ и билатералним тестовима искорак и прекорак преко препоне, величине ефекта су биле мале. Студија је потврдила супериорност пилатеса на лопти у односу на програм редовне наставе физичког васпитања у адаптацији телесне композиције, мишићног фитнеса и оних тестова функционалне покретљивости чија ефикасност доминантно зависи од стабилности језгра тела и покретљивости мишића раменог појаса.

Научна област:	Физичко васпитање и спорт
Научна дисциплина:	Научне дисциплине у спорту и физичком васпитању
Кључне речи:	Пилатес тренинг, скелетно мишићна маса, масна маса тела, издржљивост стабилизатора трупа, FMS, ученици
УДК:	009; 001.891
CERIF класификација	S 273 Физичка култура, моторичко учење, спорт

The scientific contribution of the doctoral dissertation

This doctoral dissertation's significance and scientific contribution are reflected in expanding the fund of existing knowledge on the effects of ball Pilates on body composition, functional mobility, and muscular fitness of adolescents, first-grade female high school students. The findings of this dissertation are relevant considering the gaps in the existing fund of knowledge and the lack of such and similar research among healthy female adolescents with no previous training experience. The research confirmed the effectiveness of the experimental program of exercises on the Pilates ball, previously not applied in physical education and fitness, in transformative changes in all studied areas, providing a significant original scientific contribution to the existing theories and practices of physical education and fitness. Specific exercises and appropriate load distribution were identified, which over a ten-week period were scientifically and practically proven to have a significant impact on inducing adaptive changes in body composition, functional mobility, and muscular fitness parameters. Given the established effectiveness of the applied ball Pilates program, its implementation in the regular physical education teaching and exercise programs in fitness centers is recommended. By synthesizing this dissertation's results with those of other similar studies, integration of knowledge about the effectiveness of ball Pilates on the fitness parameters monitored in this research will contribute holistically to the study of this issue.

Научни допринос докторске дисертације

Значај и научни допринос ове докторске дисертације се огледа у повећању фонда постојећих знања о ефектима пилатеса на лопти на телесну композицију, функционалну покретљивост и мишићни фитнес адолесценткиња, ученица првог разреда гимназије. Налази ове дисертације су релевантни с обзиром на празнине у постојећем фонду знања и дефицит оваквих и сличних истраживања у популацији здравих адолесцената женског пола без претходног тренажног искуства. Истраживањем је потврђена ефикасност експерименалног програма вежби на пилатес лопти који до сада није био примењиван у физичком васпитању и фитнесу, на трансформацијионе промене параметара свих проучаваних простора, што даје значајан оригинални научни допринос постојећој теорији и пракси физичког васпитања и фитнеса. Идентификоване су конкретне вежбе и одговарајућа дистрибуција оптерећења која током десетонедељног периода научно засновано и практично потврђено има значајан утицај на изазивање адаптивних промена у параметрима телесне композиције, функционалне покретљивости и мишићног фитнеса. С обзиром на утврђену ефикасност примењеног програма пилатеса на лопти, препоручује се његова имплементација у редовни програм наставе физичког васпитања и програме вежбања у фитнес центрима. Сумирањем резултата ове дисертације са резултатима других сличних студија омогућиће се интеграција знања о ефикасности пилатеса на лопти на фитнес параметре праћене у овом истраживању, што у крајњем доприноси холистичком проучавању ове проблематике.

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CONTENT:

LIST OF ABBREVIATIONS

ACE American Council on Exercise
ACSM American College of Sports Medicine
ASLR Active Straight-Leg Raise

BFM Body fat mass
BF% Body fat %
BMI Body mass index

CG Control group
CM Core mobility
CS Core stability
CSEP Canadian Society for Exercise Physiology

D Dysfunctional, aberrant, or less movable
DS Deep Squat

EG EG - experimental group

FITT Frequency, intensity, time and type of exercises
FM Functional mobility
FMS Functional Movement Screening

HS Hurdle Step

ILL In-Line Lunge

LBM Lean body mass
LPS Lumbo-pelvic stability

N Number of participants
NASM National Academy of Sports Medicine
NMC Neuromuscular control
NME Neuromuscular efficiency

1RM One-repetition maximum
ROM Functional range of motion

RS Rotary Stability

SFMA Selective Functional Movement Assessment

SHAPE Society of Health and Physical Educators

SLST Single-Leg Squat Test

SM Shoulder mobility

SMM Skeletal muscle mass

TFET Trunk Flexor Endurance Test

TEET Trunk Extensor Endurance Test

TLET Trunk Lateral Endurance Test

TFPT The Front Plank test (endurance on forearms)

TSPU Trunk Stability Push-Up

WC Waist circumference

WHO World Health Organization

WHR Waist to hip ratio

1. INTRODUCTION

The Pilates exercise method is a unique system of stretching and strength exercises that strengthens and shapes muscles, improves muscle tone, body posture, flexibility, and balance (Siller, 2003). Due to increased proprioceptive demands and the need to maintain balance during exercise, it also enhances proprioceptive abilities (Ghorbani, Yaali, Sadeghi, & Granacher, 2024). Exercises are applied for the entire body, with an emphasis on core strengthening, proper body alignment, and correct breathing (Latey, 2001; Krejg, 2005). By uniting the mind and body, Pilates effectively reduces stress levels (Lim & Park, 2019). By strengthening the core muscles, Pilates enhances body posture and postural control, thereby improving overall fitness and health (Kloubec, 2011). This system of body conditioning is relevant not only in fitness but also in physical therapy and rehabilitation (Ignjatović, 2020; Lim & Hyun 2021). This is particularly significant given that deficits in postural control have been found to lead to damage to mechanoreceptors and a reduction in somatosensory information processed by the nervous system (Cozen, 2000; Page, 2011).

This body conditioning system was founded in 1920 by Joseph Pilates, who believed that mental and physical health were closely related (Shedden & Kravitz, 2006). By combining flexibility and strengthening exercises, Pilates lengthens and tones the body, relieves stress, contributes to better self-control and greater self-confidence (Brook, 2005). Pilates focuses on the deep postural muscles, including the pelvic floor muscles, the transversus abdominis muscle and the multifidus muscle (Stanton et al., 2004).

Core training is a critical component of contemporary fitness programs (Norris, 2000). Whether conducted on a stable surface (the floor) or an unstable surface (such as Pilates balls or BOSU balls), the goal remains the same - to enhance the stability and mobility of the musculoskeletal structures that underpin postural control in all physiological positions of the spine (Ungaro, 2008). This is particularly important given that deficits in postural control during daily activities and sports can lead to loss of balance, falls, and injuries (Wells, Kolt, & Bialocerkowski, 2012). Furthermore, limited stability and mobility of the core significantly constrain the functionality of athletic performance (Wells et al., 2012).

The central region, or "core," consists of the musculoskeletal structures of the lumbo-pelvic-hip complex (LPHC) and muscles that connect the pelvis to the extremities (Clark, Lucett, McGill, Montel, & Sutton, 2018). The neuromuscular efficiency of the body core is primarily determined by the stability and mobility of certain joints and segments of the spinal column. Core stability ensures the cohesion of the spinal vertebrae across all physiological positions of the spinal column, while mobility enables movement within the functional range of motion (Louis, 1993).

As active stabilizers, the muscles of the core stabilize the spinal column across various planes of motion, facilitating the transmission of force from the body's center to the extremities during vigorous movements (Kibler, Press, & Sciascia, 2006). Given that all powerful movements originate from the core and that balance and postural control depend on its stability and mobility, these attributes are fundamental in numerous sports activities requiring stability for controlled mobility (McGill, 2001).

Through coordinated action of active, passive, and control systems (muscles, spine, and nervous system), an appropriate level of spinal stability is achieved, particularly in its lumbar part, upon which the efficiency of functional movements dominantly depends (Taspınar, Angin, & Oksuz, 2022; Willson, Dougherty, Ireland, & Davis, 2005). The active system consists of superficial (global) and deep (local) muscles of the trunk, where global muscles stabilize the trunk and perform force transfer, while the smaller and deeper-positioned local muscles cannot produce significant force but are significant in postural control, proprioception, and spinal column stability (Cartel, Beam, McMahan, Barr, & Brown, 2006; McGill, 2001; Norris, 2000).

By stabilizing the trunk, core muscles significantly influence the neuro-muscular efficiency throughout the kinetic chain system, thus improving motor behavior efficiency (Arokoski, Valta, Airaksinen, & Kankaanpää, 2001; Houglum, 2005). Their development should be planned in the initial phases of stability, mobility, and strength training, ensuring proper spine position maintenance during exercises (Cartel et al., 2006). Only through the harmonious development of global and local trunk stabilizers can disproportion in their development, leading to compensatory movements and imbalances in the global stability chain, be prevented (Cartel et al., 2006).

Studies indicate that core stability can be significantly improved through ball Pilates, a conditioning system on an unstable surface (Carter et al., 2006; Jain et al., 2019; Marani, Subarkah, & Octrialin, 2020; McCackey, 2011; Nuhmani, 2021; Prieske et al., 2016; Sekendiz, Cug, & Korkusuz, 2010; Stanton, Reaburn, & Humphries 2004; C. Sukalinggam, G. Sukalinggam, Kasim, & Yusof, 2012). Instability increases proprioceptive demands for body stability maintenance and activates additional musculature, especially deep trunk stabilizers, which are activated to a much lesser extent during standard exercises on stable surfaces (Carter et al., 2006; McCackey, 2011; Prieske et al., 2016; Sekendiz et al., 2010; Stanton et al., 2004; Sukalinggam et al., 2012). Previous studies also point to significantly higher electromyographic activity during exercise on unstable versus stable surfaces, especially among non-athletes (Behm, Leonard, Young, Bonsey, & MacKinnon, 2005; Duncan, 2009; Lehman, Hoda, & Oliver, 2005; Ostrowski, Carlson, & Lawrence, 2017; Petrofski et al., 2007; Vilaca-Alves et al., 2016).

On the other hand, results of some studies challenge the superiority of exercising on unstable surfaces, indicating that core training efficiency does not depend on training surface stability (Marani, 2020; Nuhmani, 2021; Prieske et al., 2016; Sukalinggam et al., 2012) or even indicating the superiority of exercising on a stable surface (Kamatchi et al., 2020). However, it has been established that an unstable surface induces greater stress in the neuromuscular system and allows the production of different and more diverse stimuli leading to appropriate neuromuscular adaptation, especially local trunk stabilizers (Ignjatović, 2020). Despite the aforementioned benefits, it is a fact that exercises on unstable surfaces cannot be performed with maximal or submaximal loads, thus prioritizing the development of muscle strength and power training on stable surfaces (Anderson & Behm, 2004; Ignjatović, 2020).

In addition to fitness, exercising on unstable surfaces is frequently applied in medical areas, particularly in rehabilitation, physiotherapy, and chiropractic, where it is applied to establish normal neuromuscular activity in injured or deconditioned body parts or to improve functional mobility in cases of its limitation (Behm & Colado, 2012).

Numerous studies have confirmed the effectiveness of a ball Pilates in developing functional mobility (Bagherian, Ghasempoor, Rahnama, & Wikstrom, 2018; Baumschabel, Kiseljak, & Filipović 2015; Dink, Kilins, Bulat, Erten, & Bayraktar, 2017; Liang, Wang, & Lee, 2018; Saberian, Balouchy, & Sheikhhoseini, 2019; Skotnicka, Karpowicz, Sylwia-Bartkowiak, & Strzelczy, 2017). This physiological ability enables the harmonious operation of stable and mobile body parts, significantly easing movement during performing functional activities and tasks in daily life and sports (Cook, Burton, Kiesel, Rose, & Bryant, 2010).

In addition, studies have demonstrated a positive correlation between elevated Functional Movement Screen (FMS) scores and higher levels of physical activity (Duncan & Stanley, 2012). In contrast, a negative correlation has been identified between the poor quality of FMS performance and an increased nutritional index among children and adolescents (Duncan & Stanley, 2012). Movement patterns that form the foundation of the FMS are also the foundation of the various sports and recreational activities, enabling efficient engagement in physical activity while minimizing the risk of injury (O'Brien et al., 2022). This is especially important for children and adolescents, whose sedentary lifestyle has a negative impact on their overall health.

According to Forhan and Gill (2013), functional mobility enables rapid and efficient movement adaptation, balance, and body posture during movement in different positions and planes. Similar to impaired stability, impaired functional mobility increases the risk of falls and injuries, especially during the execution of complex sports tasks (Lin et al., 2017). The functional balance of the joint-muscle system stability and mobility is crucial for normal functioning and efficiency in sports performance, thus driving research focus in sports medical sciences towards their effective development (Kibler, Press, & Sciascia, 2006).

Functional mobility is dominantly affected by age, cognitive impairment, physical limitations, vision impairment, sports injuries, depressive symptoms, arthritis, chronic diseases, and lack of vigorous physical activity (Dunlop et al., 2005). It has been established that reduced functional mobility leads to compromised movement and its dysfunction (Cook et al., 2010). Compromised movement is associated with an increased risk of pain, falls, and injuries, leading to loss of independence and ultimately reduced quality of life (Miri & Norasteh, 2024). A composite FMS score of less than 14 is associated with an increased risk of injury (Garrison, Westrick, Johnson, & Benenson, 2015; Kiesel, Butler, & Plisky, 2014; Letafatkar, Hadadnezhad, Shojaedin, & Mohamadi, 2014). Therefore, efficient development of functional mobility is a current topic of numerous clinical studies and, increasingly, studies in the field of sports sciences. When limitations, asymmetries, and weaknesses in movement patterns are detected, a corrective stability program should be implemented (Skotnicka et al., 2017). Corrective exercises should be conducted first because premature use of stability-improving exercises can accentuate incorrect movement patterns, thus increasing the risk of injury (Cook et al., 2010).

Despite the large number of studies examining the effectiveness of Pilates on a ball, existing literature reveals certain contradictions in the obtained results and a deficit of research in the adolescent population, necessitating the need for additional research. For that reason, this research determined the effectiveness of the ten-week experimental ball Pilates program on body composition, functional mobility and muscular fitness in female adolescents.

1.1 Basic Terms Definition

In this subchapter, terms that are closely related to this research topic are presented in alphabetical order.

Functional Activities include a wide range of activities, ranging from basic activities of daily living that include self-care and household chores (standing, bending, walking, and climbing) to vocational and recreational activities (Cech & Martin, 2012). These activities are crucial for a person's independent life and global health status because they enable physical, social, and psychological well-being (Cech, & Martin, 2012; Lin, Lee, Chang, Yang, & Tsauo, 2017). Functional activities include controlled movements that require optimal postural control or the optimal mobility to stability ratio of certain joints (Veeger, & van der Helm, 2007).

Functional Mobility is a person's physiological ability to move independently and safely in different environments to accomplish functional activities or tasks (Bouça-Machado, Maetzler, & Ferreira, 2018). Forhan and Gill (2013, p. 130) define functional mobility as "a manner in which people are able to move around in the environment in order to participate in the activities of daily living and move from one place to another". Functional mobility is characterized by the ability to occupy functional body positions in dynamic conditions by moving the whole body or body parts (Čvorović, 2014).

The Global Stabilization System consists primarily of muscles connected from the pelvis to the spine: m. quadratus lumborum, m. psoas major, m. external obliques, portions of the internal oblique muscle (m. internal oblique), m. rectus abdominis, m. gluteus medius and the adductor muscle complex (Clark, Lucett, McGill, Montel, & Sutton, 2018). Their primary function is to provide stability to the spinal column and pelvis and transfer loads between the upper and lower extremities (McGill, 2001).

Body mass index (BMI) represents the ratio of body weight to squared body height expressed in meters (Solway, 2013).

The Core/Body Center is composed of body structures that make up the lumbo-pelvic-hip complex (LPHC), including the lumbar part of the spinal column, the pelvic girdle, the abdomen, and the hip joint (Clark et al., 2018). The functions of the body core are LPHC stability, segmental stability of the spinal column, axial elongation, depression of the abdominal wall, and maintaining healthy intra-abdominal pressure (Gurtner, 2014). The core is located in the central body portion, where the center of gravity is located and where all movements begin (Panjabi, 1992). The core muscles encompass the local and global stabilization system muscles and the movement system muscles (Clark et al., 2018). Dynamic function of the body core is mainly conditioned by the stability of the core body and not by the skeletal muscles of the lower extremities (Kibler, Press, & Sciascia, 2006). The static function of the body core is reflected in the ability of the central muscular structures to effectively resist the force that does not change (Cabanas-Valdés et al, 2021). A strong and stable core is a crucial factor of stability, balance, and neuro-muscular efficiency throughout the entire kinetic chain of movement (Houglum, 2010).

Kinesthesia is a term that denotes awareness of the position and movement of body parts by means of sensory organs (proprioceptors) in the muscles and joints (Hillman, 2012). It is a key component in muscular memory and hand-eye coordination (Hillman, 2012).

The Local Stabilization System represents the internal unit of the body core, which is primarily made up of muscles attached to the vertebrae: m. transverse abdominis, m. internal obliques, m. multifidus, pelvic floor muscles, and diaphragm (Clark et al., 2018). Their function is to maintain intervertebral and intersegmental spinal stability and limit excessive compressive, shear, and rotational forces between the spinal segments (Clark et al., 2018). These muscles consist primarily of type I slow-twitch fibers with a high muscle spindles density (Clark et al., 2018). The deep multifidus muscle has an essential function in the stabilization and motor control of the lumbar spine (Wang et al., 2023).

Lumbopelvic Stability (LPS) is a highly complex integrated function that involves many body segments control (Kibler, Press, & Sciascia, 2006). Dynamic LPS does not necessarily refer to the movements of the pelvis and spine, but that the dynamic is inside and represents a micro-movement of muscles and joints (Gurtner, 2013). From a clinical aspect, LPS is essential for injury prevention and recovery from injuries (Perrott, Pizzari, Opar, & Cook, 2012).

Body Fat Mass is the part of the human body composed strictly of fat (Clark et al., 2018). Body fat includes essential and storage fat (Benardot, 2006). Essential fats are necessary to maintain life and reproductive functions (Going & Kyzer, 2011). Body fat is found under the skin (subcutaneous fat) or around the organs (visceral fat). It can also be found in muscular tissue (Going & Kyzer, 2011).

Muscular Endurance is the ability of the musculoskeletal system to durably maintain or develop muscular force without reducing efficiency due to fatigue (Clover, 2007; Duggan, Mercier, & Canadian Society for Exercise, 2007; Hoffman, 2008). Muscular endurance can be measured either by muscular contraction duration or the number of continuous repetitions over a certain period of time (Clover, 2007). In physiological terms, muscular endurance depends on the percentage of slow muscle fibers. Therefore, a synonym for muscular endurance is strong endurance (Goswami, 2011).

Mobility is body parts' ability to move in a functional range of motion (ROM). Foran (2012) defines mobility as the interaction of hips, pelvis, and trunk in functionally complex movements. Mobility encompasses both flexibility and stability (Čvorović, 2014). In addition, mobility implies optimal mobility of the ankle, hip joint, thoracic spine, and shoulder joint, as well as a multi-segmental interaction of body parts in functionally complex movements and positions (Foran, 2012).

Muscular Strength is the maximum force muscle can generate in a specific movement pattern at a specific velocity (Hillman, 2012). This muscular ability denotes a muscle's relative ability to resist or produce a force (Rinadi, 2010). Duggan et al. (2007) define muscular strength as the ability of a muscle to exert maximum force during a single contraction. Along with muscular endurance, muscular strength enables performing daily activities with less physiological stress, reduces the possibility of injuries, and maintains functional independence throughout life (Rinadi, 2010). Muscular strength and endurance are health-related fitness components which are significant for improving or maintaining musculotendinous integrity, bone mass, glucose tolerance, fat-free mass (FFM), and resting metabolic rate (American College of Sports Medicine, Thompson, Gordon, & Pescatello, 2010).

Lean Body Mass (LBM) includes muscles, bone, water, connective tissue, and tissue of organs and teeth (Clark, Lucett, McGill, Montel, & Sutton, 2018). Unlike fat-free mass, lean body mass includes the weight of essential fats in the organism, central nervous system, and bone marrow (Clark et al., 2018).

Neuro-Muscular Efficiency denotes the ability of the neuro-muscular system to enable muscles to produce movement and the ability of muscles which provide stability to work synergistically as an integrated functional unit (Clark et al., 2018).

Pilates is a body shaping system designed to simultaneously stretch and strengthen skeletal muscles and joints, in which the emphasis of exercise is directed towards the development of balance, body alignment, proper breathing, and stability, with the improvement of the trunk and pelvis central muscular structure strength (Page, 2011). Mikalački, Čokorilo, Korovljev, and Montero (2013) define Pilates as a method of well-designed and controlled exercises that activate muscles, increase the quality of breathing and heart work, and enable the body to maintain proper posture. By improving body posture and postural control, Pilates positively influences overall health status. This is particularly significant given that deficits in postural control have been found to lead to damage to mechanoreceptors and a reduction in somatosensory information processed by the nervous system (Xue et al., 2024). The Pilates method of body conditioning is also applied in the rehabilitation of any body part, as it enhances muscle tone, specific muscular strength, and joint mobility, thereby accelerating the muscle recovery process (Cozen, 2000; Page, 2011). For proper practice of exercises and achieving optimal results, Pilates practice is conducted in accordance with basic principles. These principles include proper breathing, concentration, control, centering, precision, and control of movement, and flow of mevement/ rhythm (Page, 2011). By focusing the mind on the goals of the practice, Pilates promotes body awareness and spatial orientation, improving kinesthetic and proprioceptive abilities during exercise (Kloubec, 2011).

Proprioception is the body's ability to voluntarily or reflexively convey affective information regarding the sense of body or body part position in space, interpret information, and consciously or unconsciously respond to stimulation by posture or movement (Hillman, 2012).

Functional Mobility Screening (FMS) is an evaluation instrument for assessing fundamental movement patterns that detect limitations and asymmetries between opposite sides of the body in the active population (Cook, Burton, & Hoogenboom, 2006a; Cook, et al., 2010). FMS consists of seven tests that require a balanced ratio between mobility and stability (Cook et al., 2006): Deep Squat, Hurdle Step, In-Line Lunge, Shoulder Mobility, Rotary Stability, Active Straight-Leg Raise and Trunk Stability Push-Up. FMS evaluates the locomotor system efficiency in healthy and active individuals without indications of pain and musculoskeletal disorders (Cook et al., 2006b). The movement patterns of FMS underlie many movements in everyday life, sports, recreation, and highly active professions. Each test is graded from zero to three points (Beardsley, Hons, & Contreras, 2014). A zero score indicates that the participant feels pain during testing (Cook, Burton, Hoogenboom, & Voight, 2014a). The participant who is not able to perform the movement pattern gets one point (Cook, Burton, Hoogenboom, & Voight, 2014b). Two points indicate that the participant performs the movement pattern with certain compensations (Cook et al., 2014b). The participant who performs the movement pattern correctly and without any compensations gets three points (Cook et al., 2014b). FMS sets minimum standards for engaging in sports activities and, as such, has excellent practical applicability for most fitness trainers (Cook et al., 2010, p. 64).

Body Core Stability is a term that denotes the ability to maintain balance and control of the spinal and pelvic body regions during movements performed only within physiological limits without compensatory movements (Lederman, 2010).

Body Composition represents the relative values of muscle mass, fat mass, bone mass, water, and other anatomical components contributing to a person's total body weight (Corbin & Lindsey, 1997; Solway, 2013). According to Clover (2007, 43), body composition consists of the amount of water, fat tissue, and lean tissue, which make up a person's total body weight.

There are three general models of body composition (Society of Health and Physical Educators [SHPE], 2011):

1. Anatomical model, according to which the body consists of muscles, bones,

adipose tissue, organs, and anatomical remains;

2. Chemical model, which takes into account the chemical composition of the body in determining the body composition: water, fats (lipids), proteins, minerals, and carbohydrates;

3. Two-component model according to which the body consists of body fat and lean body mass (bones, muscles, organs, and connective tissues).

Core Training is an exercise that is applied in fitness and rehabilitation to develop the strength and endurance of the torso stabilizer muscles (Kibler, Press, & Sciascia, 2006). Strong torso stabilizers protect the spine from excessive force and enable the efficient transfer of force from the proximal to the distal body segments and vice versa (Kibler et al., 2006).

1.2 The Core Stability Concept

The term core stability refers to an active component of the stabilization system, which consists of deep/local muscles or muscles of the inner unit of the body center and superficial/global muscles of the outer unit of the body center (Jones, 2017). Core stability is the ability to control the position and motion of the torso over the pelvis to allow optimum production, transfer and control of force and motion to the terminal segments in integrated athletic activities (Kibler, Press, & Sciascia, 2006). It is the ability of the central muscle structures of the body to resist destabilization or regain a stable position after destabilization, to maintain the posture and control movement (Kibler et al., 2006). Stabilizing the trunk, muscles transmit force from hips to shoulders and in the opposite direction.

The relevance of core stability in injury prevention and performance enhancement has gained popularity over the last decade. Core stability is an essential component in clinical rehabilitation and competitive athlete training, as well as in individual training programs aimed at improving health and physical fitness (Liemohn, Baumgartner, & Gagnon, 2005). Incorporating core stabilization exercises into injury prevention programs, particularly for the lower extremities, has been shown to reduce injury rates (Hubscher et al., 2010; Knapik et al., 2004).

Stability can be static (stabilizing) and dynamic (Örgün, Kurt, & Özsu, 2019). Static stability, unlike dynamic, is most commonly assessed in orthopedic testing (Örgün et al., 2019). Static core body exercisers, such as the front plank, lateral plank, and elevated leg or arm planks, involve the joint and muscle working against an immovable force or being held in a static position with resistance (Örgün et al., 2019). A typical static stability test is the Single Leg Stance test (Alexander, Crossley, & Schache, 2009). Apart from stabilizing, static function, the central muscular structures of the trunk also have a dynamic, moving function, because they enable the mobility of the upper and lower body parts (Jones, 2017). Dynamic stability is necessary for realization of functional movements in which the body core needs to be stabilised, such as, e.g., when performing vertical jump (Parkhouse, & Ball, 2011). Dynamic core exercises such as the glute bridge, abdominal crunch, and dead bug require the ability to produce muscle force concentrically or eccentrically over time (Parkhouse, & Ball, 2011).

According to Lawrence (2011), the body core is the part of the central body region that includes the upper (diaphragm), lower (pelvic floor muscles), anterior (abdominal muscles), posterior (paraspinal and gluteal muscles) and lateral muscles (Figure 1). The core forms a "muscular box" with the abdominal muscles in the front, paraspinals and gluteals in the back, the diaphragm as the roof of the muscle box, and the pelvic floor muscles at the bottom (Akuthota, Ferreiro, Moore, & Fredericson, 2008). This box contains 29 pairs of muscles that contribute to supporting the spinal column, pelvis, and kinetic chain during functional motions (Akuthota et al., 2008).

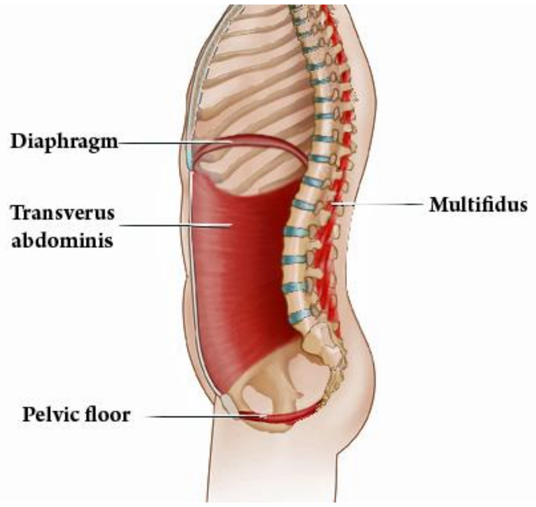


Figure 1. The inner core muscles

By maintaining the pressure in the abdominal and thoracic cavities, these muscles play a key role in stabilization of the spinal column, especially its lower, lumbar part (Lawrence. 2011). Complete stabilization of the spine is enabled by the simultaneous activity of the muscles of the anterior, lateral and posterior sides of the trunk and the seating region muscles.

By strengthening the inner unit core muscles, the trunk extensors stabilize, which leads to significant improvement in efficiency of functional activities and sports performance. Deep stabilizers are closer to the spinal column and therefore are in a mechanically more favorable position to stabilize the spinal column during motion. They, as a belt, wrap the abdominal cavity and ensure stability of trunk and pelvis (Hodges et al., 2003). Besides, they participate in all the movements of the central body structures and are particularly significant during isometric exercises, when stabilizing the trunk, they confront external forces. They contract automatically and simultaneously before any movement and provide functional stability of the lower part of the spine with 20 to 30% strength (Jarmey, 2008). Because of all mentioned above, they are of crucial importance for body posture improvement, so they should be developed in the initial stages of training, before development of superficial trunk stabilizers (Baechle, & Earle, 1994). Stability of deep trunk muscles also contributes to the faster restoration of normal muscle function after injury. For all these reasons, the body center is often referred to as the center of power (Anant & Venugopalb, 2020).

The muscles of the outer unit of the body center are the primary drivers that generate movement and control scope of movement (Jones, 2017). These anatomically superficial muscles are mainly composed of type II high-speed glycolytic fibers that can generate more force but quickly become tired (Jarmey, 2008). Although the outer unit is a phase system with large muscles that primarily produce force and move trunk, it also has an important role in stabilization (Jarmey, 2008). Synergistically working, muscles of both the inner and the outer unit enable complete stability of trunk and pelvis and generate strong and functional movements of the upper and lower extremities (Lawrence, 2011).

Due to a long-term inactivity caused by sedentary lifestyle, the functionality of the body center muscles decreases, especially of the inner unit muscles, which leads to reducing stability and increasing the curves of the spinal column (Jarmey, 2008). This also significantly reduces their ability of automatic engagement in everyday activities such as, e.g. bending or lifting. In that case, their role is taken over by other muscles, which eventually leads to muscle imbalance in agonist muscles strength compared to their functional antagonists (Jarmey, 2008). The consequence of muscle imbalance is increased risk of injury.

The anterior trunk muscles (Table 1) according to Jones (2017) compose the superficial (straight abdominal muscle and external oblique muscles) and deep muscles (transverse abdominal muscle, internal abdominal oblique muscles, pelvic floor muscles and hip flexors). On the posterior trunk (Table 2) there are one superficial (large gluteal muscle) and several deep muscles (spinal erectors, multifidus muscle, piriformis muscle and small and medium gluteal muscles). They influence the posture, balance, coordination, mobility and stability of the trunk, so they are vital for optimal functioning of the whole body (Jones, 2017).

The rectus abdominis is a long straight abdominal muscle that extends along the whole length of both sides of the abdomen (Jones, 2017) It is made up of a pair of parallel muscles that extend along the entire length of the abdominal mid-section (Jarmey, 2008). Its main function is trunk flexion, particularly of the lumbar portion of the spine as well as lifting from a lying to a sitting position (Jarmey, 2008). It also tenses the anterior abdominal wall and assists in compressing the abdominal contents (Brumitt, 2009). The external oblique abdominal muscles (lat. musculus obliquus externus abdominis), which running diagonally downward and inward, in the V shape, laterally surround the straight abdominal muscle, provide additional spine stability and enable the movement of rotation and lateral trunk flexion (Jarmey, 2008; McGill, 2001). Internal abdominal oblique muscles (lat. musculus obliquus internus abdominis) the muscle fibers of which, spreading laterally in the form of a fan, extend obliquely upward and forward, provide support to internal organs and enable trunk stability (Jarmey, 2008). Their basic function is a lateral trunk bending, although to some extent they participate in trunk rotation movements (Jarmey, 2008).

The deepest positioned muscle of the anterior trunk is the transverse abdominal muscle (lat. musculus transversus abdominis) that stabilizes the pelvis and the lower back during movements of the upper and lower extremities (Akuthota, Ferreiro, Moore, & Fredericson, 2008). The dysfunction of this muscle, positioned diagonally in the deepest layer of abdominal muscles, leads to problems in the lumbar part of the spine (Jarmey, 2008). It contracts when we pull in the abdominal wall. Most functional trainings in sports and rehabilitation include exercises to strengthen this muscle, which is much more important for stability than straight abdominal muscle (Jarmey, 2008).

The pelvic floor muscles provide foundational suport for the pelvic internal organs, such as a bladder, intestines, uterus (in females) and faciliate birth (Jones, 2017). They help maintain optimal intra-abdominal pressure. These muscles form a functional unit that enables a stable base to create movements by stabilising the pelvis and spinal column (Clark et al., 2018).

The hip flexor muscles are located on the front side of the hips, opposite the large gluteal muscle (Jones, 2017). They enable different positions and body movements such as standing, walking, running, sitting, trunk flexion, leg raise etc. The lack of mobility of hip flexor causes the pain in the lumbar spine. Spinal extensor muscles enable maintaining a good posture and trunk stability when resisting forces. The multifidus muscle is one of the smallest deep muscles whose primary role is to support the spine in an upright position and evenly distribute the weight along its entire length (Jones, 2017). The pear-shaped muscle (internally attached to the spinal column) effectively opposes lateral forces (Jones, 2017). The small, medium and large sciatic muscles perform abduction and rotation movements in the hip joint and stabilize the pelvis (Jones, 2017).

Trunk stabilizers transmit the force from one half of the body to the other. In case of their weakness, the transmission of force is incomplete. Muscles that transmit force from the trunk to the upper and lower extremities and vice versa are shown in Table 2.

Due to the functional design, body movement e.g., walking, is more conditioned by the central body region stability than by skeletal muscles (Jarmey, 2008). The primary body movers during walking are actually the body core muscles and not the lower extremity muscles that only move the stable core (Karageanes, 2004). Thus, e.g., when descending downhill, while the body resists gravity by balancing on the ground, lower extremities are not the primary drivers, as lack of trunk balance and stability would lead to a fall.

Core training favors Pilates ball use, especially for developing deep trunk stabilizers that protect the spine and play an essential role in stabilizing the spine and hips during movement.

Table 1. The anterior muscles of the trunk (Jones, 2017)

Muscle	Location	Movement	Function
• Straight abdominal muscle (m.rectus abdominis)	• Superficial	• Trunk flexion	• Bending • Lying to sitting
• Transverse abdominal muscle (m. transversus abdominis)	• Deep	• Isometry-trunk stability	• Maintaining a good posture • Maintaining intra-abdominal pressure • Support to pelvic internal organs • Help with forced expiration - coughing, sneezing, laughing
• Abdnominal external oblique muscles (m. obliquus externus abdominis)	• Superficial	• Rotation • Trunk deflection • Isometry-trunk stability	• Lateral trunk flexion and rotation • Preserving good body posture
• Abdnominal internal oblique muscles (m. obliquus internus abdominis)	• Deep	• Isometry-trunk stability • Trunk deflection	• Preserving good body posture • Maintaining intra-abdominal pressure • Support to internal organs
• Pelvic floor muscles	• Deep	• Isometry-trunk stability	• Maintaining intra-abdominal pressure • Support to pelvic internal organs • Help with lifting, urinary control and childbirth
• Hip flexor muscles	• Deep	• Bends in hip joint • Leg lifting	• Walking and running • Climbing and descending stairs

Table 2. The posterior muscles of the trunk (Jones, 2017)

Muscle	Location	Movement	Function
• Spinal extensors (m.erector spinae)	• Deep	• Trunk extension Support during trunk flexion Spinal stabilization	• Bending forward and backward • Maintaining a good posture
• The multifidus muscle (m. multifidus)	• Deep	• Trunk extension • Lateral flexion • Isometry-trunk stability	• Maintaining a good posture • Stability of the spine during resistance to the force that tends to bend it
• The pear-shaped muscle (m. piriformis)	• Deep	• Lateral Flexion	• Spinal stability during lateral loads Lifting heavy loads Carrying a bag
• Small gluteal muscle (m. gluteus minimus)	• Deep	• Movements in the hip joint: abduction, diagonal abduction, internal rotation	• Getting out of the car
• Middle gluteal muscle (m. gluteus medius)	• Deep	• Movements in the hip joint: abduction, diagonal abduction, internal and external rotation	• In-line Lunge
• Large gluteal muscle (m. gluteus maximus)	• Superficial	• Movements in the hip joint: abduction, extension and external rotation	• Walking, running, jumping, riding a bike, climbing and descending stairs

1.3 The Functional Mobility Concept

Functional mobility is a physiological ability that enables a person to independently and safely perform functional activities and tasks in different environments (Lin, Lee, Chang, Yang, & Tsauo, 2017). According to Forhan and Gill (2013), functional mobility is characterized by the easy and effortless performance of daily activities by moving body parts in the functional range of motion (ROM). Functional mobility is an essential condition for normal and unrestricted motor function in humans, as it enables rapid and efficient adaptation of movement, balance, and posture during activities (Bouça-Machado, Maetzler, & Ferreira 2018). Impaired functional mobility leads to loss of independence and increases the risk of falls and injuries (Lin et al., 2017).

Functional mobility should not be identified with flexibility as they do not denote the same ability. Mobility of joints and soft tissues is an essential but not the only condition of functional movements. A person with well-developed flexibility, but not other abilities that characterize functional mobility cannot successfully perform all functional movement patterns, such as the deep squat. Therefore, functional mobility is a broader concept than flexibility, which in addition to well-developed flexibility, implies the ability of strength, balance, and coordination (Foran, 2012). The coordination of movements depends to some extent on the ability of kinesthesia and proprioception. All these abilities are the basic condition for a person's good functional mobility. These abilities are necessary for performing functional movement patterns. The neural control of functional movements enables fast and efficient adaptation of movement, balance, and posture when performing various functional tasks (Forhan & Gill, 2013). In practice, functional movement screening is often used to detect and quantify kinetic chain dysfunction (Coogan et al., 2020).

Functional mobility is characterized by a balance of stability and mobility of certain joints of the body. Joints that have the function of stability are the knee joint, lumbar, and scapulothoracic joint, while the glenohumeral joint, the hip joint, and the thoracic part of the spine have mobility function (Thompson, Gordon, Pescatello, & American College of Sports Medicine, 2010). Many functional movements take place in several planes of motion with the activation of a number of muscle groups and joints in different positions and ranges of movement to achieve a certain goal. Thus, for example, to swing a golf club, an athlete must first stabilize the right hip and rotate shoulders over his hips, and then, without moving head, raise arms above the body and rotate the spine along one axis.

The system of evaluation and grading of movement patterns (FMS) is a clinical instrument based on a scientific approach to functional mobility evaluation. The screening included seven movement patterns (tests) that underlie human movement and identify functional limits and movement asymmetries that significantly reduce the quality of life and sports performance effects (Cook et al., 2010). Besides sports and medical sciences, FMS is also applied in all highly active professions and activities (in the army, fire service, public safety, industrial and other jobs). FMS in sports is applied to determine whether an athlete has the necessary movements needed to participate in sports activities with a reduced risk of injury and to determine whether athletes who received poor grades in individual tests use compensatory patterns of movement during activity (Beardsley & Contreras, 2014), according to Cook et al., 2006a). The minimum number of points in the evaluation system of each test is zero, and the maximum is three (Beardsley & Contreras, 2014).

A grade zero denotes that the participant feels pain while performing any part of any test (Cook, Burton, Hoogenboom, & Voight, 2014). For each of the seven functional mobility 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 (Cook et al., 2014a). The participant who performs the movement pattern optimally and without any compensation is rated with three points (Cook et al., 2014b).

The maximum composite score is 21 points (Cook et al., 2014b). The composite score below 14 is considered at risk of injury (Bonazza, Smuin, Onks, Silvis, & Dhawan, 2017). The available literature shows that the most common value of the composite score in most populations is 13-15 points. However, a higher value of the composite score does not guarantee better sports-specific performance or situational success. According to Beardsley and Contreras (2014), the test results are influenced by many factors. In general, it was found that regardless of gender, the younger and physically active persons with a lower nutritional index achieved better FMS scores than older persons (Bonazza et al., 2017).

All functional mobility tests, except the push-ups test and the deep squat test, are bilateral, so the task is performed on both sides of the body. In case one side of the body is rated poorer than the other side (for example, two points for the left and three for the right side), it has to do with detected asymmetries, and the final grade of that test is lower (Cook et al., 2014a, 2014b).

A low FMS score is associated with an increase in body mass index (BMI), aging, and decreased level of physical activity, which negatively affects health status and athletic efficiency (Mitchell, Johnson, Vehrs, Feland, & Hilton, 2016). For each screening result lower than three points, appropriate corrective strategies have been identified to re-establish mechanically correct movement patterns.

According to Cook et al. (2006a), the movement patterns assessed by FMS in its structure contain the essential movements needed to participate in sports activities with a reduced risk of injury. However, the existing literature shows an inconsistency in the opinion of different authors regarding the predictive validity of FMS for injuries. Although there are studies that have confirmed the predictive FMS validity for injury (Knapik, Bauman, Jones, Harris, & Vaughan, 1991; Schulz et al., 2013), no consensus on defining movement patterns in the basis of fundamental movement has yet been reached, calling into question the FMS validity. In this respect, Beardsley and Contreras (2014) state that movement patterns different than those assessed by FMS have been identified, which, if performed with compensations, can also lead to sports injuries.

Also, it was determined that compensatory movements are more often present in training that requires a high speed of movement and in training carried out with heavy loads

(Frost, Beach, Callaghan, & McGill, 2015). In addition, it was also noticed that the knowledge of the test evaluation criteria affects the test result because the participants who had been thoroughly acquainted with the test evaluation criteria before the screening had fewer compensatory movements. These facts call into question the external or obvious validity and indicate that the participants can manipulate the performance test and change the outcome. The assessment of the overall construct validity of the FMS requires a very precise definition of the object of measurement, which, according to Dallinga, Benjaminse and Lemmink (2012) is a problem when it comes to FMS, as many other tests can predict lower-body injuries.

Bonazza, Smuin, Onks, Silvis, and Dhawan (2017), in their review study, analyzed the results of some FMS validity studies and concluded that FMS has weak to moderate constructive, criterion, content, and concurrent validity. On the other hand, these authors point out the excellent FMS reliability, regardless of whether it is a test-retest or interrater reliability, emphasizing that interrater reliability is almost perfect. The results of the study conducted by Teyhen et al. (2012) showed that the composite FMS score showed good reliability both in repeated measurements by the same examiner (interrater reliability) and in "simultaneous" measurements (in the period from 48 to 72 hours) by different examiners (interrater reliability). Moderate to excellent FMS reliability has been confirmed by a large number of studies in which the same or very similar results were obtained regardless of whether the measurements of the same sample were performed several times by one or more measurers (Butler & McMichael, 2010; Frohm, Heijne, Kowalski, Svensson, & Myklebust., 2012; Gribble, Brigle, Pietrosimone, Pfile, & Webster, 2013; Leeder, Horsley, & Herrington, 2016; Minick et al., 2010; Onate et al., 2012; Parenteau, Luiselli, & Keeley, 2012; Shultz, Anderson, Matheson, Marcello, & Besier, 2013; Teyhen et al., 2012).

FMS is a diagnostic procedure with an elaborate system for ranking and evaluating movement patterns that are key to determining normal function. It is evident that FMS provides rapid feedback on functional limitations and asymmetries that can disrupt the ability of proprioception and reduce the effects of training and physical conditioning. In addition, FMS provides an initial insight into the musculoskeletal condition of the participants and the deficit of motor control. As such, it has great practical applicability in fitness (Cook et al., 2010). However, despite the stated advantages, top sports require much more precise and sophisticated tests than FMS.

2. OVERVIEW OF RESEARCH

This chapter displays research on the effectiveness of ball Pilates on body composition, muscular fitness and functional mobility.

In contemporary fitness, ball Pilates is widely used in body core stability and mobility training. Exercising on an unstable surface establishes normal proprioception and kinesthetic sensation and significantly improves the reflex neuromuscular response to the applied stimuli (Carter et al., 2006; McCackey, 2011; Prieske et al., 2016; Sekendiz, 2010; Stanton et al., 2004; Sukalinggam et al., 2012). Furthermore, due to the need to maintain balance during exercising, the activity of the torso stabilizer muscles is increased considerably.

Weak torso stabilizers in functional, dynamic activities do not stabilize the spine and pelvis sufficiently, so the transfer of force from the body core to the extremities is incomplete, which significantly reduces efficiency in sports activities. Training of internal and external core unit muscles on an unstable surface stabilizes the trunk during activity, improving motor control and sports performance and reducing the risk of injuries (Willardson, 2014).

Functional mobility represents an essential condition for normal and unrestricted motor functioning in humans. It enables rapid and efficient adaptation of movement, balance, and posture during movements performance across various positions and planes of movement (Forhan & Gill, 2013).

Regular implementation of the ball Pilates also results in physiological adaptations in body composition, reflected in reduced fat and increased lean body mass. Maintaining an optimal level of fat and lean body composition components is vital for a healthy body structure and overall health of individuals (Ayers & Sariscsany, 2010).

