EFFECTS OF ADJUSTED PHYSICAL ACTIVITIES IN THE PREVENTION OF OSTEOPOROSIS IN THE ELDERLY

Marković Ina[1], Durlević Slavka[1], Delibašić Ivana[1], Durlević Marija[2]
[1]Faculty of Sport and Physical Education, University of Novi Sad, Serbia
[2]Faculty of Sport and Physical Education, University of Priština – Kosovska Mitrovica, Leposavić, Serbia

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***Abstract**: Today, one of the most common diseases affecting the elderly population, more frequently women than men, is osteoporosis. Osteoporosis is characterized by the loss of bone tissue and is one of the most common complications of aging. The causes of osteoporosis are numerous, including deficiencies in vitamins and minerals in the diet, hormonal imbalances, and lack of physical activity. Adapted physical activity is individually planned and tailored to the psychophysical capabilities of the person and the goals to be achieved. Therefore, the aim of this study was a systematic review of previously published research that examined the effects of adapted physical activities in the prevention of osteoporosis in the elderly. During the collection of previous research, internet search engines "Google Scholar," "PubMed," and the academic network "ResearchGate" were used. This study adopted a systematic approach using PRISMA. Adapted physical activity in youth aims to build the best possible bones, in adulthood to maintain bone mass, and in older age to prevent the loss of bone density, reduce the risk of falls, and fractures. Adapted physical activities for the elderly contribute to maintaining bone mass and improving the quality of life.*
***Key words**: effect of adapted physical activity, prevention, osteoporosis, elderly*

INTRODUCTION

The human body is predisposed to physical activity, but due to modern lifestyles, people are increasingly facing prolonged physical inactivity (Marković et al., 2023; Muchiri et al., 2018). Prolonged physical inactivity leads to a decline in the functions of organic systems, resulting in more serious health problems (Choi & Bum, 2019; Međedović et al., 2015). Health promotion and the prevention of risk factors are not reserved only for the younger population but have a significant impact and importance for the elderly (Izquierdo et al., 2021). Public health for the elderly includes a comprehensive view of promoting physical and mental health. Therefore, it is crucial for aging individuals to be aware of key risk factors, recommendations for regular check-ups, and ways to slow down and mitigate the aging process (Izquierdo et al., 2021). This can slow the aging process, prevent many diseases, and if a chronic disease exists, prevent complications (Hung et al., 2023). Older people should take responsibility for their own health to contribute to their well-being and activities in old age. Life expectancy is not determined solely by heredity but is influenced by many other factors. One fact today is that globally, life expectancy is increasing, and consequently, the number of older people is growing. The aging process inevitably brings a decline in cognitive, morphological, and motor skills and characteristics. Healthy and active aging involves a lifestyle that includes a series of physical, psychological, and social activities that positively affect the aging process (Kwan et al., 2020). Aging is defined through a series of biopsychosocial processes (Maček et al., 2016). One of the most common diseases in the elderly population is osteoporosis. The word osteoporosis is derived from the combination of the Latin words "osteo," meaning bone, and "porosis," meaning hole. Bones have an important structural role in the body as they provide mobility, support, and protection and are a storage site for essential minerals (Grazio & Balen, 2019; Međedović et al., 2015). The World Health Organization (WHO) defines osteoporosis as "a disease characterized by low bone mass and microarchitectural deterioration of bone tissue, leading to increased bone fragility and a consequent increase in fracture risk" (World Health Organization, 2010). Osteoporosis is a systemic bone disease that leads to reduced bone density and thus deteriorates bone tissue, resulting in decreased bone strength and even fractures (Međedović et al., 2015). Bone loss due to aging occurs in both women and men and is associated with dietary deficiencies, lack of physical activity, and reduced levels of certain hormones. Ning et al. (2021) indicate that after the age of 40, bone mineral density progressively decreases by about 0.5% or more per year, especially in women. Estrogen

hormones stimulate osteoblast activity, i.e., bone formation, and in women, estrogen levels decrease after menopause. Another major factor in bone loss is a lack of vitamins and minerals, especially insufficient calcium intake. After the age of 50, the risk of bone fractures due to osteoporosis increases to more than 40% in women (Rizzoli et al., 2009). Some studies show that one in twelve men over fifty is at risk of osteoporosis (Banica et al., 2020; Xu et al., 2022). Most elderly people suffer from mineral deficiencies in the bones, i.e., osteoporosis. This condition makes bones extremely porous, increasing the risk of fractures, particularly in the hips, and leading to microfractures of the vertebrae (Black et al., 2020; Haseltine et al., 2021; Mistry et al., 2019). Physical activity is one of the first crucial steps in maintaining healthy and strong bones. It, in combination with a proper diet and estrogen supplements, can prevent osteoporosis or alleviate its symptoms if it is already present (Bouvard et al., 2021). Elderly people should engage in moderate physical activity 3 to 5 times a week, while the recommended adapted physical activity for those already suffering from osteoporosis is 30 minutes daily (Bošković et al., 2013; Brooke-Wavell et al., 2022; Marini et al., 2020). Adapted physical activity is actually tailored physical activity based on the psychophysical state of each individual, aimed at achieving specific goals (Bošković et al., 2013). In addition to bone-strengthening exercises, elderly people are also recommended coordination and balance exercises to prevent falls (Dušek et al., 2012).

The aim of this study was to systematically review previously published research on the effects of adapted physical activity in the prevention of osteoporosis in the elderly.

METHODS

In this systematic review, the following methods were used: selection method; descriptive method; systematic method; analysis and synthesis method; and comparison method.

Inclusion Criteria

The following inclusion criteria were defined for the selection of papers to be included in the final analysis: (1) original scientific papers; (2) papers not older than 2002; (3) papers written in English and Serbian; (4) sample of elderly individuals with osteoporosis.

Exclusion Criteria

Papers were excluded from further analysis based on the following criteria: (1) papers older than 2002; (2) papers not written in English or Serbian; (3) inadequate sample of participants; (4) papers where results were not adequately presented for further analysis.

Search Strategy

To collect previous research, the internet search engines "Google Scholar," "ResearchGate," and "PubMed" were used. Keywords searched in Serbian, individually or in combination, were: effects, physical activity, adapted physical exercise, osteoporosis, prevention, elderly, while in English the keywords searched were: effect, physical activity, adapted physical exercise, osteoporosis, prevention, seniors.

During the initial collection phase, 53 research papers that met the basic search criteria were included based on the content of their titles. Further selection eliminated 13 papers after reading and analyzing the abstracts, leaving 34 papers that met the narrower search criteria (Figure 1).