2.1 Overview of Research on the Ball Pilates Effects on Body Composition

Wrotniak, Whalen, Forsyth, and Taylor (2001) researched the effects of ball Pilates training on body composition and aerobic fitness in children and adolescents. The sample of participants consisted of five boys and 16 girls (N = 21; age: 7-17 years; average BMI > 25.0 kg/m^2) who underwent Pilates ball training twice a week for eight weeks. The first weekly training session lasted for 60 minutes, and the second 45 minutes. All exercises included in the training program were performed sitting on a ball at an intensity of 60–85% of maximum heart rate. During the experimental period, participants attended fifteen-minute lectures once a week on a nutritionally healthy diet regimen they followed during the experiment. At the initial and final measurements, body weight, body mass index, body fat percentage, waist-to-hip ratio, and the sum of five skinfolds were determined. Dependent aerobic fitness variables were resting heart rate and maximal oxygen consumption (VO_2 max). Significant decreases were found in body fat percentage (-1.4%) and sum of skinfolds (-9.3 mm) at the final measurement compared to the initial measurement. In other variables, improvements were numerically rather than statistically significant. The study showed that eight weeks of ball Pilates training and an appropriate nutrition effectively improve body composition but not aerobic fitness in obese children and adolescents. The exercise intensity was adequate for metabolic processes of adipose tissue but inadequate for adaptive changes in aerobic fitness. The applied training program can be recommended as an alternative to traditional exercise for improving body composition.

Cakmakçi (2011) determined the effects of Pilates training on body composition and flexibility in obese women. The sample of participants consisted of 58 obese women with no previous training experience. Participants were randomly divided into an experimental (EG; n = 34; average body height: 1.56 ± 4.13 cm, average body weight: 82.71 ± 9.48 kg; average age: 36.15 ± 9.59 years) and a control group (CG; n = 27; average body height: 160 ± 6.82 cm, average body weight = 83.74 ± 10.25 kg; average age: 38.96 ± 10.02 years). The experimental group carried out Pilates training four times a week for eight weeks, while the control group was not involved in the training process. The training sessions lasted for 60 minutes. The experimental program consisted of exercises on a Pilates ball and on the floor ("the hundred", the shoulder bridge, single leg circle, pelvic lift, trunk side bend, the "saw" exercise, forward bend with arms in front of the body, stretching the spine forward, push-ups, double leg bridge with bent knee). At the initial and final measurements in both groups of participants, the following parameters were determined: body mass index (BMI), lean body mass (LBM), body fat percentage (BF%), waist circumference (WC), waist to hip ratio (WHR), four-site skinfold thickness (m. biceps brachii, m. triceps brachii, m. subscapularis and m. iliacus), resting metabolic rate (RMR) and flexibility. The results showed a significant ($p < .05$) decrease of BMI, BF%, WC and skinfold thickness in all variables in the experimental group of participants at the end of the experimental period. In addition, the experimental group participants significantly increased LBM and RMR, and improved WHR and flexibility. No significant changes were found in the control group of participants in any of the monitored parameters. According to the obtained results, it can be concluded that the eight-week training program on Pilates ball and floor is an effective training tool for improving body composition and flexibility in obese women.

*Vispute, Smith, LeCheminant, and Hurley (2011***)** determined the effects of the combined mat and ball Pilates training on body composition and abdominal endurance in college students. The research included 14 healthy, sedentary men and 10 healthy women randomly divided into an experimental group (E; average age: 24.50 ± 4.97 years) and a control group (K; average age: 22.49 ± 0.97 years). During the six-week experimental period, the experimental group participants performed ball and mat Pilates training five times a week. The training program included a five-minute warm-up on a treadmill, followed by exercises to strengthen the abdominal muscles on a Pilates ball and on the floor (ball forward torso bending on the, forward torso bending on the floor with legs bent at the knees, Russian twists on the ball, torso twists lying on the ball, leg lifts on the bench) and lateral torso flexion. The exercises were performed slowly in two sets of 10 repetitions. The rest between sets was 10-15 seconds. The participants of the control group were not involved in the training process. During the experiment, both groups of participants followed an isocaloric diet regime. At the initial and final measurements, anthropometric measurements of height and weight and measurements of body mass index, body fat percentage, abdominal fat (android fat measured by DXA, waist circumference, and abdominal subcutaneous fat), suprailiac subcutaneous fat, and abdominal muscle endurance were conducted. The results showed no significant changes in body composition parameters between any group's initial and final measurements. However, in contrast to the control group, significant improvements were found in the abdominal endurance in the experimental group. Such results are probably a consequence of the conception of the training program, which, apart from low-intensity repetitive abdominal exercises, did not contain intense isometric endurance exercises or engage other muscle groups.

Raj and Pramod (2012) determined the effects of ball Pilates and yoga training on body composition in female students. The sample of 54 participants, aged 19-25 years, was divided into two experimental (E1 and E2) and one control group (C). The E1 group participants (n = 18) carried out Pilates ball training for 12 weeks, five times a week for 60 minutes, while the E2 group participants (n = 18) carried out yoga training during the same time period and in the same frequency and duration of training sessions. The K group participants (n = 18) were not included in any training program. The E1 group training program included warm-up exercises (15 minutes), Pilates ball strength exercises (30 minutes), and cooling exercises (15 minutes). The yoga program included prayer exercises, various asana exercises and relaxation exercises. At the initial and final measurement, the absolute and relative values of the fat and lean body mass were determined in all groups of participants using a Tanita body analyzer. The results showed significantly reduced fat level and increased lean body mass between the two measurements in both experimental groups of participants. Numerically more significant improvements were found in the E1 group. No significant improvements in body composition were found in the K group of participants. At the final measurement, the results of the analysis of covariance (ANCOVA) showed that no significant differences in body composition were found between the experimental groups, but that both experimental groups differed significantly from the control group in fat and lean body mass. The authors concluded that both experimental programs effectively improved the body composition of female students.

Anant and Venugopalb (2015) determined the effectiveness of Pilates ball training on body fat mass in athletes. The sample of 55 male athletes, aged from 18 to 28, was divided into an experimental group (n = 30), which, in addition to conditioning training, also performed Pilates on the ball, and a control group (n = 20), which practiced only conditioning training exercises. All participants competed at the inter-university level. The experimental group performed Pilates training to strengthen the trunk stabilizer muscles five times a week for eight weeks. The program of the experimental group consisted of a fifteen-minute warm-up exercises, static (front, back and lateral plank) and dynamic exercises on a Pilates ball (trunk flexion, extension and rotation exercises) and cool-down exercises. During the training period, the number of repetitions was gradually increased, from 10 repetitions in the first week to 20 repetitions in the last week. The participants performed static endurance exercises in three sets of 20 seconds (in the first week), and three sets of 60 seconds (in the last week). The control group carried out only the usual conditioning training for team games. At the initial and final measurements, body fat percentage was measured (using a skinfold caliper) in both groups of participants. At the end of the experimental period, unlike the control group, significant decrease in body fat percentage ($p < .05$) was found in the experimental group. The study confirmed the superiority of eight-week body core training on a Pilates ball compared to classic conditioning training in transforming the relative values of body fat mass in young athletes.

Welling and Nitsure (2015) compared the effectiveness of different Pilates programs on abdominal girth and skinfold thickness.in healthy individuals. The study included 60 women who were randomly divided into three experimental groups that carried out different Pilates programs: 1. ball Pilates (n =20; average age: 24.17 ± 4.25 years); 2. floor Pilates (n = 20; average age: 26 ± 6.05 years) and resistance band Pilates (n = 20; average age: 23.65 ± 4.49 years). During the five-week experimental period, all three groups of participants carried out appropriate training sessions five times a week while adhering to the prescribed diet plan. The program of all groups included trunk stabilizer strengthening exercises (straight and oblique abdominal muscles and back muscles). The number of sets and repetitions in all groups was gradually increased, starting from three sets of 15 repetitions in the first week to four sets of 25 repetitions in the last week. The following parameters were determined in all participants before the beginning and at the end of the experimental period: body mass index (BMI), thickness of the abdominal subcutaneous adipose tissue (SCAT), waist circumference (WC) and waist to hip ratio (WHR). The results of the t-test showed that all experimental groups statistically significantly reduced BMI, abdominal adipose tissue, waist circumference and waist-to-hip ratio ($p < .001$). At the final measurement, no significant intergroup differences were observed in any of the monitored parameters. Therefore, all three Pilates programs, along with a proper diet plan, are effective in reducing abdominal fat and preventing obesity.

Lee, Kim, and Lee (2016) compared the effectiveness of different exercise programs on body composition, physical fitness, and depression in obese men. The sample of 40 students with an average age of 23.10 ± 3.14 years, was divided into the experimental group (E; n = 20), which carried out ball Pilates in combination with aerobic exercise, and the control group (K; n = 20), which practiced only aerobic training. The ball Pilates program consisted of warm-up exercises, strength exercises on the ball, and cool-down exercises. The aerobic exercise of the experimental group was carried out according to the ACSM (2006). The aerobic exercise program of the control group consisted of treadmill warm-up and aerobics. Both applied programs were conducted for eight weeks, three times a week for 60 minutes. Before the beginning and at the end of the experimental period, the following parameters were determined in participants: body fat percentage, muscle strength, muscle endurance, cardiorespiratory endurance, flexibility, and psychological factors. The results showed that both groups of participants statistically significantly reduced body fat percentage and improved results in variables for assessing psychological factors ($p < .05$). In other variables better results at the numerical level were registered in the experimental group. At the final measurement, the groups of participants did not differ statistically significantly in any variables, except in the body fat percentage and variables for assessing psychological factors. This study indicates that ball Pilates exercises in combination with aerobic exercise are effective for preventing obesity, improving physical fitness and mental health in obese men.

Srinivasulu and Amudhan (2018) determined the effects of combined training of ball Pilates, mat Pilates and plyometrics on the body composition of young athletes. The sample of participants consisted of 48 volleyball players aged 13-15 years. Participants were divided into an experimental and a control group, each comprising 24 participants. In addition to regular volleyball training, the experimental group performed combined training of ball Pilates, mat Pilates and plyometric exercises. The control group only participated in the regular volleyball training and without any additional training process. The experimental period lasted for 12 weeks, during which participants of the experimental group conducted training sessions three times a week for 60 minutes. Initial and final measurements using a body structure analyzer determined the percentage of body fat and trunk fat in both groups of participants. Results showed a significant decrease in both monitored body composition parameters among participants in the experimental group compared to those in the control group ($p < .05$). The study confirmed the effectiveness of a twelve-week training program combining Pilates on a ball and mat with plyometric exercises on the body composition of athletes.

Yaprak (2018) determined the effects of the ball Pilates program on fitness components in young men. The 22 healthy students, aged 18 to 25, were divided into an experimental ($n = 12$) and a control group ($n = 10$). The experimental group performed core-strengthening exercises on an unstable surface three times a week for eight weeks. The participants conducted two static exercises on a Pilates ball (back bridge and plank) and four dynamic exercises on a BOSU ball (back extension, sitting crunches on the ball, trunk twists, and the bird-dog exercise). During the first four weeks, the exercises were performed in two sets of 15 repetitions and then in three sets of 20 repetitions. The control group was not involved in any training program. Before the beginning and at the end of the experimental period, measurements of body composition (BMI, body fat mass in percentages and kilograms, percentage values of trunk fat mass, and waist and hip circumferences), isometric strength of the back and legs (Isometric Leg Strength, Isometric Back Strength, and the Biering-Sorensen test), repetitive abdominal and back strength (Sit-up test; Back Extension test), the flexibility of the spinal column (ROM), and balance (Y Balance Test, YBT) were carried out. The results revealed that the experimental program did not significantly affect any body composition parameter. Significant changes were found in tests to assess the leg and back isometric strength, repetitive abdominal muscle strength, and spinal flexibility ($p < .05$). Given the relatively short duration and the concept of the training program, which consisted of strength and muscular endurance exercises and not aerobic exercise, a significant improvement in body composition would be unrealistic to expect.

Buttichak, Leelayuwat, Bumrerraj, and Boonprakob (2019) conducted a quasi-experimental study to determine the effects of yoga exersises on a Pilates ball on body composition and physical fitness in women. The study included 30 overweight participants (average BMI = 23.0–29.9 kg/m^2) aged 30-45 years. The training program consisted of ball

Pilates yoga exercises which the participants performed in three phases: 1. the pre-training phase (first eight weeks), 2. the training phase (next seven weeks), and 3. home training phase (last seven weeks). Before and after the study, measurements of body composition and obesity (weight, height, body mass index, waist circumference, and waist-to-hip ratio, percentage values of fat and muscle mass), and physical fitness components (flexibility, balance, muscle strength, and muscle endurance) were conducted. The results of the Repeated measures ANOVA showed a significant increase in muscle mass and significant decreases in body weight ($p = .001$), BMI ($p = .001$), waist circumference ($p = .001$), and percentage of body fat ($p = .001$) after the sixteenth week. Changes in the waist-to-hip ratio variable were numerically observed but not statistically significant. Statistically significant improvements were observed in all physical fitness variables ($p = .001$). Therefore, yoga training on a Pilates ball effectively improves body composition and physical fitness parameters in overweight women.

Lim (2019) compared the effectiveness of ball Pilates and mat Pilates on body composition and postural stability in healthy students. The sample of 30 sedentary male students (average age: 20,7 ± 1,18 years, average weight: 65,30 ± 8,87 kg, average height 171,60 ± 6,20 cm) were divided into two experimental and one control group. The participants of the first experimental group (E1; n = 10) carried out Pilates ball training for six weeks, two times a week for 60 minutes, while the participants of the second experimental group (E2; n = 10) carried out mat Pilates during the same time period and with the same frequency and duration of training sessions. The participants of the control group (K; n = 10) were not included in any training program. The ball Pilates program consisted of warm-up exercises, stabilization endurance exercises on the ball, and cool-down exercises. The participants of the E2 group carried out the same program, provided that they performed stabilization endurance exercises on the floor. Before the beginning and at the end of the experimental period, measurements of body composition (skeletal muscle mass, percentage values of body fat mass and trunk fat mass) and postural stability were taken. The results showed significantly reduced percentage values of body fat and trunk fat mass and increased skeletal muscle mass between the two measurements in both experimental groups of participants. In addition, significant improvements in postural stability were noticed in both experimental groups. At the final measurement, no significant intergroup differences in the effectiveness of the applied programs were observed in any monitored parameter. This study indicates that both ball Pilates and mat Pilates are effective training methods for improving body composition and postural stability in sedentary male students.

Ružić (2020) determined the effects of the ball Pilates training and resistance training on health-related fitness in female students. The sample of participants comprised 45 female college students (average height: 165.0 ± 4.7 cm; average weight: 62.2 ± 8.0 kg; average BMI: 22.8 ± 2.6 kg/m^2), who were randomly divided into two experimental (E1 and E2) and one control group (K). The E1 group (n = 15) carried out resistance training in a gym three times a week for twelve weeks, and the E2 group (n = 15) carried out Pilates ball training. The K group (n = 15) was not included in any training process. At the initial and final measurements, the following body composition parameters were determined: body mass [%], muscle mass [%], muscle mass [kg] and lean body mass [%]. In addition, muscular fitness (1RM Chest Press, 1RM Overhead Press, 1RM Leg Press, Core Muscle Strength and Stability Test and the McCloy Physical Fitness Test), cardiorespiratory fitness (Beep Test) and flexibility (Supine Straight Leg Raise, Spread Eagle Supine Leg Abductions, Prone Straight Leg Extensions, and Sit and Reach Test) were tested. The results of the t-test for dependent samples showed that both experimental groups significantly improved the results in all body composition parameters ($p < .05$). The largest improvements in the E1 group were noticed in the percentage increase of muscle mass (ES = 2.89) and in the E2 group in the percentage decrease of fat body mass (ES = -2.17), percentage increase of lean body mass (ES = 2.17) and decrease of fat body mass in kg (ES = -1.73). Both groups of participants statistically significantly improved cardiorespiratory endurance ($p = .00$) and results in all muscle fitness tests ($p <0.05$). In the K group of participants, no significant improvements were noticed in any variable ($p > .05$). The results of the Analysis of Covariance showed that resistance training had a greater effect on improvement of body composition and maximal leg strength when compared to Pilates ball training ($p = .00$). The author concluded that both experimental programs are effective in transforming body composition and other components of health-related fitness.

Yaprak and Küçükkubas (2020) examined gender differences in the effectiveness of the body core training on an unstable surface on physical fitness parameters in college students. The research included 24 participants randomly divided into the male group (M; n =12; average age: 20.75 ± 2.63 years; average body height:172.38 ± 4.48 cm; average body weight: 67.40 ± 8.05 kg) and the female group (F; n =12; average age: 20.66 ± 1.82 years; average body height: 165.96 ± 6.98 cm; average body weight: 53.25 ± 7,11 kg). Both experimental groups performed a training program on an unstable surface three times a week for eight weeks. The program consisted of a ten-minute warm-up and stretching, core strengthening exercises on Pilates and BOSU balls, and cool-down exercises. The program of exercises for strengthening the body core consisted of six exercises on an unstable surface

(BOSU ball side legs lift, oblique forward bend, back extension, BOSU ball quadruped opposite arm-leg lift, Pilates ball back bridge and forearm plank), performed by the participants during the first four weeks in two sets of 15 repetitions or 15 seconds each, and then in three sets of 20 repetitions or 20 seconds each. Rest between sets was at least 20 seconds and 90 seconds between exercises. Before the beginning and at the end of the experimental period, anthropometric and body composition measurements were carried out (body mass, body mass index, body fat percentage, trunk fat percentage, lean body mass in kilograms, waist circumference, and hip circumference), muscle strength and endurance measurements (sit-up and back extension test, back extensor endurance test), balance (y-balance test), flexibility (the sit and reach test) and the functional range of motion (ROM). Both experimental groups significantly improved all physical fitness parameters, except for body composition, between the initial and final measurements. At the final measurement, significant gender differences were found in body weight ($p = .000$), body mass index ($p = .001$), body fat percentage ($p = .002$), lean body mass ($p = .000$), and waist circumference ($p = .001$). Compared to the female group, the male group had significantly higher body mass, BMI, lean body mass, and waist circumference values, and significantly lower body fat percentage values. No significant gender differences were found in percentage values of body fat ($p = .270$) and hip circumference ($p = .272$). In addition, significant gender differences were found in posteromedial balance, where female participants achieved better results, and posterolateral balance on the left leg, where male participants achieved better results. The study showed that gender affects dynamic balance parameters, but not body composition, strength, flexibility, and muscular endurance in students.

Anant and Venugopalb (2021) determined the effects of body core training on body composition and physical fitness components in athletes. The sample of participants consisted of 55 young athletes who competed in various team games. The participants were randomly divided into an experimental (n = 30; average age: 25.3 ± 1.52 years; average BMI = 21.50 ± 0.60 kg/m^2) and a control group (n = 25; average age: 26.4 ± 1.63 years; average BMI = 22.12 ± 0.58 kg/m^2). The experimental group performed Pilates training to strengthen the trunk stabilizer muscles for eight weeks, five times a week. The control group carried out only usual conditioning training for team games, which included running, jumping, and full-body exercises. The participants of the experimental group practiced exercises on a Pilates ball (kneeling alternate arm and leg lift, ball supine bridge, both leg lifts with a ball, abdominal crunches with a ball, ball hamstring curl exercises) and on the floor (prone bridge, kneeling alternate arm and leg lift, plank with one arm and one leg lift). At the initial and final measurements, body weight, body fat percentage, essential fat mass, non-essential fat mass, absolute total body fat, trunk lateral endurance, abdominal muscular endurance, and explosive leg strength were measured in both groups of participants. At the end of the experimental period, unlike the control group, significant improvements in all parameters of body composition, except for the lean and fat free body mass were found in the experimental group. The study confirmed the superiority of eight-week body core training on a Pilates ball compared to classic conditioning training in transforming fitness components in young athletes.

Prakash, James, Sivakumar, and Dharini (2021) conducted a quasi-experimental study to determine the effects of different exercise programs on abdominal subcutaneous adipose tissue in female college students. The research included 20 female students (average age: 23.05 ± 1.2 years, average BMI: 28.5±1.5 kg/m^2) divided into an experimental and a control group. The experimental group (E1; n = 10) carried out the combined training, including ball Pilates and aerobic exercise, for 12 weeks, six times a week for 40 minutes, while the control group (K; n = 10) carried out only aerobic training. At the initial and final measurements, body weight and abdominal fat tissue measured using circumference measurement were determined in both groups. After a ten-minute aerobic warm-up, the participants of the E1 group did exercises on a Pilates ball to strengthen the trunk stabilizer muscles (abdominal crunch, oblique abdominal crunch, back extension, front plank and side plank) for 20 minutes. After that, they did static stretching exercises for ten minutes. The results showed that the E1 group significantly reduced body weight and abdominal fat at the end of the experimental period ($p< .05$). In the K group, only a significant decrease in abdominal fat and not body weight was noticed. The applied exercise program on the Pilates ball, combined with aerobic training, effectively reduces female students' body weight and abdominal fat tissue.

2.2 Overview of Research on the ball Pilates Effects on Functional Mobility

Baumschabel, Kiseljak, and Filipović (2015) determined the effects of ball Pilates on functional mobility in women. The sample of 30 non-athletes aged 20-45 years was randomly divided into two experimental groups. Participants of the first experimental group (n = 15) carried out the mat Pilates training five times a week for ten weeks. Participants of the second experimental group (n=15) carried out the ball Pilates training with dumbbells in the same time period. Training sessions lasted for 40-50 minutes. Measurements of participants' functional mobility were taken before the beginning and at the end of the experimental period. Functional mobility was assessed using seven standard FMS tests (Deep Squat, Hurdle Step, In-Line Lunge, Shoulder Mobility, Active Straight-Leg Raise, Trunk Stability

Push-Up and Rotary Stability). Differences in functional mobility between the initial and final measurements of the participants were determined by the t-test for dependent samples. The results showed that the group of participants who practiced ball Pilates significantly improved results in all functional mobility tests ($p < .01$). However, no significant improvements were found in any variable in participants who performed mat Pilates ($p > .01$). The results of the t-test for independent samples showed that at the final measurement the groups of participants differed statistically significantly ($p < .01$) in all FMS tests in favor of the group that exercised on the ball. The study showed that Pilates on the ball was more effective than mat Pilates in improving functional mobility in female non-athletes.

Dinc, Kilinc, Bulat, Erten, and Bayraktar (2017) determined the effects of ball Pilates on functional mobility and injury prevention in young football players. The sample of 67 sixteen-year-olds was divided into an experimental (n=24; average age: 16.13±0.38 years; average body height: 175±4.16 cm; average body weight: 69.07±4.55 kg) and a control group (n=43; average age: 16.42±1.57 years; average body height: 175.75±4.44 cm; average body weight: 70.29±4.89 kg). During the twelve-week experimental period, the experimental group in addition to regular football training, carried out a functional mobility and stability exercise program on a Pilates ball twice a week for 60 minutes. The program contained 21-24 training sessions in total. The control group was not involved in the training process but only practiced regular football training. The participants' functional mobility was assessed by the FMS test battery at the initial and final measurements. In addition to FMS testing, the number of contact and non-contact sports injuries was recorded during the experimental period. The results of the t-test for dependent samples showed that both groups significantly improved the overall FMS score ($p < .05$), provided that significant improvements in the experimental group were recorded in a larger number of individual FMS tests (Deep Squat, Hurdle Step, In-Line Lunge and Trunk Stability Push-Up) compared to the control group (Deep Squat and Trunk Stability Push-Up). In addition, the frequency of non-contact injuries in the experimental group was significantly lower than in the control group ($p < 0.05$). The results indicate that ball Pilates effectively improves functional mobility and reduces the frequency of injuries in young football players. Therefore, exercising on a Pilates ball effectively improves the functional mobility, which is a fundamental condition for effective physical performance and injury prevention.

Skotnicka, Karpowicz, Sylwia-Bartkowiak, and Strzelczy (2017) determined the effects of Pilates ball training and corrective exercises on functional mobility in female dancers. The sample of 187 participants was divided into an experimental (n = 9; average age: 22.02 ± 2.26 years) and a control group (n=9; average age: 21.72 ± 1.33 years). Both groups of participants were involved in the training process at the Faculty of Physical Education. During the twelve-week experimental period, the experimental group participants additionally practiced the ball Pilates training, which included stabilization endurance exercises and corrective exercises to improve functional mobility. The experimental program was carried out once a week for 90 minutes. Both groups of participants were tested at the initial and final measurements by the FMS battery tests (deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up and rotary stability). The total FMS score was also calculated. At the end of the experimental period, the experimental group participants were found to have significantly improved the results in the deep squat, hurdle step, in-line lunge, and trunk stability push-up tests. The control group significantly improved the result only in the deep squat test. Significantly larger effects at the final measurement ($p < .05$) were determined in the experimental group of participants in the total FMS score and results of the deep squat and in-line lunge tests. Due to its efficiency in improving functional mobility and preventing injuries, a ball Pilates program and corrective exercises should be included in the standard dancer exercise program.

From a functional aspect, the mobility and stability of the core muscles are of vital importance for the effectiveness of daily and sports activities. *Lago-Fuentes et al. (2018)* determined the effects of torso stabilizer training on physical fitness and functional mobility in professional futsal players. The sample of participants consisted of 14 athletes, who were randomly divided into the group that exercised on a stable surface (n = 7; average age: 23.6 ± 4.8 years; average body height: 166.5 ± 5.9 cm; average body weight: 63.9 ± 7.5 kg) and the group that exercised on an unstable surface (n = 7; average age: 23.8 ± 5.8 years; average body height: 164.8 ± 4.8 cm; average body weight: 63.9 ± 6.8 kg). The participants exercised three times a week for 20 minutes during the six-week experimental period. The exercise program of both groups of participants consisted of four endurance exercises (shoulder bridge, side bridge, prone plank, and crunch) participants practiced in three sets of 30 s during the first two weeks; then, they increased the load by reducing support surface and by increasing the endurance time by 10 seconds every other week. The sample of measuring instruments consisted of tests for assessing functional mobility (FMS test battery) and physical fitness of participants (vertical squat jump, the 10 m sprint, and repeated sprint ability test). The results of the repeated measures analysis of variance (ANOVA) showed that the group that practiced on an unstable surface improved the total FMS score by 11.10% ($p <.05$) and the group that practiced on a stable surface by 10.39% ($p< .05$). In addition, both groups of participants significantly improved physical fitness ($p< .05$). No significant intergroup differences were found at the final measurement in any variable ($p>.05$) The study confirmed the effectiveness of both stable and unstable surface exercise protocols in improving functional mobility and physical fitness in young athletes.

Liang, Wang, and Lee (2018) determined the effects of torso stabilizer training on functional mobility and postural stability in female students. The sample of 28 participants was divided into two equal groups: an experimental (n = 14; average age = 20.1 ± 1.1) and a control group (n = 14; average age = 20.1 ± 1.4). The experimental group of participants carried out the combined ball (bridge, plank, jackknife, and crunch) and mat Pilates training (jackknife, leg pull front, the hundred exercises, shoulder bridge, leg lift exercise) to strengthen the trunk stabilizers for six weeks, twice a week for 50 minutes. The control group participants carried out only flexibility training in the same time period and with the same number of training sessions. The functional mobility was tested (deep squat, hurdle step, in-line lunge, shoulder mobility, active straight-leg raise, trunk stability push-up and rotary stability) according to the FMS protocol at the initial and final measurements. In addition, postural stability was evaluated using the 8-direction limits of stability test (LOS test). The results of the repeated measures analysis of variance showed that the experimental group, in contrast to the control group, statistically significantly improved functional mobility and postural stability. Therefore, the study confirmed the efficiency of combined training on an unstable and a stable surface in improving the functional movement patterns and dynamic postural stability in female students.

The aim of the study carried out by *Bagherian, Ghasempoor, Rahnama, and Wikstrom (2019)* was to determine the effects of the body core Pilates ball training on functional mobility and dynamic postural control in athletes. The sample of 100 male athletes who performed usual daily off-season activities was divided into two groups - an experimental group (n = 60; average age: 18.1 ± .9) and a control group (n = 40; average age: 18.03 ± .9). In addition to the usual sports activities, the experimental group participants carried out ball Pilates training for trunk stabilizer muscles strengthening for eight weeks, three times a week for 90 minutes. At the initial and final measurements, the functional mobility of both groups of participants was assessed using the standard FMS battery tests, balance using the Y balance test, and strength and endurance of the hips and legs using the Single Leg Lateral Squat test. The results showed that the participants of the experimental group, in contrast to the participants of the control group, significantly improved balance ($p \leq .01$) and the results in all functional mobility tests ($p \leq .01$). Numerically more significant improvements in functional mobility were noticed in participants with poorer initial measurement FMS test results. This study showed that an eight-week torso stabilizer strengthening training performed on a Pilates ball effectively improves functional mobility and dynamic postural control in young athletes, especially those with initially poorer results.

Saberian Amirkolaei, Balouchy, and Sheikhhoseini (2019) determined the effects of ball Pilates on functional mobility and balance in teenagers. The sample of 29 participants who played badminton recreationally was randomly divided into an experimental (n = 16; average age: 13.31±1.2 years) and a control group (n = 13; average age: 13.31±1.2 years). The experimental group performed Pilates ball training three times a week for eight weeks, while the control group performed only usual recreational activities. The experimental program consisted of a ten-minute warm-up, a twenty-five-minute exercise on a Pilates ball, and cool-down exercises. Participants performed the following exercises: ball rolling, reverse bridge, side bend, plank, hamstring bridge, push-ups, back extension, and reverse plank. During the first four weeks, all exercises, except for the ball rolling exercise, were performed in two sets of 10 repetitions and then in three sets of 12 repetitions. During the entire experimental period, the ball rolling exercise was performed in three sets, in the first four weeks of 10 and then 12 repetitions. Before the beginning of the experiment, an initial measurement was performed; after four weeks, a transit measurement and at the end of the experiment, a final measurement of functional mobility and balance was performed. The results of the transitional measurement of the experimental group showed a significant improvement in the results in all functional mobility tests ($p \leq .01$) and the Y balance test of the upper ($p \leq .01$) and lower extremities ($p \leq .01$). Furthermore, a significant improvement in all monitored variables was registered between the transitional and final measurements of the experimental group ($p \leq .01$). In the control group of participants, no significant improvements were found in any test ($p > .01$). The results of this study confirmed the efficiency of ball Pilates on the functional mobility and balance of young badminton players, so implementing the applied exercise protocol is recommended in their training process.

Functional movement is at the basis of the performance development of athletes, but also of untrained individuals. Its monitoring identifies functional limitations, asymmetries, and the effects of applied programs. *Šćepanović et al. (2020)* conducted a quasi-experimental study to determine the impact of core stability training on functional mobility in college students. The sample of 138 students of the Faculty of Sport and Physical Education, with an average age of 20 ± 0.5 years, was divided into two groups: an experimental (n= 73) and a control group (n= 65). In addition to the program contents at the faculty, the experimental group also implemented the experimental program on the Pilates ball and the floor, while the control group implemented only the program contents at the faculty. The experiment lasted for six weeks, and the training sessions were performed three times a week for 30 minutes.

The experimental program was conducted throughout three phases, each lasting two weeks. The basis of the program was various exercises to improve the stability and mobility of the spinal column. The sample of measuring instruments consisted of seven standard tests for assessing functional mobility: deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raises, trunk stability push-up and rotary stability. At the end of the experimental period, both groups were found to have significantly improved their total FMS score. The experimental group significantly improved the results in all tests except for the shoulder mobility test. The control group did not achieve significant changes in the rotary stability and hurdle step tests, while statistically significant changes were found in other tests. At the final measurement, statistically significant intergroup differences were found in the total FMS score and the hurdle step, in-line lunge, and rotatory stability tests in favour of the experimental group. Isometric core strengthening exercises performed in different planes effectively improve functional movement patterns.

Vurgun and Edis (2021) determined the effects of ball Pilates training on functional mobility and torso stabilizer muscles endurance in athletes. The sample of participants consisted of 16 young handball players (mean age: 18.31 ± 0.47, average height: 177 ± 0.96 cm, average weight: 64.3 ± 10.42 kg, average BMI: 20.28 ± 2.79 kg/m^2). Participants practiced Pilates ball training three times a week during the six-week experimental period. The program consisted of seven static endurance exercises participants performed in three sets of 15 s (first two weeks), three sets of 30 s (third and fourth weeks), and three sets of 45 s (fifth and sixth weeks). The participants' functional mobility and muscular endurance were tested before and after the experimental period. Functional mobility was assessed by a standard FMS test battery (deep squat, hurdle step, inline lunge, trunk stability, and rotary stability), and torso stabilizer endurance was assessed by trunk flexors, extensors, and lateral muscle endurance tests. A significant improvement in the total FMS score ($p = .001$, ES = 0.61), as well as the results of the deep squat test ($p = .003$, ES = 0.50) and the hurdle step test ($p = .020$, ES = 0.33) was determined at the final measurement. In other FMS battery tests and muscle endurance tests, the observed improvements were not at a statistically significant level. Therefore, ball Pilates effectively improves functional movement patterns, which is of particular importance for reducing injuries and increasing the efficiency of sports performance.

2.3 Overview of Research on the Ball Pilates Effects on Muscular Fitness

Cosio-Lima, Reynolds, Winter, Paolone, and Jones (2003) conducted research to determine the effects of short-term Pilates ball training on trunk core stability, electromyographic activity (EMG) of trunk stabilizers, balance, knee strength, and heart rate in non-athletes. The sample of 30 participants with an average age of 23 +/-5.80 years was divided into the experimental and control group. The experimental group participants (n=15) practiced training on Pilates ball to strengthen the trunk stabilizer muscles and improve balance, five times a week for five weeks. The control group participants (n=15) practiced the same exercises in the same period of time and with the same frequency of exercises but on the floor. During the training period, the number of sets and repetitions was gradually increased, from 3 sets of 15 repetitions in the first week to 5 sets of 25 repetitions in the fifth week. The sample of measuring instruments was composed of tests for assessing the isometric strength of the trunk and knee flexor and extensor muscles, the EMG activity of the trunk flexors and extensors, balance, and heart rate. The t-test results showed that the experimental group, in contrast to the control group, significantly improved the EMG of the trunk flexors ($p = .04$) and extensors ($p = .01$) and the muscle balance ($p < .01$). However, no significant improvements in isometric strength of trunk flexor and extensor muscles and heart rate were found in any group ($p > .05$). At the final measurement, groups of participants did not differ statistically significantly ($p > .05$) neither in strength and endurance of trunk and knee stabilizers nor in heart rate. The research confirmed the effectiveness of the applied ball Pilates program for improving balance and increasing EMG activity of trunk stabilizers in non-athletes. A longer period of time is required for adaptations of heart rate and isometric strength of trunk stabilizers.

Literature data showed that exercising in unstable conditions may be more suitable than exercising in stable conditions for improving core stability. *Stanton, Reaburn, and Humphries (2004)* determined the effects of Pilates ball training on body core stability, aerobic capacity, and running economy in young athletes. The sample of 18 basketball and football players, with an average age of 15.5 +/- 1.4 years, was divided into an experimental (n=8) and a control (n=10) group. In addition to regular technical-tactical and running training, the experimental group of participants also practiced ball Pilates training for six weeks, twice a week for 25 minutes. Participants of the control group exercised as usual, performing only usual technical-tactical and running training. The Sahrmann core stability test, front plank test, and VO_2 max test were applied at the initial and final measurement. Running economy was calculated using linear regression. The results of the analysis of variance for repeated measures showed that the experimental group, in contrast to the control group, significantly improved trunk core stability ($p < .05$). In other tests, no significant improvements were found in any group ($p > .05$) which the authors explained by insufficiently specific choice of exercises.

Pilates ball training improves spinal stability and reduces the risk of lumbar back pain syndrome. *Carter, Beam, McMahan, Barr, and Brown (2006)* carried out research to determine the effects of ball Pilates on core muscles endurance in sedentary persons. Twenty participants of both genders was randomly assigned to either an experimental group (n = 10; average age: 36.1 ± 7.8 years; average weight: 73.5 ± 25.2 kg; average height: 172.5 ± 11.4 cm) or to a control group (n = 10; average age: 39.8 ± 10.4 years; average weight: 80.1 ± 18.8 kg; average height: 175.5 ± 15.6 cm). The experimental group practiced Pilates ball training for 10 weeks, twice a week for 30 minutes, while the control group performed only usual activities. The experimental program included static and dynamic exercises for strengthening trunk stabilizers. The sample of measuring instruments consisted of tests for assessing trunk extensor endurance and trunk lateral muscles endurance. Results of the repeated measures ANOVA showed that the experimental group statistically significantly improved trunk extensor endurance ($p < .05$) and trunk lateral endurance ($p < .05$) between two measurements. The control group did not significantly improve the result in any test. The authors emphasize the importance of the applied Pilates ball program for improving core muscles endurance and preventing lumbar pain in sedentary individuals.

Core training improves endurance of the local and global trunk stabilizer muscles that stabilize the spinal column in dynamic activities. *Sekendiz, Cug, and Korkusuz (2010)* determined the effectiveness of Pilates ball training on strength and endurance of trunk stabilizer muscles, flexors and extensors of lower extremities, flexibility, and dynamic balance in sedentary people. The sample of participants consisted of 21 women (average age: 34 ± 8.09; average height: 1.63 ± 6.91 cm; average weight: 64 ± 8.69 kg) without previous training experience. The participants practiced large muscle groups strengthening Pilates ball training for 12 weeks. Training sessions were conducted three times a week for 45 minutes. The exercising protocol included a five-minute running and stretching warm-up, seven dynamic exercises on Pilates ball (ball straight crunch, ball wall squat, ball alternate arm and leg extension, ball shoulder bridge, ball back extension, ball hamstring curl and ball leg raise) and static stretching exercises for large muscle groups (2 x 15 s). The following tests were applied at the initial and final measurements, in addition to isokinetic measurements of the trunk and lower extremities flexors and extensors strength: the modified Biering-Sorensen test for assessing trunk extensor endurance, abdominal crunch, squats, the sit and reach test, and the functional reach test. Results of the repeated measures ANOVA showed that participants statistically significantly improved results in all monitored variables ($p \leq .05$). The authors point out the efficiency of the applied training program on improving fitness parameters in female non-athletes, and the possibility of its practical application in physiotherapy and conditioning.

The deficit in strength and endurance of trunk stabilizer muscles impairs motor control and increases the risk of injuries. *McCaskey (2011)* investigated the effects of four-week trunk stabilizer training on global muscular endurance and dynamic balance in female students. The sample of 30 participants aged 18-29 was randomly divided into the experimental (n =15) and control group (n =15). Within the 4-week training program, the experimental group did the front, back, and side bridge on the Pilates ball, while the control group did the same exercise on the floor. The measuring instruments consisted of the Sahrmann stability test, the SEBT dynamic balance test, and tests for assessing the endurance of flexors, extensors, and lateral trunk muscles. Differences between the initial and final measurements were evaluated using the t-test for independent samples. The results showed that the experimental group statistically significantly improved the reach in posterolateral direction (p= .007), posteromedial direction (p= .042), and trunk lateral endurance on the right (p= .021) and on the left body sides (p= .002). However, the registered improvements were only at the numerical level in other tests, probably due to the relatively short experimental period.

Sukalinggam, Sukalinggam, Kasim, and Yusof (2012) compared the effectiveness of ball Pilates and floor Pilates on trunk core stability in non-athlete students. The sample of 42 participants of both genders (average age: 23.62 2.89 years; average body height: 165.89 ± 9.21 cm; average body mass: 64.31 14.52 kg) was randomly divided into two experimental and one control group. Participants of the first experimental group (n=14) practiced Pilates ball trunk stabilizer muscle strengthening training three times a week during the six-week experimental period. Participants of the second experimental group (n = 14) did the same program of exercises with the same class load and in the same period, only on the floor. The control group of participants (n = 14) was not included in the training program. The experimental program included eight trunk stabilizer strengthening exercises. The measuring instrument sample consisted of tests for estimating the maximum strength (1RM) of the trunk flexors and extensors. The best result of a total of three attempts with a five-minute break between attempts was recorded. The results showed that the group that exercised on the Pilates ball significantly improved ($p < .001$) the strength of the trunk flexors (29.51%) and trunk extensors (25.79%). Considering the participants' gender, greater improvements were registered among females. The group that exercised on the floor achieved a smaller percentage of improvements in the strength of trunk flexors (8.47%) and extensors (10.28%).

The unstable surface is assumed to activate neuroadaptive mechanisms to a greater extent than the stable surface, resulting in more efficient strength development.

Lee, Kim, and Lee (2016) compared the effectiveness of different exercise programs on physical fitness, and depression in obese men. The sample of 40 students of both genders, with an average age of 23.10 ± 3.14 years, was divided into the experimental group (n = 20), which carried out ball Pilates in combination with aerobic exercise, and the control group (n = 20), which practiced only aerobic training. The ball Pilates program consisted of warm-up exercises, strength exercises on the Pilates ball for all large muscle groups, and cooling exercises. The aerobic exercise of the experimental group was carried out according to the American College of Sports Medicine recommendations (ACSM, 2006). The aerobic exercise program of the control group consisted of treadmill warm-up and aerobics. Both applied programs were conducted for eight weeks, three times a week for 60 minutes. Before the beginning and at the end of the experimental period, the following parameters were determined in participants: body fat percentage, muscle strength, muscle endurance, cardiorespiratory endurance, flexibility, and psychological factors. The t-test results revealed that both groups of participants significantly reduced body fat percentage and improved all physical fitness variables. In tests used to assess psychological characteristics, the experimental group achieved numerically better results ($p > .05$). At the final measurement, the groups of participants did not differ statistically significantly in any variables, except in the body fat percentage and variables for assessing psychological factors. This study indicates that ball Pilates exercises combined with aerobic exercise are effective in preventing obesity and improving physical fitness and mental health in obese men.

Studies have shown that core training on an unstable surface is an effective stimulus for improving the fitness components in young athletes. *Prieske et al. (2016)* compared the effectiveness of ball Pilates and mat Pilates on trunk core stability, agility, speed, and sports performance in young football players. The sample of 39 male participants was divided into two experimental groups. Both groups of participants practiced progressive body core strengthening training provided that only the first experimental group (n=19; average age:16.6 ±1.1 years; average body height: 1.82 ±0.05 cm; average body mass: 72.5 ±6.3 kg; average BMI: 22.0 ±1.2 kg/m^2) conducted it on a Pilates ball and the second one (n=19; average age:16.6 ±1.1; average body height: 1.82 ±0.05; average body weight: 72.5 ±6.3; average BMI: 22.0 ±1.2) practiced on the floor. Training sessions were carried out for 9 weeks, two to three times a week. The following measurements were taken at the initial and final measurements: the 1RM test to assess the maximum strength of the trunk flexors and extensors, maximal vertical CMJ test, 20-m linear sprint test, the Agility T-test, and kicking performance test. At the final measurement compared to the initial one, both groups were found to have significantly improved trunk extensors strength ($p < .05$), sprint time at 10-20m ($p < .05$), and kicking performance ($p< .01$). The authors concluded that both applied programs effectively improved trunk core stability and sports performance in young football players.

Yaprak (2018) determined the effects of the ball Pilates training on fitness components in young men. The sample of 22 healthy students (average age: 20.68 ± 2.27 years, average body height: 175.23 ± 5.17 cm, average body weight: 66.81 ± 7.85 kg) was divided into an experimental (n = 12) and a control group (n = 10). The experimental group performed core strengthening exercises on an unstable surface three times a week for eight weeks. The examinee performed two static exercises on a Pilates ball (back bridge and plank) and four dynamic exercises on a BOSU ball (back extension, crunches sitting on a ball, trunk twists, and the bird-dog exercise). During the first four weeks, the exercises were performed in two sets of 15 repetitions and then in three sets of 20 repetitions. The control group was not involved in the training process. Before the beginning and at the end of the experimental period, the following measurements were taken: body height, body weight, BMI, body composition (absolute and relative values of the body fat mass, relative values of the trunk fat mass), trunk extensor endurance (Biering-Sorensen Test), isometric strength of the back and legs (using a dynamometer), repetitive abdominal strength (Sit-up test), repetitive back strength (Trunk Extension test), the flexibility (The sit and reach test), and balance (Y Balance Test). The results showed that the experimental program did not significantly improve any body composition parameter. Significant changes were found in tests to assess the leg and back isometric strength, repetitive abdominal muscle strength, and spinal flexibility. The core-strengthening training on a ball effectively improves physical fitness components but not body composition in young men. Given the relatively short duration and the concept of the training program, which consisted of strength and muscular endurance exercises and not aerobic exercise, a significant improvement in body composition would be unrealistic to expect.

Jain at al. (2019) compared the effectiveness of Pilates on a standard and small Pilates ball on the endurance of the trunk stabilizer muscles and dynamic balance in persons with lumbar pain syndrome. The sample of 38 participants of both genders (26 female and 12 male), aged 18-25 years, was divided into two experimental groups, each consisted of 19 participants. Participants of the first experimental group performed training on a standard Pilates ball, and participants of the second experimental group on a small Pilates ball. The experimental period lasted for four weeks, during which both groups of participants practiced training sessions five times a week. The measuring instrument sample consisted of tests for assessing the strength and endurance of trunk flexors (the curl-up test) and extensors (the modified Sorenson's trunk extensor endurance test,), the SEBT balance test (standing on right and left legs), and a lumbar pain intensity assessment questionnaire (MODQ). The results showed that both experimental programs statistically significantly influenced improving the strength and endurance of the trunk flexors and extensors and reducing pain in the lumbar spine ($p \leq .05$). At the final measurement, no statistically significant intergroup differences in the efficiency of the applied exercise programs were found in any variable. More significant effects in muscle fitness, but only at the numerical level, were found in the group that exercised on a small Pilates ball.

The trunk stabilizer muscle strength is positively correlated with swimming performance, so the central body region training is essential for the swimmer's training process. *Marani, Subarkah, and Octrialin (2020)* conducted research to determine the effectiveness of Pilates ball training on abdominal muscle strength in junior swimmers. The sample of 30 participants of both genders (16 boys and 14 girls), aged 10-13 years was divided into an experimental (n=15) and a control group (n=15). Participants of the experimental group practiced on Pilates ball for six weeks with a frequency of three training sessions per week. The experimental program consisted of 10 exercises to strengthen the trunk stabilizers. The intensity and duration of exercising were gradually increased. The exercises were performed in three sets of 15 repetitions (in the first week), three sets of 20 repetitions (in the second week), four sets of 20 repetitions (throughout the third and fourth weeks) and four sets of 25 repetitions, throughout the fifth and sixth weeks. The control group was not involved in the training process. The dolphin-style swimming time at 50 m was measured at the initial and final measurements. In addition, trunk stabilizer endurance was assessed by a one-minute sit-up test. The t-test results showed that the experimental Pilates ball program significantly improved the torso stabilizer strength and the dolphin-style swimming time at 50 m ($p \leq .05$). The research confirmed the efficiency of the applied experimental program on body core stability in young swimmers, and thus its efficiency in swimming.

Team games are characterized by short-term repetitive activities with sudden shifts in direction, jumps, and arm movements in various positions. These sudden movements require good posture and strong trunk stabilizers. *Anant and Venugopalb (2021)* determined the effects of body core training on physical fitness components in athletes. The sample of participants consisted of 55 young athletes who competed in various team games. The participants were randomly divided into an experimental (n = 30; average age: 25.3 ± 1.52

years) and a control group (n = 25; average age: 26.4 ± 1.63 years). In addition to regular conditioning training the experimental group performed Pilates training to strengthen the trunk stabilizer muscles five times a week for eight weeks. The control group carried out only the usual conditioning training for team games, which included running, jumping, and full-body exercises. The participants of the experimental group practiced exercises on a Pilates ball (ball alternate arm and leg extension lying on a ball, ball supine bridge, both leg lifts with a Pilates ball, abdominal crunches with a Pilates ball, hamstring curl exercises with a ball) and on the floor (prone bridge, kneeling alternate arm and leg extension, plank). At the initial and final measurements, trunk lateral endurance, abdominal muscular endurance, and explosive leg strength were measured in both groups of participants. At the end of the experimental period, unlike the control group, significant improvements in all physical fitness tests were found in the experimental group. Medium effects were found in lateral trunk endurance and explosive leg strength, while small effects were found in abdominal muscle endurance. The study confirmed the superiority of eight-week training on a Pilates ball compared to classic conditioning training in transforming fitness components in young athletes.

Strengthening the trunk stabilizers is crucial for improving athletic performance and reducing injury risk. *Nuhmani (2021)* studied the effectiveness of dynamic Pilates ball training on trunk stabilizer strength in athletes. The study involved 49 men and 18 women (average age: 24.32 ± 3.53 years, average body height 162 ± 5.73 cm, average body mass 64.41 ± 8.80 kg) with experience in load training and without experience in unstable surface training. Participants were randomly divided into an experimental (24 men, 9 women) and a control group (25 men, 9 women). The training programs of both groups of participants consisted of the same body core strengthening exercises provided that the experimental group performed them on Pilates ball and the control group on the floor. Both groups of participants trained three times a week for 45 minutes during the six-week experimental period. The load was gradually increased, from two sets of eight repetitions in the first week to two sets of 16 repetitions in the last week. The measuring instruments consisted of the front plank test, the Sorenson's trunk extensor endurance test, tests to assess bilateral trunk endurance, and the double-leg lowering test. The results of the t-test showed that both groups of participants significantly improved the results in all tests. The determined improvements in the double-leg lowering test in both groups of participants were at the $p = .01$ level of significance. In all other tests, the improvements found in the experimental group were at the $p \leq 0.01$ level of significance and in the control group at the $p \leq .05$ level of significance. This study confirmed the significant effect of both applied programs in improving the stability of the body core in athletes.

Vurgun and Edis (2021) determined the effects of ball Pilates training on body core endurance and functional mobility in athletes. The sample of participants consisted of 16 young handball players (average age: 18.31 ± 0.47 years, average height: 177 ± 0.96 cm, average weight: 64.3 ± 10.42 kg, average BMI: 20.28 ± 2.79 kg/m^2). Participants practiced Pilates ball training three times a week during the six-week experimental period. The program consisted of seven static endurance exercises participants performed in three sets of 15 seconds (in the first two weeks), three sets of 30 seconds (in the third and fourth weeks) and three sets of 45 seconds (in the fifth and sixth weeks). The participants' functional mobility and muscular endurance were tested before and after the experimental period. Functional mobility was assessed using the Deep Squat, Hurdle Step, In-Line Lunge, Trunk Stability, and Rotary Stability tests. Trunk stabilizer endurance was assessed using trunk flexors, extensors, and lateral muscle endurance tests. A significant improvement in the total FMS score (p =.001, ES = 0.61), as well as the deep squat (p =.003, ES = .50), and the hurdle step test results (p = .20, ES = 0.33) was determined at the final measurement. In other FMS tests and muscle endurance tests, the observed improvements were not on a statistically significant level. Therefore, ball Pilates effectively improves functional movement patterns, which is of particular importance for reducing injuries and increasing the efficiency of sports performance.

Rakesh and Nipa (2022) determined the effects of Pilates ball training on trunk stabilizer muscle endurance and agility in young basketball players. The sample of participants consisted of 20 male basketball players aged 18-22, was randomly divided into an experimental group (n = 10; average age: 19.6 ± 1.74) and a control group (n = 10; average age: 19.9 ± 1.81). Along with technical and tactical basketball training, the experimental group carried out trunk stabilizer training on a Pilates ball, while the control group performed only the usual basketball training. The training sessions of the experimental program were conducted throughout four weeks, five times a week, for 60 minutes. The program of the experimental group consisted of warm-up exercises, static and dynamic exercises on a Pilates ball (balanced sitting, crunch, the front, back and lateral bridge on a ball, back extension, push-ups, hamstring exercise, superman and pike) and cool-down exercises. At the initial and final measurement, agility (Illinois Agility Test) and endurance of the body core were determined in participants by McGill's tests battery for assessing the endurance of flexors, extensors, and lateral trunk muscles. The results showed that in the experimental group, in contrast to the control one, statistically significant improvements were found in all trunk stabilizer endurance and agility tests ($p < .05$). At the final measurement, statistically significant intergroup differences were found in favor of the experimental group. The significance of the differences in the trunk stabilizer endurance tests was at the $p < .01$ level of significance and in the agility test at the $p < .05$ level of significance. A study showed that Pilates ball training significantly improves trunk stabilizer endurance and agility in young basketball players.

Tabular Overview of Research

Table 3. Effects of Ball Pilates on Body Composition /Data extracted from each study included for overview

Study	**Research aim**	**Participants/ N/F/M**	**Age /Mean Age ± SD (Years)**	**Activity /BMI (kg/m^2)**	**Pilates intervention Characteristics/ Program**	**Outcome measures/ Dependent variables**	**Duration and frequency**	**Results**
Wrotniak et al. (2001)	▪ to determine the influence of Pilates ball training on body composition and aerobic fitness in children and adolescents	▪ 21/16/5	▪ 1EG = 7-17 /NS	▪ sedentary, over-nourished / BMI >25	▪ EG: ball Pilates: front bridge, back bridge, lateral bridge. Exercise intensity: 60-85% of maximum heart rate.	▪ body mass index (BMI); ▪ body fat percentage (BF%); ▪ waist-to-hip ratio (WHR); ▪ skinfold thickness (SF); ▪ resting heart rate (RHR); ▪ maximal oxygen uptake (VO2 max).	▪ 8 weeks / 2 times a week for 45-60 minutes	▪ EG: BMI↓, SF↓, BF%↓, WHR↓, RHR ↓, VO2 max ↔, RHR↔.

Raj and Pramod (2012)	Cakmakçi (2011)	Vispute et al. (2011)
▪ to determine the effects of ball Pilates and yoga training on body composition in woman	▪ to determine the effects of Pilates training on body composition in women	▪ to determine the effects of the combined mat and ball Pilates training on body composition and abdominal endurance in college students
▪ 54/54/0	▪ 58/58/0	▪ 24/10/14
▪ 19-54/NR	▪ EG = 36.15 ± 9.59; ▪ CG = 38.96 ± 10.02	▪ EG = 24.50 ± 4.97; ▪ CG = 22.49 ± 0.97.
▪ NS	▪ sedentary, obese/ NS	▪ Sedentary, over-nourished / BMI =24.47± 3.61
▪ EG1: ball Pilates: strength exercises (HR: 60-70 % of maximal HR for the age). ▪ EG2: yoga prayer exercises, asana exercises and relaxation exercises. ▪ CG was not involved in the training process.	▪ EG: Ball Pilates: bent-knee bridge, leg stretch, Lie back stretch, knee stretch (1S/8R); ▪ EG: Mat and Ball Pilates: "The saw exercise", roll-up exercise, "the hundred", spine stretch forward, push-ups (1S/8R); ▪ EG: Mat Pilates: "the hundred", the shoulder bridge (1S/8R); ▪ CG was not involved in the training process.	EG: ball and mat Pilates: forward torso bending on the ball, forward torso bending on the floor with legs bent at the knees, Russian twists on the ball, torso twists lying on the ball, leg lifts on the bench and lateral torso flexion (2 sets of 10 repetitions, 10-15 seconds of rest between sets). ▪ CG: activities of daily living.
▪ body fat percentage (BF%); ▪ body fat mass in kilograms (BFM-kg); ▪ lean body mass in percent (LBM-%); ▪ lean body mass in kilograms (LBM-kg).	▪ body weight (BW); ▪ body mass index (BMI); ▪ lean body mass (LBM); ▪ body fat percentage (BF%); ▪ skinfold thickness Biceps, Triceps, subscapular and suprailiac (4-ST); ▪ waist circumference (WC); waist to hip ratio (WHR); ▪ resting metabolic rate (RMR).	▪ body mass index (BMI); ▪ body fat percentage (BF%); ▪ abdominal subcutaneous fat tissue (AST); ▪ waist-to-hip ratio (WHR); ▪ suprailiac subcutaneous fat tissue (SIF); ▪ abdominal muscle endurance (AME).
▪ 12 weeks / 5 times a week for 60 minutes	▪ 8 weeks / 4 times a week for 60 minutes	▪ 6 weeks / 5 times a week/NS
▪ EG1: BF% ↓, BFM- kg ↓, LBM -% ↑, LBM -kg↑. ▪ EG2: BF% ↓, BFM- kg ↓, LBM -% ↑, LBM -kg↑. ▪ CG: BF% ↔, BFM- kg ↔, LBM-% ↔.	▪ EG: BMI↓, BF%↓, WC↓, 4-ST ↓, LBM ↑, RMR↑, WHR↑. ▪ CG: BMI↔, BF%↔, WC↔, 4-ST ↔, FFM ↔, RMR↔, WHR↔.	▪ EG: BMI↔, BF%↔, AST ↔, WHR↔, SIF↔, AI ↔. ▪ CG: BMI↔, BF%↔, AST ↔, WHR↔, SIF↔, AI ↔.

Lee et al. (2016)	Welling and Nitsure (2015)	Anant and Venugopal (2015)
▪ To determine the effects of ball Pilates on body composition, physical fitness, and depression in obese persons.	▪ To determine the effects of different Pilates programs on subcutaneous fat tissue in healthy persons.	▪ to determine the effects of ball Pilates on body fat in athletes
▪ 40/20/20	▪ 60/60/0	▪ 55/0/55
▪ EG: 23 ± 5.80 ▪ CG: 22.30 ± 2.70	▪ 18-40 / NR	▪ 18-28/NR
▪ obese, physically inactive /NS	▪ pre-obese/ BMI = 25- 29.9 and obese/ BMI = 30.0-34.9	▪ physically active NS
▪ EG: ball Pilates: push up, sit-ups, back extension, back bridge, bent knee hip extension, jackknife with bent knees (60-70% of HRmax) + the aerobic training – 20 minutes; ▪ CG: the aerobic training: treadmill warm-up and aerobics.	▪ EG1: ball Pilates: curl up, oblique curl up in bridge, knee tuck on the ball, back extension; ▪ EG2: mat Pilates: Plank, V- up, oblique crunch, Scissors, crunch; Scissors, crunch ▪ EG3: Pilates with elastic band: core stability exercises ▪ W1: 3S/15R; W2: 4S/15R; W3: 4S/20R; W4: 4S/20R; W5: 4S/25R.	▪ EG: trunk flexion, extension and rotation exercises (W1-10R; W8-20R); front, back and lateral plank; ▪ CG was not involved in the training process.
▪ body fat percentage (BF%); ▪ physical fitness parameters (PF).	▪ body mass index (BMI); ▪ abdominal skinfold thickness (AST); ▪ waist circumference (WC); ▪ waist-to-hip ratio (WHR).	▪ body fat percentage (BF%).
▪ 8 weeks / 3 times a week for 60 minutes	▪ 5 weeks / 5 times a week	▪ 8 weeks / 5 times a week /NS
▪ EG: BW↔, BF%↓; ▪ CG: BW↔, BF%↓. ▪ At the final measurement, the groups of participants did not differ significantly in BW and BF%.	▪ EG1: BMI↓, ASF↓, WC↓ и WHR↓; ▪ EG2: BMI↓, ASF↓, WC↓ и WHR↓; ▪ EG3: BMI↓, ASF↓, WC↓ и WHR↓.	▪ EG: BF% ↓; ▪ CG: BF% ↔.

Yaprak (2018)	Srinivasulu and Amudhan (2018)	Khajehlandi and Mohammadi (2021)
▪ To determine the effects of the ball Pilates training on fitness components in young men.	▪ To determine the effects of combined training of ball Pilates and mat Pilates on the body composition of young volleyball players.	▪ To determine the effects of Pilates training on body composition, lipid profile, and serum 25-hydroxy vitamin D levels in women
▪ 22/0/22	▪ 48/24/24	▪ 28/28/0
▪ EG: 20.75 ± 2.63; ▪ KG: 21.20 ± 3.22	▪ EG and CG: 13-15	▪ EG = 29.61 ± 3.61; ▪ KG = 30.12 ± 4.01.
▪ BMI = NS	▪ inactive, BMI = 22.33 ± 2.00	▪ inactive, overweight/ NS
▪ EG: ball Pilates: back bridge and plank, back extension, sitting crunch on the ball, trunk twists, and the bird-dog exercise). W1-4: two sets of 15 repetitions W5-8: three sets of 20 repetitions. ▪ CG was not involved in the training process.	▪ EG: combined training of ball Pilates, mat Pilates and plyometric exercises + the usual volleyball training ▪ CG: the usual volleyball training.	▪ EG: mat Pilates (the first six weeks) + ball Pilates with elastic bands (the second six weeks ▪ CG was not involved in the training process.
▪ body mass index (BMI); ▪ abdominal skinfold thickness (AST); ▪ body fat mass in kilograms (BFM-kg); ▪ waist-to-hip ratio (WHR).	▪ body fat percentage (BF%); ▪ trunk fat percentage (TF%).	▪ body weight (BW-kg); ▪ body mass index (BMI- kg/m^2); ▪ body fat percentage (BF%); ▪ the waist-to-hip ratio (WHR).
▪ 8 weeks / 3 times a week	▪ 12 weeks / 3 times a week for 60 minutes	▪ 12 weeks / 3 times a week for 60 minutes
▪ EG: BMI ↔, BF% ↔, BFM- kg ↔, WHR↔. ▪ CG: BMI ↔, BF% ↔, BFM- kg ↔, WHR↔.	▪ EG: BF% ↓, TF% ↓; ▪ CG: BF% ↔, TF% ↔.	▪ EG: BW↓, BMI↓, BF%↓, WHR↓; ▪ CG: BW↔, BMI↔, BF%↓↔, WHR↔.

Ружић (2020)	Lim (2019)	Buttichak et al. (2019)
▪ To determine the effects of ball Pilates training and weight training on the body composition in female students	▪ To determine the effects of ball Pilates and mat Pilates on body composition and postural stability in healthy students	▪ To determine the influence of the ball Pilates training on body composition and physical fitness in women.
▪ 45/45/0	▪ 30/0/30	▪ 30/30/0
▪ 21 +/- 1.8	▪ 20.7 ± 1.18	▪ 30-45
▪ physically active, BMI = 22.8±2.6	▪ sedentary, BMI = 22.2	▪ inactive, BMI =23.0 -29.9
▪ EG1: weight training in the gym ▪ EG2: Pilates ball training (W I-IV: stabilization endurance exercises; W V-VIII: strong endurance exercises; W IX-XII: exercises for the development of muscle hypertrophy); ▪ KG was not involved in the training process.	▪ EG1: ball Pilates: front, back and lateral bridge; ▪ EG2: mat Pilates: front, back and lateral bridge; ▪ KG was not involved in the training process.	▪ yoga exercises on Pilates balls: the pre-training phase (W1-W8), the training phase (W9-W16), and the home training phase (W17-W24).
▪ body fat percentage (BF%); ▪ body fat mass ((BFM -kg); ▪ muscle mass percentage (MM%); ▪ muscle mass (LBM-kg); ▪ fat free mass (FFM -%).	▪ skeletal muscle mass (SMM); ▪ body fat percentage (BF%); ▪ trunk fat mass percentage (TF%); ▪ postural stability (PS).	▪ body weight (BW); ▪ body mass index (BMI); ▪ body fat percentage (BF%); ▪ muscle mass percentage (MM%); ▪ waist circumference (WC); ▪ waist-to-hip ratio (WHR); ▪ maximum strength of the back and legs (S-LB).
▪ 12 weeks / 3 times a week for 45 minutes	▪ 6 weeks / 2 times a week for 60 minutes	▪ 24 weeks / 3 times a week for 60 minutes
▪ EG1: BF%↓, BFM -kg↓, MM%↑, MM-kg ↑; ▪ EG2: BF%↓, BFM -kg↑, MM%↑, MM-kg ↑, FFM -%↑; ▪ KG: BF%↔, MM%↔, MM-kg ↔, FFM -% ↔.	▪ EG1: SMM-kg↑; BF%↓, TF%↓, PS↑; ▪ EG2: SMM-kg↑; BF%↓, TF%↓, PS↑; ▪ KG: BF%↔, BF% ↔, SMM-kg↔, PS↔.	▪ EG: BW↓, BMI↓, BF%↓, MM% ↑, WC↓, WHR↔. S-LB↑.

Prakash et al. (2021)	Anant and Venugopal (2021)	Yaprak and Küçükkubas (2020)
▪ to determine the effects of different exercise programs on abdominal subcutaneous adipose tissue in female college students.	▪ to determine the effect of core muscles ball Pilates training on body composition in athletes	▪ to determine gender differences in the effectiveness of the core training on an unstable surface on body composition in college students
▪ 20/20/0	▪ 52/0/52	▪ 24/12/12
▪ EG и CG = 20–25 (MA=23.05 ± 1.2)	▪ EG = 25.3 ± 1.52 ▪ KG =26.4 ± 1.63	▪ MG = 20.75 ± 2.63; ▪ FG=20.66 ± 1,82.
▪ sedentary, BMI = 28.5±1.5	▪ physically active/ NS	▪ physically active/ NS
▪ EG: ball Pilates (abdominal crunch, oblique abdominal crunch, back extension, front plank and side plank): 20 minutes, 3 Circuits, Intensity - Borg Scale 12-13 + aerobic exercise ▪ CG: aerobic training.	▪ .EG: Pilates-ball alternate arm and leg extension, front, back and lateral bridge on a ball, alternate arm and leg lift on the floor, bridge with arm lift, Abdominal crunches with Swiss ball, Swiss-ball back Extension, Plank with one arm and one leg lift, Swiss-ball hamstring Curl (W I-II: 2S/10R; W III-IV: 3S/13R; W V-VI: 4S/15R; W VII-VIII; 4S/17R); ▪ KG was not involved in any training process.	▪ MG и FG: BOSU ball Exercises: two leg raises from side on BOSU ball, quadruped opposite arm-leg raise ▪ on a ball; Pilates ball Exercises: oblique forward bend, back extension, back bridge and Forearm Plank. ▪ W1-W4: 2S, 15R/15S; W4-W8: 3S, 20R/20S.
▪ body weight (BW) ▪ abdominal fat tissue (AST)	▪ body fat percentage (BF%), ▪ lean body mass (LBM), ▪ fat-free body mass (FFBM-kg), ▪ essential fat mass (EFM), ▪ non-essential fat mass (NEFM-kg), ▪ absolute total body fat (ATBF-kg)	▪ body weight (BW-kg), ▪ body mass index (BMI- kg/m^2), ▪ body fat percentage (BF%), ▪ lean body mass (LBM -kg), ▪ trunk fat percentage (TF-%), ▪ waist circumference (WC-cm); ▪ hip circumference (HC-cm).
▪ 12 weeks / 5 times a week for 40 minutes	▪ 8 weeks / 5 times a week for 60 minutes	▪ 8 weeks / 3 times a week for 60 minutes
▪ EG: BW ↓, AST↓; ▪ CG: BW ↔, AST↓.	▪ EG: BF%↓, LBM-kg ↔, FFBM-kg ↔, EFM-kg↓, NEFM-kg↓, ATBF-kg; ▪ KG: BF%↔, LBM-kg ↔, FFBM-kg ↔, EFM-kg↔, NEFM-kg ↔, ATBF-kg ↔.	▪ MG and FG: BW-kg ↔, BMI- kg/m^2 ↔, BF-% ↔, LBM -kg ↔, TF-%↑, WC-cm ↔, HC-cm ↔; ▪ Compared to the FG, MG had significantly higher BW, BMI, LBM-kg, и WC, and significantly lower BF%. ▪ No significant gender differences were found in TF and HC. ▪

Legend: ↑ - statistically significant increase; ↓ - statistically significant decrease; ↔: without statistically significant changes; A - age; EG - experimental group; F - female gender; FG - female group; HR - heart rate; HRmax - the maximum heart rate; CG - control group; M - male gender; MA - average age; MG - male group; NS - not specified. R - number of repetitions; S - number of sets; W - a period of one week.

Table 4. Effects of Ball Pilates on Functional Mobility/Data extracted from each study included for review

Study	Research aim	Number, age and gender of participants	Groups of participants	Pilates Intervention Characteristics/ Program	Outcome Measures/ dependent variables	Duration and frequency	Results
Baumschabel et al. (2015)	▪ To determine the effects of ball Pilates on functional mobility and dynamic stability in women.	▪ N =30 F ▪ A (EG1 and EG2) = 20-40	▪ EG1 (n=15); EG2 (n=15)	▪ EG1: mat Pilates; ▪ EG2: ball Pilates with dumbbells.	▪ FMS test batery: DS, ILL-RL, ILL-LL, SM-RA, SM-LA, RS-RS, RS-LS, ASLR, TSPU, HS-RL, HS-LL.	▪ 10 weeks / 5 times a week / NS	▪ EG1: DS↑, ILL-RL↑, ILL-LL↑, SM-RA↑, SM-LA↑, RS-RS↑, RS-LS↑, ASLR↑, TSPU↑, HS-RL↑, HS-LL↑; ▪ EG2: DS↔, ILL-RL↔, ILL-LL↔, SM-RA↔, SM-LA↔, RS-RS↔, RS-LS↔, ASLR↔, TSPU↔, HS-RL↔, HS-LL↔.
Dinc et al. (2017)	▪ to determine the effects of ball Pilates on functional mobility and prevention of injuries in football players.	▪ N = 67 M; ▪ MA (EG) = 16.13±0.387; MA (CG)= 16.13±0.387	▪ EG (n=24); CG (n=43)	▪ EG: Pilates ball and roller exercises to improve FM (4 weeks) + exercises to improve stability (4 weeks) + a combination of FM and stability exercises + standard football program; ▪ CG: Standard football program.	▪ FMS test batery: DS, ILL-RL, ILL-LL, SM-RA, SM-LA, RS-RS, RS-LS, ASLR, TSPU, HS-RL, HS-LL; ▪ Total FMS scor (FMS-T); ▪ Contact and noncontact sports injuries during one season.	12 weeks / 2 times a week for 60 minutes	▪ EG: FMS-T↑, DS↑, HS ↑, ILL↑, TSPU↑, SM-RA ↔, SM-LA↔, RS-RS↔, RS-LS↔, ASLR↔; ▪ CG: FMS-T↑, DS↑, TSPU↑, SM-RA ↔, SM-LA↔, RS-RS↔, RS-LS↔, ASLR↔, HS-RL↔, HS-LL↔, SM-RA↔, SM-LA↔.

Lago-Fuentes et al. (2018)	**Bagherian et al. (2018)**	**Skotnicka et al. (2017)**
▪ to determine the effects of different Pilates programs on the functional mobility and physical fitness of futsal players	▪ to determine the effects of Pilates ball trunk stabilizers training on functional mobility (FM) ▪ and dynamic postural control (DPC) in students athletes.	▪ to determine the effects of ball Pilates and corrective exercises on functional mobility (FM) in female dancers.
▪ N = 14 M; ▪ A = 23.7 ± 5.1	▪ N =100 M; ▪ A(EG)= 18.1 ±.9; A (CG) = 18.03 ±.9	▪ N =187 F; ▪ A (EG) = 22.02 ± 2.26; A(CG) =21.72 ± 1.33
▪ EG1 (n=7); EG2 (n=7)	▪ EG (n=60); CG (n=40)	▪ EG (n=9); CG (n=9)
▪ EG1: ball Pilates: shoulder bridge, side bridge, prone plank, and crunch; ▪ EG2: mat Pilates: shoulder bridge, side bridge, prone plank, and crunch.	▪ EG: training on Pilates ball + usual daily off-season activities; CG: usual daily off-season activities.	▪ EG: ball Pilates: stabilization endurance exercises + CE program for FM on the floor + standard program at the Faculty of Physical Education; ▪ CG: standard program at the Faculty of Physical Education
▪ FMS test battery: DS, ILL-RL, ILL-LL, SM-RA, SM-LA, RS-RS, RS-LS, ASLR, TSPU, HS-RL, HS-LL; ▪ FMS total scor (FMS-T); ▪ CMJ, 10 m sprint, and repeated sprint ability RSA test.	▪ FMS test battery: DS, ILL-RL, ILL-LL, SM-RA, SM-LA, RS-RS, RS-LS, ASLR, TSPU, HS-RL, HS-LL; ▪ Y balance test (YBT); ▪ Lateral Squat (LS).	▪ FMS test batery: DS, ILL-RL, ILL-LL, SM-RA, SM-LA, RS-RS, RS-LS, ASLR, TSPU, HS-RL, HS-LL; ▪ Total FMS scor (FMS-T).
▪ 6 weeks / 3 times a week for 20 minutes	▪ 8 weeks / 3 times a week for 90 minutes	▪ 12 weeks / once a week for 90 minutes
▪ EG1: FMS-T↑; ▪ EG2: FMS-T↑.	▪ EG: DS↑, ILL-RL↑, ILL-LL↑, SM-RA↑, SM-LA↑, RS-RS↑, RS-LS↑, ASLR↑, TSPU↑, HS-RL↑, HS↑, LL↑, YBT↑; ▪ CG: DS↔, ILL-RL↔, ILL-LL↔, SM-RA↔, SM-LA↔, RS-RS↔, RS-LS↔, ASLR↔, TSPU↔, HS-RL↔, HS↔, LL↔; YBT↔.	▪ EG: DS ↑, HS↑, ILL↑, TSPU ↑; ▪ CG: DS ↑; ▪ Significantly greater effects were found in EG in FMS-T and the DS and ILL tests.

Šćepanović et al. (2020)	**Saberian-Amirkolaei et al. (2019)**	**Liang et al. (2018)**
▪ to determine the effects of core stability training on the functional mobility (fm) of students.	▪ to determine the ball Pilates effects on functional mobility (FM) and balance in teenagers.	to determine the effects of Pilates ball trunk stabilizer training on functional mobility (FM) and postural stability (PS) in female students.
▪ N =138 M и F; ▪ A (EG и CG) = 20 ± 0.5 years.	▪ N =29 M и F; ▪ A (EG) = 11±1.6; A (CG) = 11±1.6.	▪ N = 28 F; ▪ A (EG) = 20.1 ± 1.1; A (CG) = 20.1 ± 1.4.
▪ EG (n=73); CG (n=65).	▪ EG (n=16) ;CG (n=13)	▪ EG (n=14); CG (n=14)
▪ EG: Training on Pilates ball and on the floor: exercises to improve the stability and mobility of the spinal column; ▪ CG: program contents at the faculty.	▪ EG: Pilates ball training; ▪ CG was not involved in the training process.	▪ EG: TSB training on Pilates ball and the floor (endurance exercises + trunk bending) + warm-up exercises and stretching exercises; ▪ CG: warm-up exercises and stretching exercises.
▪ FMS test batery: DS, ILL-RL, ILL-LL, SM-RS, SM-LS, RS-RS, RS-LS, ASLR, TSPU, HS-RL, HS-LL; ▪ Total FMS scor (TFMS).	▪ FMS test battery: DS, ILL-RL, ILL-LL, SM-RA, SM-LA, RS-RS, RS-LS, ASLR, TSPU, HS-RL, HS-LL; ▪ Y balance test (YBT).	▪ FMS test battery: DS, ILL-RL, ILL-LL, SM-RA, SM-LA, RS-RS, RS-LS, ASLR, TSPU, HS-RL, HS-LL; ▪ Evaluation of the limits of stability test (LOS test).
▪ 6 weeks / 3 times a week for 30 minutes	▪ 8 weeks / 3 times a week /NS	▪ 6 weeks / 2 times a week for 50 minutes
▪ EG: TFMS↑, DS↑, ILL-RL↑, ILL-LL↑, SM-RA↔, SM-LA↔, RS-RS↑, RS-LS↑, ASLR↑, TSPU↑, HS-RL↑, HS-LL↑; ▪ CG: TFMS ↑, TFMS ↑, DS↑, ILL-RL↔, ILL-LL↔, SM-RS↑, SM-LS↑, RS-RS↔, RS-LS↔, ASLR↑, TSPU↑, HS-RL↑, HS-LL↑.	▪ EG: DS↑, ILL-RL↑, ILL-LL↑, SM-RA↑, SM-LA↑, RS-RS↑, RS-LS↑, ASLR↑, TSPU↑, HS-RL↑, HS↑, ILL-RL↑, ILL-LL↑,YBT↑, YBT ↑; ▪ CG: DS↔, ILL-RL↔, ILL-LL↔, SM-RA↔, SM-LA↔, RS-RS↔, RS-LS↔, ASLR↔, TSPU↔, HS-RL↔, HS↔, LL↔, YBT↔, YBT ↔.	▪ EG: LOS ↑, ILL-RL↑, ILL-LL↑, ASLR↑, TSPU ↑, RS-RS↑, RS-LS↑.($p < 0.05$); ▪ CG: LOS ↔, ILL-RL↔, ILL-LL↔, ASLR↔, TSPU ↔, RS-RS↔, RS-LS↔.

Vurgun and Edis (2021)	**Anant and Venugopal (2021)**
▪ to determine the influence of ball Pilates on functional mobility and trunk stabilizer muscles endurance in young handball players.	▪ to determine the effect of core muscles strength training on body composition in athletes.
▪ N=16 M ▪ A= 18.31±0.47	▪ N =52 M; ▪ A (EG) = 25.3 ± 1.52; A(CG) =26.4 ± 1.63
▪ 1EG	▪ EG (n=30; CG (n=25)
▪ EG: ball Pilates: prone, right plank, lateral and supine plank, single leg supine bridge, double leg raises, supine plank with hands on cervical region: three sets of 15 s (first two weeks), three sets of 30 s (third and fourth weeks) and three sets of 45 s (fifth and sixth weeks).	▪ EG: Swiss-ball alternate arm and leg extension, ball supine Bridge, Prone Bridge, Side bridge with shoulder abduction, Bridge with arm lift, abdominal crunches with a ball, -ball back Extension, Plank with one arm and one leg lift, ball hamstring curl ▪ CG was not involved in the training program.
▪ FMS battery: DS, ILL-RL, ILL-LL, SM-RA, SM-LA, RS-RS, RS-LS, ASLR, TSPU, HS-RL, HS-LL; ▪ tests to assess the endurance of flexors, extensors and lateral trunk muscles.	▪ body fat percentage (BF%), ▪ lean body mass (LBM), ▪ fat-free body mass (FFBM-kg), ▪ essential fat mass (EFM-kg), ▪ non-essential fat mass (NEFM-kg), ▪ absolute total body fat (ATBF-kg) ▪ body surface area (BSA-(sq.m.).
▪ 6 weeks / 3 times a week /NS	▪ 8 weeks / 5 times a week for 60 minutes
▪ EG: FMS-T↑, DS↑, HS-RL↑, HS-LL↑, ILL-RL↔, ILL-LL↔, SM-RS↔, SM-RS↔.	▪ EG: BF%↓, LBM ↔, FFBM-kg ↔, EFM-kg↓, NEFM↓, ATBF↓, BSA↓; ▪ CG: BF%↔, LBM ↔, FFBM-kg ↔, EFM-kg↔, NEFM↔, ATBF↔, BSA↔.

Legend: ↑ - statistically significant increase; ↓ - statistically significant decrease; ↔ - without statistically significant changes; A- age; ASLR- LL - The Active Straight Leg Raise – left leg; ASLR- RL - The Active Straight Leg Raise - right leg; CE - corrective exercise; CG - control group; CMJ - Countermovement Jump; DS - Deep Squat; EMG - electromyographic activity; EG - experimental group; EMG - trunk flexor and extensor activity (mVs); F - female; FM - functional mobility; HS-RL - Hurdle Step - right leg; HS-LL- Hurdle Step - left leg; ILL-RL - In-Line Lunge - right leg; ILL-LL - In-Line Lunge - left leg; M - male; NS - not specified; R - the number of repetitions; RSA - repeated sprint test; RS-LS - Rotary Stability - left side; RS-RS - Rotary Stability - right side; RT - resistance training; S - the number of sets; SM-LA - Shoulder Mobility – left side; SM-RA - Shoulder Mobility - right side; TTT – technical- tactical training; TSPU - Trunk Stability Push-up; W - week.

Table 5. Effects of Ball Pilates on Muscular Fitness//Data extracted from each study included for overview

Study	Research aim	Number, age and gender of participants	Groups and number of participants	Pilates Intervention Characteristics/ Program	Outcome Measures/ dependent variables	Duration and frequency	Results
Cosio-Lima et al. (2003)	▪ to determine the effects of Pilates on the ball on isokinetic strength and EMG of the trunk stabilizer muscles, balance, knee strength, and heart frequency in non-athletes.	▪ N=30 F ▪ A (EG) = 19.47 +/-5.80; A (CG) = 22.87 +/-5.87.	▪ EG=15; CG=15	▪ EG: Ball Pilates: trunk flexion and extension; ▪ CG: Mat Pilates: trunk flexion and extension. ▪ W1: 3S/15R; W2: 4S/15R; W3: 4S/20R; W4: 4S/20R; W5: 4S/25R.	▪ Isokinetic strength of trunk flexors (ITF); ▪ Isokinetic strength of trunk extensors (ITE); ▪ Isokinetic strength of knee flexors (INF); ▪ Isokinetic strength of knee extensors (INE). ▪ EMG of the recturs abdominis muscle (EMG-TF); ▪ EMG of the trunk extensor muscles (EMG-TE); ▪ The Single Leg Stance (SLS);	▪ 5 weeks / 5 times a week for 15 mnutes	▪ EG: EMG-TF↑, EMG-TE ↑, BT↑, ITF↔, ITE↔, INF ↔, ITE↔; ▪ CG: EMG-TF↔, EMG-TE ↔, SLS ↔, ITF↔ITE↔, INF ↔, ITE↔.
Stanton et al. (2004)	▪ to determine the effects of Pilates on the ball on trunk stabilizer muscles strength, aerobic capacity and body posture in athletes.	▪ N =18 M ▪ A= 15.5 +/- 1.4	▪ EG=8; CG=10	▪ EG: Ball Pilates: strides, Supine Lateral Ball Roll, superman, Ball Roll from kneeling position, Supine bridge, Supine Russian twist + usual TTT + RT; ▪ CG: usual TTT + RT.	▪ The Sahrmann Core Stability Test (SCST); ▪ The Front Plank Test (FPT); ▪ EMG of abdominal and back muscles (EMG-AB); ▪ Aerobic capacity assessment test: VO2 max.	▪ 6 weeks / 2 times a week for 25 mnutes	▪ EG: SCST ↑, FPT ↑, EMG-AB ↔, EMG-AB ↔, VO_2 max ↔; ▪ CG: SCST ↔, EMG-AB ↔, EMG-AB ↔, VO_2 max ↔.

McCaskey (2011)	Sekendiz et al. (2010)	Carter et al. (2006)
▪ to determine the effects of ball Pilates on body core stability and dynamic balance in female students.	▪ To determine the effects of Pilates on the ball on trunk flexor and extensor strength, flexibility and balance in sedentary women.	▪ to determine the effects of Pilates on the ball ▪ on trunk stabilizer muscles strength (TSB) in sedentary individuals.
▪ N=30 ▪ A (EG and CG) =18-29	▪ N =21 F ▪ A= 34 ± 8.09	▪ N =20 M и F ▪ A (EG) = 36.1 +/- 7.8; A (CG) =39.8 +/- 10.4
▪ EG =15; CG =15	▪ 1EG = 21	▪ EG = 10; CG =10
▪ EG: ball Pilates: front, back and lateral bridge; ▪ CG was not involved in the training process.	▪ Ball Pilates: Straight Arm Crunch, Alternate Arm and Leg Extension, Wall Squat, Back Extension, Hamstring Curl, Leg Raise; Hamstring exercise; ▪ W I -II: 2 sets of 10 repetitions; ▪ W III-XII: 3 sets of 12 repetitions.	▪ EG: Ball Pilates + cardiovascular training and / or strength training on the floor: bridge (calves on ball), w arms raised over shoulders, w arms raised over head; plank position above and below knee (30-60 s). ▪ CG: common activities.
▪ The Sahrmann Core Stability Test (SCST); ▪ Trunk Flexor Endurance Test (TFET); ▪ Trunk Extensor Endurance Test (TEET); ▪ Trunk Lateral Endurance Test (TLET); ▪ SEBT anterior (SEBT-A), posteriolateral (SEBT -PL) and posteriomedial (SEBT-PM).	▪ Isokinetic measurement of trunk extensor (IMTES);and flexor strength (IMTFS); ▪ Isokinetic measurement of lower limb extensor (IMLLE) and flexor strength (IMLLF); ▪ The curl-up test (CUT); ▪ The Sit and Reach Test (SART); Squat test (ST); Functional Reach Test (FRT).	▪ Trunk Extensor Endurance Test (TEET); ▪ Trunk Lateral Endurance Test (TLET).
▪ 4 weeks / twice a week for 60 minutes	▪ 12 weeks / 3 times a week for 45 minutes	▪ 10 weeks / 2 times a week for 30 minutes
▪ EG: SCST↔, TFET↔, TEET↔, TLET↑, SEBT-A↔, SEBT -PL↑, SEBT-PM↑; ▪ CG: SCST↔, TFET↔, TEET↔, TLET↔, SEBT-A↔, SEBT -PL↔, SEBT-PM↔.	▪ EG: IMTES↑, IMTFS↑, IMLLE↑, IMLLF↑, CUT↑, ST↑, FRT↑.	▪ EG: TEET ↑, TLET ↑; ▪ CG: TEET ↔, TLET ↔.

Prieske et al. (2016)	Lee et al. (2016)	Sukalinggam et al. (2012)
▪ to determine the effects of ball Pilates on trunk stabilizer muscles strength and sports performance in young football players.	▪ To determine the effects of different exercise programs on physical fitness, and depression in obese men.	▪ to determine the effects of ball Pilates on trunk core stability in students.
▪ N =39 M ▪ A= 17±1	▪ N=40 F and M ▪ A= 23 +/-5.80	▪ N = 42 F and M ▪ A= 23.62 ± 2.89
▪ EG1 (n=19); ▪ EG2 (n=15).	▪ EG1 (n=20); ▪ EG2 (n=20).	▪ EG1 (n=14); EG2 (n=14); CG (n=14)
▪ EG1: Ball Pilates: plank, shoulder bridge, side bridge, crunch, and back extension + usual TTT; ▪ EG2: Mat Pilates: the same exercises as EG + usual TTT.	▪ EG1: ball Pilates: push up, sit-ups, back extension, back bridge, bent knee hip extension, jackknife with bent knees + the aerobic training – 20 minutes; ▪ EG2: the aerobic training: treadmill warm-up and aerobics.	▪ EG1: ball Pilates: back extension and forward trunk bending; ▪ EG2: mat Pilates: back extension and forward trunk bending; ▪ CG was not involved in the training process.
▪ Trunk muscle flexor (MIFF- N and MAVF-%) and extensor strength/activity (MIFE-N and MAVE-%); ▪ Athletic performance: maximal vertical countermovement jump (CMJ-cm); sprint time: 0-10-m (s);10-20-m (s); 0-20-m (s); T test (s); ▪ Kicking performance (km/h).	▪ Back muscle strength (BMS-kg); ▪ Muscle endurance (ME); ▪ Aerobic endurance (AE-ml/kg/min); ▪ Flexibility (F-cm); ▪ Body fat percentage (BF%); ▪ Psychological factors (PF).	▪ Strength of trunk flexors and extensors (1RM test).
▪ 9 weeks / 2-3 times a week for 30 minutes	▪ 8 weeks / 3 times a week for 60 minutes	▪ 6 weeks / 3 times a week for 45 minutes
▪ EG1: MIFF- N and MAVF-% ↔, MIFE-N and MAVE-%↑ (5%), CMJ-cm ↑, 0–20-m (s); ↑, T test ↑, KP-km/h ↑; ▪ EG2: MIFF- N and MAVF-% ↔, MIFE-N and MAVE -%↑ (5%), CMJ-cm ↑, 0–20-m (s); ↑, T test ↑, KP-km/h ↑.	▪ EG1 and EG2: BF% ↓, BMS-kg↑, ME↑, AE↑, F-cm↑ and PF↑. ▪ At the final measurement, the groups of participants differed significantly in all variables in favor of the EG1 group, except in BF% and PF.	▪ EG1: 1RM test of trunk flexors↑; 1RM test of trunk extensors↑; ▪ EG2:1RM test of trunk flexors↑; 1RM test of trunk extensors↑; ▪ CG: 1RM test of trunk flexors ↔; 1RM test of trunk extensors ↔.

Kamatchi et al. (2020)	Jain et al. (2019)	Yaprak (2018)
▪ to determine the effects of different Pilates programs on strengthening the core muscles of young athletes.	▪ to determine the effects of standard and small ball Pilates on trunk muscle endurance and dynamic balance in students.	▪ To determine the effects of the ball Pilates training on fitness components in young men.
▪ N = 30 M and F ▪ A= 18-25	▪ N =38 M and F ▪ A= 18-25	▪ N=22 F and M ▪ A = 18-25 years
▪ EG1 (n=15); EG2 (n=15)	▪ EG1 (n=19); EG2 (n=16)	▪ EG =12; KG =10.
▪ EG1: ball Pilates: dolphin plank, bridge, crunch + usual TTT; ▪ EG2: mat Pilates: bent knee crunch, supine single leg stretch, supine double straight leg stretch + usual TTT.	▪ EG1: Standard ball Pilates: abdominal contractions: supine, quadrupedal, side bridge, DB, SS, squat, crunch, SS, BRO, pike, NU. ▪ EG2: Small ball Pilates: abdominal contractions: supine, quadrupedal, side bridge, trunk flexion and extension, oblique crunch, CPE+WE.	▪ EG: ball Pilates: back bridge and plank, back extension, sitting crunch on the ball, trunk twists, and the bird-dog exercise. W1-4: two sets of 15 repetitions W5-8: three sets of 20 repetitions. ▪ CG was not involved in any training program.
▪ Double leg lowering test (DLLT-°) to assess the abdominal muscles strength (sphygmomanometer and goniometer).	▪ Trunk Flexor Endurance Test (TFET-s); ▪ Trunk Extensor Endurance Test (TEET-s); ▪ Trunk Lateral Endurance Test (TLET-s); ▪ 60° curl up test (SUT-N); ▪ Dynamic balance test (SEBT test).	▪ In Line Lunge (ILL); ▪ Isometric Back Strength (IBS); ▪ Biering-Sorensen test (BST); ▪ Sit-up test (SUT-N); ▪ Back Extension test (BET); ▪ Y Balance Test (YT); ROM;
▪ 6 weeks / 4 times a week for 30 minutes	▪ 4 weeks / 5 times a week/NS	▪ 8 weeks / 3 times a week/NS
▪ EG1: DLLT-° ↔; ▪ EG2: DLLT-°↑.	▪ EG1: TFET-s ↑, TEET-s↑, TLET-s ↔, SUT-N↑, SEBT TECT ↔; ▪ EG2: TFET-s ↑, TEET-s↑, TLET-s ↔, SUT-N↑, SEBT test ↔; ▪ EG1 achieved numerically more significant changes compared to EG2.	EG: ILS↑, IBS↑, BST↑, SUT↑, BET↑, ROM↑, Y T↑; ▪ CG: ILS↔, IBS↔, BST↔, SUT↔, BET↔, ROM↔, Y T↔.