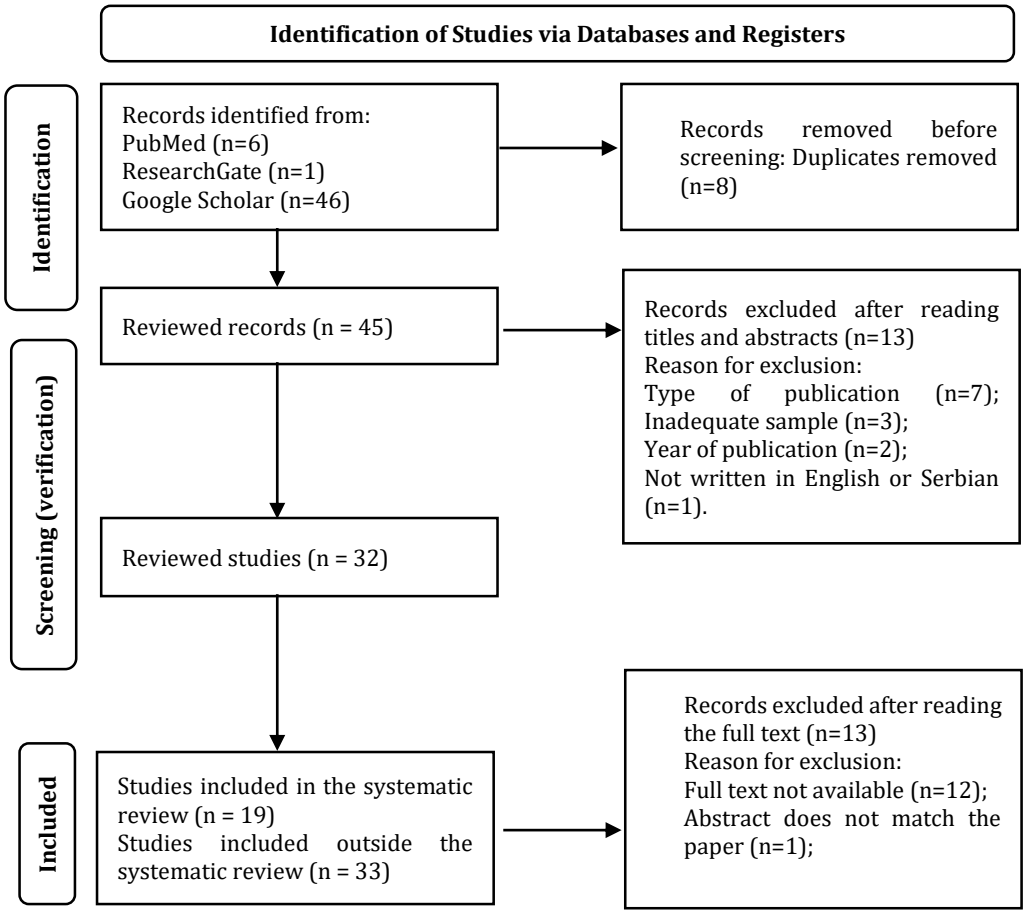

Figure 1 Schematic representation of the selection of collected studies

RESULTS

Table 1 Overview of Existing Literature

	Sample				Experimental Treatment		
Reference	**No.**	**Age**	**Gender**	**No. of Groups**	**Study Aim**	**Exercise Program, Measurement Instruments, Duration, and Frequency**	**Results and Conclusions**
Warming et al. (2002)	620	20–89	398 F, 222 M	/	The aim of the study was to assess normal bone mineral density (BMD) in the forearm, hip, and spine, and to study the concordance between changes in BMD assessed based on cross-sectional data and actual longitudinal changes.	BMD was measured twice over 2 years using dual-energy X-ray absorptiometry.	The hip and forearm are the sites with the best concordance between cross-sectional and longitudinal age-related changes in BMD.

Liu-Ambrose et al. (2004)	98	75-85	F	3	The aim of the study was to compare the effects of three types of training on osteoporosis in women.	A 25-week, single-blind, randomized controlled trial was conducted to compare the effects of resistance and agility group training on bones, measured by dual-energy X-ray absorptiometry (DXA) and peripheral quantitative computed tomography (pQCT) in older women with low bone mass.	By the end of the study, the agility training group significantly increased cortical bone density by 0.5 ± 0.2% in the tibia compared to a loss of 0.4 ± 0.3% in the stretching group. The resistance training group significantly increased cortical bone density (1.4 ± 0.6%) in the radius compared to a loss of 0.4 ± 0.5% in the agility training group.
Ryan et al. (2011)	234	70,6	M	/	The aim of the study was to investigate the prevalence of risk factors, secondary causes, and laboratory abnormalities in men with and without previously known causes of osteoporosis.	In addition to chemistry screening, 25-hydroxyvitamin D, testosterone, luteinizing hormone, follicle-stimulating hormone, thyroid-stimulating hormone, and urine calcium-to-creatinine ratio were measured.	Vitamin D deficiency and insufficiency were very common, and other common risk factors for osteoporosis included age >65 years, current smoking, and previous fracture. Half of the participants had ≥4 risk factors. Assessment identified a specific cause in about half of the men considered to have primary osteoporosis. Among men with known secondary osteoporosis, additional risk factors and secondary causes were often identified.
Muir et al. (2013)	9423	+75	F	/	The aim of the study was to determine the effect of increased regular physical activity on bone mineral density.	Participants provided information on their daily activity levels, including the amount of time spent each week engaging in physical activity of varying intensity. Multiple and linear regression analyses were used to determine the effect of increasing the amount of this regular physical activity on bone mineral density.	Gradual increases in daily physical activity had a positive effect on bone density in the hip and femoral neck ($p<0.05$). The data suggest that gradually increasing the amount of daily activity through simple, everyday tasks can help prevent the reduction in bone mineral density after menopause.