Nuhmani (2021)	Anant and Venugopal (2021)	Marani (2020)
▪ to determine the effects of ball Pilates and mat Pilates on trunk stabilizer endurance in athletes.	▪ to determine the effect of core muscles strength training on physical fitness in male players of team games.	▪ to determine the effects of ball Pilates on trunk ▪ stabilizer muscles strength in junior swimmers.
▪ N =67 M и F (49 M и 18 F) ▪ A= 24.32 ± 3.53	▪ N =52 M; ▪ A (EG) = 25.3 ± 1.52; A(CG) =26.4 ± 1.63	▪ N =30 M and F (16M and 14 F) ▪ A= 10-13
▪ EG (n=26) ▪ CG (n=26)	▪ EG (n=30; CG (n=25)	▪ EG1 (n=15) ▪ EG2 (n=15)
▪ EG: Ball Pilates: "jack knife" exercise (switch), russian twist, reverse hyperextension, lateral ball rolling lying on the ball, reverse crunch + usual TTT; ▪ CG: Mat Pilates: the same exercises as EG + usual TTT;	▪ EG: ball Pilates: alternate arm and leg extension, supine bridge, abdominal crunches, back extension, hamstring curl + usual TTT; ▪ EG: mat Pilates: Prone Bridge, Side Bridge with shoulder abduction, Supine position alternate arm and leg Lift, Bridge with arm lift, Plank with one arm and one leg lift + usual TTT; ▪ CG was not involved in any training program.	▪ EG1: Ball Pilates: 10 core strength exercise (NS). + usual TTT; ▪ EG2: Mat Pilates: 10 core stability exercise (NS) + usual TTT; ▪ The number of S and R per week: W1: 3Sx15R; W2: 3Sx10R; W3-4: Sx20R; W5-6:4Sx25R.
▪ Trunk Extensor Endurance Test (TEET-s); ▪ Trunk Lateral Endurance Test (TLET-s); ▪ Plank test (PT-s); ▪ The double leg lowering test ((DLLT-°).	▪ Trunk Lateral Endurance Test (TLET-s); ▪ Standing Broad Jump Test (SBJT-cm); ▪ The curl-up test (CUT- min).	Sit-ups in one minute (TFB-min); ▪ Swimming 50-m butterfly style (SW50m-s).
▪ 6 weeks /3 times a week for 45 minutes	▪ 8 weeks / 5 times a week for 60 minutes	▪ 6 weeks / 2-3 times a week/16 training sesssions
▪ EG: TEET-s↑, TLET-s↑, PT-s↑ DLLT-°↑; ▪ CG: TEET-s↑, TLET-s↑, PT-s↑ DLLT-°↑; ▪ At the final measurement, the groups of participants differed statistically significantly in favor of EG.	▪ CG: TLET-s↑, SBJT-cm↑; CUT- min↑; ▪ CG: TLET-s↔, SBJT-cm↔; CUT- min↔.	▪ EG1: TFB-min↑, SW50m-s↑; ▪ EG2: TFB-min↑, SW50m-s↑; ▪ At the final measurement, statistically significantly greater effects in favor of EG1 were determined.

Vurgun and Edis (2021)	▪ to determine the influence of ball Pilates on trunk stabilizer muscles endurance in young handball players.	▪ N=16 M ▪ A= 18.31±0.47	▪ 1EG	▪ EG: ball Pilates: prone, right plank, lateral and supine plank, single leg supine bridge, double leg raises, supine plank with hands on cervical region: 3 sets of 15 s (first two weeks), three sets of 30 s (third and fourth weeks) and three sets of 45 s (fifth and sixth weeks) + usual TTT.	▪ Prone plank test (PPT-s); ▪ Supine plank test (SPT-s); ▪ Right plank test (RPT-s); ▪ Left plank test (LPT-s); ▪ FMS total score (FMS-n).	▪ 6 weeks / 3 times a week/NS	▪ EG: PPT-s↔, SPT-s↔, RPT-s↔, LPT-s↔, FMS-n↑.

Legend: A: ↑ - statistically significant increase; ↓ - statistically significant decrease; ↔: without statistically significant changes; A - age; BRO - fitness ball double-arm roll out; CPE - crunch pulse exercise; DB - "dead bug" exercises; EG - experimental group; F - female; CG- control group; M - male; N - number of participants; NS - not specified; NU - knee up; R - the number of repetitions; RT – resistance training; S – the number of sets; SS - sprinting speed; TTT – technical-tactical training; W - week; WE - wiper exercise.

2.4 Critical Overview of Previous Research

The primary goal of using Pilates balls in the training process is to create an unstable exercise surface that enables effective strengthening of the superficial and deep muscles of the body core. The body core muscles connect the upper and lower body parts, so the efficiency of generating and transferring the force from the body center to the upper and lower extremities depends directly on their strength, endurance, and stability, which is of particular importance for sports performance efficiency. Deep muscles are closer to the spine, so they are in a mechanically more favorable position to stabilize the spine, especially its lumbopelvic part, in dynamic conditions. Only a stable core allows effective dynamic motor control and greater movement functionality, whereas its weakness results in force dissipation, incomplete transmission, and a predisposition to injury (Karageanes, 2004). For these reasons, the researchers' interest is increasingly focused on their more efficient development.

2.4.1 The Effects of Ball Pilates on Body Composition

A total of 15 studies that studied the effectiveness of ball Pilates on participants' body composition were included in the qualitative analysis. All studies, except studies conducted by Cakmakçi (2011) and Buttichak et al. (2019), were conducted with two or more groups of participants to compare the efficiency of ball Pilates and some other fitness program.

In some studies, along with the study of the effectiveness of Pilates on the ball on the body composition, the effectiveness of this fitness program on other parameters, such as obesity parameters (Buttichak et al., 2019; Cakmakçi, 2011; Vispute et al., 2011; Wrotniak et al., 2001; Yaprak, 2018; Yaprak and Küçükkubas, 2020) health-related fitness parameters (Anant &Venugopalb, 2021; Cakmakçi, 2011; Lee, et al., 2016; Ружић, 2020; Vispute et al., 2011; Welling & Nitsure, 2015; Wrotniak et al., 2001; Yaprak, 2018; Yaprak & Küçükkubas, 2020), physical fitness parameters (Yaprak & Küçükkubas, 2020), blood parameters (Khajehlandi, 2018), resting metabolic rate (Cakmakçi, 2011; Wrotniak et al., 2001) and psychological factors (Lee, et al., 2016) was also studied. Those parameters are listed for insight into the complexity of the study, but were not subjected to critical analysis because they are not related to the research topic.

Three studies were conducted on a sample of participants of both genders (Vispute et al., 2011; Wrotniak et al., 2001, Yaprak and Küçükkubas, 2020), six on a sample of female participants (Buttichak, et al., 2019; Cakmakçi, 2011; Prakash et al., 2021; Raj & Pramod, 2012, Ружић, 2020; Welling & Nitsure, 2015) and five on a sample of male participants (Anant & Venugopalb, 2021; Lee, Kim et Lee, 2016; Lim, 2019; Srinivasulu & Amudhan, 2018; Yaprak, 2018). A selection of participants in all studies was randomized.

Most studies were carried out on a sample of college-aged participants (Anant & Venugopal, 2021; Lee, Kim, & Lee, 2016; Lim, 2019; Prakash, James, Sivakumar, & Dharini, 2021; Raj & Pramod, 2012; Ружић, 2020; Vispute, Smith, LeCheminant, & Hurley, 2011; Welling & Nitsure, 2015; Yaprak, 2018; Yaprak, & Küçükkubas, 2020). The youngest participants, aged 7-17 years, were in the study conducted by Wrotniak, Whalen, Forsyth & Taylor (2001) and the oldest in the study conducted by Cakmakçi (2011) in which the average age of the participants was 36.15 ± 9.59 years. In the study by Srinivasulu and Amudhan (2018), participants aged 13-15 years.

Significant improvements in body composition were found in all studies except for the studies conducted by Vispute et al. (2011), Yaprak (2018), and Yaprak and Küçükkubas (2020). While some studies indicates that an 8-week period with two 45-60 minute training sessions per week is sufficient stimulus to induce adaptive changes in body composition in obese children and adolescents (Wrotniak et al., 2001), the majority of studies indicate that a higher frequency of training sessions is necessary to achieve significant training effects (Anant & Venugopal, 2021; Cakmakçi, 2011; Prakash et al., 2021; Vispute, Smith, LeCheminant, & Hurley, 2011; Welling & Nitsure, 2015) or a longer training period (Buttichak et al., 2019; Khajehlandi & Mohammadi, 2021; Prakash et al., 2021; Raj & Pramod, 2012; Srinivasulu & Amudhan, 2018).

Studies have generally shown that adaptations are primarily reflected in a significant decrease in body fat mass (Anant & Venugopalb, 2021; Buttichak et al., 2019; Cakmakçi, 2011; Lee et al., 2016; Lim, 2019; Prakash et al., 2021; Raj & Pramod, 2012; Ружић, 2020; Srinivasulu & Amudhan, 2018; Welling & Nitsure, 2015) and to a lesser extent in a significant increase in skeletal (Lim, 2019; Ružić, 2020) and muscle body mass (Anant & Venugopal, 2021; Buttichak et al., 2019; Raj & Pramod, 2012; Lim, 2019; Ružić, 2020).

Although the established decrease in body fat mass can generally be attributed to increased oxidation of fatty acids during exercise in the low to moderate intensity zone, the application of plank exercises is also associated with a tendency to decrease the fat component of body composition and increase the basal metabolic rate (Park, Lee, Heo, & Jee, 2021). In addition, plank exercises significantly increase body muscle mass because they engage the muscles of the whole body and not just the body's core muscles (Akuthota, Ferreiro, Moore, & Fredericson, 2008; Behm, Drinkwater, Willardson, Cowley, & Canadian Society for Exercise Physiology, 2010). However, given that variations in the degree of adaptation depend on many other endogenous and exogenous factors that affect body composition (genetic factors, food quality and caloric intake, gender, age, sleep quality, stress and other factors), more accurately determining the effects of ball Pilates on body composition requires significantly more comprehensive studies.

2.4.2 The Effects of Ball Pilates on Functional Mobility

Recent research published from 2015 until present was analyzed in order to determine the effectiveness of Pilates on the ball in improving functional mobility. The research was generally aimed at determining the effectiveness of various programs of stability and mobility exercises performed on an unstable surface (a Pilates ball) on the functional mobility of athletes or non-athletes.

Research on a sample of non-athletes was conducted by Baumschabel et al. (2015), Liang et al. (2018), Saberian-Amirkolaei et al. (2019) and Šćepanović et al. (2020), while in most studies the participants were athletes (Bagherian et al., 2018; Dinc et al., 2017;

Saberian-Amirkolaei et al., 2019; Skotnicka et al., 2017; Lago-Fuentes et al., 2018; Vurgun & Edis, 2021).

A certain number of studies were conducted on a sample of participants divided into one experimental and one control group (Anant & Venugopal, 2021; Bagherian et al., 2018; Dinc et al., 2017; Liang et al., 2018; Saberian-Amirkolaei et al., 2019; Skotnicka et al., 2017; Šćepanović et al., 2020).

In addition to the usual training in a particular sport, the experimental group also conducted Pilates ball training, while the control group conducted only the usual sports activities (Bagherian et al., 2018; Dinc et al., 2017), a standard program at the Faculty of Sports and Physical Education (Skotnicka et al., 2017; Šćepanović et al., 2020) or warm-up and stretching exercises (Liang et al., 2018).

To compare the effectiveness of exercise on a stable and an unstable surface, two studies were conducted with two experimental groups, one of which performed Pilates on a ball and the other Pilates on the floor (Baumschabel et al., 2015; Lago-Fuentes et al., 2018). In only one study, the control group was not included in any exercise program (Saberian-Amirkolaei et al., 2019).

The studies were conducted on a sample of participants of both genders (Saberian-Amirkolaei et al., 2019; Šćepanović et al., 2020), female (Baumschabel et al., 2015; Liang et al., 2018; Skotnicka et al., 2017) and males (Bagherian et al., 2018; Dinc et al., 2017; Lago-Fuentes et al., 2018; Vurgun & Edis, 2021). The youngest participants (average age: 11±1.6 years) were in the study by Saberian-Amirkolaei et al. (2019), and the oldest (20-40 years) in the study by Baumschabel et al. (2015). The smallest number of participants (14 female students) was in the research by Lago-Fuentes et al. (2018) and the largest (138 male non-athletes) in the research by Šćepanović et al. (2020).

The studies lasted for six weeks (Lago-Fuentes et al., 2018; Liang et al., 2018; Šćepanović et al., 2020; Vurgun & Edis, 2021), eight weeks (Anant and Venugopal, 2021; Bagherian et al., 2018; Saberian-Amirkolaei et al., 2019), 10 weeks (Baumschabel et al., 2015) or 12 weeks (Dinc et al., 2017; Skotnicka et al., 2017). Training sessions were performed once a week (Skotnicka et al., 2017), twice a week (Dinc et al., 2017; Liang et al., 2018), or three times a week (Bagherian et al., 2018; Lago-Fuentes et al., 2018; Saberian-Amirkolaei et al., 2019; Šćepanović et al., 2020; Vurgun & Edis, 2021). The weekly frequency of training sessions is not reported in the study by Baumschabel et al. (2015).

The shortest duration of training sessions (20 minutes) was in the study by Lago-Fuentes et al. (2018) while in other studies the trainings lasted for 30 minutes (Šćepanović et al., 2020), 50 minutes (Liang et al., 2018), 50-60 minutes (Baumschabel et al., 2015), 60 minutes (Anant & Venugopal, 2021; Dinc et al., 2017) or 90 minutes (Bagherian et al., 2018; Skotnicka et al., 2017). Saberian-Amirkolaei et al. (2019) did not cite the duration of training sessions.

Significant changes in the improvement of functional mobility under the influence of training on a Pilates ball were found in the studies by Bagherian et al. (2019), Baumschabel et al. (2015), Dinc et al. (2017), Lago-Fuentes et al. (2018), Liang et al. (2018), Saberian-Amirkolaei et al. (2019), Skotnicka et al. (2017), Šćepanović et al. (2020) and Vurgun and Edis (2021). Adaptations in functional mobility are presumed to result from an unstable exercise surface that provokes more complex interactions of passive (joints and spinal ligaments) and active (neural and muscular) subsystems that maintain intervertebral neutral zones within physiological limits (Ignjatović, 2020). Despite the established opinion that body core training on an unstable surface is more effective in non-athletes and persons with initially limited functional mobility, studies by these authors refuted this assumption.

It is evident that exercise on an unstable surface improved the stability and mobility of the core muscles as well as neuromuscular control of movement, which contributed to a significant improvement in the results of FMS tests and the overall FMS score. Namely, a period of eight to twelve weeks with a frequency of two to three training sessions per week lasting for 30 to 60 minutes, assuming that the FITT directives are aligned with the exerciser's initial fitness, is an adequate training stimulus to improve the quality of movement patterns in young healthy people.

2.4.3 The Effects of ball Pilates on Muscular Fitness

There is a general tendency in the analyzed literature to compare the effects of Pilates on an unstable (standard or mini Pilates ball) and a stable surface (on the floor or bench) on the endurance and/or strength of the torso stabilizer muscles.

Extensive research diversity can be observed in the experimental period duration, training sessions weekly frequency and duration, choice of exercises, and participants' previous training experience. Generally, short-term research is characterized by a high weekly frequency of training sessions (Vispute et al., 2011; Welling & Nitsure, 2015) and vice versa (Carter et al., 2006; Prieske et al., 2016; Ружић, 2020; Sekendiz et al., 2010; Sukalinggam et al., 2012).

Most studies were carried out on a sample of participants divided into one experimental and one control group, with the experimental group carrying out only ball Pilates (Cosio-Lima et al., 2003; McCackey, 2011; Yaprak, 2018) or, in addition to ball Pilates, standard technical-tactical training (Anant & Venugopal, 2021; Kamatchi et al., 2020;

Prieske et al., 2016; Marani, 2020; Nuhmani, 2021; Stanton et al., 2004; Vurgun & Edis, 2021), strength training (Carter et al., 2006; Stanton et al., 2004) and/or cardiovascular training that were also practiced by the control group (Carter et al., 2006; Prieske et al., 2016; Stanton et al., 2004).

In addition, it can be noticed that research carried out on a sample of participants of both genders (Carter et al., 2006; Jain et al., 2019; Kamatchi et al., 2020; Marani, 2020; Nuhmani, 2021; Sukalinggam et al., 2012) and on a sample of male participants (Anant & Venugopal, 2021; Lee et al., 2016; Prieske et al., 2016; Stanton et al., 2004; Vurgun & Edis, 2021; Yaprak, 2018) predominates. Research on a sample of female participants was carried out by Cosio-Lima et al. (2003), McCaskey (2011) and Sekendiz et al. (2010),

Sukalinggam et al. (2012) conducted the study on a sample of participants divided into two experimental (E1 – ball Pilates; E2 – mat Pilates) and one control group that was not involved in the training process. The study with only one group of participants was carried out by Sekendiz et al. (2010) and Vurgun and Edis (2021).

The studies were conducted on a sample of athletes (Anant & Venugopal, 2021; Kamatchi et al., 2020; Marani, 2020; Nuhmani, 2021; Prieske et al., 2016; Stanton et al. 2004; Vurgun & Edis, 2021) and non-athletes (Behm et al. 2005; Carter et al., 2006; Cosio-Lima et al. 2003; Jain et al., 2019; Lee et al., 2016; McCackey, 2011; Prachiet et al., 2019; Sekendiz et al. 2010; Sukalinggam et al. 2012; Yaprak, 2018).

Significant efficacy of the ball Pilates on strengthening the trunk stabilizers has been found in a number of studies (Carter et al., 2006; Cosio-Lima et al., 2003; Jain et al., 2019; Lee et al., 2016; Marani, 2020; Nuhmani, 2021; Prieske et al., 2016; Sekendiz, 2010; Stanton et al., 2004; Sukalinggam et al., 2012; Yaprak, 2018). Increased muscular form can be attributed to muscles' physiological and neural adaptation. Neural adaptation includes functional adaptations of the nervous system reflected in more efficient neuronal recruitment, increased conduction impulse velocity and improved synchronization of motor units (Ananta & Venugopal, 2020).

However, it is evident that exercise on a stable compared to an unstable surface, especially exercise with additional load, can produce significantly greater effects on muscle strength and power. In this regard, it can be assumed that significant effects on torso stabilizer muscles endurance in participants who carried out the training program on an unstable surface were found in part because the participants, along with the ball Pilates training, practiced other standard technical and tactical training for a particular sport or strength training on a stable surface. Even though they were not necessarily specific for torso stabilizer development, these additional training activities are assumed to have contributed to their development to some extent. Therefore, in those studies, the exclusive efficiency of the experimental ball Pilates program cannot be specified without considering other training activities.

Hence, Stanton et al. (2004) established significant improvements in torso stabilizer endurance after only 12 ball Pilates training sessions in combination with additional technical-tactical and cardiovascular training. Similar training effects were achieved by athlete participants from other studies (Carter et al., 2006; Marani, 2020; Nuhmani, 2021; Prieske et al., 2016).

However, Cosio-Lima et al. (2003) found in a sample of young non-athletes that not even 25 progressive Pilates ball training sessions were an adequate training stimulant to cause significant adaptive changes in the torso stabilizer muscles ($p > 0.05$). Given that the participants practiced high-intensity short-term training with a high weekly frequency, it can be assumed that the training variables was inconsistent with their functional capabilities and that, therefore, training effects were lacking. Therefore, the gradual training load increase principle was not respected, which probably led to the overtraining syndrome, primarily due to the high training intensity and inadequate recovery time.

3. RESEARCH SUBJECT AND PROBLEM

3.1 Research Subject

Considering the requirements of contemporary sports and health benefits, body composition and muscular fitness are among the most studied fitness components in sports and medical sciences. On the other hand, functional mobility has been dominantly studied in clinical studies and, to a lesser extent, in sports, primarily top-level sports. Considering that fast and efficient adaptation of movement, balance, and body posture in all sports and recreational activities depends on functional mobility to a large degree (Forhan & Gill, 2013; McCaskey, 2011), its importance in the fitness field is also evident.

The subject of this research is an experimental exercise program on the Pilates ball, program contents of regular physical education curriculum, body composition, functional mobility, and muscular fitness of female adolescents, first-grade high school students.

3.2 Research Problem

In a broader context, the research problem concerns the evaluation of the proposed Pilates ball exercise model (experimental factor) in the main part of a physical education class (in the experimental group of participants) and the evaluation of regular physical education curriculum contents (in the control group of participants). In a narrower sense, it involves assessing the quantitative and qualitative changes in the parameters monitored in this research (body composition, functional mobility, and muscular fitness). The relevance of this problem stems from the scarcity of such and similar research in Physical Education teaching.

Based on the defined research subject, the research problem was formulated as follows: will the ten-week experimental ball Pilates program have statistically significantly greater effects on the body composition, functional mobility, and muscular fitness of participants of the experimental group compared to the control group following the standard Physical Education program? In addition, it was necessary to determine which of the listed programs would be more effective in transforming all monitored parameters in this research.

4. RESEARCH OBJECTIVE AND TASKS

4.1 Research Objective

Based on the research subject and problem, the following research objective is defined:

The research objective was to determine the effects of the ten-week experimental ball Pilates program on the body composition, functional mobility, and muscular fitness of female adolescents.

4.2 Research Tasks

The following tasks were carried out to accomplish the defined research objective:

1. A sample of first-grade high school participants was selected;
2. Consent was obtained from participants' parents and the school principal for their participation in the research;
3. Body composition components and tests to assess functional mobility and muscular fitness were selected;
4. Adequate spatial and organizational conditions for implementing the experimental program were provided;
5. Adequate measuring and testing equipment was provided;
6. Participants were classified into the experimental and control groups;
7. The initial status of selected parameters of body composition, functional mobility, and muscular fitness of participants in the experimental and control groups was determined;
8. Differences in the body composition, functional mobility, and muscular fitness between the experimental and control groups of participants at the initial measurement were determined;
9. The experimental ball Pilates program was implemented with participants in the experimental group, and the standard physical education program was implemented with participants in the control group.
10. The final status of selected parameters of body composition, functional mobility, and muscular fitness of participants in the experimental and control groups was determined;

11. Changes in body composition, functional mobility, and muscular fitness between the initial and the final measurements in the experimental group of participants were determined;
12. Changes in body composition, functional mobility, and muscular fitness between the initial and the final measurements in the control group of participants were determined;
13. Differences in body composition, functional mobility, and muscular fitness between the experimental and control groups of participants were determined at the final measurement;
14. The effects of the ten-week experimental ball Pilates program on transformational processes of body composition, muscular fitness, and functional mobility of adolescents were determined.

5. RESEARCH HYPOTHESES

Based on the defined goal and tasks of the research, the following hypotheses were formulated:

H_1 - There are statistically significant differences in body composition, functional mobility, and muscular fitness between the experimental and control groups of participants at the initial measurement;

$H_{1.1}$ - There are statistically significant differences in body composition between the experimental and control groups of participants at the initial measurement;

$H_{1.2}$ - There are statistically significant differences in functional mobility between the experimental and control groups of participants at the initial measurement;

$H_{1.3}$ - There are statistically significant differences in muscular fitness between the experimental and control groups of participants at the initial measurement;

H_2 - The experimental ball Pilates program will statistically significantly affect changes in body composition, functional mobility and muscular fitness of the experimental group of participants;

$H_{2.1}$ - There are statistically significant changes in body composition between the initial and final measurement of the experimental group of participants;

$H_{2.2}$ - There are statistically significant changes in functional mobility between the initial and final measurement of the experimental group of participants;

$H_{2.3}$ - There are statistically significant changes in muscular fitness between the initial and final measurement of the experimental group of participants;

H_3 - The standard physical education program will statistically significantly affect changes in body composition, functional mobility and muscular fitness of the control group of participants;

$H_{3.1}$ - There are statistically significant changes in body composition between the initial and final measurement of the control group of participants;

$H_{3.2}$ - There are statistically significant changes in functional mobility between the initial and final measurement of the control group of participants;

$H_{3.3}$ - There are statistically significant changes in and muscular fitness between the initial and final measurement of the control group of participants;

H_4 - There are statistically significant differences in body composition, functional mobility, and muscular fitness between the experimental and control groups of participants at the final measurement;

$H_{4.1}$ - There are statistically significant differences in body composition between the experimental and control groups of participants at the final measurement;

$H_{4.2}$ - There are statistically significant differences in functional mobility between the experimental and control groups of participants at the final measurement;

$H_{4.3}$ - There are statistically significant differences in muscular fitness between the experimental and control groups of participants at the final measurement;

H_5 - The ten-week experimental ball Pilates program significantly transforms body composition, functional mobility, and muscular fitness of female adolescents compared to the standard physical education program.

$H_{5.1}$ **-** The ten-week experimental ball Pilates program significantly transforms body composition of female adolescents compared to the standard physical education program.

$H_{5.1}$ **-** The ten-week experimental ball Pilates program significantly transforms functional mobility of female adolescents compared to the standard physical education program.

$H_{5.1}$ **-** The ten-week experimental ball Pilates program significantly transforms muscular fitness of female adolescents compared to the standard physical education program.

6. RESEARCH METHOD

6.1 The Sample of Participants

The sample of participants consisted of 48 female adolescents, first-grade students of the "Svetozar Marković" high school in Niš. All participants were clinically healthy, without any bone joint or other disorders that would contradict participation in the experiment. Apart from regular physical education teaching, the participants were not additionally involved in any training process for the last six months.

The participants were first thoroughly informed about the goal and concept of this experimental research in written form. Then, since they were underage, they submitted a signed written consent of their parents to be included in the research. The participants were told in advance that they could withdraw from the research at any time if they wanted to, for any reason.

The research guaranteed the anonymity of the participants in accordance with the recommendations for clinical research established by the World Medical Association's Declaration of Helsinki (2013).

The participants were randomly allocated into an experimental and a control group, each consisting of 24 participants. The experimental group of participants conducted the ten-week experimental ball Pilates program in regular Physical Education teaching instead of the standard Physical Education program. The control group conducted standard Physical Education program prescribed by the Institute for the Advancement of Education and Upbringing of the Republic of Serbia.

Table 6. Descriptive characteristics of the participants

Participants	N	MA	BH	BM	BMI
EG	24	15.28 ± 0.48	162.76 ± 2.33	56.77 ± 4.08	21.43 ± 1.10
CG	24	15.06 ± 0.29	163.13 ± 2.25	54.04 ± 4.77	20.68 ± 1.54

Legend: N - number of participants; MA - average age (years); BH - average body height (cm); BW - average body weight (kg); BMI - average body mass index (kg/m^2).

Statistical data processing included the testing results of only those participants who did not have more than two absences during the experimental period.

6.2 The Sample of Measuring Instruments

For the purposes of this research, measuring instruments for assessing the sample characteristics, body composition, functional mobility, and muscular fitness,were used.

Anthropometric measurements were performed to determine the sample's general (overall) characteristics and not for the statistical analysis.

6.2.1 Sample Characteristics Measuring Instruments

Characteristics of the experimental and control groups of participants were evaluated using the following measures (Table 7):

Table 7. Parameters for assessing sample characteristics

Ordinal number	Measures and abbreviations	A unit of measurement
1.	Body height (BH)	cm
2.	Body mass (BM)	kg
3.	Body mass index (BMI)	kg/m^2

6.2.2 Body Composition Measuring Instruments

Body composition was measured using the latest generation of the body structure analyzer (Inbody 720 Tetrapolar; 8-Point Tactile Electrode System - Biospace Co. Ltd) which segmentally analyzes body composition parameters using bioresonance waves.

The following parameters were calculated (Table 7):

Table 8. Parameters for assessing body composition

Ordinal number	Body Composition Parameters	A unit of measurement
1.	Skeletal muscle mass (SMM) - absolute values;	kg
2.	Body fat mass (BFM) - absolute values;	kg
3.	Body fat percentage (BF%) - relative values.	%

6.2.3 Functional Mobility Measuring Instruments

The functional mobility of the participants was assessed using seven standard tests (FMS) that are integral parts of the essential movement patterns screening. Five of seven FMS tests are bilateral (Table 9). Tests were taken by Cook, Burton, Hoogenboom, and Voight (2014a, 2014b).

Minick et al. (2010) confirmed the excellent reliability of functional mobility tests between raters (so-called "inter-rater" reliability). Moderate to good "inter-rater" and "intra-rater" reliability (internal rater reliability) of the functional mobility tests was confirmed by the studies of Frohm, Heijne, Kowalski, Svensson, and Myklebust (2012), Onate et al. (2012), Shultz, Anderson, Matheson, Marcello, and Besier (2013) and Teyhen et al. (2012).

Although the FMS has a high face and content validity, the criterion (congruent) validity (discriminant and convergent) is low (Warren, Lininger, Chimera, & Smith, 2018). Despite the contradictory results of numerous studies regarding construct validity, functional mobility screening has some degree of predictive validity for identifying athletes at increased risk of injury (Beardsley & Contreras, 2014) and differentiating individuals with and without lumbar spine pain (Alkhathami, Alshehre, Wang-Price, & Brizzolara (2021).

Table 9. Measuring instruments for assessing functional mobility

Ordinal number	**Tests**	**Evaluation**
1.	Deep squat (DS)	Points
2.	In-Line Lung - right leg (ILL-RL)	
3.	In-Line Lung - left leg (ILL-LL)	
4.	Shoulder Mobility - right side (SM-RS)	
5.	Shoulder Mobility - left side (SM-LS)	
6.	Rotary Stability - right side (RS-RS)	
7.	Rotary Stability - left side (RS-LS)	
8.	Active Straight Leg Raise - right leg (ASLR-RL)	
9.	Active Straight Leg Raise - left leg (ASLR-LL)	
10.	Trunk Stability Push-Up (TSPU)	
11.	Hurdle Step - right leg (HS-RL)	
12.	Hurdle Step - left leg (HS-LL)	

6.2.4 Muscular Fitness Measuring Instruments

Muscular fitness was assessed using five tests, two of which are bilateral (Table 10).

Tests for the flexor, extensor, and lateral trunk muscles' isometric endurance assessment were taken from the American Council on Exercise (ACE, 2015) which recommends McGill's testing protocol. Their reliability and validity were confirmed by the studies of Evans, Kathryn, Refshaugea, and Adams (2007) and del Pozo-Cruz et al. (2014).

The Front Plank test was taken from Thompson, Gordon, Pescatello, and American College of Sports Medicine (ACSM, 2010). The reliability and validity of this test were confirmed by the study of Tong, Wu, and Nie (2014). In addition, the clinical, bilateral The

Single-Leg Squat Test was taken from Miller (2012), and its validity and reliability were confirmed by the study of Crossley, Zhang, Schache, Bryant, and Cowan (2011).

Table 10. Measuring instruments for assessing muscular fitness

Ordinal number	Tests	A unit of measurement
1.	Trunk Flexor Endurance Test (TFET)	s
2.	Trunk Extensor Endurance Test (TEET)	s
3.	Trunk Lateral Endurance Test - right side (TLET- RS)	s
4.	Trunk Lateral Endurance Test - left side (TFET-LS)	s
5.	The Front Plank Test (TFET)	s
6.	Single-Leg Squat Test - right leg (SLS-RL)	Evaluation: the number of repetitions
7.	Single-Leg Squat Test - left leg (SLS-LL)	

6.2.5 Description of measuring instruments

6.2.5.1 Description of the sample characteristics assessment instrument

Body height was measured using Martin's 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). The Martin's anthropometer consists of a vertical bar divided into four sections engraved in centimeter and millimeter intervals. There are two horizontal rulers on the upper part of the anthropometer, with the upper one fixed and attached to the bar and the lower movable and containing a metal sliding ring. During measurement, the participants were barefoot in a standard upright position, with their backs and knees outstretched and their heels joined. The participants' head was in the so-called Frankfort horizontal position, denoting a plane passing through the upper margin of the ear canal and the inferior margin of the left orbit. The examiner stood on the left side of the examinee and placed the horizontal anthropometer arm vertically along the back of the examinee's body. He then lowered the metal sliding ring to the vertex of the subject's head. The result is read on a scale at the height of the upper side of the triangular slit. The measurement was repeated three times, and the mean measurement was recorded with an accuracy of 0.1 cm.

Body mass and body mass index were measured using the body structure analyzer (Inbody 720 Tetrapolar; 8-Point Tactile Electrode System - Biospace Co. Ltd).

6.2.5.2 Description of body composition assessment instrument

Body composition parameters were measured using the "Inbody 720" body structure analyzer. Participants stood barefoot on the metal part of the device that contains the appropriate foot electrodes while holding the hand electrodes (Figure 2). By multifunctional bioelectric impedance, the "Inbody 720" analyzer automatically recorded the values of the measured parameters.

Figure 2. Measuring body composition

6.2.5.3 Description of functional mobility assessment instrument

Deep Squat (Cook et al., 2014a)

The deep squat is a test that involves whole-body movements. Proper test performance requires an appropriate rhythm of pelvic movements, a closed kinetic chain of dorsal flexion movements of the ankle, knee and hip flexion, thoracic spine extension, and shoulder flexion and abduction. The shoulders and thoracic spine's bilateral, symmetrical, and functional mobility is assessed by holding the stick above the head.

Test protocol:

The test begins from a stride position with feet hip-width apart, a stick placed on top of the head, and elbows bent at an angle of 90º. The feet should be straight, without inversion and eversion movements. The knees should be in line with the feet without falling into the valgus position. From that position, the examinee simultaneously outstretches his arms above his head and slowly descends into the deepest possible squatting position (Figure 3). The test can be repeated up to three times, but there is no need for additional repetitions if the initial performance meets the result criteria.

Figure 3. The Deep Squat Test

Test evaluation:

The test is graded with points from zero to three according to the criteria shown in Table 11. Participants whose score on this test is less than two points should avoid plyometric exercises and traditional variants of back squats with weights.

Table 11. Scoring of the Deep Squat Test

Movement pattern is performed as directed	Score of “3” = All criteria are met.
Perform movement pattern with compensation/imperfection	Score of “2” = Criteria achieved with heels on board
Unable to perform movement pattern	Score of “1” = Criteria for score of “2” are not achieved
There is pain with the movement pattern	Score of “0”

In-Line Lunge (Cook et al., 2014a)

The In-Line Lunge test evaluates hip and ankle joint mobility and stability and knee flexibility and stability. A long and narrow board and a PVC bar are needed to perform the test. Before the test, the length of the examinee's tibia should be measured.

Test protocol:

The test begins with the examinee placing the big toe of the rear foot on the starting line marked on the board and the front foot heel in line with the board, which is the tibia length away from the rear foot toes. Then, the examiner gives the PVC bar to the examinee behind his back, the upper part of which the examinee grabs at the cervical spine level with a hand on the opposite side of the anterior foot. The examinee holds the PVC bar at the lumbar spine level with the other arm. The PVC bar must be in a vertical position so that it touches the head, the thoracic spine, and the sacrum. The examinee then drops the knee of the rear leg to the board behind the front foot heel and returns to the starting position. If necessary, the examinee can do the test three times with each foot, and the best attempt is evaluated.

Test evaluation:

The test is graded with points from one to three according to the criteria shown in Table 12.

Table 12. Scoring of the Inline Lunge Test

Perform pattern as directed	Score of "3" = All criteria are met.
Perform pattern with ompensation/imperfection	Score of "2" = Any of the criteria for a score of "3" are not achieved.
Unable to perform pattern	Score of "1" = Any of the criteria for a score of "2" are not achieved
Pain with pattern regardless of quality	Score of "1"

If the examinee cannot perform the movement pattern even with compensation or feels pain while performing the movement pattern, the test result is one point. In the case of an asymmetric result, for example, "one" for the left leg and "two" for the right one, the examinee is given one point. The result "one" indicates that the traditional addition of weights to the movement pattern is not acceptable. Examinees with asymmetric test scores should avoid performing the inline lunge and running until they achieve a score of "two" with the help of corrective strategies.

Figure 4. The In-Line Lunge Test

Shoulder Mobility (Cook et al., 2014b)

The Shoulder Mobility test assesses the bilateral shoulder range of motion, combining internal rotation with adduction and external rotation with abduction. The test requires optimal mobility of the shoulder blade and extension of the thoracic spine. Before performing the test, it is necessary to measure the hand span.

Test protocol:

The test begins so that the examinee stands with their heels joined together, stretches their arms to the side, bends their thumbs, and then bends fingers around the thumbs to form fists (Figure 5).

The examinee then performs the opposite pattern of grasping movement by placing one arm above (external shoulder rotation) and the other below the shoulder (internal shoulder rotation). The examinee has three attempts to bring the fists as close as possible to each other (Figure 6). When the fists are on the back, the examinee must not try to bring them closer to each other by wiggling. The examiner then measures the distance between the fists.

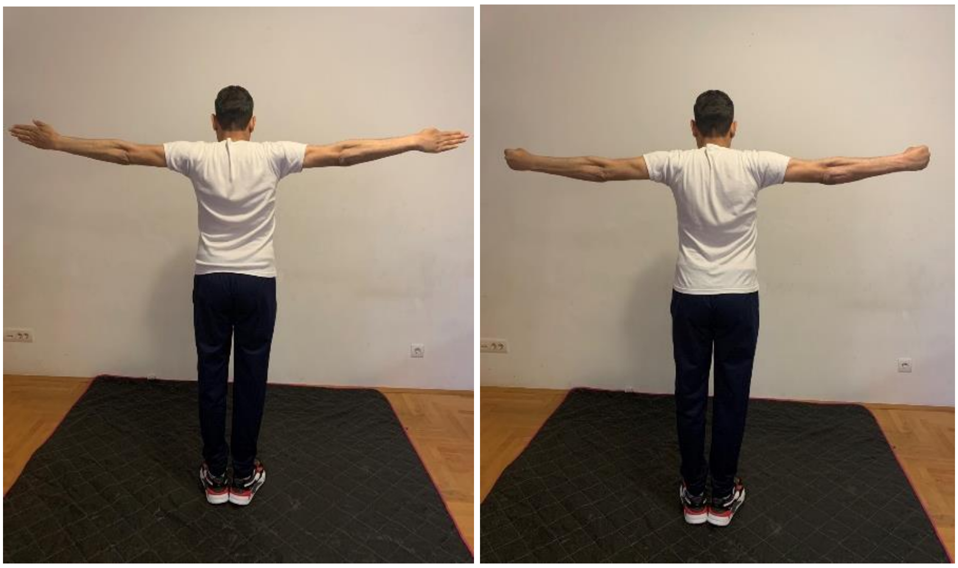


Figure 5. Starting position for performing the test

Test evaluation: (Table 13):

The test is graded with points from zero to three according to the criteria shown in Table 13.

An asymmetric result, for example, one point for the left side and two points for the right one, counts as one and indicates that the traditional addition of weights to the movement pattern is not acceptable.

Table 13. Scoring of the Shoulder Mobility Test:

A movement pattern is performed as directed	A score of "3" = Fists are within one hand length
A movement pattern is performed with compensation/imperfection	Score of “2” = Fists are within one-and-a-half hand lengths
Unable to perform a movement pattern	Score of “1” = Fists are not within one-and-a-half hand lengths
Pain while performing a movement pattern, regardless of quality	A score of "1" = Any criteria for a score of "2" are not achieved.

The examinee performs a reciprocal movement pattern by placing the palm on the opposite shoulder and raising the elbow as high as possible while maintaining contact between the palm and the shoulder (Figure 6).

Figure 6. A reciprocal reaching pattern

Rotary Stability (Cook et al., 2014b)

The Rotary Stability test assesses asymmetric multi-plane trunk stability during a combined upper and lower extremity motion. This test of a complex structure requires proper neuromuscular coordination and energy transfer from one segment of the body to another through the torso.

The examinee assumes quadruped position with a board on the floor between the hands and knees (Figure 7). The board should be in line with the spine. The shoulders should be above the wrists and the hips should be above the knees. The ankles should be in a neutral position and the soles of the feet should be perpendicular to the floor. The fingers should be splayed with the thumbs touching the board. The inner side of the knees and big toes should be touching the board.

Figure 7. Starting position for performing the test

From that position, the examinee raises and extends the right arm and leg to the horizontal and then brings the elbow and knee closer to each other, trying to stay in alignment over the board. The examinee then returns to the starting position and repeats the same movements with the left arm and leg (Figure 8).

Figure 8. The rotary stability screening on the left side

Before performing the test, the examinee is allowed three attempts per side.

Test evaluation:

The scoring of the Rotary Stability test is shown in Table 14. If a score of "3" is not achieved, the examinee should be instructed to perform a "bird-dog" diagonal movement pattern using the opposite shoulder and hip in the same manner as in the movement described above. An asymmetric result, for example “one” for the left side and “two” for the right, results in a score of "one".

Table 14. Scoring of the Rotary Stability test

Same-side movement pattern meets criteria	Score of “3”
Diagonal movement pattern meets criteria	Score of “2”
Unable to perform the diagonal movement pattern	Score of “1”

Activ Straight Leg Raise (Cook et al., 2014b)

The Active Straight-Leg Raise test requires the functional flexibility of the muscles of the rear of the thigh and lower leg, which is necessary during training and competition. The participants perform the test supine with a board placed under their knees. Both feet are in a neutral position, and the heels are perpendicular to the floor (Figure 9).

Figure 9. Starting position for performing the test

The examiner determines the point between the anterior superior iliac spine (ASIS) and the knee, then places a bar perpendicular to the floor (Figure 10).

Figure 10. Placing the bar at the starting position

The examinee raises his left leg, maintaining the position of the knee and ankle as in the starting position. During the test performing, the other knee remains in contact with the board. The toes should remain in a neutral position, and the head should remain flat on the floor. Once reaching the end range, the position of the raised ankle relative to the non-moving limb is recorded (Figure 11). The test is then repeated similarly by raising the right leg.

Figure 11. The Active Straight Leg Raise test

Test evaluation:

A score of “3” is achieved if the malleolus of a raised leg is behind the bar held by the examiner. If the malleolus is behind the board placed on the floor, the test result is two points; if it is in front of the board, the result is one point. If the examinee feels pain during the test, the result is “0,” and the examinee is referred to a doctor. An asymmetrical result, e.g., “2” for one leg and “1” for the other leg, results in a score of “1.”

Trunk Stability Push-Up (Cook et al., 2014b)

The Trunk Stability Push-Up is a test to assess the stability of the spinal column in a closed kinetic chain of upper body movements. The ability to perform this test requires symmetrical trunk stability in the sagittal plane during symmetrical movements of the upper extremities. Many functional activities require the trunk stabilizers to symmetrically transfer the force from the upper to the lower extremities and vice versa. Movements such as blocking in football are an example of this type of energy transfer. If the trunk does not have adequate stability during these activities, kinetic energy will disperse, leading to functionally inefficient performance.

Test protocol:

The examinee assumes a prone position with his knees fully extended, ankles in a neutral position, and feet perpendicular to the floor (Figure 12). The arms are placed at the sides, in a wide push-up position, with the thumbs at the forehead level (for men) or chin level (for women).

Figure 12. Starting position for performing the test

The examinee then performs a push-up from this position, lifting the body off the floor without slumping in the lower part of the spine (Figure 13).

Figure 13. The Trunk Stability Push-Up test

If a male examinee cannot perform a push-up in this starting position, the hands are placed in an easier position recommended for women, but the score is reduced. For the female examinee, placing the hands at shoulder level makes the starting position easier.

Test evaluation:

The test is graded with points from zero to three according to the criteria shown in Table 15.