Kemmler et al. (2013)	/	+45	M F	/	The aim of the study was to assess the effectiveness of exercise in preventing fractures in older adults.		No significant heterogeneity of trial results was found. Although there is evidence that exercise reduces overall, to a lesser extent, vertebral fractures in older adults, the possibility of bias weakens our results and shows the imperative for large exercise studies with dedicated protocols focusing on fractures as the primary endpoint.
Zhu et al (2015)			M F		The aim of the study was to determine the effect of lifestyle on osteoporosis		The study found that smoking and excessive alcohol consumption negatively affect bone health and increase the risk of fractures. There is evidence indicating that adequate protein intake and higher consumption of fruits and vegetables are beneficial for bone health.
Ishimi (2015)			M F	/	The aim of the study was to assess the impact of lifestyle habits on the onset and prevention of osteoporosis.		A healthy diet, including calcium, vitamins D and K, and proteins, along with regular physical activity, helps maintain bone health and delays or prevents osteoporosis.
Halvarsson et al. (2015)	96	66 - 87	M F	3	The aim of the study was to assess the effect of a balance training program, including exercises with 2 or more tasks, on fall-related self-efficacy, fear of falling, gait performance, and balance performance, as well as physical function in older adults with osteoporosis and an increased risk of falls, and to determine whether additional physical activity would enhance the effects.	A randomized controlled trial including three groups: 2 intervention groups (training, or training + physical activity) and one control group, with a 12-week follow-up.	Both intervention groups significantly improved their fall-related self-efficacy compared to the control group and improved balance performance. Significant differences over time and between groups were found in favor of the intervention groups for dual-task walking speed (p=0.003). This balance training program, including dual and multiple tasks, improves fall-related self-efficacy, walking speed, balance performance, and physical function in older adults with osteoporosis.
Kemmler et al. (2015)	137	/	F	2	The aim of the study was to assess the effect of exercise on overall clinical incidence of fractures and bone mineral density (BMD) in older adults at risk.	Participants in the exercise group (n = 86) performed two supervised training sessions and two home training sessions per week, while the control group (n = 51) was asked to maintain their physical activity.	