If a score of “3” is not achieved at the first attempt, the examinee should be instructed to perform the movement again for a score of “2.” This movement is performed a maximum of three times if necessary. The body should be lifted from the floor as a unit. If the examinee feels pain during the test, the examinee should be referred to a doctor.

Table 15. Scoring of the Trunk Stability Push-Up Test

Perform pattern as directed	Score of "3" = Men: Hands at Forehead / Women: Hands at Chin
Perform pattern with ompensation/imperfection	Score of "2" = Men: Hands at Chin / Women: Hands at Shoulders
Unable to perform pattern	Score of "1" = Criteria for a score of "2" are not achieved
Pain with pattern regardless of quality	0

Hurdle Step (Cook et al., 2014a)

The Hurdle Step is a functional test that assesses bilateral functional mobility and stability of the hips, knees, and ankles. The movement requires proper coordination, core stability, and the ability to stand on one leg. Before performing the test, the examiner should measure the length of the examinee's tibia (Image 14).

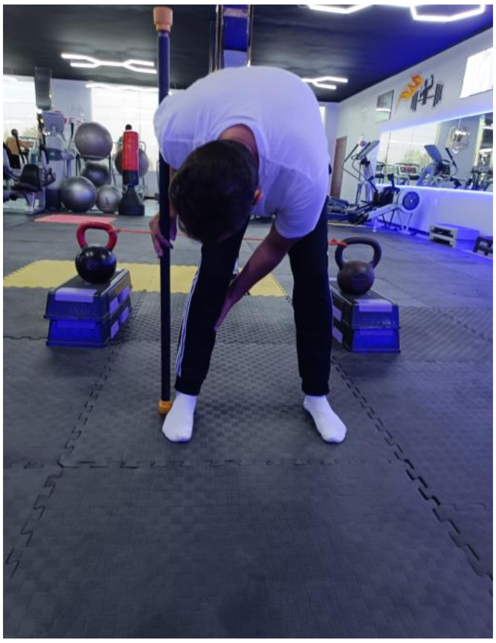


Figure 14. Measuring the tibia length

Test protocol: The examiner places an obstacle (hurdle) at a suitable height equal to the length of the tibia (Image 15).

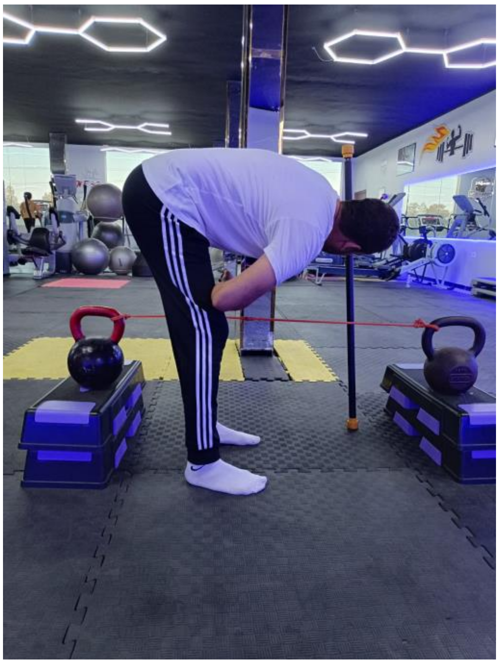


Figure 15. Adjust the hurdle at the height of the length of the tibia

The examinee should stand behind the obstacle with the feet together pointing towards the hurdle. The examiner places the PVC bar over the examinee's shoulders behind the neck, and the examinee holds it with his hands at a width greater than the width of the shoulders.

The examinee then slowly and controlled steps over the obstacle with one leg and touches the floor with the heel and then returns to the starting position keeping the spine outstretched (Image 16). During the exercise, the feet should be parallel to the floor.

Figure 16. The Hurdle Step test

Since the test is bilateral, it is performed first with one leg and then with the other leg. The examinee may repeat the test up to three times, and the best attempt is evaluated.

Test evaluation:

The test is graded with points from zero to three according to the criteria shown in Table 16.

An asymmetrical score, for example one point for the left side and two points for the right side, is scored by one point. Examinees whose score of this test is one point should avoid running and plyometric exercises until they improve their score with the help of corrective strategies.

Table 16. Scoring of the Hurdle Step Test

Perform pattern as directed	Score of “3” = All criteria are met.
Perform pattern with compensation/imperfection	Score of “2” = Any of the criteria for a score of “3” are not achieved.
Unable to perform pattern	Score of “1” = Any of the criteria for a score of “2” are not achieved.

6.2.5.4 Description of Muscular Fitness Assessment Instrument

Trunk Flexor Endurance Test (ACE, 2015)

The Trunk Flexor Endurance Test is a timed test used to assess the endurance of torso flexors (m. rectus abdominis, mm. external and internal obliques, and m. transverse abdominis). This test involves static isometric contraction of the trunk muscles.

Contraindications:

This test may not be suitable for people who have pain in the lower part of the spinal column, as well as people who have had spine surgery.

Equipment:

A stopwatch, dashboard (or sepenic) and belt (optional).

Pre-test procedure:

Before starting the test, the examinee should be explained the purpose of the test as well as the correct body position during the test. The starting position requires the examinee to sit on the floor with the knees bent at an angle of 90º and the arms bent over the chest touching the opposite shoulder with each hand. It is important that the feet are supported on the floor along the entire length (or fastened with a belt) and that the hips, knees and second toe are in line. The examinee should first lean on the board that the examiner holds behind his back at a slope of 60 º. In doing so, the shoulders of the examinee should be leaning against the board and the head in a neutral position. The test begins when the examiner removes the board and the examinee maintains the given position without support, engaging the abdominal muscles and not bending the back (Figure 17). The goal of this test is for the examinee to maintain a correct 60º position for as long as possible without back support.

Test evaluation:

The result of the test is the holding time of the examinees in the correct position, expressed in seconds.

In the appropriate list for recording, the time spent by the examinee in the given position is recorded.

Test protocol:

The examiner moves the board 10 cm backwards and turns on the stopwatch as soon as the examinee manages to maintain the given position of the spine at an angle of 60º without support. The test is interrupted when a change in the position of the torso is noticeable, ie if the examinee’s back is bent and the shoulders are rounded forward, or if the arch in the lower part of the back is increased. The backrest must not be touched by any part

of the back (Figure 17)

Figure 17. The Trunk Flexor Endurance Test (ACE, 2012, p. 24)

Trunk Extensor Endurance Test (ACE, 2015)

The Trunk Extensor Endurance test is generally used to assess muscular endurance of the spine extensor muscles (m. erector spinae, m. longissimus, m. iliocostalis, and m. multifidi). It is a timed test involving a static, isometric contraction of the trunk extensor muscles that stabilize the spine.

Contraindications:

This test may not be suitable for:

• examinees with major strength deficiencies, who cannot even lift the torso from a forward flexed position to a neutral position;

• examinees with a high body mass, in which case it would be difficult for the examiner to support the examinee's upper-body weight;

• examinees who suffer from low-back pain, have had recent back surgery, and/or have pain in the lower part of the spine.

Equipment:

• An elevated, sturdy exam table, a nylon strap, and a stopwatch

Pre-test procedure:

• After explaining the purpose of the test, explain the proper body position. The starting position requires the examinee to be prone, positioning the iliac crests at the table edge while supporting the upper part of the body on the arms, which are placed on the floor or on a riser.

While the examinee is supporting the weight of his or her upper body, anchor the examinee’s lower legs to the table using a strap. If a strap is not used, the examiner will have to use his or her own body weight to stabilize the examinee’s legs.

• The goal of the test is to hold a horizontal, prone position for as long as possible. Once the examinee falls below horizontal, the test is terminated.

• Encourage the examinee to practice this position prior to attempting the test.

Test protocol (Figure 18):

When ready, the examinee lifts the torso until it is parallel to the floor with his or her arms crossed over the chest.

• Start the stopwatch as soon as the examinee assumes this position.

• Terminate the test when the examinee can no longer maintain the position.

Test evaluation:

The result of the test is the holding time of the examinees in the correct position, expressed in seconds. In the appropriate list for recording, the time spent by the examinee in the given position is recorded.

Figure 18. The Trunk Extensor Endurance Test (ACE, 2012, p. 26)

Trunk Lateral Endurance Test (ACE, 2015)

The Trunk Lateral Endurance Test, known as the Side-Bridge Test, is a timed test that assesses the endurance of side trunk stabilizers (m. transversus abdominis, m. obliquus internus abdominis, m. obliquus externus abdominis, m. quadratus lumborum, and m. erector spinae). The test involves static isometric contractions of the lateral muscles that stabilize the spinal column.

Contraindications:

This test may not be suitable for people who have pain in the shoulder or lower back, as well as people who have had spinal surgery.

Equipment:

- A stopwatch and an exercise mat (optional)

Pre-test procedure:

• The examiner should first explain to the examinee the purpose of the test as well as the correct body position during the test.

The starting position requires that the examinee lie on his side with his legs outstretched, feet over each other or in a tandem position (heel to toe). The examinee rests on the forearm of the lower arm bent at the elbow and resting on the floor and on the sides of the foot on the floor. The elbow of the lower arm should be directly below the shoulder with the forearm facing outwards or downwards to maintain balance with the palm. The torso should be supported only by the examinee's foot (s) and the elbow/forearm of the lower arm. The upper arm should be extended along the side of the body. The hips should be raised off the floor and the body should be in a straight line (head, neck, torso, hips, and legs). The test begins when the examinee assumes the correct position in the lateral bridge by keeping both legs outstretched and the sides of the feet on the floor (Figure 19). The examiner then turns on the stopwatch and measures the endurance time of the examinee in the lateral bridge in seconds, which represents the result achieved in this test.

- The goal of this test is for the examinee to maintain this position for as long as possible. When the examinee violates the position (usually by lowering the hips towards the floor) the test is completed.

Test protocol:

The examiner turns on the stopwatch when the examinee takes the position of the side-bridge and turns it off when a change in the position of the torso is noticeable, usually due to lowering the hips or moving them forward or backward in an attempt to maintain balance and stability.

Grade:

The test result is the examinees' holding time in the correct position, expressed in seconds. Since the test is bilateral, the endurance time in the bridge is measured on both the left and right side of the body.

Figure 19. Trunk Laterl Endurance Test

The Front Plank Test (American College of Sports Medicine, Thompson, Gordon, & Pescatello, 2010)

The Front Plank test assesses the core musculature's ability hold the spine in neutral alignment when the body is in a forearm plank position. To perform this test, the examinee adopts a prone plank position in which the forearms and toes are in contact with the floor. The elbows should be aligned directly underneath (or below) the shoulders, and the body should maintain a straight line from shoulders to heels (i.e., the hips should not rise above or fall below shoulder level).

Equipment:

• A stopwatch and an exercise mat

Pre-test procedure:

• After explaining the purpose of the front plank test, explain and demonstrate the proper technique.

• Allow for adequate warm-up and stretching if needed

Test protocol:

Instruct the examinee to adopt the forearm plank position (Figure 20). As soon as the examinee is in the proper position with the proper spine alignment, start the stopwatch and cue the examinee to hold the position for as long as possible.

• The test's goal is that the examinee keeps a plank position with the body in proper alignment for as long as possible. If the examinee breaks the appropriate position, the test should be terminated, and the number of seconds achieved should be recorded.

Test evaluation:

The result of the test is the holding time of the examinees in the correct position, expressed in seconds. In the appropriate list for recording, the time spent by the examinee in the given position is recorded. If the examinee is unable to maintain a correct alignment for a minimum of 30 s, the result is poor.

After completing the test, ask the examinee where he or she felt the muscles working the most and if he felt pain in the lower back or abdomen. Lower back pain during the test is an indicator of insufficient torso stabilizer strength. If the examinee felt pain mainly in the abdominal muscles, this indicates engaging the appropriate muscles to support the spine in the plank position.

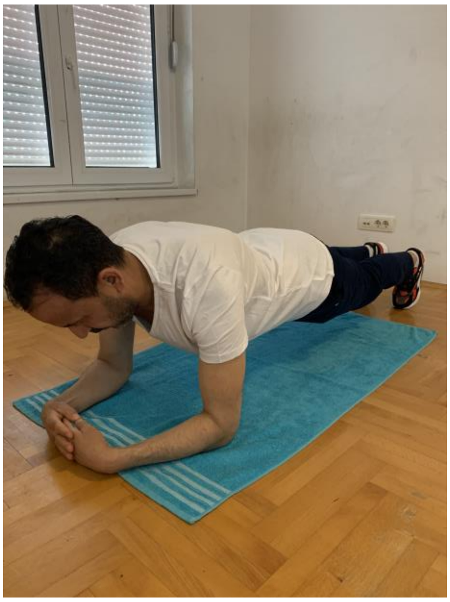


Figure 20. The Front Plank Test

The Single-Leg Squat test (Alexander, Crossley, & Schache, 2009)

The Single Leg Squat is a functional test for the hips and lower legs, which includes some elements of balance, mobility and strength. The test is used to assess the lower body strength, particularly the hip stabilizers and flexors, the gluteal muscles and the knee extensors (m. quadriceps femoris, m. gluteus maximus, m. gluteus medius, m. adductor magnus, m. adductor longus, m. biceps femoris). Furthermore, this test is used to help identify athletes who are at risk for lower extremity injuries (Willson, Ireland, & Davis, 2006).

Test protocol:

The examinee should stand on one leg while the other leg is lifted off the floor in front of the body so that the hips are bent at an angle of approximately 45° and the knee of the non-stance leg is flexed at an angle of 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 (Figure 21). Clinical observation usually involves knee and hip stability assessment. During the test, the knees, feet, and hips should remain in line. Moving the knee inward is a risk factor for injury of the anterior cruciate ligaments of the knee.

Test evaluation:

The examinee should perform five consecutive repetitions with each leg where each squat is worth 15 points with a maximum score of 75 points per leg. In the case of compensatory movements (torso rotation, turning hips inwards or outwards, or the movements of the knee inwards), the test is interrupted. 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 et al., 2009).

Figure 21. The Single-Leg Squat test

6.3 Organization of measurements

Prior to the start and at the end of the ten-week experimental period, appropriate initial and final measurements of parameters for evaluation of the sample characteristics, body composition, muscular fitness, and functional mobility were carried out to determine the variability of results from the initial to the final condition of the experimental and control groups of participants.

In the morning hours, previously trained measurers, PhD students of the Faculty of Sports and Physical Education conducted measurements. Before starting the measurements, all the measurers were familiar with the measurement and testing protocol. 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.

The measurement of the parameters for assessing the sample characteristics was carried out on the first day of measurement in the appropriate premises of the Faculty of Sports and Physical Education in Niš. On the second, third, and fourth day of measurement, functional mobility, and muscular fitness were measured in the “Svetozar Markovic” Grammar School gym in Niš. During the measurements, the participants were barefoot and minimally dressed. Testing was conducted under identical conditions for all participants.

6.4 Experimental Research Design

This longitudinal research was conducted in the "Svetozar Marković" high school in Niš, in regular physical and health education classes. A total of 48 participnats were randomly divided into the experimental (EG) and control group (CG), consisting of 24 participants in each group. The program of the experimental and control groups was conducted twice a week for 45 minutes. The experimental group carried out Pilates ball program to strengthen the body core muscles (Table 18) and the control group practiced a standard physical and health education program (Table 20), prescribed by the Institute for the Advancement of Education and Upbringing of the Republic of Serbia.

The training sessions of the experimental group participants consisted of (Table 17): a) warm-up exercises (jogging and dynamic stretching exercises); b) a ball Pilates exercise program to strengthen the body’s core muscles and c) cool-down exercises (static stretching exercises with an emphasis on stretching the core muscles).

The physical education classes for the control group participnats followed a traditional four-part structure, comprising an introductory, preparatory, main, and final phase. In the introductory phase of class, the participants warmed up physiologically by running, and then in the preparatory phase they did different complexes of shaping exercises with and without props. In the main phase of the class, the regular physical education curriculum was carried out, covering topics such as volleyball, athletics, artistic gymnastics, aerobics and fitness exercises (strength exercises with dumbbells, polygons). The contents of the final phase of the class were static stretching exercises for all major muscle groups.

Table 17. The structure and content of the experimental and control group program

Experimental group program	Control group program
▪ Physiological warming: jogging and dynamic stretching exercises (10 min);	▪ Physiological warming: jogging (3-5 min); ▪ A set of shaping exercises (8-10 min);
▪ A ball Pilates program (25-30 min);	▪ The regular physical education curriculum (25-30 min);
▪ Static stretching exercises (5 min).	▪ Static stretching exercises (5 min).

6.4.1 The Experimental Pilates Ball Program

The Pilates ball program was designed following the guidelines of Clark, Lucett, McGill, Montel, & Sutton (2018). The basis of the ball Pilates program was endurance exercises on the Pilates ball and trunk flexion, extension, and rotation dynamic exercises. By optimal development of neuromuscular efficiency and gradual increasing of proprioceptive requirements during the training period, the necessary conditions for efficient development of muscles of the global and local stabilization system were created, which enabled the improvement of the functional strength of movements.

The program of Pilates ball exercises was executed through three phases:

- The Foundational Phase of Neural-Adaptation
- The Developmental Phase of Accumulation
- The Advanced Phase of Specialization

In the basic phase of neural adaptation, which lasted for three weeks, the emphasis was on performing the basic exercises that were necessary for establishing motor control and getting used to an unstable exercise surface. During this phase, participants were performing exercises for the development of static stability of the front, side and back of the body core as well as the flexion, extension and trunk rotation dynamic exercises that were necessary to improve the functional training outcomes.

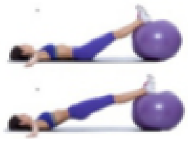
The movements were one-dimensional and performed with a minimal movement of the spinal column and pelvis in order to improve neuromuscular efficiency and intervertebral stability. The emphasis was more on quality than quantity of exercises, so the exercises were done at a slow pace. During exercising, the respondents tried to maintain stability and optimal neuromuscular control which enables coordinated movement.

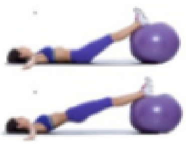
In the developmental phase of accumulation, which is characterized by increased neural requirements, the respondents did significantly more complex and more intensive exercises for improving core muscles dynamic stability (trunk core stabilization during limb movements) as well as lateral and rotational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

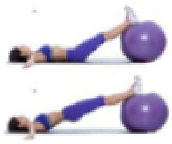
The last, advanced phase of specialization was characterized by structurally more complex and energetically more demanding multidimensional exercises that include a larger number of components in one movement, and was conducted with the aim of increasing force production of the trunk stabilizer muscles for the sake of improving dynamic core stability (Clark et al., 2018). Trunk lateral and rotational flexion and extension exercises were done at a faster pace compared to exercises in the previous phase, but not too fast so that the coordination of movements would not be disturbed.

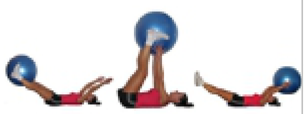
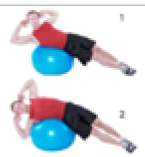
Exercise progression is achieved, among other things, by reducing support surface, increasing proprioceptive requirements and time of exercising, changing the number of repetitions and sets, and, in case of time-limited exercises, by increasing time of exercising. The applied exercises evenly engaged the front and back muscle groups of the body, which enabled the harmonious development of the muscles and prevented the possibility of injuries due to possible imbalances.

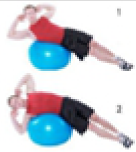
Table 18. Characteristics of the Experimental Group Program

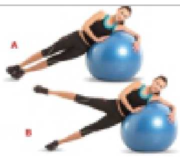
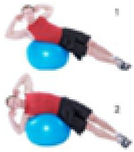
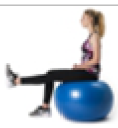
Phase 1			**The first week**		
Component	The exercise tempo for dynamic exercises: slow		Number of sets	Number of repetitions	Time (s)
Stability	Balanced Sitting		1	/	:60
	Ball Prone Bridge		2	/	:60
	Ball Lateral Bridge		2 es	/	:60 es
	Ball Supine Bridge		2	/	:60

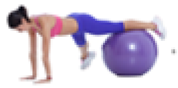
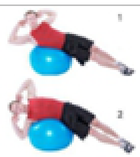
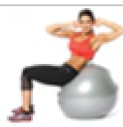
Flexion	Ball Forward Bend		3	10	/
Extension	Ball Trunk Hyperextension		3	10	/
Rotation	Ball Hips Rotation		2	8 es	/
Phase 1			**The second week**		
Component	The exercise tempo for dynamic exercises: slow		Sets	Repetition	Time (s)
Stability	Balanced Sitting		1	/	:60
	Ball Prone Bridge		3	/	:45
	Ball Side Bridge		3 es	/	:45 es
	Ball Supine Bridge		3	/	:45
Flexion	Ball Reverse Crunch		3	10	/
Extension	Ball Reverse Hyperextension		3	10	/
Rotation	Ball Hips Rotation		3	8 es	/

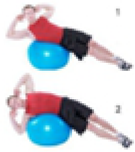
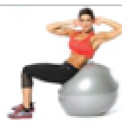
Phase 1			**The third week**		
Component	The exercise tempo for dynamic exercises: slow		Sets	Repetition	Time (s)
Stability	Balanced Sitting		2	/	:45
	Ball Prone Bridge		3	/	:60
	Ball Side Bridge		3 es	/	: 60 es
	Ball Supine Bridge		3	/	:60
Flexion	Ball Forward Bend		2	10	/
	Ball Reverse Crunch		2	10	/
Extension	Ball Trunk Hyperextension		2	10	/
	Ball Reverse Hyperextension		2	10	/
Rotation	Ball Hip Rotation		3	10 es	/
Phase 2			**The fourth week**		
Component	The exercise tempo for dynamic exercises: slow to moderate		Sets	Repetition	Time (s)

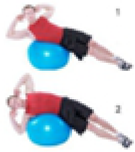
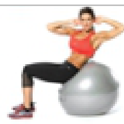
Stability	Balanced Sitting - one leg up		1	/	:60 el
	Single Leg Ball Prone Bridge		2	/	:35 el
	Ball Side Bridge - upper leg up		2	/	:30 el
	Ball Supine Bridge - one leg up		2	/	:30 el
Flexion	Ball V-Pass		3	10	/
	Ball Lateral Crunch		2	8 es	/
	Ball Diagonal Crunch		2	8es	/
Extension	Superman on a Ball Exercise		2	8	/
Rotation	Ball Single-Leg Hip Rotation		1	10 el	/
Phase 2			**The fifth week**		
Component	The exercise tempo for dynamic exercises: slow to moderate		Sets	Repetition	Time (s)

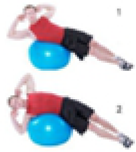
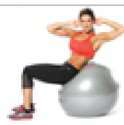
Stability	Balanced Sitting - one leg up		2	/	:40 el
	Single Leg Ball Prone Bridge		2	/	:40el
	Ball Side Bridge - upper leg up		2	/	:40 el
	Ball Supine Bridge - one leg up		2	/	:40 el
Flexion	Ball Pike		1	6	/
	Ball Lateral Crunch		2	10 es	/
	Ball Diagonal Crunch		2	10 es	/
Extension	Superman on a Ball Exercise		2	10	/
Rotation	Ball Hip Rotation		2	10 es	/
	Ball Single-leg Hip Rotation		2	7 el	/
Phase 2			**The sixth week**		
Component	The exercise tempo for dynamic exercises: moderate		Sets	Repetition	Time (s)

Stability	Balanced Sitting - one leg up		3	/	:30 el
	Single Leg Ball Prone Bridge		3	/	:30 el
	Ball Side Bridge - upper leg up		3	/	:30 el
	Ball Supine Bridge - one leg up		3	/	:30 el
Flexion	Ball Pike		1	10	/
	Ball Lateral Crunch		3	8 es	/
	Ball Diagonal Crunch		3	8 es	/
Extension	Superman on a Ball Exercise		2	12	/
Rotation	Ball Single-leg Hip Rotation		2	10 el	/
Phase 2			**The seventh week**		
Component	The exercise tempo for dynamic exercises: moderate		Sets	Repetition	Time (s)
Stability	Balanced Sitting - one leg up		3	/	:35 el

	Single Leg Ball Prone Bridge		2	/	:50el
	Ball Side Bridge - upper leg up		2	/	:50 el
	Ball Supine Bridge - one leg up		2	/	50 el
Flexion	Ball Pike		2	6-8	/
	Ball Lateral Crunch		3	10 es	/
	Ball Diagonal Crunch		3	10 es	/
Extension	Superman on a Ball Exercise		3	10	/
Rotation	Ball Single-leg Hip Rotation		3	8 el	/
Phase 3			**The eighth week**		
Component	The exercise tempo for dynamic exercises: As fast as can be controlled		Sets	Repetition	Time (s)
Stability	Ball 4- point Kneeling		2	/	:30
	Ball Plank		3	/	:30

	Side Plank - elbow on ball		3	/	:30 es
	Ball Supine Bridge - one leg up		3	/	:35 el
Flexion	Ball Pike		2	8-10	/
	Ball Lateral Crunch		3	12 es	/
	Ball Diagonal Crunch		3	12 es	/
Extension	Superman on a Ball Exercise		3	10	/
Rotation	Ball Single-leg Hip Rotation		3	10 el	/
Phase 3			**The ninth week**		
Component	The exercise tempo for dynamic exercises: As fast as can be controlled		Sets	Repetition	Time (s)
Stability	Ball 4- point Kneeling		2	/	:45
	Ball Plank		3	/	:45
	Side Plank - elbow on ball		3	/	:45 es

	Ball Supine Bridge - one leg up		3	/	:45 el
Flexion	Ball Pike		2	10-12	/
	Ball Lateral Crunch		3	15 es	/
	Ball Diagonal Crunch		3	15 es	/
Extension	Superman on a Ball Exercise		3	12	/
	Ball Single-leg Hip Rotation		3	12 el	/
Phase 3			**The tenth week**		
Component	The exercise tempo for dynamic exercises: As fast as can be controlled		Sets	Repetition	Time (s)
Stability	Ball 4- point Kneeling		2	/	:60
	Ball Plank		3	/	:60
	Side Plank - elbow on ball		3 es		:60 es

	Ball Supine Bridge - one leg up		3	/	:60 el
Flexion	Ball Pike		3	10	/
	Ball Lateral Crunch		3	17 es	/
	Ball Diagonal Crunch		3	17 es	/
Extension	Superman exercise		3	15	/
Rotation	Ball Single-leg Hip Rotation		3	15 el	/

Legend: el - each leg (with both left and right leg); es - each side (left and right body side).

6.4.2 The Standard Physical Education Program

Table 19. Recommended program contents for first-grade high school students according to the Institute for the Advancement of Education and Upbringing of the Republic of Serbia

TEACHING TOPICS	RECOMMENDED PROGRAM CONTENTS
Health culture and physical activity	Shaping exercises Corrective gymnastics exercises The assessment of motor and functional abilities
Development of motor and functional abilities	Strength exercises without and with dumbbells – up to 4 kg
	60-m dash; 100-m dash
	800-m run (female students); 1000-m run (male students)
	Stretching exercises
	Dexterity and agility polygons
	Sport games
	Aerobics
Athletics	Track and field: improvement of short (100 m) and medium (800 m) distance running technique; relay 4 x 100 m. Cross country running: autumn and spring (800 m). Jumps: long jump using the hang technique ; high jump with the Fosbury-Flop technique Throwing: shot put (4 kg), one of the rational techniques. Class competitions in all realized athletic disciplines.
Gymnastics: gymnastic apparatus and floor exercises	Floor exercises: - Arabesque into forward roll; - Handstand to forward roll; - Two cartwheel consecutively The vaulting horse jump: Squat through vault; Straddle over vault. Gymnastic rings exercises Uneven bars exercises Balance beam exercises Minimum educational requirements: teaching contents from the exercises program on the floor, vaults, beams, and uneven bars.
Sports game in accordance with the students choices	Advanced training of previously trained elements of the game; Improvement of the technical and tactical elements in accordance with the elective program for a given game.
Physical activity in accordance with the school's possibilities	Realization of classes from the program chosen by the students and in accordance with the school possibilities.

Table 20. Control Group Program - realized program contents

Week	Lesson	Teaching units
Initial measurement		Measurement of the sample characteristics and body composition
		Measurement of functional mobility and muscular fitness
I	1.	Volleyball: passing the ball in a jump and with a change of direction
	2.	Volleyball: float and a jump smash serve
II	3.	Volleyball: The Overhand Float Serve and the serve reception
	4.	Volleyball: Side jump serve and the serve reception
III	5.	Volleyball: spike from short, high and long pass
	6.	Volleyball: spike over the block (double and triple block)
III	7.	Volleyball technical-tactical exercises: 3:3 in three contacts and 4:2
	8.	Volleyball technical-tactical exercises; Game 6:6
IV	9.	Track and field (running): improvement of short (100 m) and medium (800 m) distance running technique; relay 4 x 100 m.
	10.	Track and field (throwing): shot put (4 kg), one of the rational techniques
V	11.	Gymnastics (floor exercises): arabesque into forward roll; handstand to forward roll
	12.	Gymnastics: Uneven bars exercises
VI	13.	Gymnastics (floor exercises): a headstand against a wall barr
	14.	Gymnastics (floor exercises): Headstand with the help of a partner and independently
VII	15.	Gymnastics (floor exercises): two sequacious cartwheels to the right and left
	16.	Gymnastics (floor exercises): two sequacious cartwheels to the right and left
VIII	17.	Aerobics
	18.	Aerobics
IX	19.	Strength exercises without and with dumbbells – up to 4 kg
	20.	Strength exercises without and with dumbbells – up to 4 kg
X	21.	Dexterity and agility polygons
	22.	Dexterity and agility polygons
Final measurement		Measurement of the sample characteristics and body composition
		Measurement of functional mobility and muscular fitness

6.5 Data Processing Methods

For all sample characteristics, body composition, functional mobility and muscular fitness variables, basic descriptive parameters at the initial and final measurement were calculated: arithmetic mean (Mean), minimum (Min) and maximum (Max) value of results, standard deviation (St.dev.) and a range of results (R). Given the violated assumption of normality of the distribution of non-parametric test results, measures of the shape of the distribution - skewness and kurtosis, were calculated only for the variables of sample characteristics, body composition and muscular fitness, but not for the non-parametric variables of functional mobility. The normality of distribution was tested using the Shapiro-Wilk test, before conducting the statistical analysis. The Shapiro-Wilk test was used in line with findings of the study which point out that this test is more reliable in assessing the normality of distribution in situations when research is conducted in small samples of participants (Marques de Sà, 2007).

To verify the accuracy of the first and fourth general hypotheses, the Multivariate Analysis of Variance (MANOVA) was calculated. The MANOVA test was also applied at the final measurement, considering that by checking the first general hypothesis of the research, it was found that the experimental and control groups did not differ statistically significantly in any of the researched domains at the initial measurement but that it was a research design with an equivalent control group. Therefore, based on the results, it was ascertained that no correlates would have to be included in the data analysis at the final measurement. Before conducting the MANOVA test, it was checked whether the following criteria for the application of the specified statistical technique were met: multivariant normality, absence of outliers, homogeneity of variance, linearity and multicollinearity (Tabachnick & Fidell, 2017). The level of statistical significance was set at $p < .05$.

Although the assumption about the normality of the functional mobility results distribution is violated, some researchers believe that applying MANOVA test in such conditions gives more reliable results than nonparametric multivariate tests, but with condition that the covariance matrix is homogeneous and that the Pillay coefficient is used to interpret the results, and not Wilkes' Lambda (Finch, 2005). Therefore, to determine multivariate statistical significance, the statistical significance of Pillay's criterion was calculated for the variables of functional mobility. For the variables of body composition and muscular fitness, Wilks's Lambda ($p \leq .05$) was calculated.

At the univariate level, in order to verify the accuracy of the first and third sub-hypotheses of the first and fourth general research hypotheses, the t-test for independent samples was applied. Considering the fact that the assumption of normality of distribution of functional mobility results had been violated, the Mann-Whitney U test was conducted to check the second sub-hypothesis of the first and fourth general hypothesis.

To verify the accuracy of the second and third general hypotheses, the one-way repeated measures Multivariate Analysis of Variance (i.e., the one-way repeated measures MANOVA) was applied. At the univariate level, to verify the accuracy of sub-hypotheses of the second and third general research hypotheses, the t-test for dependent samples for body composition and muscular fitness variables was applied, while the Wilcoxon Signed-Rank Test was applied for functional mobility variables.

The magnitude of the effects achieved in body composition and muscular fitness was interpreted according to the recommendations of Ferguson (2009) who, classifying the values of the squared eta size effect (η^2p) for the social sciences states that the recommended minimum effect size of the squared eta (η^2) amounts to .04 and that the mentioned measure represents "practically" a significant effect for the data of social sciences. Furthermore, the mentioned author states that the effect sizes of η^2p of .25 and .64 (and more) indicate a medium and a large effect size, respectively.

To estimate the effect size in nonparametric tests (the Man-Whitney U test and Wilcoxon Signed-Rank Test), the Rosenthal's measure of the effect size (r) was used, which represents the quotient of the Z value and the square root of the number of participants in the sample (Fritz, Morris, & Richler, 2011). Fritz et al. (2011) according to Coolican (2009) state the following measures of the magnitude of the effect of the coefficient r: if $r \sim 0.1$ then the effect is small; if $r \sim 0.3$ then the effect is medium; if $r > 0.5$ then the effect is large.

The software package for social sciences, IBM SPSS Statistics for Windows, version 23.0 (SPSS, Inc., Chicago, IL, United States) was used for statistical data processing.

7. RESULTS

7.1 The Basic Descriptive Parameters

For the purposes of describing the groups of participants, basic descriptive parameters at the initial and final measurements for the experimental and control groups are shown further in the text. Descriptive parameters were calculated for the sample characteristics, body composition, functional mobility and muscular fitness variables.

7.1.1 Descriptive Sample Characteristics Parameters of the Experimental and Control Groups at the Initial and Final Measurements

Table 21. Descriptive sample characteristics parameters of the experimental group at the initial and final measurements

Parameter	N	M	Min.	Max.	R	SD	Skew.	Kurt.	S-W
$VT_i^{(cm)}$	24	162.76	160.6	165.1	4.5	2.33	.148	-.570	.650
$MT_i^{(kg)}$	24	56.77	52.6	63.5	10.9	4.08	-.313	-.335	.559
$BMI_i^{(kg/m2)}$	24	21.43	20.39	23.3	2.91	1.10	.196	-.727	.688
$VT_f^{(cm)}$	24	163.13	160.95	165.4	4.45	2.25	-.196	-.587	.661
$MT_f^{(kg)}$	24	54.04	50.5	61.0	10.5	4.77	-.312	-.349	.588
$BMI_f^{(kg/m2)}$	24	20.68	19.50	22.30	2.8	1.54	-.183	-.743	.697

Legend: $VT_i^{(cm)}$ - body height at the initial measurement; $MT_i^{(kg)}$- body mass at the initial measurement; $BMI_i^{(kg/m2)}$ - body mass index at the initial measurement; $VT_f^{(cm)}$ - body height at the final measurement; $MT_f^{(kg)}$ - body weight at the final measurement; $BMI_f^{(kg/m2)}$- body mass index at the final measurement; N - number of participants; M - arithmetic mean; Min - minimum values of results; Max - maximum values of results; R – the range of data; SD - standard deviation; Skew. - asymmetry of the distribution curve; Kurt. - flattening of the distribution curve; S-W - the significance of the Shapiro-Wilk coefficient.

Table 21 shows descriptive data of the sample characteristics of the experimental group participants at the initial and final measurements. For each sample characteristics parameter, the following descriptive parameters were calculated: arithmetic mean, standard deviation, minimum and maximum value, the range of the results and symmetry, flatness and normality indicators of results distribution.

At the initial measurement, the height of the participants was in the range between 160.6 cm and 165.1 cm and the average height was 162.76 cm (SD = 2.33 cm). The weight of the participants was in the range between 52.6 kg and 63.5 kg, and the average weight was 56.77 kg (SD = 4.08). The average body mass index was 21.43 kg/m^2 (SD =1.10), while values were in the range between 20.39 and 23.3 kg/m^2.

The skewness and kurtosis data at the initial measurement indicate that the distributions of body height and body mass index results are slightly positively skewed and platykurtic while the distribution of body mass is moderately negatively skewed and platykurtic. At the initial measurement, the Shapiro-Wilk test of the body height (*S-W*(24) =.650), body mass (*S-W*(24) = .559) and body mass index results (*S-W*(24) = .688) did not show a significant deviation from normal distribution (*S-W* > 0.05).

At the final measurement, the height of the participants was in the range between 160.95 cm and 165.4 cm and the average height was 163.13 cm (SD = 2.25 cm). The weight of participants was in the range between 50.5 kg and 61.0 kg, and the average weight was 54.04 kg (SD = 4.77). The average body mass index was 20.68 kg/m^2 (SD =1.54), while values were in the range between 19.50 and 22.30.

The skewness and kurtosis data at the final measurement indicate that the distributions of all the sample characteristics parameters are slightly negatively skewed (left-skewed) and platykurtic. At the final measurement, the Shapiro-Wilk test of the body height (*S-W(24)* =.661), body mass (*S-W*(24) = .588) and body mass index results (*S-W*(24) = .697) did not show a significant deviation from normal distribution (*S-W* > 0.05).

The range of the body height and body mass index results at the initial measurement indicates their relatively small variability, while slightly greater variability, but within the limits of a normal distribution, was observed in the distribution of body mass results.

Table 22. Descriptive sample characteristics parameters of the control group at the initial and final measurements

Parameter	N	M	Min.	Max.	R	SD	Skew.	Kurt.	S-W
$VT_i^{(cm)}$	24	163.25	159.7	164.7	5	2.07	-.414	-.565	.557
$MT_i^{(kg)}$	24	57.40	53.13	61.50	8.37	4.82	-.322	-.273	.663
$BMI_i^{(kg/m2)}$	24	21.54	20.83	22.67	1.84	1.47	-.128	-.702	.597
$VT_f^{(cm)}$	24	163.6	160	165.1	5.1	2.02	-.421	-.677	.660
$MT_f^{(kg)}$	24	56.39	52.05	60.25	8.2	4.70	.337	-.295	.571
$BMI_f^{(kg/m2)}$	24	21.06	20.33	22.10	1.77	1.09	-140	-.718	.633

Legend: $VT_i^{(cm)}$ - body height at the initial measurement; $MT_i^{(kg)}$- body mass at the initial measurement; $BMI_i^{(kg/m2)}$ - body mass index at the initial measurement; $VT_f^{(cm)}$ - body height at the final measurement; $MT_f^{(kg)}$ - body weight at the final measurement; $BMI_f^{(kg/m2)}$- body mass index at the final measurement; N - number of participants; M - arithmetic mean; Min - minimum values of results; Max - maximum values of results; R – the range of data; SD - standard deviation; Skew. - asymmetry of the distribution curve; Kurt. - flattening of the distribution curve; *S-W* - the significance of the Shapiro-Wilk coefficient.

Table 22 shows descriptive data of the sample characteristics of the control group participants at the initial and final measurements. For each sample characteristics parameter, the following descriptive parameters were calculated: arithmetic mean, standard deviation, minimum and maximum value, the range of the results and symmetry, flatness and normality indicators of results distribution.

At the initial measurement, the height of the participants was in the range between 159.7 cm and 164.7 cm and the average height was 163.25 cm (SD = 2.07 cm). The weight of the participants was in the range between 53.13 kg and 61.50 kg and 73.1 kg, and the average weight was 57.40 kg (SD = 4.82). The average body mass index was 21.54 kg/m^2, while values were in the range between 20.83 and 22.67 kg/m^2.

Based on the values of skewness and kurtosis at the initial measurement, it can be noticed that the distributions of all sample characteristics results are slightly negatively asymmetric (left-skewed) and platykurtic.

At the initial measurement, the Shapiro-Wilk test of the body height ($S\text{-}W(24) = .557$), body mass ($S\text{-}W(24) = .663$) and body mass index results ($S\text{-}W(24) = .597$) did not show a significant deviation from normal distribution ($S\text{-}W > 0.05$).

At the final measurement, the height of the participants was in the range between 160 cm and 165.1 cm and the average height was 163.25 cm (SD = 2.07 cm). The weight of the participants was in the range between 52.05 kg and 60.25 kg and the average weight was 56.39 kg (SD = 4.70). The average body mass index was 21.06 kg/m^2 (SD =1.09), while values were in the range between 20.33 and 22.10 kg/m^2.

The range of the body height and body mass index results at the initial and final measurements indicates their relatively small variability, while slightly greater variability, but within the limits of a normal distribution, was observed in the distribution of body mass results.

Based on the values of skewness and kurtosis at the final measurement, it can be noticed that body height results distribution is moderately negatively asymmetric and platykurtic, body fat mass results distribution is slightly positively asymmetric and platykurtic and body mass index results distribution is slightly negatively asymmetric and platykurtic.

At the final measurement, the Shapiro-Wilk test of the body height ($S\text{-}W(24) =. 660$), body mass ($S\text{-}W(24) = .571$) and body mass index results ($S\text{-}W(24) = .633$) did not show a significant deviation from normal distribution ($S\text{-}W > 0.05$).

7.1.2 Descriptive Body Composition Parameters of the Experimental and Control Groups at the Initial and Final Measurements

Table 23. Descriptive body composition parameters of the experimental group at the initial and final measurements

Parameter	N	M	Min.	Max	R	SD	Skew.	Kurt.	S-W
$SMM_i^{(kg)}$	24	22.08	17.8	26.4	8.6	3.86	-.175	-.481	.584
$BFM_i^{(kg)}$	24	17.23	13.7	25.1	11.4	4.29	.215	-.208	.569
$BFP_i^{(\%)}$	24	30.35	26	39.5	13.5	5.08	.252	-.231	.772
$SMM_f^{(kg)}$	24	23.98	18.2	27.1	8.9	3.93	-.187	-.497	.687
$BFM_f^{(kg)}$	24	15.32	12.8	23.6	10.8	4.52	-.207	-.223	.559
$BFP_f^{(\%)}$	24	27.83	24.3	38.6	14.3	5.66	-.203	-.204	.790

Legend: SMMi - skeletal muscle mass at the initial measurement; BFMi - body fat mass at the initial measurement; BFPi - percentage of body fat at the initial measurement; SMMf - skeletal muscle mass at the final measurement; BFMf - body fat mass at the final measurement; BFP_f - percentage of body fat at the final measurement; N - number of participants; M - arithmetic mean; Min - minimum values of results; Max - maximum values of results; SD - standard deviation; R – the range of data; Skew. - asymmetry of the distribution curve; Kurt. - flattening of the distribution curve; *S-W* - the significance of Shapiro-Wilk coefficient.

Table 23 shows descriptive data of the body composition of the experimental group participants at the initial and final measurements. For each body composition parameter, the following descriptive parameters were calculated: arithmetic mean, standard deviation, minimum and maximum value, the range of the results and symmetry, flatness and normality indicators of results distribution.

The absolute skeletal muscle mass values of the experimental group of participants at the initial measurement are in the range between 17.8 and 26.4 kg and the average value is 22.08 kg (SD = 3.86). The absolute body fat mass values are in the range between 13.7 and 25.1 kg, and the mean value is 17.23 kg (SD = 4.29). The relative values of the body fat mass at the initial measurement are in the range from 26 to 39.5 % and the average value is 30.35 % (SD = 5.08). The range of results for all body composition parameters indicates their moderate variability at the initial measurement.

Data on skewness at the initial measurement indicate that the distributions of the results of all body composition parameters are slightly asymmetric, namely, for skeletal muscle mass negatively, and for body fat mass in kilograms and percentages positively. Negative values of the kurtosis of all body composition parameters indicate their platykurtic distribution.

At the initial measurement, the Shapiro-Wilk test of the skeletal muscle mass (*S-W*(24) = .584), body fat mass in kilograms (S-W(24) = .569) and percentages (*S-W*(24) = .772) did not show a significant deviation from a normal distribution (*S-W* > 0.05).

At the final measurement, the absolute skeletal muscle mass values are in the range between 18.2 and 27.1, and the mean value is 23.98 kg (SD = 2.93). The absolute body fat mass values are in the range between 12.8 and 23.6 kg, and the mean value is 15.32 kg (SD = 4.52). The mean relative values of the body fat mass at the final measurement are in the range from 24.3 to 38.6 %, and the average value is 27.83 % (SD = 5.66). The range of results for all body composition parameters indicates their moderate variability at the final measurement.

Data on skewness and kurtosis at the final measurement indicate that the distributions of the results of all body composition parameters are slightly negatively asymmetric and platykurtic.

At the final measurement, the Shapiro-Wilk test of the skeletal muscle mass ($S\text{-}W(24) = .687$), body fat mass in kilograms ($S\text{-}W(24) = .559$) and percentages ($S\text{-}W(24) = .790$) did not show a significant deviation from normal distribution ($S\text{-}W > 0.05$).

Table 24. Descriptive body composition parameters of the control group at the initial and final measurements

Parameter	N	M	Min.	Max.	R	SD	Skew.	Kurt.	*S-W*
$SMM_i^{(kg)}$	24	22.74	16.9	25.7	8.8	3.22	.284	.464	.588
$BFM_i^{(kg)}$	24	18.59	13.5	23.7	10.2	4.70	-.327	-.352	.591
$BFP_i^{(\%)}$	24	32.38	24.8	38.5	13.7	4.96	-.286	-.224	.534
$SMM_f^{(kg)}$	24	23.44	17.0	25.9	8.9	3.85	.292	-.442	.604
$BFM_f^{(kg)}$	24	17.89	13.0	22.4	9.4	4.52	-.489	-.401	.665
$BFP_f^{(\%)}$	24	31.72	24.5	37.2	12.7	4.64	-.281	-.237	.586

Legend: SMMi - skeletal muscle mass at the initial measurement; BFMi - body fat mass at the initial measurement; BFPi - percentage of body fat at the initial measurement; SMMf - skeletal muscle mass at the final measurement; BFMf - body fat mass at the final measurement; BFPf - percentage of body fat at the final measurement; N - number of participants; M - arithmetic mean; Min - minimum values of results; Max - maximum values of results; R – the range of data; SD - standard deviation; Skew. - asymmetry of the distribution curve; Kurt. - flattening of the distribution curve; *S-W* - the significance of Shapiro-Wilk coefficient.

Table 24 shows descriptive data of the body composition of the control group participants at the initial and final measurements. For each body composition parameter, the following descriptive parameters were calculated: arithmetic mean, standard deviation, minimum and maximum value, the range of results and symmetry, flatness and normality indicators of results distribution.

At the initial measurement, the absolute skeletal muscle mass values of the control group participants are in the range between 16.9 and 25.7 kg, and the average value is 22.74 kg (SD=3.22). The absolute body fat mass values at the final measurement are in the range from 13.5 kg to 23.7 kg, and the average value is 18.59 kg (SD=4.70). The relative value of the body fat mass is 32.38% (SD=4.96), while the values range between 24.8 % and 38.5 %. The range of results for all body composition parameters indicates their moderate variability at the initial measurement.

Data on skewness at the initial measurement indicate that the distributions of the results of all body composition parameters are slightly asymmetric, namely, for skeletal muscle mass positively, and for body fat mass in kilograms and percentages negatively. Negative values of the kurtosis of all body composition parameters indicate their platykurtic distribution.

At the initial measurement, the Shapiro-Wilk test of the skeletal muscle mass ($S\text{-}W(24) = .588$), body fat mass in kilograms ($S\text{-}W(24) = .591$) and percentages ($S\text{-}W(24) = .534$) did not show a significant deviation of the results from normal distribution ($S\text{-}W > 0.05$).

At the final measurement, the absolute skeletal muscle mass values of the control group participants are in the range between 17 and 25.9 kg, and the average value is 23.44 kg (SD = 3.85). The absolute body fat mass values are in the range from 13.0 kg to 22.4 kg and the average value is 17.89 kg (SD = 4.52). The mean relative value of the body fat mass is 31.72% (SD = 4.64), while the values range between 24.5 % and 37.2%. The range of results for all body composition parameters indicates their moderate variability at the final measurements.

Data on skewness at the final measurement indicate that the distributions of skeletal muscle mass results is slightly positively skewed while the distributions of body fat in kilograms and percentages are slightly negatively skewed. Negative values of the kurtosis of all body composition parameters indicate their platykurtic distribution.

At the final measurement, the Shapiro-Wilk test of the skeletal muscle mass ($S\text{-}W(24) = .604$), body fat mass in kilograms ($S\text{-}W(24) = .665$) and percentages ($S\text{-}W(24) = .586$) did not show a significant deviation from normal distribution ($S\text{-}W > 0.05$).

Given that the distribution of results of body composition parameters did not significantly deviate from normal neither at the initial nor at the final measurement, one of the conditions for applying parametric statistical tests for body composition data was fulfilled.

7.1.3 Descriptive Functional Mobility Parameters of the Experimental and Control Groups at the Initial and final Measurements

The assessment of the examinee's functional mobility was carried out using seven standard FMS tests. Since five of the seven tests are bilateral, descriptive functional mobility data were calculated for a total of 12 variables.

Table 25. Descriptive functional mobility parameters of the experimental group at the initial and final measurements

Test	N	M	Min.	Max.	R	SD	*S-W*
DS$_i$	24	2.17	1	3	2	0.56	.000**
ILL-R$_i$	24	2.21	1	3	2	0.55	.000**
ILL-L$_i$	24	2.20	1	3	2	0.58	.000**
SM-R$_i$	24	2.54	2	3	1	0.29	.000**
SM-L$_i$	24	2.49	1	3	2	0.55	.000**
RS-R$_i$	24	1.82	1	2	1	0.42	.000**
RS-L$_i$	24	1.80	1	2	1	0.46	.000**
ASLR-	24	2.39	1	3	2	0.58	.000**
ASLR-L$_i$	24	2.34	1	3	2	0.61	.000**
TSPU$_i$	24	2.40	1	3	2	0.58	.000**
HS-R$_i$	24	2.42	2	3	2	0.49	.000**
HS-L$_i$	24	2.41	2	3	2	0.50	.000**
DS$_f$	24	2.30	2	3	1	0.51	.000**
ILL-R$_f$	24	2.30	2	3	1	0.49	.000**
ILL-L$_f$	24	2.26	2	3	1	0.51	.000**
SM-R$_f$	24	2.70	2	3	1	0.48	.000**
SM-L$_f$	24	2.65	2	3	1	0.50	.000**
RS-R$_f$	24	1.99	1	3	2	0.63	.000**
RS-L$_f$	24	1.96	1	3	2	0.62	.000**
ASLR-	24	2.51	2	3	1	0.51	.000**
ASLR-	24	2.45	2	3	1	0.50	.000**
TSPU$_f$	24	2.64	2	3	1	0.44	.000**
HS-R$_f$	24	2.48	2	3	1	0.48	.000**
HS-L$_f$	24	2.46	2	3	1	0.44	.000**

Legend: DSi - Deep Squat at the initial measurement; ILL-Ri - In-Line Lunge-right leg, at the initial measurement; ILL-Li - In-Line Lunge - left leg, at the initial measurement; SM-Ri - Shoulder Mobility- right side, at the initial measurement; SM-Li - Shoulder Mobility- left side, at the initial measurement; RS-Ri - Rotary Stability - right side, at the initial measurement; RS-Li - Rotary Stability - left side, at the initial measurement; ASLR-Ri - Active Straight Leg Raise - right leg, at the initial measurement; ASLR-Li - Active Straight-Leg Raise - left leg, at the initial measurement; TSPUi - Trunk Stability Push-Up at the initial measurement; HS-Ri - Hurdle Step - right leg, at the initial measurement; HS-Li - Hurdle Step- left leg, at the initial measurement; DSf - Deep Squat at the final measurement; ILL-Rf - In-Line Lunge - right leg, at the final measurement; ILL-Lf - In-Line Lunge - left leg, at the final measurement; SM-Rf - Shoulder Mobility - right side, at the final measurement; SM-Lf - Shoulder Mobility - left side, at the final measurement; Rotary Stability - right side, at the final measurement; RS-Rf - Rotary Stability - left side, at the final measurement; ASLR-Rf - Active Straight Leg Raise - right leg, at the final measurement; ASLR-Lf - Active Straight Leg Raise - left leg, at the final measurement; TSPUf - Trunk Stability Push Up, at the final measurement; HS-Rf - Hurdle Step - right leg, at the final measurement; HS-Lf - Hurdle Step - left leg, at the final measurement; N - number of participants; M - arithmetic mean; Min - minimum values of results; Max - maximum values of results; R – the range of data; SD - standard deviation; *S-W* - the significance of the Shapiro-Wilk coefficient. ** - statistical significance at the level of .01.

Table 25 shows descriptive data of the functional mobility of the experimental group participants at the initial and final measurements. For all functional mobility variables, the following descriptive parameters were calculated: arithmetic mean, standard deviation, minimum and maximum value and the range of data. The normality of the distribution of the results was calculated by the Shapiro-Wilk test.

By checking the assumption of normality, it was determined that it was necessary to apply non-parametric tests for the functional mobility tests.

At the initial measurement, the lowest average results were observed in the Rotary Stability - left side (M = 1.80; SD = 0.46) and Rotary Stability - right side tests (M = 1.82; SD = 0.42) and the highest in Shoulder Mobility - right side (2.54; SD = 0.29) and Shoulder Mobility - left side tests (M = 2.49; SD = 0.55).

The range of the results for all functional mobility tests is minimal, both at the initial and final measurements, according to the evaluation method of functional mobility tests with points from zero to three.

The minimum and maximum values of the Shoulder Mobility - right side and bilateral Hurdle Step test results range from two to three while the minimum and maximum values of other tests range from one to three.

At the initial measurement, the Shapiro-Wilk test of all functional mobility parameters did show a significant deviation from normal distribution (S-$W < 0.05$).

At the final measurement, as at the initial one, the lowest average results are observed in the Rotary Stability - left side (M = 1.96; SD = 0.62) and Rotary Stability - right side tests (M = 1.99; SD = 0.63) and the highest in Shoulder Mobility - right side (M = 2.70; SD = 0.48) and Shoulder Mobility - left side tests (M = 2.65; SD = 0.50). The largest range at the final measurement (R=2) is observed in the Shoulder Mobility - right side test and the smallest (R=1) in all other functional mobility tests. The Shapiro-Wilk test of all functional mobility parameters did show a significant deviation from normal distribution (S-$W < 0.05$) at the final measurement.

Table 26 shows descriptive data of the functional mobility of the control group participants at the initial and final measurements. For each functional mobility variable, the following descriptive parameters were calculated: arithmetic mean, standard deviation, minimum and maximum value and the range of data. The normality of the distribution of the results was calculated by the Shapiro-Wilk test.

Table 26. Descriptive functional mobility parameters of the control group at the initial and final measurements

Test	N	M	Min.	Max.	R	SD	*S-W*
DS$_i$	24	2.22	1	3	2	0.68	.000**
ILL-R$_i$	24	2.21	1	3	2	0.51	.000**
ILL-L$_i$	24	2.16	1	3	2	0.41	.000**
SM-R$_i$	24	2.50	2	3	1	0.23	.000**
SM-L$_i$	24	2.45	1	3	2	0.63	.000**
RS-R$_i$	24	1.77	1	3	2	0.43	.000**
RS-L$_i$	24	1.74	1	3	2	0.41	.000**
ASLR-	24	2.42	2	3	1	0.50	.000**
ASLR-	24	2.38	1	3	2	0.55	.000**
TSPU$_i$	24	2.43	1	3	2	0.39	.000**
HS-R$_i$	24	2.40	2	3	1	0.50	.000**
HS-L$_i$	24	2.37	2	3	1	0.51	.000**
DS$_f$	24	2.24	1	3	2	0.59	.000**
ILL-R$_f$	24	2.23	2	3	1	0.49	.000**
ILL-L$_f$	24	2.20	1	3	2	0.50	.000**
SM-R$_f$	24	2.52	2	3	1	0.46	.000**
SM-L$_f$	24	2.48	1	3	2	0.65	.000**
RS-R$_f$	24	1.81	1	3	2	0.58	.000**
RS-L$_f$	24	1.79	1	3	2	0.48	.000**
ASLR-	24	2.45	2	3	1	0.51	.000**
ASLR-	24	2.40	1	3	2	0.58	.000**
TSPU$_f$	24	2.45	2	3	1	0.46	.000**
HS-R$_f$	24	2.42	2	3	1	0.51	.000**
HS-L$_f$	24	2.40	2	3	1	0.48	.000**

Legend: DSi - Deep Squat at the initial measurement; ILL-Ri - In-Line Lunge-right leg, at the initial measurement; ILL-Li - In-Line Lunge - left leg, at the initial measurement; SM-Ri - Shoulder Mobility- right side, at the initial measurement; SM-Li - Shoulder Mobility- left side, at the initial measurement; RS-Ri - Rotary Stability - right side, at the initial measurement; RS-Li - Rotary Stability - left side, at the initial measurement; ASLR-Ri - Active Straight Leg Raise - right leg, at the initial measurement; ASLR-Li - Active Straight-Leg Raise - left leg, at the initial measurement; TSPUi - Trunk Stability Push-Up at the initial measurement; HS-Ri - Hurdle Step - right leg, at the initial measurement; HS-Li - Hurdle Step- left leg, at the initial measurement; DSf - Deep Squat at the final measurement; ILL-Rf - In-Line Lunge - right leg, at the final measurement; ILL-Lf - In-Line Lunge - left leg, at the final measurement; SM-Rf - Shoulder Mobility - right side, at the final measurement; SM-Lf - Shoulder Mobility - left side, at the final measurement; Rotary Stability - right side, at the final measurement; RS-Rf - Rotary Stability - left side, at the final measurement; ASLR-Rf - Active Straight Leg Raise - right leg, at the final measurement; ASLR-Lf - Active Straight Leg Raise - left leg, at the final measurement; TSPUf - Trunk Stability Push Up, at the final measurement; HS-Rf - Hurdle Step - right leg, at the final measurement; HS-Lf - Hurdle Step - left leg, at the final measurement; N - number of participants; M - arithmetic mean; Min - minimum values of results; Max - maximum values of results; SD - standard deviation; *S-W* - the significance of the Shapiro-Wilk coefficient. ** - statistical significance at the level of .01.

At the initial measurement, the lowest average results were observed in the Rotary Stability - left side (M = 1.74; SD = 0.41) and Rotary Stability - right side tests (M = 1.77; SD = 0.43) and the highest in Shoulder Mobility - right side (M = 2.50; SD = 0.23) and Shoulder Mobility - left side tests (M = 2.45; SD = 0.63).

The range of results for all functional mobility tests indicates very low variability at the initial measurement. The minimum and maximum values of the Shoulder Mobility - right side, Active Straight-Leg Raise - right leg and bilateral Hurdle Step test results are in the range from two to three, while the minimum and maximum values of other tests are in the range from one to three. The Shapiro-Wilk test of all functional mobility parameters did show a significant deviation from normal distribution (*S-W* < 0.05) at the initial measurement.

At the final measurement, as at the initial one, the lowest average results are observed in the Rotary Stability - right side (M = 1.81; SD = 0.58) and Rotary Stability - left side tests (M = 1.79; SD = 0.48) and the highest in Shoulder Mobility- right side (M = 2.52; SD = 0.46) and Shoulder Mobility- left side tests (2.48; SD = 0.65).

The range values of the functional mobility test results at the final measurement indicate a minimal variability of results.

The minimum and maximum values of the In-Line Lunge - right leg, Shoulder Mobility - right side, Active Straight Leg Raise - right leg, Trunk Stability Push-Up and the bilateral Hurdle Step tests results are in the range from two to three, while the minimum and maximum values of other tests are in the range from one to three.

The Shapiro-Wilk test for all functional mobility parameters did show a significant deviation from normal distribution (*S-W* < 0.05) at the final measurement. In this regard, considering that the distribution of the results at the initial and final measurements significantly deviates from normal, for the needs of further statistical analyzes of functional mobility data, non-parametric tests were applied.

7.1.4 Descriptive Muscular Fitness Parameters of the Experimental and Control Groups at the Initial and Final Measurements

Table 27 shows descriptive data of the muscular fitness of the experimental group participants at the initial and final measurements. For each muscular fitness parameter, the following descriptive parameters were calculated: arithmetic mean, standard deviation, minimum and maximum values, the range of the results and symmetry, flatness and normality indicators of results distribution.

Table 27. Descriptive muscular fitness parameters of the experimental group at the initial and final measurements

Test	N	M	Min.	Max.	R	SD	Skew.	Kurt.	*S-W*
TFETi	24	88.58	60	129	69	19.29	-.240	-.222	.316
TEETi	24	91.24	58	142	84	21.27	.224	.208	.528
TLET-R_i	24	72.71	30	84	54	15.83	.499	-.306	.238
TLET-L_i	24	71.29	25	79	54	14.57	.501	-321	.438
TFPTi	24	71.21	39	107	68	18.30	.725	-.437	.324
SLST-R_i	24	35.00	0	60	60	17.51	.186	-.416	.357
SLST-L_i	24	35.25	0	45	45	16.94	.256	-.829	.362
TFETf	24	97.95	85	148	63	23.34	-.221	-.319	.219
TEETf	24	100.12	88	156	68	24.08	-.594	-.410	.382
TLET-Rf	24	79.75	39	98	59	16.50	-.201	-.390	.688
TLET-L_f	24	78.45	38	92	54	15.25	-.305	-.281	.572
TFPTf	24	78.35	58	162	104	25.38	-.572	-.186	.207
SLST-R_f	24	36.77	30	75	45	13.25	-.855	-.841	.366
SLST-L_f	24	36.37	15	75	60	18.68	-.221	-.312	.372

Legend: TFETi - trunk flexor endurance at the initial measurement; TEETi - trunk extensor endurance at the initial measurement; TLET-Ri - trunk lateral endurance - right side, at the initial measurement; TLET-Li - trunk lateral endurance - left side, at the initial measurement; TFPTi -endurance on forearms (the front plank), at the initial measurement; SLST-Ri - single leg squat - right leg at the initial measurement; SLST-Li - single leg squat - left leg at the initial measurement; TFETi - trunk flexor endurance at the final measurement; TEETi - trunk extensor endurance at the final measurement; TLET-Ri - trunk lateral endurance - right side, at the final measurement; TLET-Li - trunk lateral endurance - left side, at the final measurement; TFPTi - endurance on forearms (the front plank) at the final measurement; SLST-Ri - single leg squat - right leg at the final measurement; SLST-Li - single leg squat - left leg at the final measurement; N - number of participants; M - arithmetic mean; Min - minimum values of results; Max - maximum values of results; R – the range of data; SD - standard deviation; Skew. - distribution curve asymmetry; Kurt. - distribution curve flattening; *S-W* - the significance of Shapiro-Wilk coefficient.

At the initial measurement, the lowest average results were observed in the single leg squat - right leg (M=35.00; SD=17.51) and single leg squat - left leg tests (M=35.25; SD=16.94), and the highest in the trunk extensor (M=91.24; SD=21.27), and trunk flexor endurance tests (M=88.58; SD=19.29). The range of the results of all muscular fitness tests at the initial measurement indicates moderate to high variability. The smallest range at the initial measurement is observed in the single leg squat - left leg result distribution (R=45) and the largest in the trunk extensor endurance test (R=84).

Data on muscular fitness results distribution skewness at the initial measurement indicate a slight to moderate positive asymmetry in all tests except for the trunk flexor endurance test, whose distribution is moderately negatively asymmetric (left-skewed). Data on kurtosis at the initial measurement show that the distribution of the trunk extensor endurance test results is leptokurtic, while the distributions of all other muscular fitness tests are platykurtic.

At the final measurement, the lowest average results were observed in the Single Leg Squat - left leg (M = 36.77; SD = 18.68) and Single Leg Squat - right leg tests (M = 36.77;

SD = 13.25), and the highest in the Trunk Extensor (M = 100.12; SD = 24.08) and Trunk Flexor Endurance tests (M = 97.95; SD = 23.34). The range of the results of all muscular fitness tests at the final measurement, indicates moderate to high variability of the results. The smallest range at the final measurement is observed in the Single Leg Squat - left leg result distribution (R=45) and the largest in the Front Plank test (R=104).

The distributions of all muscular fitness tests results at the final measurement are negatively asymmetric and platykurtic. At the initial and final measurements, the Shapiro Wilk test for all muscular fitness tests did not show a significant deviation of the results from normal distribution (*S-W* > 0.05).

Table 28. Descriptive muscular fitness parameters of the control group at the initial and final measurements

Test	N	M	Min.	Max.	R	SD	Skew.	Kurt.	*S-W*
$TFET_i$	24	88.73	66	112	46	11.30	-.598	-.344	.548
$TEET_i$	24	90.80	57	124	67	16.62	-.252	-.319	.729
TLET-Ri	24	72.29	33	72	39	10.56	-.185	.503	.736
TLET-Li	24	71.10	23	67	44	9.64	-.634	.476	.309
$TFPT_i$	24	71.49	20	111	91	21.09	.144	-.104	.468
$SLST\text{-}R_i$	24	34.55	0	45	45	13.93	-.531	-.484	.077
$SLST\text{-}L_i$	24	34.40	0	60	60	15.74	-.132	-.228	.072
$TFET_f$	24	92.91	91	133	42	11.84	.740	-.449	.041
$TEET_f$	24	94.85	76	136	60	15.93	-.285	-.167	.426
TLET-Rf	24	75.33	36	81	45	11.01	-.132	-.128	.999
TLET-Lf	24	74.40	29	77	48	10.46	-.568	-.152	.430
$TFPT_f$	24	74.65	25	120	95	22.08	.198	.144	.862
$SLST\text{-}R_f$	24	36.05	15	75	60	17.08	-.117	-.460	.069
$SLST\text{-}L_f$	24	35.95	15	60	45	15.74	-.237	-.405	.079

Legend: TFETi - trunk flexor endurance at the initial measurement; TEETi - trunk extensor endurance at the initial measurement; TLET-Ri - trunk lateral endurance - right side, at the initial measurement; TLET-Li - trunk lateral endurance - left side, at the initial measurement; TFPTi -endurance on forearms (the front plank), at the initial measurement; SLST-Ri - single leg squat - right leg at the initial measurement; SLST-Li - Single Leg Squat Test - left leg at the initial measurement; TFETi - trunk flexor endurance at the final measurement; TEETi - trunk extensor endurance at the final measurement; TLET-Ri - trunk lateral endurance - right side, at the final measurement; TLET-Li - trunk lateral endurance - left side, at the final measurement; TFPTi - endurance on forearms (the front plank) at the final measurement; SLST-Ri - single leg squat - right leg at the final measurement; SLST-Li - single leg squat - left leg at the final measurement; N - number of participants; M - arithmetic mean; Min - minimum values of results; Max - maximum values of results; R – the range of data; SD - standard deviation; Skew. - distribution curve asymmetry; Kurt. - distribution curve flattening; *S-W* - the significance of Shapiro-Wilk coefficient.

Table 28 shows descriptive data of muscular fitness of the control group participants at the initial and final measurements. For all muscular fitness tests, the following descriptive parameters were calculated: arithmetic mean, standard deviation, minimum and maximum values, the range of the results and symmetry, flatness and normality indicators of results distribution.

At the initial measurement, the lowest average results were observed in the Single Leg Squat - right leg (M = 34.55; SD = 13.93) and Single Leg Squat - left leg tests (M = 34.40; SD = 15.74), and the highest in the Trunk Extensor (90.80; SD = 16.62) and trunk Flexor Endurance tests (88.73; SD = 11.30).

The range of the results of all muscular fitness parameters, both at the initial and at the final measurement, indicates moderate to high variability of the results. The smallest range of the results at the initial measurement is observed in the Trunk Lateral Endurance - right side (R = 39) and Trunk Lateral Endurance - left side tests (R = 44) and the largest in the Front Plank test (R = 91).

Data on muscular fitness results distribution skewness at the initial measurement indicate a slight to moderate negative asymmetry in all tests except for the Front Plank test, whose distribution is positively asymmetric (right-skewed). Distributions of the bilateral trunk lateral muscles endurance test results are leptokurtic, while other test results distributions are platykurtic.

At the final measurement, the lowest average results were observed in the single leg squat test - left leg (M= 35.95; SD = 15.74) and Single Leg Squat test - right leg tests (M= 36.05; SD = 17.08), and the highest in the Trunk Extensor (M= 94.85; SD = 15.93) and Trunk Flexors Endurance tests (M= 92.91; SD = 11.84). The smallest range was observed in the Trunk Flexor Endurance test (R =42) and the largest in the Front Plank test (R =95).

The skewness of the results of all muscular fitness tests at the final measurement, except for the Trunk Flexor Endurance test and the Front Plank test whose distributions are slightly positively asymmetric, indicates a slight to moderate negative asymmetry.

At the initial and final measurements, the Shapiro Wilk test for all muscular fitness tests did not show a significant deviation of the results from normal distribution ($S\text{-}W > 0.05$).

Given that the distribution of results of muscular fitness did not significantly deviate from normal distribution neither at the initial nor at the final measurement, one of the conditions for applying parametric statistical tests for muscular fitness data has been fulfilled.

7.2 Intergroup Differences in Initial Measurement

In order to verify the validity of the first general hypothesis with the corresponding sub-hypotheses, the following tables show the results of multivariate and univariate intergroup differences in body composition, functional mobility and muscular fitness at the initial measurement.

7.2.1 Intergroup Differences in Initial Body Composition Measuring

Table 29. The multivariate differences in body composition between groups of participants at the initial measurement

Wilks-lambda	F	Effect-df	Error-df	p	η^2_p
0.978	0.332	3	44	.802	.022

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).

Table 29 shows the results of the Multivariate Analysis of Variance between the experimental and control groups of participants in body composition at the initial measurement. Based on the values of the Wilks-lambda criterion (Λ = 0.978, F (3.44) = 0.332, p > 0.05, η^2_p = .022), it can be noticed that at the multivariate level there are no statistically significant differences between groups of participants in body composition.

Table 30. The univariate differences in body composition between groups of participants at the initial measurement

Parameter	Group	M	SD	t	p	η^2_p
$SMM_i^{(kg)}$	E	22.08	2.86	-0.117	.907	.000
	C	22.74	2.82			
$BFM_i^{(kg)}$	E	17.23	4.29	0.023	.982	.000
	C	18.59	4.30			
$PBF_i^{(\%)}$	E	30.35	6.48	0.038	.314	.011
	C	32.38	4.76			

Legend: $SMM_i^{(kg)}$- skeletal muscle mass; $BFM_i^{(kg)}$- body fat mass; $PBF_i^{(\%)}$ - body fat percentage; E - experimental group; C -control group; M - arithmetic mean; SD - standard deviation; t - value of t-test coefficient; p - coefficient of significance of t-statistics; η^2_p - partial squared eta (measure of effect size).

Intergroup differences in the arithmetic means of body composition parameters at the initial measurement, determined by the t-test for independent samples, are shown in Table 30. The coefficients of statistical significance of the t-statistics show that no statistically significant differences were found at the univariate level between the experimental and control groups in the individual variables of body composition (p > .05).

7.2.2 Intergroup Differences in Initial Functional Mobility Measuring

Table 31. The multivariate differences in functional mobility between groups of participants at the initial measurement

Pillai's trace (V)	F	Effect-df	Error-df	p	η^2_p
0.384	0.597	24	23	.892	.138

Legend: Pillay's trace - the value of the coefficient for the equality of group centroids; F - the value of the F-test coefficient; Effect df and Error df - degrees of freedom; p - coefficient of significance of F-statistics; η^2_p - partial squared eta (measure of effect size).

Table 31 shows the results of the Multivariate Analysis of Variance between the experimental and control groups of participants in functional mobility at the initial measurement. Based on the values of the Wilks-lambda criterion (V = 0.384, $F(24,23) = .892$, $p > .05$; $\eta^2_p = .138$) it can be noticed that at the multivariate level there are no statistically significant differences between groups of participants in functional mobility.

In further analysis, to verify the validity of the second sub-hypothesis of the firts general hypothesis, the Mann-Whitney U-test was calculated.

Table 32. The univariate differences in functional mobility between groups of participants at the 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-R	E	2.21	0.55	-0.575	.565	.08
	C	2.21	0.51			
ILL-L	E	2.20	0.58	-0.942	.346	.14
	C	2.16	0.41			
SM-R	E	2.54	0.51	-0.864	.388	.12
	C	2.50	0.29			
SM-L	E	2.49	0.55	-0.353	.724	.05
	C	2.45	0.63			
RS-R	E	1.82	0.42	-0.130	.897	.02
	C	1.77	0.59			
RS-L	E	1.80	0.46	-0.235	.795	.04
	C	1.74	0.51			
ASLR-R	E	2.39	0.58	-0.167	.868	.02
	C	2.42	0.50			
ASLR-L	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	2.42	0.49	-0.292	.770	.04
	C	2.40	0.50			
HS-L	E	2.41	0.50	-0.573	.566	.08
	C	2.37	0.51			

Legend: DS - Deep Squat; ILL-R - In-Line Lunge- right leg; ILL-L - In-Line Lunge - left leg; SM-R - Shoulder Mobility-right side; SM-L - Shoulder Mobility - left side; RS-R - Rotary Stability - right side; RS-L - Rotary Stability- left side; Active Straight-Leg Raise - right leg; ASLR-L - Active Straight-Leg Raise - left leg; TSPU - Trunk Stability Push-Up; HS-R - Hurdle Step - right leg; Hurdle Step - left leg; 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.

Intergroup differences in the arithmetic means of functional mobility variables at the initial measurement are shown in Table 32. The coefficients of statistical significance of the Z -statistics show that no statistically significant differences were found at the univariate level between the experimental and control groups in the individual variables of functional mobility ($p > .05$).

7.2.3 Intergroup Differences in Initial Muscular Fitness Measuring

Table 33. The multivariate differences in muscular fitness between groups of participants at the initial measurement

Wilks-lambda	F	Effect-df	Error-df	p	η^2p
0.716	2.266	7	40	.063	.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).

Table 33 shows the results of the Multivariate Analysis of Variance between the experimental and control groups of participants in muscular fitness at the initial measurement. Based on the values of the Wilks-lambda criterion ($\Lambda = 0.716$, $F(7.40) = 2.266$, $p > 0.05$, $\eta^2p = .084$) it can be noticed that at the multivariate level there are no statistically significant differences between groups of participants in muscular fitness.

In further analysis, the t-test for independent samples was calculated to verify the validity of the third sub-hypothesis of the first general hypothesis, which presumes that there are statistically significant differences in muscular fitness parameters between the experimental and control groups of participants at the initial measurement.

Table 34. The univariate differences in muscular fitness between groups of participants at the initial measurement

Test	Group	M	SD	t	p	η^2p
TFET	E	88.58	19.29	1.086	.283	.025
	C	88.73	11.30			
TEET	E	91.24	21.27	-0.544	.589	.006
	C	90.80	16.62			
TLET-R	E	72.71	15.83	-0.150	.881	.000
	C	72.29	10.56			
TLET-L	E	71.29	14.57	-0.701	.487	.011
	C	71.10	9.64			
TFPT	E	71.21	18.30	-0.629	.533	.009
	C	71.49	21.09			
SLST-R	E	35.00	17.51	0.821	.416	.010
	C	34.55	13.93			
SLST-L	E	35.25	16.94	0.139	.890	.006
	C	34.40	15.74			

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 on forearms (the front plank); SLST-R - Single Leg Squat - right leg; SLST-L - Single Leg Squat- left leg; E - experimental group; C-control group; M - arithmetic mean; SD - 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).

Intergroup differences in the arithmetic means of muscular fitness parameters at the initial measurement, determined by the t-test for independent samples, are shown in Table 34. The coefficients of statistical significance of the t-statistics show that no statistically significant differences were found at the univariate level between the experimental and control groups in the individual variables of muscular fitness ($p > .05$).

7.3 Changes in Body Composition, Functional Mobility and Muscular Fitness: Initial vs. Final Measurements (Experimental Group)

In order to verify the accuracy of the second general hypothesis with corresponding sub-hypotheses, the following tables show the results of multivariate and univariate changes in the body composition, functional mobility and muscular fitness at the final compared to the initial measurement of the experimental group.

7.3.1 Changes in Body Composition: Initial vs. Final Measurements (Experimental Group)

Table 35. The multivariate changes in body composition at the final compared to the initial measurement of the experimental group

Wilks-lambda	F	Effect-df	Error-df	p	η^2p
0.131	40.896	3	21	0.044*	.592

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^2_p - partial squared eta (measure of the effect size); * - statistical significance at the level of .05.

Table 35 shows the results of the one-way repeated measures MANOVA in body composition of the experimental group. The statistical significance of Wilks' lambda indicates that at the multivariate level there are statistically significant changes in the body composition at the final compared to the initial measurement (Λ = 0.131, F(3.21) = 40.896, p <0.05). The value of the partially squared eta coefficient indicates a medium effect (η^2p = .592).

Table 36. The univariate changes in body composition at the final compared to the initial measurement of the experimental group

Parameter	Meas.	M	SD	t	p	η^2p
SMM$^{(kg)}$	I	22.08	2.86	7.078	.042*	.522
	F	23.98	1.93			
BFM$^{(kg)}$	I	17.23	4.29	- 8.507	.047*	.610
	F	15.32	4.52			
PBF$^{(\%)}$	I	30.35	6.48	- 7.249	.039*	.545
	F	27.83	6.66			

Legend: SMM - skeletal muscle mass; BFM - body fat mass; PBF - body fat percentage; I - initial measurement; F- final measurement; M - arithmetic mean; Meas.- Measurement; SD - standard deviation; t - the value of the coefficient (statistics) of the t-test; p - coefficient of significance; t - statistics; η^2p - partial squared eta (measure of effect size); * - statistical significance at the level of .05.

The results of the t-test for dependent samples (Table 36) show that at the univariate level, there are statistically significant changes (t_{smm}= 7.078, p <.05; t_{bfm}= -8.507, p <.05; t_{pbf} = -7.249, p < .05) in all body composition parameters at the final compared to the initial measurement of the experimental group. The measure of the effect size indicates medium effects in absolute values of skeletal muscle mass (η^2p = .522) and absolute (η^2p = .610) and relative values of body fat mass (η^2p = .545).

7.3.2 Changes in Functional Mobility: Initial vs. Final Measurements (Experimental Group)

Table 37. The multivariate changes in functional mobility at the final compared to the initial measurement of the experimental group

Pillai's trace (V)	F	Effect-df	Error-df	p	η^2_p
0.511	4.248	12	12	.026*	.511

Legend: Pillay's trace (V) - the value of the 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 .05.

Table 37 shows the results of the one-way repeated measures MANOVA in functional mobility of the experimental group. The statistical significance of Pillai's criterion (V= 0.511, $F(12,12) = 4.248$, $p < 0.05$) indicates that at the multivariate level there are statistically significant changes in the functional mobility at the final compared to the initial measurement of the experimental group. The value of the partially squared eta coefficient indicates a medium effect (η^2p = .511).

Table 38. The univariate changes in functional mobility at the final compared to the initial measurement of the experimental group

Test	Meas.	M	SD	Z	p	r
DS	I	2.17	0.56	-1.732	0.083	.25
	F	2.30	0.51			
ILL-R	I	2.21	0.55	-1.324	0.180	.19
	F	2.30	0.49			
ILL-L	I	2.20	0.58	-1.000	0.317	.14
	F	2.26	0.51			
SM-R	I	2.54	0.29	-2.121	0.034*	.31
	F	2.70	0.48			
SM-L	I	2.49	0.55	-2.000	0.046*	.29
	F	2.65	0.50			
RS-R	I	1.82	0.46	-2.530	0.011*	.36
	F	1.99	0.63			
RS-L	I	1.80	0.46	-2.449	0.014*	.35
	F	1.96	0.62			
ASLR-R	I	2.39	0.58	-1.732	0.083	.25
	F	2.51	0.51			
ASLR-L	I	2.34	0.61	-1.633	0.102	.24
	F	2.45	0.50			
TSPU	I	2.40	0.58	-2.828	0.005**	.41
	F	2.64	0.44			
HS-R	I	2.42	0.49	-0.864	0.388	.12
	F	2.48	0.48			
HS-L	I	2.41	0.50	-0.942	0.346	.14
	F	2.46	0.44			

Legend: DS - Deep Squat; ILL-R - In-Line Lunge- right leg; ILL-L - In-Line Lunge - left leg; SM-R - Shoulder Mobility - right side; SM-L - Shoulder Mobility - left side; RS-R - Rotary Stability - right side; Rotary Stability- left side; Active Straight-Leg Raise - right leg; ASLR-L - Active Straight-Leg Raise - left leg; TSPU - Trunk Stability Push-Up; HS-R - Hurdle Step - right leg; HS-L Hurdle Step - left leg; 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 38) show that statistically significant changes were found at the final compared to the initial measurement of the experimental group in the Trunk Stability Push-Up ($p < .01$), Rotatory Stability - right side ($p< .05$), Rotatory Stability - left side ($p < .05$), Shoulder Mobility-right side ($p < .05$) and Shoulder Mobility-left side tests ($p < .05$). In other functional mobility tests, the determined changes were not statistically significant ($p> .05$).

According to Fritz et al. (2011), the measures of the effect size indicate medium effects in the Trunk Stability Push-Up test (r = .41) and the bilateral Rotary Stability - right side (r = .36), Rotary Stability - left side (r = .35), Shoulder Mobility - right side (r = .31) and Shoulder Mobility - left side (r = .29) tests. Effects in the range from small to medium were found in the Deep Squat test and the bilateral Active Straight-Leg Raise tests, and small effects were found in the bilateral in-Line Lunge and Hurdle Step tests.

7.3.3 Changes in Muscular Fitness: Initial vs. Final Measurements (Experimental Group)

Table 39. The multivariate changes in muscular fitness at the final compared to the initial measurement of the experimental group

Wilks-lambda	F	Effect-df	Error-df	p	η^2p
0.110	188.549	7	17	.000**	.890

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^2_p - partial squared eta (measure of the effect size); ** - statistical significance at the level of .01.

Table 39 shows the results of the one-way repeated measures MANOVA in muscular fitness of the experimental group. The statistical significance of Wilks' lambda ($\Lambda = 0.010$, F (7.17) = 188.549, p <0.01) indicates that at the multivariate level there are statistically significant changes in the muscular fitness at the final compared to the initial measurement. The value of the partially squared eta coefficient indicates a large effect ($\eta^2p = .890$).

Table 40. The univariate changes in muscular fitness at the final compared to the initial measurement of the experimental group

Test	Meas	M	SD	t	p	η^2p
TFET	I	88.58	19.29	-13.903	.000**	.861
	F	97.95	23.34			
TEET	I	91.24	21.27	-13.108	.000**	.852
	F	100.12	24.08			
TLET-R	I	72.71	15.83	-12.966	.000**	.845
	F	79.75	16.50			
TLET-L	I	71.29	14.57	-13.205	.000**	.870
	F	78.45	15.25			
TFPT	I	71.21	18.30	-12.970	.000**	.837
	F	78.35	25.38			
SLST-R	I	35.00	17.51	-4.827	.044*	.601
	F	36.77	13.25			
SLST-L	I	35.25	16.94	-4.951	.041*	.612
	F	36.37	18.68			

Legend: TFET - Trunk Flexor Endurance; TEET - Trunk Extensor Endurance; TLET-R - Trunk Lateral Muscle Endurance - right side; TLET-L - Trunk Lateral Muscle Endurance - left side; TFPT - endurance on forearms (The Front Plank); SLST-R - Single Leg Squat - right leg; SLST-L - Single Leg Squat Test - left leg; I – initial measurement; F-final measurement; Meas. – measurement; M - arithmetic mean; SD - standard deviation; t - value of 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; * - statistical significance at the level of .05.

The results of the t-test for dependent samples (Table 40) show that statistically significant changes were found at the univariate level in all muscular fitness tests at the final compared to the initial measurement of the experimental group (t_{tfet}= - 13.903, p < .01, t_{teet}= - 13.108, p < .01, t_{tlet-r}= - 12.966, p < .01; t_{tlet-l} = - 13.205, p < .01; t_{tfpt}= - 12.970, p < .01; t_{slst-r}= - 4.827, p < .05; t_{slst-l}= - 4.951, p < .05). The measure of the effect size indicates large effects in the endurance tests of trunk flexors (η^2_p = .861), trunk extensors (η^2_p = .852), lateral trunk muscles on the left (η^2_p = .870) and right side of the trunk (η^2_p = .845) and in the Front Plank Test (η^2_p = .837). In the bilateral Single Leg Squot Test - left leg (η^2_p =.612) and Single Leg Squot Test - right leg (η^2_p = .601), the established effect size measure is medium.

7.4 Changes in body composition, functional mobility and muscular fitness: initial vs. final measurements (Control Group)

In order to verify the validity of the third general hypothesis with corresponding sub-hypotheses, the following tables show the results of multivariate and univariate changes in the body composition, functional mobility and muscular fitness, at the final compared to the initial measurement of the control group.

7.4.1 Changes in Body Composition: Initial vs. Final Measurements (Control Group)

Table 41. The multivariate changes in body composition at the final compared to the initial measurement of the control group

Wilks-lambda	F	Effect-df	Error-df	p	η^2_p
0.977	0.524	3	21	.808	.130

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^2_p - partial squared eta (measure of the effect size).

Table 41 shows the results of the one-way repeated measures MANOVA in body composition of the control group. The statistical significance of Wilks' lambda (Λ= 0.977, $F(3,21) = 0.524$, $p > .05$) indicates that at the multivariate level, there are no statistically significant changes in the body composition at the final compared to the initial measurement of the control group. The value of the partially squared eta coefficient indicates a small effect (η^2p = 0.13).

Table 42. The univariate changes in body composition at the final compared to the initial measurement of the control group

Parameter	Meas.	M	SD	t	p	η^2_p
SMM$^{(kg)}$	I	22.74	1.83	0.117	.052	.132
	F	23.44	1.85			
BFM$^{(kg)}$	I	18.59	4.30	- 0.122	.057	.135
	F	17.89	4.33			
PBF$^{(\%)}$	I	32.38	5.76	- 0.097	.059	.128
	F	31.72	5.79			

Legend: SMM - skeletal muscle mass; BFM - body fat mass; PBF - body fat percentage; I - initial measurement; F- final measurement; Meas – measurement; M - arithmetic mean; S - standard deviation; t - the value of the t-test coefficient (statistics); p - coefficient of significance; t - statistics; η^2_p - partial squared eta (measure of effect size);

The results of the t-test for dependent samples (Table 42) show that no statistically significant changes were found at the univariate level (t_{smm} = 0.117, p > .05; t_{bfm} = - 0.122, p > .05; t_{pbf} = - 0.097, p > .05) in body composition parameters at the final compared to the initial measurement of the control group. The effect size data indicate small effects in absolute values of skeletal muscle mass (η^2p = .132), and absolute (η^2p = .135) and relative values of body fat mass (η^2p = .128).

7.4.2 Changes in Functional Mobility: Initial vs. Final Measurements (Control Group)

In further analysis, the hypothesis which assumes that there are significant changes in the functional mobility at the final compared to the initial measurement of the control group of participants was tested. To assess the validity of the stated hypothesis at the multivariate level, the one-way repeated measures MANOVA was applied while its validity at the univariate level was verified by the Wilcoxon signed-rank test.

Table 43. The multivariate changes in functional mobility at the final compared to the initial measurement of the control group

Pillai's trace (V)	F	Effect-df	Error-df	p	η^2_p
0.747	2.401	12	12	.068	.235

Legend: Pillay's trace (V) - the value of the 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 the F-statistics; η2p - partial squared eta (measure of effect size).

The results of the one-way repeated measures MANOVA (Table 43) indicate that at the multivariate level, there are no statistically significant changes in functional mobility at the final compared to the initial measurement of the control group (V= 0.747, $F(12,12)$ = 2.401, $p > .05$). The value of the partially squared eta coefficient indicates a small effect (η^2p = .235).

Table 44. The univariate changes in functional mobility at the final compared to the initial measurement of the control group

Test	Meas.	M	SD	Z	p	r
DS	I	2.22	0.68	-0.728	.481	.015
	F	2.24	0.59			
ILL-R	I	2.21	0.51	-0.164	.866	.002
	F	2.23	0.49			
ILL-L	I	2.16	0.41	-0.190	.849	.004
	F	2.20	0.50			
SM-R	I	2.50	0.23	-0.130	.897	.002
	F	2.52	0.46			
SM-L	I	2.45	0.63	-0.190	.797	.005
	F	2.48	0.65			
RS-R	I	1.77	0.43	-0.147	.863	.002
	F	1.81	0.58			
RS-L	I	1.74	0.41	-0.192	.870	.005
	F	1.79	0.48			
ASLR-R	I	2.42	0.50	-0.286	.775	.004
	F	2.45	0.51			
ASLR-L	I	2.38	0.55	-0.192	.850	.003
	F	2.40	0.58			
TSPU	I	2.43	0.39	-0.130	.875	.002
	F	2.45	0.46			
HS-R	I	2.40	0.50	-0.413	.681	.007
	F	2.42	0.51			
HS-L	I	2.37	0.51	-0.309	.760	.005
	F	2.40	0.48			

Legend: DS - Deep Squat; ILL-R - In-Line Lunge- right leg; ILL-L - In-Line Lunge - left leg; SM-R - Shoulder Mobility-right side; SM-L - Shoulder Mobility - left side; RS-R - Rotary Stability - right side; RS-L - Rotary Stability- left side; Active Straight-Leg Raise - right leg; ASLR-L - Active Straight-Leg Raise - left leg; TSPU - Trunk Stability Push-Up; HS-R - Hurdle Step - right leg; HS-L Hurdle Step - left leg; M - arithmetic mean; Meas – measurement; SD - standard deviation; Z - the value of the Wilcoxon signed rank test; p - coefficient of significance; Z - statistics; r - Rosenthal's measure of the effect size.

The results of the Wilcoxon signed-rank test (Table 44), indicate that there are no statistically significant changes in arithmetic means of the functional mobility results at the final compared to the initial measurement of the control group ($p > 0.05$). According to Fritz et al. (2011), the measures of the effect size indicate trivial effects that are below the limit of the recommended minimum effect size in all functional mobility tests ($r < 0.1$).

7.4.3 Changes in Muscular Fitness: Initial vs. Final Measurements (Control Group)

Table 45. The multivariate changes in muscular fitness at the final compared to the initial measurement of the control group

Wilks-lambda	F	Effect-df	Error-df	p	$\eta^2 p$
0.349	6.331	7	17	.039*	.228

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^2_p - partial squared eta (measure of the effect size); * - statistical significance at the level of .05.

Table 45 shows the results of the one-way repeated measures MANOVA in muscular fitness of the control group. The statistical significance of Wilks' lambda (Λ= 0.349; $F(7,17) = 6.331$; $p < .05$) indicates that at the multivariate level, there are statistically significant changes in the muscular fitness at the final compared to the initial measurement of the control group. The value of the partially squared eta coefficient ($\eta^2 p = .228$) indicates a small effect.

Table 46. The univariate changes in muscular fitness at the final compared to the initial measurement of the control group

Variable	Meas.	M	SD	t	p	$\eta^2 p$
TFET	I	88.73	11.30	-4.816	.029*	.250
	F	92.91	11.84			
TEET	I	90.80	16.62	-4.737	.031*	.245
	F	94.85	15.94			
TLET-R	I	72.29	10.56	-4.190	.044*	.157
	F	75.33	11.01			
TLET-L	I	71.10	9.64	-4.225	.046*	.161
	F	74.40	10.46			
TFPT	I	71.49	21.10	-4.698	.034*	.245
	F	74.65	22.01			
SLST-R	I	34.55	13.93	-4.691	.039*	.194
	F	35.40	17.08			
SLST-L	I	34.40	15.74	-4.703	.041*	.188
	F	35.35	15.74			

Legend: TFET - Trunk Flexor Endurance; TEET - Trunk Extensor Endurance; TLET-R - Trunk Lateral Endurance - right side; TLET-L - Trunk Lateral Endurance - left side; TFPT - The Front Plank: forearm endurance; SLST-R - Single Leg Squat - right leg; SLST-L - Single Leg Squat- left leg; E - experimental group; K-control group; Meas. – measurement; M - arithmetic mean; SD - standard deviation; t - value of the t-test coefficient; p - coefficient of significance of t-statistics; η2p - partial squared eta (measure of effect size). * - statistical significance at the level of .05.

The results of the t-test for dependent samples (Table 46) indicate that at the final compared to the initial measurement of the control group, there are statistically significant changes in all muscular fitness tests (t_{tfet}= -4.816, p < .05, t_{teet}= -4.737, p < .05, t_{tlet-r}= - -4.190, p < .05; t_{tlet-l} = -4.225, p < .01; t_{tfpt}= - -4.698, p < .01; t_{slst-r}= - -4.691, p < .05; t_{slst-l}= - -4.703, p < .05). The measures of the effect size indicate small effects in all muscular variables (.05 ≤ η^2p < .26).

7.5 Intergroup differences in Final Measurement /Effects of the experimental program

In order to verify the validity of the fourth general hypothesis with the corresponding sub-hypotheses, the following tables show the results of multivariate and univariate intergroup differences in body composition, muscular fitness and functional mobility at the final measurement.

7.5.1 Intergroup Differences in Final Body Composition Measuring

Table 47. The multivariate differences in body composition between groups of participants at the final measurement

Wilks-lambda	F	Effect-df	Error-df	p	η^2_p
0.298	6.426	3	44	.000*	.527

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 .05.

Table 47 shows the results of the Multivariate Analysis of Variance between the experimental and the control groups of participants in body composition at the final measurement. Based on the values of the Wilks-lambda criterion (Λ = 0.298, F(3.44) = 6.426, p < 0.01), it can be noticed that at the multivariate level there are statistically significant differences between groups of participants in body composition. A medium effect size of the applied experimental treatment was determined (η^2p = .527), explaining 52.7% of the variance in the body composition results.

Table 48. The univariate differences in body composition between groups of participants at the final measurement

Parameter	Group	M	SD	t	p	η^2p
SMM (kg)	E	23.98	1.93	5.220	0.00**	.497
	C	23.44	1.85			
BFM (kg)	E	15.32	4.52	-6.180	0.00**	.526
	C	17.89	4.10			
PBF (%)	E	27.83	5.66	-5.623	0.00**	.513
	C	31.72	4.05			

Legend: SMM - skeletal muscle mass; BFM - body fat mass; PBF - body fat percentage; E - experimental group; C-control group; M - arithmetic mean; SD - standard deviation; t - value of t-test coefficient; p - coefficient of significance of t-statistics; η^2_p - partial squared eta (measure of effect size); ** - statistical significance at the level of .01.

The results of the t-test for independent samples (Table 48) show that statistically significant intergroup differences were found at the univariate level in all body composition parameters at the final measurement (t_{smm} = 5.220, p <.01; t_{bfm} = - 6.180, p <.01; t_{pbf} = -5.623, p <.01). The effect size data indicate the medium effects of the applied experimental program in absolute values of skeletal muscle mass (η^2_p = .497), and absolute (η^2_p =. 526) and relative values of body fat mass (η^2_p = .513).

7.5.2 Intergroup Differences in Final Functional Mobility Measuring

Table 49. The multivariate differences in functional mobility between groups of participants at the final measurement

Pillai's trace (V)	F	Effect-df	Error-df	p	η^2p
0.627	0.665	12	35	.000**	.622

Legend: Pillay's trace - the value of the coefficient for the equality of group centroids; F - the value of the F-test coefficient; Effect df and Error df - degrees of freedom; p - coefficient of significance of F-statistics; η^2_p - partial squared eta (measure of effect size); * - statistical significance at the level of .05; ** - statistical significance at the level of .01.

Table 49 shows the results of the Multivariate Analysis of Variance between the experimental and control groups of participants in functional mobility at the final measurement. Based on the values of the Pillai's trace criterion (V = 0.627, $F(12,35)$ = .622, p < .01), it can be noticed that at the multivariate level there are statistically significant differences between groups of participants in functional mobility. A medium effect size of the applied experimental treatment was determined, explaining 62.2% of the variance in the functional mobility results.

Table 50. The univariate differences in functional mobility between groups of participants at the final measurement

Variable	Group	M	SD	Z	p	r
DS	E	2.30	0.51	-0.626	.531	.01
	C	2.24	0.59			
ILL-R	E	2.30	0.49	-0.924	.355	.13
	C	2.23	0.49			
ILL-L	E	2.26	0.51	-0.717	.473	.01
	C	2.20	0.50			
SM-R	E	2.70	0.48	-2.530	.011*	.36
	C	2.52	0.46			
SM-L	E	2.65	0.50	-2.449	.014*	.35
	C	2.48	0.65			
RS-R	E	1.99	0.63	-2.000	.046*	.29
	C	1.81	0.58			
RS-L	E	1.96	0.62	-2.121	.034*	.31
	C	1.79	0.48			
ASLR-R	E	2.51	0.51	-1.414	.157	.20
	C	2.45	0.51			
ASLR-L	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			
HS-L	E	2.46	0.44	-0.620	.532	.01
	C	2.40	0.48			

Legend: DS - Deep Squat; ILL-R - In-Line Lunge- right leg; ILL-L - In-Line Lunge - left leg; SM-R - Shoulder Mobility-right side; SM-L - Shoulder Mobility - left side; RS-R - Rotary Stability- right side; Rotary Stability-left side; Active Straight-Leg Raise - right leg; ASLR-L - Active Straight-Leg Raise - left leg; TSPU - Trunk Stability Push-Up; HS-R - Hurdle Step - right leg; Hurdle Step - left leg; 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 univariate differences between groups of participants in the variables of functional mobility at the final measurement, determined by the Mann-Whitney U-test (Table 50), show that statistically significant intergroup differences were found in the Trunk Stability Push-Up test (Z = -2.828; p < .01) and the bilateral Shoulder Mobility - right side (Z = - 2.530; p < .05), Shoulder Mobility - left side (Z = -2.449; p < .05), Rotatory Stability - right side (Z = -2.000; p < .05) and Rotatory Stability - left side tests (Z = -2.121; p < .05). In the Deep Squat test and the bilateral in-Line Lunge, Active Straight-Leg Raise and Hurdle Step tests, determined intergroup differences were not statistically significant (p > .05).

Effect size measures, determined by the r coefficient according to Fritz et al. (2011), indicate medium effects in the Trunk Stability Push-Up test (r =.41), Shoulder Mobility -

right side (r =.36), Shoulder Mobility - left side (r =.35), Rotatory Stability - right side (r =.29) and Rotatory Stability - left side (r =.31) tests. In other functional mobility tests determined effects were small (r = 0.1).

7.5.3 Intergroup Differences in Final Muscular Fitness Measuring

Table 51. The multivariate differences differences in muscular fitness between groups of participants at the final measurement

Wilks-lambda	F	Effect-df	Error-df	p	η^2p
0.324	8.427	7	40	.000**	.656

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 51 shows the results of the Multivariate Analysis of Variance between the experimental and control groups of participants in muscular fitness at the final measurement. Based on the values of the Wilks-lambda criterion (Λ= 0.324, *F* (7,40) = 8.427, p < 0.01, η^2_p = .656), it can be noticed that at the multivariate level there are statistically significant differences between groups of participants in muscular fitness. A large effect size of the applied experimental treatment was determined, explaining 65.6% of the variance in the body composition results.

Table 52. The univariate differences in muscular fitness between groups of participants at the final measurement

Variable	Group	M	SD	t	p	η^2p
$TFET_f$	E	97.95	23.34	8.871	.000**	.664
	C	92.91	11.84			
$TEET_f$	E	100.12	24.08	8.758	.000**	.651
	C	94.85	15.93			
$TLET\text{-}R_f$	E	79.75	16.50	8.740	.000**	.644
	C	75.33	11.01			
$TLET\text{-}L_f$	E	78.45	15.25	8.777	.000**	.660
	C	74.40	10.46			
$TFPT_f$	E	78.35	25.38	8.769	.000**	.655
	C	74.65	22.08			
$SLST\text{-}R_f$	E	36.77	13.25	3.140	.047*	.240
	C	36.05	17.08			
$SLST\text{-}L_f$	E	36.37	18.68	3.505	.042*	.251
	C	35.95	15.22			

Legend: TFET - trunk flexor endurance; TEET - trunk extensor endurance; TLET-R - trunk lateral endurance - right side; TLET-L - trunk lateral endurance - left side; TFPT - forearm endurance (the front plank); SLST-R -

single leg squat - right leg; SLST-L - single leg squat- left leg; E - experimental group; C - control group; M - arithmetic mean; SD - 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 .05; ** - statistical significance at the level of .01.

The results of the univariate differences between groups of participants in the variables of muscular fitness at the final measurement, determined by the t-test for independent samples (Table 52), show that statistically significant differences were found in all muscular fitness tests (t_{tfet}= 8.871, $p < .01$, t_{teet}= 8.758, $p < .01$, t_{tlet-r}= 8.740, $p < .01$; t_{tlet-l} = 8.777, $p < .01$; t_{tfpt}= 8.769, $p < .01$; t_{slst-r}= 3.140, $p < .05$; t_{slst-l}= 3.505, $p < .05$).

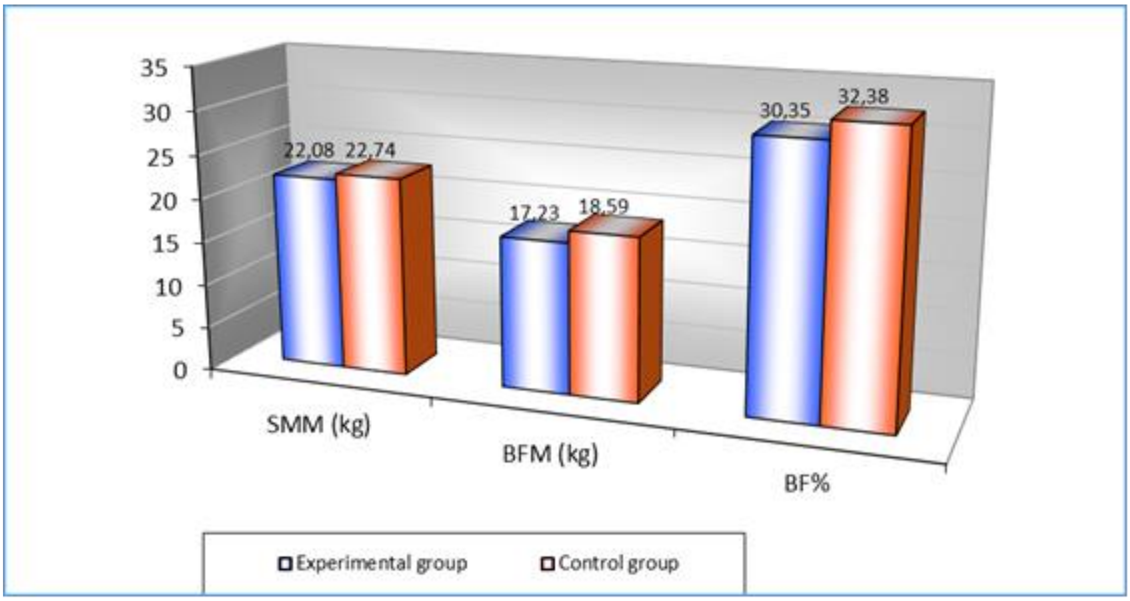
The magnitude of the partial squared eta coefficient shows that large effects were found in all trunk endurance tests (η^2_p [tfet] = .664; η^2_p [teet] = .651; η^2_p [tlet-r] = .644); η^2_p [tlet-l] = .660); η^2_p [tfpt] = .655), while small effects, close to the limit of medium effects, were found in the bilateral Single Leg Squat test - right leg (η^2_p [slst-r] = .240) and Single Leg Squat test - left leg (η^2_p [slst-l] = .251).

8. DISCUSSION

This research determined the effects of the ball Pilates training on body composition, functional mobility, and muscular fitness in female adolescents. Participants were divided into an experimental group undertaking Pilates on a ball and a control group following a standard physical education program. Following a ten-week experimental period, specific changes were observed in all researched domains among participants from both groups, and the effects of the applied experimental treatment were identified.

8.1 Intergroup Differences in Initial Body Composition Measuring

The results of intergroup differences in body composition at baseline (Graph 1; Table 30) indicated that the participant groups did not differ significantly in any body composition parameter ($p > .05$). Rather, they were equivalent groups with similar values across all monitored body composition parameters before the commencement of the experiment.



Graph 1. Intergroup differences in initial body composition measuring

The average absolute values of skeletal muscle body mass and relative and absolute values of body fat mass at the initial measurement (Graph 1) were numerically slightly lower in the experimental group of participants than in the control group.

According to McCarthy, Samani-Radia, Jebb, and Prentice (2014), the average values of skeletal muscle mass for both groups of participants were within the age and gender reference values at baseline measurement.

According to Fitnessgram body composition standards for girls, taken from Ayers and Sariscsany (2011), body fat percentage values for fifteen-year-old girls range from 14.6% to 29.1%, and for sixteen-year-olds from 15.3% to 29.7%, falling within the health form zone. According to their criteria, the average body fat values for both groups at baseline were slightly higher than the recommended values. This was also confirmed by the obesity classification criteria defined by Egger, Champion, and Bolton (1999), where reference values for female non-athletes range from 17% to 27%, and body fat values from 27% to 33% are categorized by these authors as "moderately excessive". However, according to Ayers and Sariscsany (2011), the average body fat mass of the control group participants was slightly increased, while in the experimental group, they were at the upper limit of the reference values.

Comparing the mean values of body mass index (BMI) among participants of the experimental (BMI = 21.43 kg/m^2) and control groups (BMI = 21.54 kg/m^2) with reference values for female students aged 15 (16.4-23.5 kg/m^2) and 16 years (16.9-24.1 kg/m^2), it was determined that both groups of participants were normally nourished before commencing the experiment, with BMI values close to the upper limit. Given that BMI values are specific to chronological age and gender, standard BMI values defined for those over 18 years were not applicable to the sample of participants in this study. Instead, recommended values appropriate for this sample were adopted from Ayers and Sariscsany (2011).

The maximum body mass index values of participants in the experimental group (BMI = 23.3 kg/m^2) and the control group (BMI = 22.67 kg/m^2), according to Ayers and Sariscsany (2011), were close to the zone of certain health risk. However, because the body mass index is not a reliable indicator of nutrition due to its inability to consider the proportion of muscle and fat in total body mass, the obtained results should be interpreted cautiously.

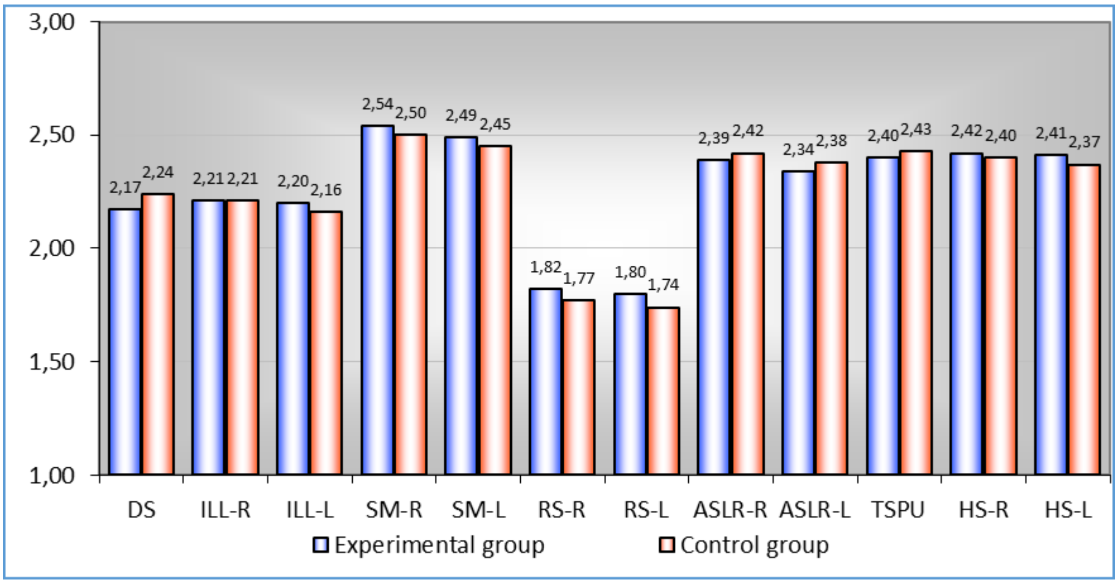
High body fat values were also observed in baseline in studies conducted by Lee et al. (2016) and Vispute et al. (2011) on samples of non-athlete students of both genders (27.50 ± 5.67%; 35.66 ± 9.33%, respectively), as well as in studies conducted by Buttichak et al. (2019) and Cakmakçi (2011) on samples of overweight women (35.45+3.08%; 35.65 ± 3.31%; редом). Lower percentages of body fat than those observed in this study were reported in the study conducted by Yaprak (2018) on a sample of male students and in studies involving physically active students (Anant and Venugopalb, 2021; Ружић, 2020), adolescent swimmers (Bulunmak, 2019) and volleyball players (Srinivasulu & Amudhan, 2018).

Contrary to slightly increased body fat mass values, the average values of skeletal muscle mass for participants in both groups were within the age and gender reference values, according to McCarthy et al. (2014).

8.2 Intergroup Differences in Initial Functional Mobility Measuring

The functional mobility of participants was assessed using seven standard FMS tests, five of which are bilateral. Given that bilateral functional mobility tests yield a weaker final result, the results of all 12 variables can be condensed into 7 variables. However, an examination of all variables is necessary to observe potential asymmetries in basic movement patterns.

The results of differences in functional mobility between the experimental and control groups at baseline (Graph 2; Table 32) showed that the participant groups did not differ statistically significantly in any functional mobility parameter ($p > .05$). They were homogeneous groups with approximately the same characteristics of functional mobility before the experiment was conducted.



Graph 2. Intergroup differences in initial functional mobility measuring

The average results indicate that both groups of participants had the same result in the initial measurement of the In-Line Lunge test performed with the right leg (ILL-Ri = 2.21). In all other tests, except for the In-Line Lunge test performed with the left leg and the Shoulder Mobility test performed with the left arm, where participants in the experimental group achieved numerically better results, participants in the control group had numerically better results.

The results of bilateral tests indicate that there were no pronounced asymmetries in basic movement patterns among participants in both groups at the initial measurement. Screening of functional mobility in participants of both groups at the initial measurement, according to Cook, Burton, and Hoogenboom (2006a, 2006b), revealed a moderate deficit in mobility and stability of functional movement in the Rotatory Stability test, while a mild deficit was observed in other tests.

During the execution of the bilateral Rotatory Stability test, both groups of participants were unable to perform the diagonal movement pattern correctly on both sides but performed them with certain compensations or irregularities. The reason for this was deficient asymmetrical trunk stability in the sagittal and transverse planes during the execution of asymmetrical movements with the upper and lower extremities. This further indicates a deficit in neuromuscular coordination and transference of energy from one body segment to another, primarily due to insufficient stability of the pelvis, trunk, and scapula during the execution of combined movements involving upper and lower extremities. The final result of this test is determined by the performance of participants executing this test with the extremities of the left side of the body (RS-L =1.80 in E group; RS-L =1.74 in K group).

The average initial values of the Deep Squat test results (DS_i =2.17 in the E group; DS_i =2.22 in the K group) indicate that participants from both groups performed this movement pattern with compensations, using their heels on the board. It is an indication of moderate postural control of the pelvis and trunk, moderate bilateral mobility of the shoulder girdle, scapular region, and thoracic spine before the start of the experiment.

In both groups of participants, average results in the In-Line Lung test performed with the right leg (ILL-Ri = 2.21) and left leg (ILL-Li = 2.20 in the experimental group; ILL-Li = 2.16 in the control group) indicate that participants executed the movement pattern in this test with minor compensations or irregularities. These observed compensations are a consequence of moderately deficient bilateral mobility and stability of the hip, knee, and ankle joints, as well as insufficiently developed dynamic control of the trunk and pelvis before the start of the experiment. The final result of this test is the result achieved by participants performing this test with the left leg (SM-L = 2.49 in the E group; SM-L = 2.45 in the K group).

By comparing the average values of bilateral Shoulder Mobility test results performed with the right (SM-Ri = 2.54 in E group; SM-Ri = 2.50 in K group) and left arm (SM-Li = 2.49 in the E group; SM-Li = 2.45 in the K group) across both groups of participants, a numerically better result is observed when performing this test with the right arm above the shoulder. This suggests slightly greater scapular mobility and thoracic spine extension on the right side of the body. The distance between fists in the Shoulder Mobility test performed with the right arm was slightly greater than the length of a hand span but smaller than the length of one and a half hand spans, indicating that participants executed the test on the right side with very minor compensations/irregularities, less than on the left side. The final result in this test (SM-L =2.49 in the E group; SM-L = 2.45 in the K group) is the result achieved by participants performing this test with the left arm above the shoulder (external rotation with abduction) and the right arm below the shoulder (internal rotation with adduction).

According to Cook et al. (2014a), the average initial values of results in both groups of participants in this test indicate that traditional weightlifting patterns are acceptable if participants engage in exercises such as overhead lifting (dumbbells, barbells) or lifting weights from a horizontal starting position in conditions of an open kinetic chain (weights lifting on a bar lying on a bench, variants of lifting dumbbells lying on a bench).

The results of the bilateral Active Straight Leg Raise test for both groups of participants were better when performed with the right leg, but small asymmetries in movement patterns were observed. Participants from both groups performed the movement pattern with some compensations/irregularities, indicating insufficient hip mobility and functional flexibility of the hamstrings, gastrocnemius, and soleus muscles. The final result in this test is the outcome achieved by participants performing the test with the left leg leading (ASLR = 2.34 in the E group; SM-L = 2.38 in the K group).

Participants from both groups performed the movement pattern in Trunk Stability Push-up test with minor compensations/irregularities during the initial measurement. They exhibited excessive extension and rotation of the trunk due to insufficient strength in the trunk stabilizer muscles.

With very minor compensations, participants from both groups also performed the Hurdle Step test indicating a mild deficit in coordination, bilateral mobility, and stability of the hips, knees, and ankles, as well as unilateral stability and control of the pelvis and trunk. The final result of this test reflects the performance achieved by the participants using their left leg (HS-L = 2.41 in the E group; HS-L = 2.37 in the K group).

8.3 Intergroup Differences in Initial Muscular Fitness Measuring

Muscular fitness was assessed using five tests, two of which were bilateral (Trunk Lateral Endurance test and Single-Leg Squat test).

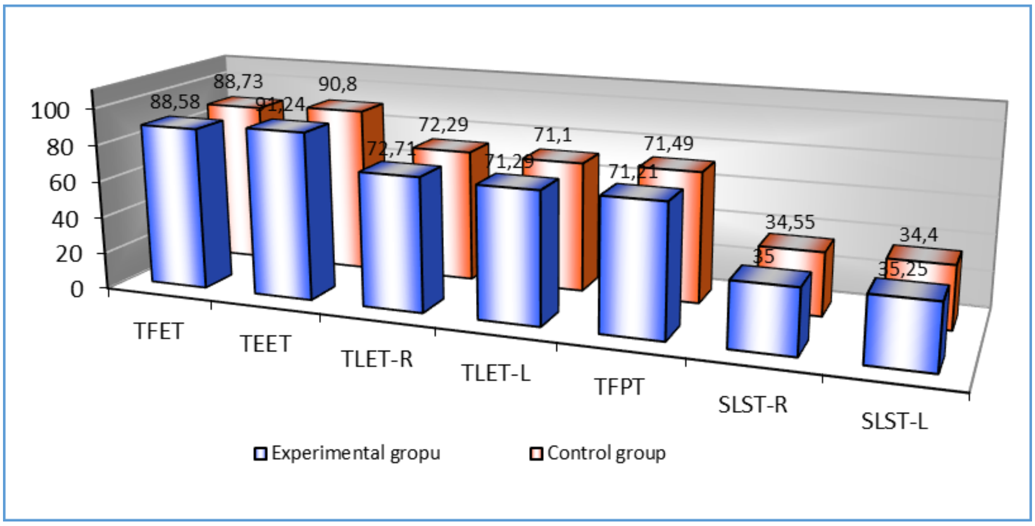
The results of differences in muscular fitness between the experimental and control groups at the baseline measurement (Graph 3; Table 34) showed that the participant groups did not significantly differ in any parameter of muscular fitness ($p>0.05$). This indicates that the groups were equivalent, having approximately the same characteristics of muscular fitness before the experiment commenced.

The mean values of the results for the Trunk Flexor Endurance test and the Front Plank test at the baseline measurement were numerically, but not statistically significantly, higher in the control group of participants. In all other tests, numerically higher and therefore better results were observed at the baseline in the experimental group (Graph 3).

According to Dejanovic, Cambridge, and McGill (2014), the average muscular fitness results of both groups of participants were within the reference values for girls aged 15 and 16 years at the initial measurement.

Participants of both groups achieved the best results in tests for assessing trunk flexor and extensor endurance at the baseline and the weakest in the bilateral Single-Leg Squat test, which indicates insufficient stability and balance of the pelvis and lower extremities.

Vurgun and Edis (2020), in their study on a sample of handball players with an average age of 18.31±0.47 years, found significantly better initial results in the Front Plank test (130.93±40.04 s) compared to the participants in this study (71.21±18.30 s in the E group; 71.49 ± 21.09 s in the K group), while the results in other endurance tests were similar to those in this study. The better results were expected since the participants in their study were athletes.



Graph 3. Intergroup differences in initial muscular fitness measuring

Yaprak (2018), in a study conducted on a sample of non-athlete male students, found better initial results in the trunk extensor endurance test compared to this study, which is expected as male participants generally perform better in muscular fitness than female participants. However, it is surprising that young athletes of both genders in the study conducted by Nuhmani (2021) had lower initial values in the Front Plank test, Trunk Extensor Endurance test, and Lateral Trunk Muscle Endurance test compared to the participants of this study. Lower initial results in lateral trunk muscle endurance were also found in a study by Anant and Venugopal (2021) conducted on a sample of young athletes.

Since there were no statistically significant differences between the experimental and control groups in any of the researched domains at the initial measurement, it is concluded that the experimental design of the study featured an equivalent control group design.

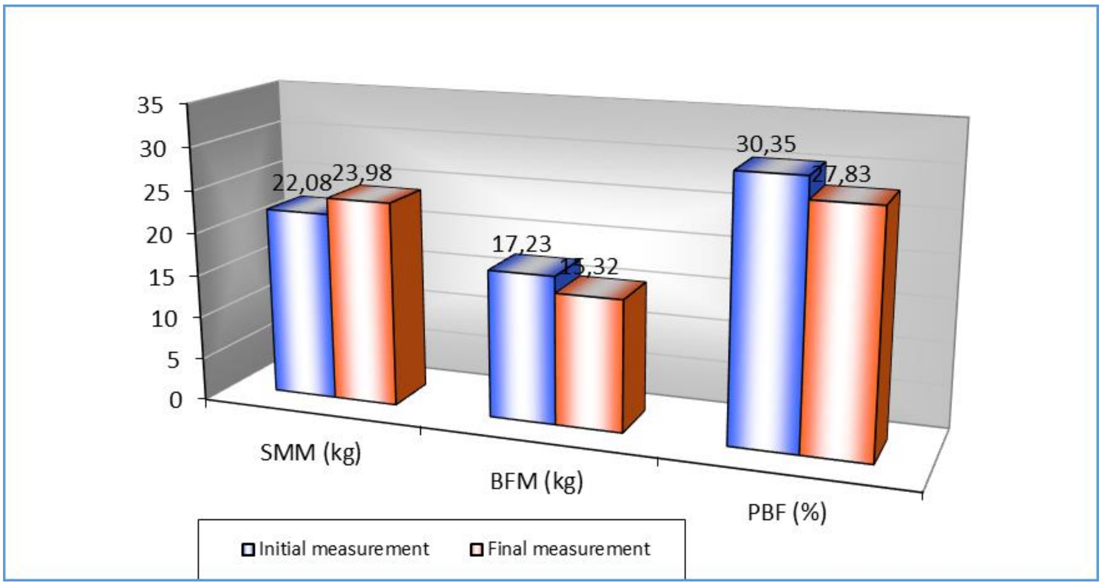
8.4 Changes in Body Composition: Initial vs. Final Measurements (Experimental and Control Groups)

The result of differences in body composition between the initial and final measuring of the experimental group (Graph 4; Table 36) confirmed the significant impact of the ten-week experimental treatment on improving results across all monitored body composition variables. The experimental ball Pilates program significantly influenced the increase in absolute values of skeletal muscle mass ($p < .05$) and the decrease in absolute ($p <.05$) and relative values ($p < .05$) of body fat mass. Partial eta squared coefficients indicated moderate effects of the applied experimental program on adaptations in all monitored variables of body composition.

In contrast to slightly elevated values of body fat mass, the average values of the skeletal muscle mass of the participants of both groups at the final measurement were within the reference values for age and gender, according to McCarthy, Samani-Radia, Jebb, and Prentice (2014). It should be noted that skeletal muscle mass values increase physiologically not only due to the training process but also to a lesser extent with increases in body weight (Forbes, 2009; McCarthy et al., 2013).

From a health aspect, the ratio of fat to lean body mass is particularly important, considering that increased values of body fat mass represent a risk factor because they are highly correlated with certain cardiovascular diseases (Heyward & Wagner, 2004; Wang et al., 1995; Yasumura et al., 2000).

Alongside the reduction in body fat mass and changes in the height and weight of the participants, decreased values of body mass index (BMI) were also recorded at the final measurement, which were lower in the experimental group ($BMI_f^{(kg/m2)}$ = 20.68) compared to the control group ($BMI_f^{(kg/m2)}$ = 21.06). By comparing the average BMI values of participants in the experimental and control groups with reference values for female students aged 15 (16.4-23.5 kg/m^2) and 16 (16.9-24.1 kg/m^2), it was determined that both groups of participants were normally nourished at the final measurement, but with lower BMI values compared to the initial measurement.



Graph 4. Differences between initial and final measurement in body composition of the experimental group

According to Fitnessgram body composition standards for females defined by Aeurs and Serisccany (2011), the percentage of body fat in 15-year-old girls should not exceed 29.1%. According to their criteria, the average percentage values of body fat in the experimental group at the final measurement fell within the category of healthy individuals, while a slightly higher percentage of body fat than recommended standards was observed in the control group. However, according to Egger, Champion, and Bolton (1999), the percentage of body fat in both groups of participants at the final measurement was elevated (greater than 27%), although negligibly so in the experimental group.

A lower percentage of body fat than in this study was recorded at the final measurement among male students in the study conducted by Yaprak (2018), as well as in studies involving physically active students (Anant & Venugopalb, 2021; Ружић, 2020), adolescent swimmers (Bayrakdar et al., 2019), and volleyball players (Srinivasulu & Amudhan, 2018). In these mentioned studies, a lower percentage of body fat was expected because they involved athletes who generally have lower body fat percentages compared to non-athletes.

According to Zdravković, Milenković, Mitrović, Živanović, and Vuković (2011), the body fat content in children and adolescents predominantly depends on chronological age, gender, fitness level, stage of puberty, and ethnic origin. The so-called "adiposity rebound" begins around the end of the fifth and beginning of the sixth year of life and continues until adolescence, during which girls, due to the influence of female hormones, have a significantly higher percentage of body fat compared to boys (Zdravković et al., 2011).

The obtained results are consistent with the findings of numerous other studies that have confirmed the effectiveness of Pilates ball training in increasing lean body mass (Anant & Venugopal, 2021; Buttichak et al., 2019; Lim, 2019; Raj & Pramod, 2012; Ружић, 2020) and reducing body fat mass (Buttichak et al., 2019; Cakmakçi, 2011; Lee et al., 2016; Lim, 2019; Prakash et al., 2021; Raj & Pramod, 2012; Ружић, 2020; Srinivasulu & Amudhan, 2018; Welling & Nitsure, 2015; Wrotniak et al., 2001; Yaprak & Küçükkubas, 2020).

Results from some studies indicate that significant adaptations in reducing body fat mass can be achieved in a shorter period compared to this study, specifically during a six-week period (Vispute et al., 2011) and an eight-week training period (Anant & Venugopalb, 2021; Lee et al. 2016). It should be noted that in the study by Vispute et al. (2011), participants were on an isocaloric diet regimen that contributed to reducing body fat, which was not the case in this study. Additionally, in both the aforementioned study and the eight-week study by Anant and Venugopalb (2021), training sessions were conducted with a significantly higher weekly frequency than in this study (five times per week), which contributed to the observed effects in a relatively short time period.

In studies conducted by Lee et al. (2016) and Srinivasulu and Amudhan (2018), participants underwent not only Pilates on the ball but also aerobic training, which is assumed to have significantly contributed to reducing body fat. In addition to aerobic training and Pilates on the ball, participants in the mentioned studies also performed plyometric exercises during training sessions, resulting in a three-fold greater percentage reduction in body fat compared to this study. Specifically, young volleyball players in their study reduced body fat percentage by as much as 25.98% after 12 weeks of training sessions three times a week for 60 minutes, in contrast to this study where reductions in body fat mass amounted to 8.30%.

It is evident that the significantly higher training volume in their study compared to the training volume in this study contributed to the observed results. Additionally, all those additional predominantly aerobic activities greatly contributed to reducing body fat among the participants in their study. Furthermore, unlike the participants in this study, their studies involved athletes who generally have a significantly higher percentage of lean mass compared to body fat mass. Therefore, the higher percentage of muscle mass, which actively burns calories, contributed to more effective reduction in body fat mass.

In the eight-week study conducted by Cakmakçi (2011), overweight participants reduced their body fat by 6.70% (at the initial measurement 35.65± 3.31%; at the final measurement 33.26 ± 3.08%), indicating a similar dynamic of fat loss as observed in this study, where participants in the experimental group reduced their body fat by 8.30% over a period of ten weeks. Significant effects in the adaptation of body fat mass were also found in the study conducted by Prakash et al. (2021). In the aforementioned study, participants of the experimental group performed Pilates ball program, while participants of the control group performed aerobic training. In contrast to the results of this study, in their study the control group also statistically significantly reduced abdominal fat at the final measurement. It was expected, given that they performed aerobic activities with a higher frequency of training sessions and during a longer training period (12 weeks) than in this research.

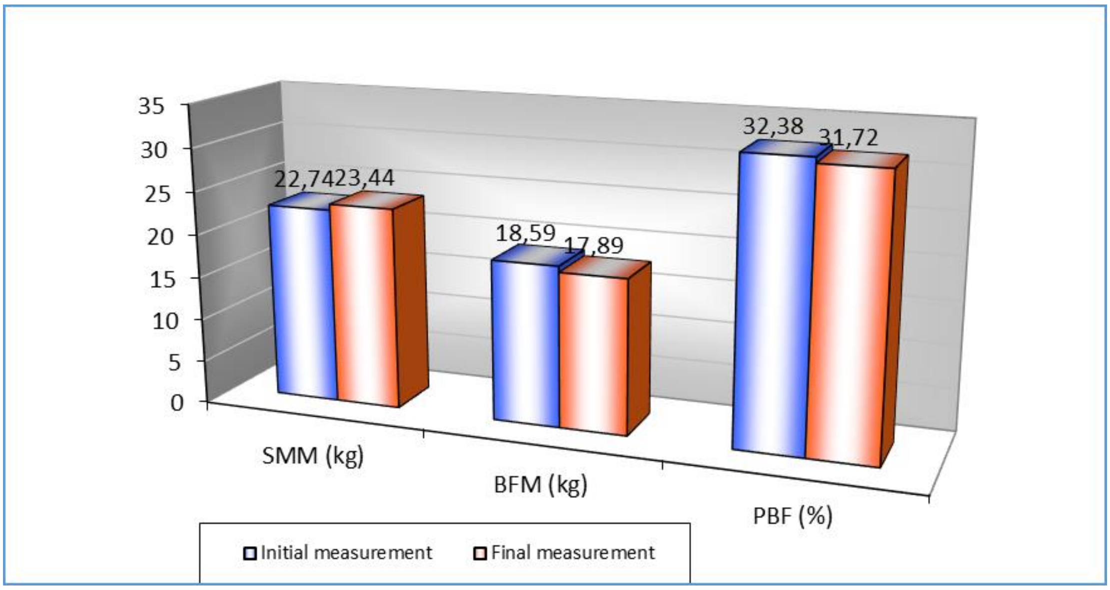
Although warm-up exercises and dynamic exercises on the Pilates ball performed at low to moderate intensity zone predominantly contributed to reducing body fat mass, it is undeniable that plank exercises performed at higher intensity also contributed to the observed effects. It is known that performing plank exercises is associated not only with an increase in muscle mass (Akuthota, Ferreiro, Moore, & Fredericson, 2008; Behm, Drinkwater, Willardson, Cowley, & Canadian Society for Exercise Physiology, 2010) but also with a tendency to reduce the fat component of body composition (Park & Park, 2019; Park, Lee, Heo, & Jee, 2021). Specifically, performing plank exercises is characterized by high calorie expenditure for energy production, utilizing carbohydrate reserves initially and accelerating fatty acid oxidation in later stages of training.

However, it is evident that Pilates on the ball does not represent a specific training stimulus for increasing skeletal muscle mass. Significant increases in lean body mass would certainly be achieved more effectively through exercises using weights on stable surfaces, especially when combined with plyometric exercises that can also increase bone density.

Contrary to the results of this study, Bayrakdar, Demirhan, and Zorba (2019), who conducted an eight-week Pilates training on a sample of adolescent swimmers, despite having more frequent training sessions than in this study, did not find a significant reduction in body fat. The reason for this could be the short duration of training sessions in their study, which lasted only 20 minutes, whereas according to Olson, Dengel, Leon, & Schmitz (2007), the minimum duration of fat-burning exercises should not be less than 30 minutes.

Similar to the results of the study conducted by Bayrakdar et al. (2019), Yaprak (2018) also did not find a significant reduction in body fat among student-aged participants after eight weeks of Pilates ball training. Furthermore, only numerical, not statistically significant reductions in body fat were also noted among recreationally active women in the study by Aksen-Cengizhan et al. (2018) and non-athlete students in the study by Vispute et al. (2011), following six weeks of Pilates ball training with a frequency of three training sessions per week. Although adaptations in body composition depend on numerous endogenous and exogenous factors, the inefficiency of the applied programs in the aforementioned studies can generally be attributed to inadequate adherence to FITT guidelines in the training process or their mismatch with the initial fitness levels of the participants.

In the participants of the control group (Graph 5; Table 42), numerical but not statistically significant improvements ($p > 05$) and small effects were observed in increasing absolute skeletal muscle mass values ($\eta^2p = .232$) and reducing absolute ($\eta^2p = .235$) and relative ($\eta^2p = .228$) body fat values. The implemented program contents, exercise frequency, duration, and intensity did not provide adequate training stimuli to induce significant changes in body composition. The identified small effects can be attributed to changes in body composition that occurred alongside improvements in muscular fitness, despite these effects being small in all muscle parameters.



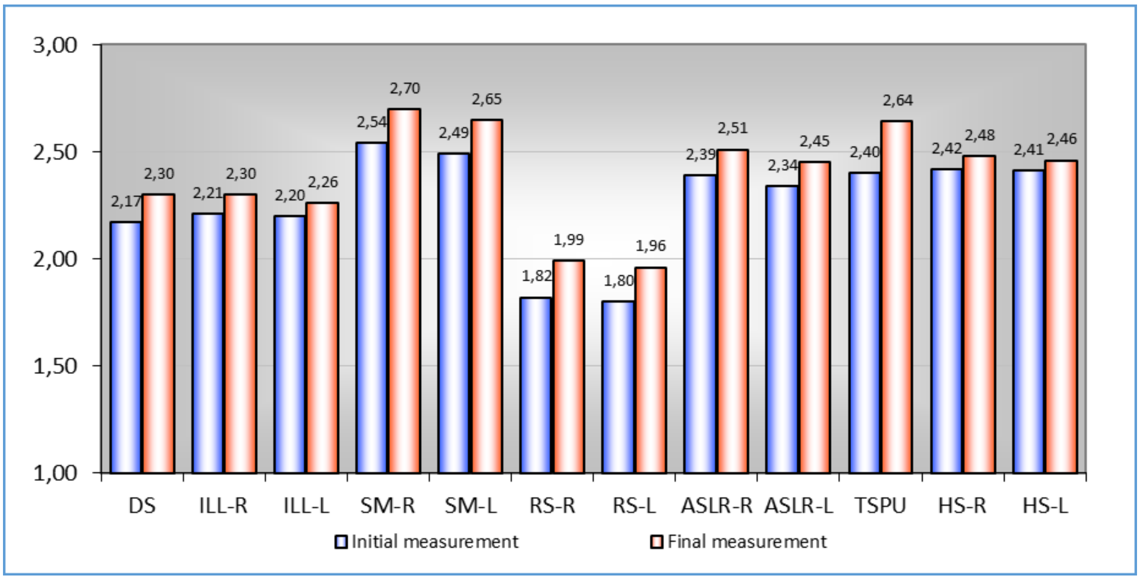
Graph 5. Differences between the initial and final measurements in body composition of the control group

8.5 Changes in Functional Mobility: Initial vs. Final Measurements (Experimental and Control Groups)

The results of the univariate differences between initial and final measurements of functional mobility in the experimental group (Graph 6; Table 38) demonstrated significant effectiveness of the applied experimental treatment in improving outcomes in those functional mobility tests that heavily rely on stability and mobility of the central body region. Among the seven FMS tests, five of which are bilateral, statistically significant improvements were found in the Trunk Stability Push-Up, Rotatory Stability - right side, Rotatory Stability - left side, Shoulder Mobility - right side, and Shoulder Mobility - left side tests.

According to Coolican (2009), the observed effects in the Trunk Stability Push-Up test were at the threshold between moderate and large effects (r = .41). Additionally, moderate effects were identified in the bilateral tests for Shoulder Mobility - right side (r = .31), Shoulder Mobility - left side (r = .29), Rotational Stability - right side (r = .36) and Rotational Stability - left side (r = .35).

In the In-Line Lunge, Deep Squat, Active Straight Leg Raise, and Hurdle Step tests, the determined improvements were only at the numerical level (p > .05), and the determined effects were small.



Graph 6. Differences between the initial and final measurement of the functional mobility of the experimental group

Dynamic and static stretching exercises, along with dynamic exercises in the main phase of training, contributed significantly to improving functional mobility. Since many functional movements involve transferring force from the body's center to the upper or lower extremities, enhancing the stability and flexibility of trunk stabilizers also improved results in tests like Trunk Stability Push-Up and Rotatory Stability, albeit to a lesser extent. Specifically, the successful execution of the Rotatory Stability test depends on asymmetric trunk stability in the sagittal and transverse planes during movements involving the upper and lower extremities (Cook at al, 2014b). The experimental program included exercises aimed at enhancing both mobility and central stability, which notably improved trunk stability in push-up and rotatory stability among participants in the experimental group.

The results in the bilateral Shoulder Mobility test were improved through exercises from the program content, as well as through the transfer of force impulses from the body centre to the upper extremities. This test requires shoulder mobility involving combinations of movements such as abduction/external rotation, flexion/extension, adduction/internal rotation, and adequate mobility of the scapula and thoracic spine (Cook at al, 2014b; Kraus, Schütz, Taylor & Doyscher, 2014; Teyhen et al., 2012).

Significant training effects were not observed in the Active Straight Leg Raise test because the applied experimental program did not include specific exercises to improve the flexibility of the posterior chain muscles of the thighs, but rather focused generally on strengthening and stretching the muscles of the central body region. Furthermore, specific exercises that could significantly improve bilateral, symmetric functional mobility and stability of the hips, knees, and ankle joints were not applied. Therefore, no significant training effects were found in the In-Line Lunge, Hurdle Step, and Deep Squat tests.

Due to significantly different training concepts in studies where participants performed other exercises in addition to Pilates on a ball, comparing the obtained results with the results of this research can can hardly be objective.

Skotnicka et al. (2017) included not only stabilization endurance exercises on a Pilates ball but also corrective exercises to improve functional mobility on the ground in young female dancers. Moreover, the participants were students from the Faculty of Physical Education engaged in recreational dancing, which suggests a variety of activities the participants undertook during the experimental period, likely contributing significantly to the observed effects.

Despite the numerous applied training stimuli, significant effects in the mentioned study, as well as in the study conducted by Dinc et al. (2017), who combined exercises on a Pilates ball and a foam roller during training sessions, were observed only in four out of seven tests of functional mobility.

Bagherian et al. (2018) conducted a study with student athletes, incorporating not only training on a Pilates ball but also typical off-season daily activities, and found significant improvements in all tests of functional mobility. Similarly, in eight-week study by Saberian-Amirkolaei et al. (2019) it was observed that teenagers who engaged in recreational badminton, and who trained with a higher volume of load compared to this research, showed improvements in all tests.

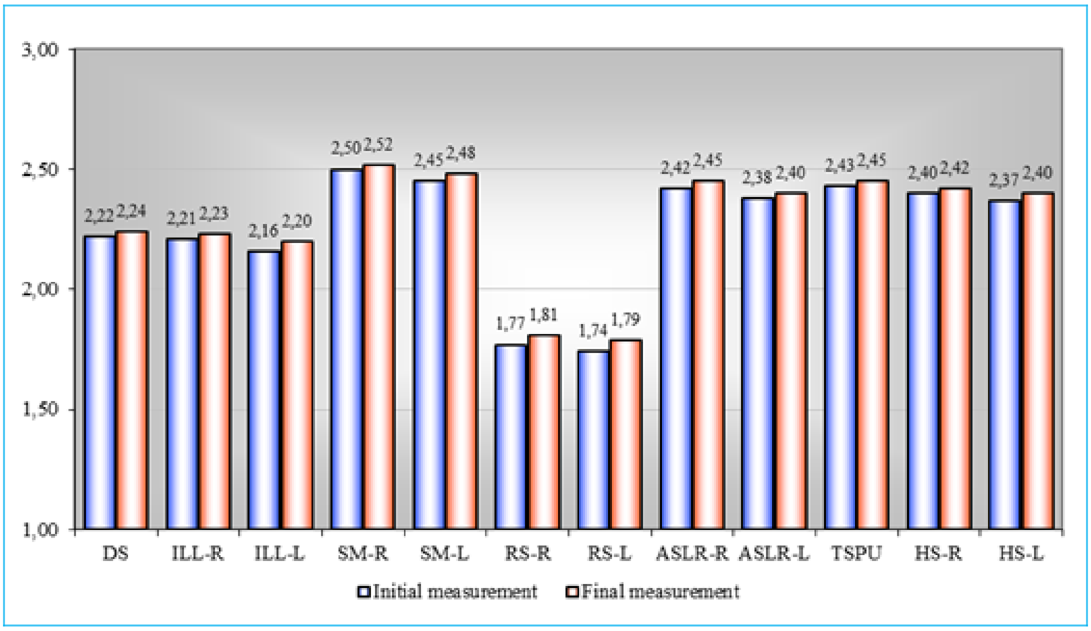
Then, Liang et al. (2018) and Šćepanović et al. (2020) performed floor Pilates in addition to ball Pilates with student-aged participants and found significant adaptations in all monitored variables. Six-week studies conducted by Lago-Fuentes et al. (2018) and Vurgun and Edis (2021) confirmed the effectiveness of stabilization endurance exercises in improving the overall FMS score, but on a sample of young athletes who also performed usual training activities in addition to the experimental program.

Therefore, in contrast to this research, in which the exclusive effectiveness of Pilates on the ball was monitored, the various additional activities that the participants in other analyzed studies carried out alongside Pilates on the ball significantly increased the load volume and contributed to the established significant adaptations.

The effects of the ball Pilates without any additional training activities were monitored in a ten-week study conducted by Baumschabel, Kiseljak, and Filipović (2015). In the aforementioned study, significant adaptations in all FMS tests were likely achieved due to a significantly higher frequency of training sessions (five times a week) than in this study.

Despite the significant improvement in the functional mobility of the central body region in the experimental group of participants, certain compensations or irregularities in the performance of movement patterns in certain tests at the final measuring indicate that the experimental program did not improve functional mobility to the expected extent.

The results of differences between the initial and final measurements for the control group (Graph 7; Table 44) showed that the standard physical education program did not have a statistically significant impact on improving the functional mobility of the control group participants.



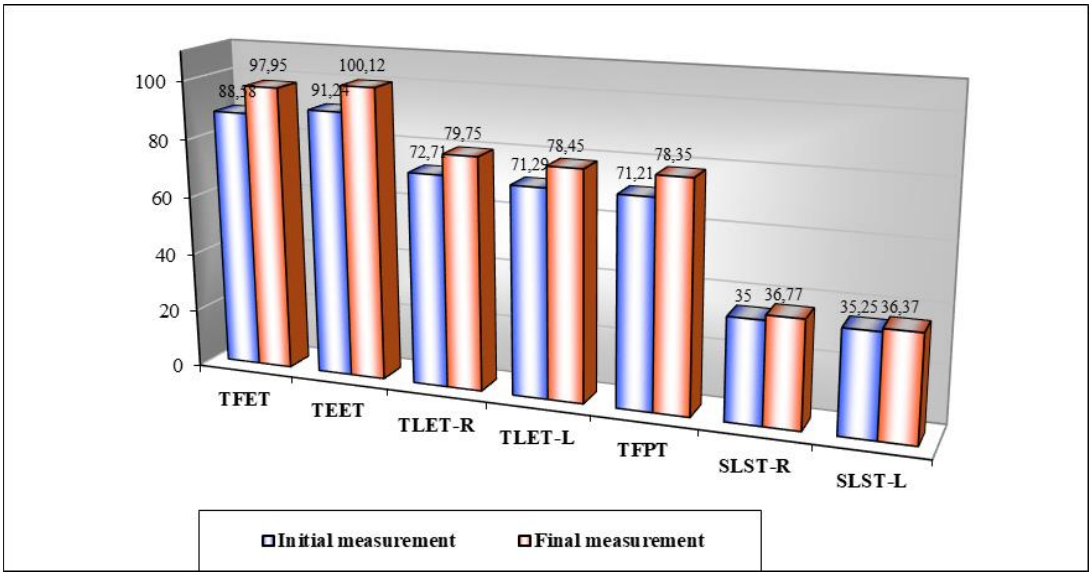
Graph 7. Differences between the initial and final measurement of the functional mobility of the control group

The minimal improvements observed indicate only numerical, rather than statistically significant differences in all tests of functional mobility. It is assumed that the slight numerical improvements observed at the final measurement are due to the experience gained in performing the tests at baseline measurement, and to a lesser extent, the contents of the standard physical education program.

According to Coolican (2009), effect size measures indicated trivial effects that were below the limit of the recommended minimum effect size (r < 0.1) in all functional mobility tests. Bearing in mind that functional mobility not only depend on the mobility of joints and soft tissues, but also on the ability of strength, balance and movement coordination (Foran, 2012), it is evident that the standard physical education program does not sufficiently contribute to their development.

8.6 Changes in Muscular Fitness: Initial vs. Final Measurements (Experimental and Control Groups)

The results of the univariate differences in muscular fitness between the initial and final measurements of the experimental group (Graph 8; Table 40) showed statistically significant improvements ($p < .01$) and large effects in the endurance tests of flexors (10.58%; $\eta^2p = .861$), extensors (9.73%; $\eta^2p = .852$), lateral muscles of the trunk on the right (9.68%; $\eta^2p = .845$) and on the left side of the body (10.04%; $\eta^2p = .870$) and in the Front Plank test (10.03%; $\eta^2p = .837$). In the bilateral Single-Leg Squat test performed with the right (5.06%; $\eta^2p = .611$) and left leg (3.18%; $\eta^2p = .632$), the determined improvements were at the $p < .05$ level of statistical significance and the measure of the effect size was medium. The training stimuli applied throughout the ten-week experimental period were adequately dosed and caused the expected neurophysiological adaptations of the muscular system.



Graph 8. Differences between the initial and final measurement of the muscular fitness of the experimental group

An effective training response of exercise on an unstable surface was expected given the concept of the training program which, in addition to dynamic exercises, also included exercises of isometric endurance of core muscles in conditions of increased postural requirements for maintaining stability during exercise on an unstable surface. This, in addition to the global stabilizers, also activated local and deep stabilizers (Carter et al., 2006). Although training in unstable conditions produces less force, Pilates ball training demands an additional load on trunk stabilizers to maintain balance in unstable conditions, which contributes to their strengthening. Isometric endurance exercises, in addition to strengthening the trunk stabilizers, significantly improved the strength of the hip stabilizers, which affects the result in the Single-Leg Squat test.

Unlike dynamic exercises, during isometric exercises such as plank and lateral plank, muscles produce force without changing muscle length. Isometric exercises increase static strength and increase depends on the number of performed muscular actions, duration of isometric muscular contractions, load intensity, angle of performing exercise and training frequency (American College of Sports Medicine, Thompson, Gordon, & Pescatello (2010).

The applied exercises to develop the endurance of the anterior, lateral, and posterior body core, as well as dynamic exercises of the trunk flexion, extension and rotation, significantly improved the functional training outcomes already in the first phase of neural adaptation. In the following developmental phase of accumulation, due to increased neural demands during performing more complex and intense exercises of lateral and rotational flexion and extension of the trunk, the participants significantly improved both muscle strength and isometric endurance of the trunk stabilizer muscles (Clark, Lucett, McGill, & Sutton, 2018). In the last phase of specialization, by carrying out structurally more complex and energetically more demanding multidimensional exercises, the strength of the trunk stabilizer muscles was increased and the dynamic stability of the core of the body was improved and to a lesser extent the strength of the hip stabilizers.

The results of this research are consistent with the results of previous studies that have shown that Pilates ball training conducted over a period of six to twelve weeks can significantly improve the endurance of trunk stabilizers (Anant & Venugopal, 2021; Carter et al., 2006; Lee et al., 2016; Marani, 2020; Nuhmani, 2021; Prieske et al., 2016; Sekendiz et al., 2010; Stanton et al., 2004; Sukalinggam et al., 2012; Yaprak, 2018). Studies conducted by Jain et al. (2019) and McCaskey (2011) indicate that similar training effects as in this research can be achieved in a significantly shorter experimental period if the program is conducted with a higher load volume, achieved by higher intensity and frequency (Jain et al., 2019) or a longer duration of the training sessions (McCaskey, 2011).

Stanton et al. (2004) conducted a six-week Pilates ball training program on a sample of 15-year-old athletes and found significant improvements in core stabilizer endurance tests ($p < 0.05$) after just 12 training sessions. Unlike this study, exercise progression in their study was achieved solely by increasing the number of sets and repetitions of exercises, rather than by increasing the intensity of the exercises. A similar progression method was observed in the twelve-week study by Sekendiz et al. (2010), which confirmed the significant effectiveness of Pilates on a ball for muscle fitness development. Participants in their study, unlike those in this research, performed only dynamic exercises on the Pilates ball and did not include isometric endurance exercises, which are thought to contribute more significantly to muscle fitness improvement.

Significant improvements in trunk flexor and extensor strength were also found in a six-week study conducted by Sukalinggam et al. (2012) on a sample of college-aged participants, applying only dynamic exercises on a Pilates ball. More significant changes were determined in female participants who had poorer results at baseline.

The training concept in the eight-week study conducted by Anant and Venugopalb (2021) on a sample of male college-aged participants was, like in this research, based on trunk stabilizer endurance exercises. However, unlike the results of this study where lateral trunk endurance increased by 9.68% on the right side and 10.04% on the left side, Anant and Venugopalb (2021) found improvements in lateral trunk endurance that were up to four times greater. Additionally, their study observed significantly larger improvements in abdominal trunk endurance, reaching as much as 71.23%. The considerably larger effects in their study can be attributed to the high weekly frequency of training sessions and the fact that the participants combined Pilates ball exercises with floor-based Pilates exercises.

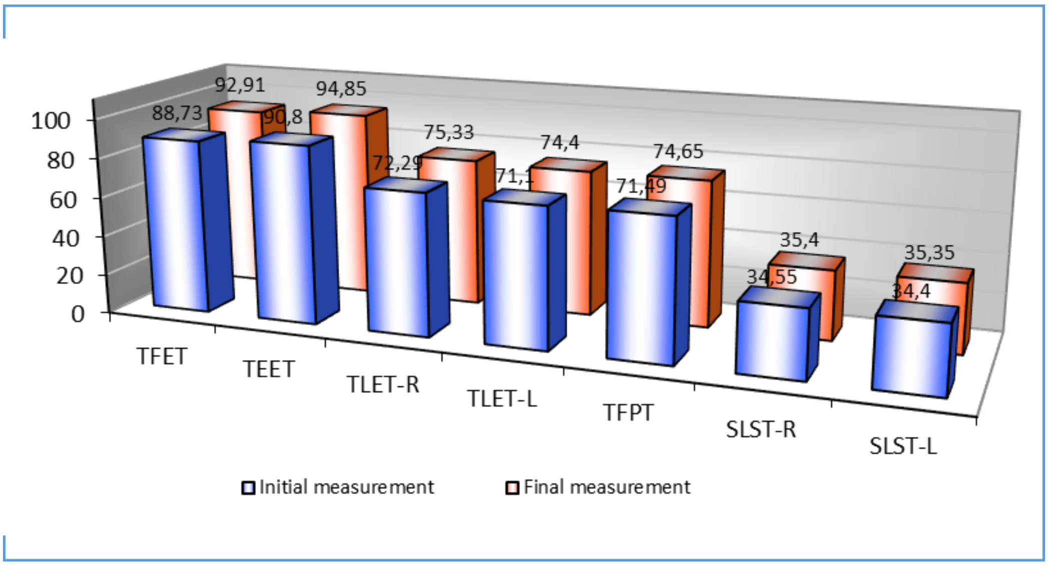
On the other hand, Cosio-Lima et al. (2003) did not determine significant improvements in muscular fitness ($p > 0.05$) after five weeks of conducting high-frequency training (five times a week) in student non-athletes, but only noticed significant improvements in EMG activity of trunk flexors and extensors. In their study, in contrast to this research, participants performed only dynamic trunk flexion and extension exercises and not plank exercises to improve the endurance of the trunk stabilizer muscles. During the first week, participants did exercises in three sets of 15 repetitions, and from the second to the fifth week, they only increased the number of repetitions (from 15 to 25 repetitions) and not the number of sets. The same exercises were applied during the entire experimental period, which was not the case in this research, in which, depending on the training phase, different training operators were applied, proving to be more effective in transforming muscular fitness.

In addition, only numerical improvements were also found in Sharman's core stability test and trunk flexor and extensor endurance tests in the four-week study conducted by

McCaskey (2011), primarily due to the very short duration of the experimental period during which the participants performed only eight training sessions.

Prieske et al. (2016) conducted a study on a sample of young football players who performed trunk stabilizer training two to three times a week over nine weeks. They found significant effects in both the group that trained on the floor and the group that trained on an unstable surface. This challenges the assertion that training on an unstable surface produces greater effects in muscular fitness adaptation.

The results of differences in muscular fitness between the initial and final measuring of the control group (Graph 9; Table 46) showed that the the realized contents of the standard physical education program caused statistically significant ($p < .05$) but small effects in all tests of muscular fitness.



Graph 9. Differences between the initial and final measurement in muscular fitness of the control group

The control group program most effectively improved the endurance of trunk flexors ($\eta^2p = .257$; 4.71%), trunk extensors ($\eta^2p = .245$; 4.46%), and trunk stabilizers assessed by the Front Plank test ($\eta^2p = .245$; 4.42%). Although small, the effects found in these tests are close to the threshold of medium effects. Small effects were also found in the tests for evaluating lateral trunk endurance on the right ($\eta^2p = .157$; 4.21%) and left side of the body ($\eta^2p = .161$; 4.64%), and in the bilateral Single-Leg Squat test performed with the right ($\eta^2p = .188$; 2.46%) and left leg ($\eta^2p = .194$; 2.76%).

Comparing the effects of the experimental and standard physical education programs, it is evident that the experimental Pilates ball program is significantly more effective than the standard physical education program in transforming muscular fitness.

Intergroup Differences in Final Measurement

After a ten-week experimental period, the effects of the applied experimental ball Pilates program were assessed both multivariately and univariately.

At the multivariate level, the effects of ball Pilates across all researched domains were evaluated using Multivariate Analysis of Variance. Since the groups of participants did not differ statistically significantly at the initial measurement in any of the researched domains, Multivariate Analysis of Covariance was not required.

At the univariate level, the effects of the experimental program on body composition and muscular fitness parameters were assessed using the t-test for independent samples. For functional mobility variables, the non-parametric Mann-Whitney U test was used. The magnitude of the effects on body composition and muscular fitness was interpreted using partial eta squared (Ferguson, 2009, 2), while effects on functional mobility were interpreted using the r-value (Fritz et al., 2011, према Coolican, 2009).

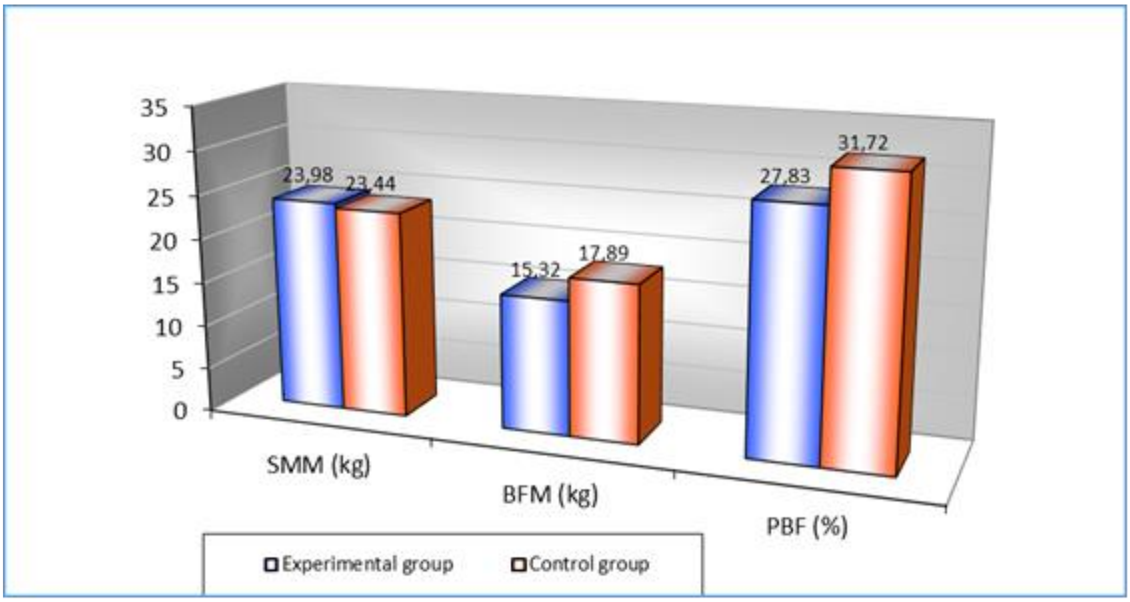
8.7 Intergroup differences in final body composition measuring

The results of the Multivariate Analysis of Variance of body composition between the experimental and control groups at the final measurement (Table 47) indicated that the groups of participants differed statistically significantly in this research domain at the end of the experimental treatment ($p < .01$). The partial squared eta coefficient suggested a medium effect of the experimental treatment on the differences between the groups at the final measurement, explaining 52.7% of the variance in the body composition results.

The results of the univariate intergroup differences in the applied variables for assessing body composition at the final measurement (Graph 10; Table 48), showed that statistically significant intergroup differences ($p < .01$) were established in absolute values of skeletal muscle mass and absolute and relative values of body fat mass. The results of the determined intergroup differences in the mean values of all body composition parameters align with the t-test results and the determined effect size coefficients.

The intergroup differences in body composition parameters at the final measurement favour better results for the participants in the experimental group. This means that, for these participants, statistically significantly higher absolute values of skeletal muscle mass ($p < .01$) and lower absolute ($p < .01$) and relative values of body fat mass were found ($p < .01$).

The magnitude of the partial eta squared coefficient indicated the medium effects of the applied experimental treatment on the differences between the groups in absolute values of skeletal muscle mass ($\eta2p = .497$), and absolute ($\eta2p =. 526$) and relative values of body fat mass ($\eta2p = .513$). The determined differences at the final measurement confirmed the superiority of the ten-week experimental ball Pilates program compared to the standard physical education program on the adaptation of both skeletal muscle mass and body fat mass.



Graph 10. Intergroup differences in final body composition measuring

The results of this research are in line with the results of the study conducted by Srinivasulu and Amudhan (2018) on a sample of participants of similar age as in this research (13-15 years), who determined significantly greater effects of the experimental compared to the control group program at the final measurement in reducing body fat. But it should be borne in mind that in their study the experimental program, in addition to exercises on a Pilates ball also included exercises on the floor as well as plyometric exercises, while the control group carried out only usual volleyball training.

The content related to volleyball, despite the recommended content, predominated in the control group in this study as well. Therefore, it can be stated that the control group's program in their study was similar to that in this research. However, the training volume in the experimental group in their study was significantly higher than in this research due to the longer duration of the experimental period and the higher frequency and longer duration of the training sessions. Thus, the significantly greater effects of the experimental program compared to the control group’s program in their study can be attributed to the greater training volume in the experimental group relative to the control group participants.

In the study conducted by Prakash et al. (2021), the experimental group participants performed Pilates on a ball in addition to their usual aerobic training, with a higher training volume than the participants in this study. In their study, these additional aerobic activities significantly contributed to the reduction of body fat by the end of the experimental period.

On the other hand, unlike the results of this study, the study conducted by Lee et al. (2016) on a sample of overnourished students found no statistically significant differences between the experimental and control groups in relative body fat values at the final measurement. Both the experimental group, which performed ball Pilates (BF% = 27.25 ± 3.73 at the initial measurement; BF% = 26.26 ± 5.76 at the final measurement; p<.05) and the control group, which performed aerobics (BF% = 27.50 ± 5.67 at the initial measurement; BF% = 25.05 ± 4.44; at the final measurement; p<.05), significantly reduced body fat mass between the two measurements. Their study confirmed similar effectiveness of ball Pilates and aerobics, but also significantly higher effectiveness of aerobic training compared to a standard physical education program in reducing body fat. However, their study found significant differences in muscle strength and endurance at the final measurement, favoring the experimental group, suggesting that participants also significantly increased their muscle mass, although this component of body composition was not monitored in their study.

In most studies, the control group was not involved in any training activities (Anant and Venugopal, 2021; Cakmakçi, 2011; Khajehlandi, 2018; Raj & Pramod, 2012; Ружић, 2020; Vispute et al., 2011; Yaprak, 2018), so significantly greater effects of the experimental program compared to the control group in the adaptation of body composition parameters at the final measurement were expected.

Inconsistencies in the results of different studies generally stem from differences in the dosing of FITT training variables and their mismatch with participants' initial fitness levels, as well as various other factors that influence body composition. Adaptations in body fat mass typically require prolonged activities in the low-to-moderate intensity zone, preferably combined with strength training and dietary changes. Additionally, variations in the degree of adaptation also depend on sleep quality, stress, hormones, and other factors not monitored in this or most other studies. For a more precise determination of the effects of ball Pilates on body composition, significantly more comprehensive studies are needed.

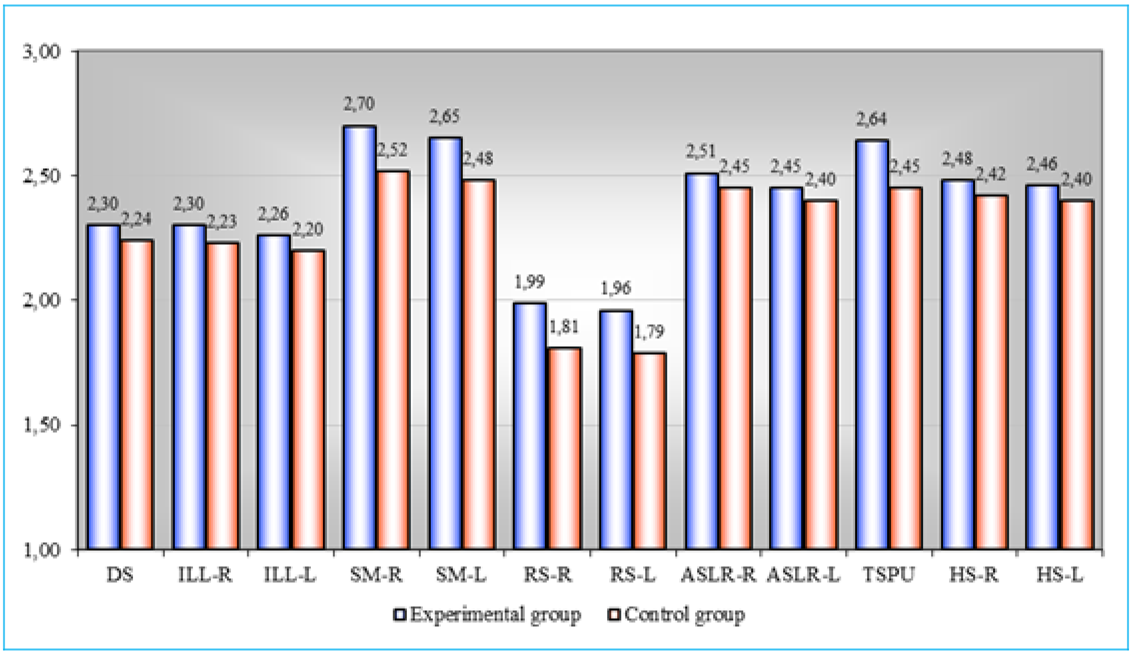
8.8 Intergroup differences in final functional mobility measuring

The results of the Multivariate Analysis of Variance of functional mobility between the experimental and control groups at the final measurement (Table 49) showed that the groups of participants differed statistically significantly ($p < .01$) in this domain at the end of the experimental period. The magnitude of the partial eta squared coefficient indicated medium effects of the applied experimental treatment on the differences between the groups at the final measurement, explaining 62.2% of the variance in functional mobility results.

Although medium, the determined value of η^2p coefficient is very close to the threshold for large effects.

An examination of the results of univariate intergroup differences in the applied variables for assessing functional mobility at the final measurement (Graph 11; Table 50), revealed statistically significant intergroup differences favouring the experimental group in tests where performance predominantly depends on core stability and shoulder girdle mobility. Specifically, significant intergroup differences and medium effects of the applied experimental treatment on group differences at the final measurement were found in the Trunk Stability Push-Up test ($p < .01$; $r = .41$), Shoulder Mobility - right side ($p < .05$; $r = .36$), Shoulder Mobility - left side ($p < .05$; $r = .35$), Rotatory Stability - right side ($p < .05$; $r = .29$) and Rotatory Stability - left side ($p < .05$; $r = .31$) tests. These effects can be attributed to the experimental program, which was specifically designed to enhance core stability and mobility, factors that heavily influence the results in functional mobility tests.

In the Deep Squat test (DS: $r = .01$) and the bilateral tests of the left ($r = .01$) and right In-Line Lunges ($r = .13$), Active Straight Leg Raise with the left ($r = .19$) and right legs ($r =.20$), and Hurdle Step with the left ($r = .01$) and right legs ($r = .01$), the intergroup differences were not statistically significant ($p > .05$), and the effects of the experimental treatment were small ($r \sim 0.1$).



Graph 11. Intergroup differences in final functional mobility measuring

These results are the consequence of slightly deficient flexibility in the hamstrings, gastrocnemius, and soleus muscles, as well as deficient bilateral mobility and stability of the hip, knee, and ankle joints, as identified during the initial measurement in the FM screening, which were not improved to the expected extent by the end of the experiment.

Overall, the results of this study confirmed the significantly greater effectiveness of the ten-week ball Pilates program compared to the standard physical education program in the transformative processes of functional mobility in young female adolescents. Given the applied training stimuli, the observed effects were as expected.

8.9 Intergroup differences in final muscular fitness measuring

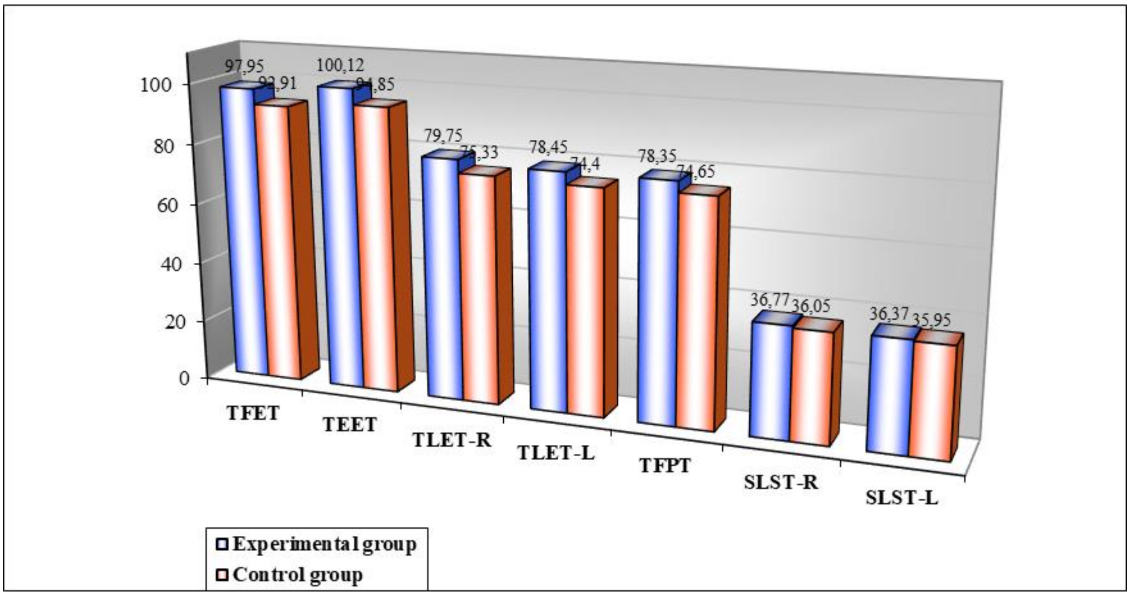
The results of the Multivariate Analysis of Variance of muscular fitness between the experimental and control groups at the final measurement (Table 51) showed that the groups of participants differed statistically significantly ($p < 0.01$) in this researched domain at the end of the experimental period. Large effects of the applied experimental treatment on the differences between the groups at the final measurement were found ($\eta^2_p = .656$), explaining 65.6% of the variance in muscular fitness results.

The results of the univariate intergroup differences in the applied variables for assessing muscular fitness at the final measurement (Graph 12; Table 52) showed statistically significant intergroup differences in the arithmetic means of all muscular fitness tests. The intergroup differences at the final measurement favoured better results in the experimental group, indicating that this group had statistically significantly higher values in all muscular fitness tests. In the trunk stabilizer endurance tests, assessed by the Front Plank and endurance tests for flexors, extensors, and lateral trunk muscles, the significance of differences was at the $p < .01$ level, while in the Single-Leg Squat test, the significance of differences was at the $p < .05$ level.

The results of intergroup differences in the mean values of all muscular fitness variables correspond with the t-test results and the established effect size coefficients.

The magnitude of the effects observed at the univariate level indicates large effects of ball Pilates on differences between groups at the final measurement in all trunk stabilizer endurance tests ($\eta^2 p \geq 0.64$), while small effects close to the threshold of medium effects were found only in the bilateral Single-Leg Squat test performed with the right ($\eta^2 p =.240$) and left legs ($\eta^2 p = .251$).

Comparing the effects of the experimental and standard physical education programs, it is evident that the experimental ball Pilates program is significantly more effective than the standard physical education program in transforming muscular fitness, particularly in trunk stabilizer muscles.



Graph 12. Intergroup differences in final muscular fitness measuring

The obtained results are a logical consequence of the implemented experimental ball Pilates program, which, unlike the standard physical education program, was specifically aimed at strengthening the central region of the body, i.e., increasing the stability and mobility of the trunk stabilizer muscles.

Significantly greater effects of the experimental program compared to the control group program in transforming muscular fitness have also been recorded in other similar studies, where the experimental group performed ball Pilates and the control group engaged in usual technical-tactical training from a specific sport (Srinivasulu & Amudhan, 2018; Stanton et al., 2004), conditioning programs (Anant & Venugopal, 2021), aerobic training (Lee et al., 2016) or daily life activities (Cakmakçi, 2011; Khajehlandi, 2018; Raj & Pramod, 2012).

9. CONCLUSION

This dissertation examined the effectiveness of the experimental Pilates ball program and a standard Physical Education program on body composition, functional mobility, and muscular fitness in female adolescents. The research encompassed 48 participants divided into an experimental and a control group, each consisting of 24 participants. The experimental group carried out the experimental Pilates ball program in physical education classes twice a week for 10 weeks, while the control group performed a standard Physical Education program over the same period and with the same class load. The sample of measuring instruments consisted of three parameters for assessing body composition, five tests for assessing muscular fitness and seven tests for assessing functional mobility.

The research was based on the assumptions defined by corresponding hypotheses and sub-hypotheses that both applied programs will significantly affect changes in all researched domains and that the ball Pilates program will have significantly greater effects than the standard physical education program in transforming all monitored variables. By checking the defined hypotheses and sub-hypotheses, answers to the research questions were obtained and the following conclusions were drawn:

The MANOVA results indicated that the experimental and control groups of participants did not differ statistically significantly in any of the researched domains at the initial measurement. Accordingly, hypothesis $\mathbf{H_1}$**,** that reads: “There are statistically significant differences in body composition, functional mobility, and muscular fitness between the experimental and control groups of participants at the initial measurement,” **is completely rejected.**

The independent samples t-test results indicated that no statistically significant intergroup differences were found in any body composition parameter at the initial measurement. Accordingly, the sub-hypothesis $\mathbf{H_{1.1}}$**,** that reads: “There are statistically significant differences in body composition between the experimental and control groups of participants at the initial measurement,” **is completely rejected.**

The results of the Mann-Whitney U test indicated that no statistically significant intergroup differences were found at the initial measurement in any functional mobility variable. Accordingly, the sub-hypothesis $\mathbf{H_{1.2}}$, that reads: “There are statistically significant differences in functional mobility between the experimental and control groups of participants at the initial measurement,” **is completely rejected.**

The independent samples t-test results indicated that no statistically significant intergroup differences were found in any muscular fitness variable at the initial measurement. Accordingly, the sub-hypothesis **$H_{1.3}$,** that reads: “There are statistically significant differences in muscular fitness between the experimental and control groups of participants at the initial measurement,” **is completely rejected.**

The results of the one-way repeated measures MANOVA indicated that statistically significant changes in all researched domains were established between the initial and final measurement of the experimental group. Accordingly, hypothesis **H_2,** that reads: "The experimental ball Pilates program will statistically significantly affect changes in body composition, functional mobility and muscular fitness of the experimental group of participants,” **is fully accepted.**

The t-test results for dependent samples indicated that statistically significant changes were found in all body composition parameters between the initial and final measurement of the experimental group. Accordingly, the sub-hypothesis **$H_{2.1}$**, that reads: “There are statistically significant changes in body composition between the initial and final measurement of the experimental group of participants,” **is fully accepted.**

The results of the Wilcoxon signed-rank test indicated that statistically significant changes were found between the initial and final measurement of the experimental group in three of seven FMS tests, i.e., five of the twelve monitored functional mobility variables. Accordingly, the sub-hypothesis **$H_{2.2}$**, that reads: “There are statistically significant changes in functional mobility between the initial and final measurement of the experimental group of participants,” **is partially accepted.**

The t-test results for dependent samples indicated that statistically significant changes were found in all muscular fitness variables between the initial and final measurement of the experimental group. Accordingly, the sub-hypothesis **$H_{2.3}$**, that reads: “There are statistically significant changes in muscular fitness between the initial and final measurement of the experimental group of participants,” **is fully accepted.**

The results of the one-way repeated measures MANOVA indicated that statistically significant changes in muscular fitness were found between the initial and final measurement of the control group, whereas the significance of changes in body composition and functional mobility was not statistically significant. Accordingly, hypothesis **H_3,** that reads: “The standard physical education program will statistically significantly affect changes in body composition, functional mobility and muscular fitness of the control group of participants,” **is partially accepted.**

The t-test results for dependent samples showed no statistically significant changes in any body composition parameter between the initial and final measurement of the control group. Accordingly, the sub-hypothesis **$H_{3.1}$**, that reads: “There are statistically significant changes in body composition between the initial and final measurement of the control group of participants,” **is completely rejected.**

The results of the Wilcoxon signed-rank test indicated that no statistically significant changes were found in any functional mobility variables between the initial and final measurement of the control group. Accordingly, the sub-hypothesis **$H_{3.2}$**, that reads: “There are statistically significant changes in functional mobility between the initial and final measurement of the control group of participants, **is completely rejected.**

The t-test results for dependent samples indicated that statistically significant changes were found in all muscular fitness tests between the initial and final measurement of the control group. Accordingly, the sub-hypothesis **$H_{3.3}$**, that reads: “There are statistically significant changes in muscular fitness between the initial and final measurement of the control group of participants,” **is fully accepted.**

The MANOVA results indicated that the experimental and control groups of participants differ statistically significantly in in all researched domains, at the final measurement. Accordingly, hypothesis **H_4,** that reads: “There are statistically significant differences in body composition, functional mobility, and muscular fitness between the experimental and control groups at the final measurement,” **is fully accepted.**

The independent samples t-test results indicated that statistically significant intergroup differences were found in all body composition parameter at the final measurement. Accordingly, the sub-hypothesis **$H_{4.1}$,** that reads: “There are statistically significant differences in body composition between the experimental and control groups of participants at the final measurement,” **is fully accepted.**

The results of the the Mann-Whitney U test indicated that statistically significant intergroup differences were found at the final measurement in three of seven FMS tests, i.e., five of the twelve monitored functional mobility variables. Accordingly, the sub-hypothesis **$H_{4.2}$**, that reads: “There are statistically significant differences in functional mobility between the experimental and control groups of participants at the final measurement,” **is partially accepted.**

The independent samples t-test results indicated that statistically significant intergroup differences were found in all muscular fitness tests at the final measurement. Accordingly, the sub-hypothesis **$H_{4.3}$,** that reads: “There are statistically significant differences in muscular fitness between the experimental and control groups of participants at the final measurement," **is fully accepted.**

Given that significant intergroup differences were found in all researched domains in favor of the experimental group at the final measurement, it can be ascertained that hypothesis $\mathbf{H_5}$, that reads: "The ten-week experimental ball Pilates program significantly transforms body composition, functional mobility, and muscular fitness of female adolescents compared to the standard physical education program," **is fully accepted**.

Given that significant intergroup differences were found in all body composition parameters in favor of the experimental group at the final measurement, it can be ascertained that hypothesis $\mathbf{H_{5.1}}$, that reads: "The ten-week experimental ball Pilates program significantly transforms body composition of female adolescents compared to the standard physical education program," **is fully accepted**.

Given that significant intergroup differences were not found in all functional mobility tests at the final measurement, it can be ascertained that hypothesis $\mathbf{H_{5.2}}$, that reads: "The ten-week experimental ball Pilates program significantly transforms functional mobility of female adolescents compared to the standard physical education program," **is partially accepted**.

Given that significant intergroup differences were found in all muscular fitness tests in favor of the experimental group at the final measurement, it can be ascertained that hypothesis $\mathbf{H_{5.3}}$, that reads: "The ten-week experimental ball Pilates program significantly transforms muscular fitness of adolescents compared to the standard physical education program," **is fully accepted**.

In general, the findings of this study confirmed the superiority of the applied Pilates ball stability and mobility exercise program over the standard physical education program in enhancing the body composition, functional mobility and muscular fitness of young adolescent girls. 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 body composition, muscular fitness and functional mobility in those tests where effectiveness is predominantly influenced by core stability and the mobility of the shoulder girdle.

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11.APPENDIX

STATEMENT OF AUTHORSHIP

I declare that the doctoral dissertation, titled:

EFFECTS OF BALL PILATES ON BODY COMPOSITION, FUNCTIONAL MOBILITY AND MUSCULAR FITNESS IN ADOLESCENTS

which was defended at the Faculty of Sport and Physical Education, University of Niš

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In Niš,

Signature of the author of the dissertation:

Ashrf Nouri M. Abohllala

CONSENT TO PARTICIPATE IN RESEARCH

Dear parents and guardians of the students of the Svetozar Marković grammar school in Niš, we invite you to give them your consent to participate in the research entitled:

"EFFECTS OF BALL PILATES ON BODY COMPOSITION, FUNCTIONAL MOBILITY AND MUSCULAR FITNESS IN ADOLESCENTS"

which will be conducted under the leadership of Nataša Branković, PhD, full professor at the Faculty of Sports and Physical Education in Niš and master professor Abohllala N. Ashrf, a doctoral student at the Faculty of Sports and Physical Education in Nis.

Description of the research

The research aims to determine the effects of the ten-week experimental ball Pilates program on female adolescents' body composition, muscle fitness, and functional mobility. The experimental program will be conducted in regular physical education teaching, lasting 45 minutes. The program will include Pilates ball exercises to strengthen the trunk stabilizer muscles. Before and after the research, the student's body composition, muscle fitness and functional mobility will be measured.

The experimental program of exercises is easily applicable and helpful, first of all from a functional aspect and then also in the fitness field. The choice of exercise is such that there is no risk of injury during exercise.

Privacy protection of participants

The research will be conducted by fundamental ethical principles, such as respect for the right to protect the privacy and identity of the students, respect for the persons involved in the experiment, voluntariness, benevolence, and harmlessness. Students can withdraw from the research anytime if the proposed program does not suit them.

Data on research operators

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E-mail: Ashlibya@yahoo.com; Ashrfly1976@gmail.com

CONSENT

I am familiar with the essential characteristics and purpose of the research entitled "Effects of ball Pilates on body composition, functional mobility and muscle fitness in adolescents."

I give my written consent to participate in the research.

Name and surname of the student: ______________________________________

Name and surname of the student's parent/guardian: ______________________________

Signature of the student's parent/guardian _____________________________

Place and datum: ______________________________________

CV: ASHRF NOURI ABOHLLALA

Contact Information: E-mail: Ashrfly1976@gmail.com

Ashrf Nouri M. Abohllala was born in 1976 in Tripoli (Libya) where he finished both elementary and high school. After having finished high school, he enrolled at the Faculty of Physical Education (teaching department) within the University of Tripoli, which he successfully completed in 1999, and earned a Bachelor's degree in Physical Education.

After having finished undergraduate studies in Physical Education, he enrolled in master studies at the Faculty of Physical Education, University of Tripoly, completed them in 2005, and earned the degree Master of Science in Physical Education. Afterward, he enrolled in Doctoral academic studies in sports sciences at the Faculty of Sport and Physical Education, University of Niš, completed them in 2020 with a GPA of 8.40, and earned the degree Doctor of Philosophy in Physical Education and Sports.

In the period from 2004 to 2008, he was a lecturer at the Higher Comprehensive Professions & Teachers Preparation Centre in Al-Azizia, the capital of the Jafara District in northwestern Libya, and later, from 2009 to 2010, he taught at the Seventh of April University in Libya.

Since 2008, he has been engaged as a senior lecturer at the Al Jabal Al Gharbi University in Libya, where he, apart from teaching experience, also gained scientific research experience by managing students' research projects.

He has published several scientific papers in journals of M33, M51, M53 and M24 categories.

He is married and has four children.