Dohrn et al. (2016)	94	75,6 ± 5,4	M F	/	The aim of the study was to describe objectively measured physical activity levels and patterns among community-dwelling older adults with osteoporosis, impaired balance, and fear of falling, and to explore associations with gait, balance performance, fall-related self-efficacy, and health-related quality of life (HRQoL).	Steps per day were analyzed, dichotomized into < 5,000 or ≥ 5,000 steps/day, and time spent in various intensities of physical activity was measured. Gait was assessed using the GAITRite walkway, balance performance was assessed using the modified eight-foot up-and-go test and one-leg stance, fall-related self-efficacy was assessed using the international Falls Efficacy Scale, and HRQoL was assessed using the short form-36.	The average steps per day were 6,201 (range 991–17,156), with 40% reporting < 5,000 steps/day. Participants with < 5,000 steps/day spent more time sitting, had slower gait speed, poorer balance performance, and lower HRQoL than participants with ≥ 5,000 steps/day. None of the participants with < 5,000 steps/day met the recommended level of physical activity.
Stief et al. (2016)	41	/	F	/	The aim of the study was to identify differences in gait performance, quadriceps strength, and physical activity (PA) between fallers and non-fallers in women with osteoporosis.	Gait analysis showed that fallers walked at a slower gait speed and had shorter step lengths. Additionally, fallers demonstrated reduced ankle joint power generation.	Gait speed, step length, ankle joint power generation, and quadriceps strength can be used to differentiate between fallers and non-fallers in women with osteoporosis.
Bijelic et al. (2017)	200	/	F	2	The aim of this study was to determine whether smoking, coffee, and alcohol consumption in postmenopausal women contribute to reduced bone mass and osteoporosis, as well as to assess the impact of physical activity on bone mass.	To collect demographic data and information on risk factors for osteoporosis and patients' lifestyles, the Bone Mineral Density Questionnaire - Female Irish Association for Osteoporosis was used.	Testing the significance of differences regarding smoking showed that the examined groups differed significantly in terms of smoking (χ^2 = 24.025, p = 0.000). Regarding coffee consumption, a statistically significant difference was found between the case group and the control group (χ^2 = 0.615, p = 0.735). Univariate logistic regression analysis of our study data showed that smoking (p = 0.000) was statistically significantly associated with osteoporosis, while physical activity was a protective factor for bone mass (p = 0.036). Multivariate logistic regression results showed that smoking was an independent risk factor for osteoporosis in postmenopausal women (OR = 1.665; p = 0.006).

Holland, A. (2017)	60	17-30	M F	/	Most osteoporosis prevention education is designed for older adults, making it difficult to apply these programs to younger adults. Designing programs for young adults requires understanding their information-seeking practices so that osteoporosis knowledge can be effectively translated.	Individual interviews were conducted to explore both the sources and types of information sought when looking for information on nutrition or bone health.	Creating short, action-oriented messages designed to encourage small behavior changes, packaged with information that young adults actively seek, is more likely to result in active engagement in preventive behaviors.
Zhou et al. (2017)	175	≥ 80	M F	/	The aim of this study was to examine the prevalence of osteoporosis, falls, and fragility fractures in this population and to analyze related factors to provide a basis for standardized prevention and treatment.	A questionnaire, fall risk assessment, grip strength, and gait speed were measured, and the Timed Up and Go test (TUG) and chair rise test (CRT) were conducted.	The overall prevalence of osteoporosis was 24.6%, significantly higher in women than in men (52.5% vs. 9.6%, $P < 0.01$). Among these subjects, 62.9% had a history of falls after age 80, with a higher rate in women than in men (77% vs. 55.3%, $P < 0.01$). The overall prevalence of fragility fractures was 25.1%, higher in women than in men (45.9% vs. 14.0%, $P < 0.01$). Risk factors included falls after age 80, high FRA score, and decreased lumbar spine bone mineral density (BMD) (odds ratios (OR) = 12.195, 1.339, and 0.076, respectively, $P < 0.01$). Osteoporosis therapy was administered to only a small number of patients with fractures.
García-Gomáriz et al. (2018)	36	/	F	2	The aim of the study was to analyze the effects of endurance and high-impact training on osteoporosis prevention in postmenopausal women, with the addition of calcium and vitamin D.	The control group's training included walking at a brisk pace. The experimental group performed high-impact training specifically aimed at osteoporosis prevention.	Significant differences were found in the femoral neck (Δ Control = -0.04, Δ Experimental = 0.28). Differences were not significant in the lumbar spine (Δ Control = 0.27, Δ Experimental = 0.47). Cohen's effect size (d = 0.52) indicates moderate practical significance of the study. Power was 51%. The addition of calcium and vitamin D, combined with specifically targeted exercises, had a greater impact on the femoral neck than brisk walking.

Miko et al. (2018)	100	/	F	2	The aim was to investigate the effect of a 12-month complex balance training program on static and dynamic postural balance, aerobic capacity, and fall frequency in women with established osteoporosis.	To assess balance, the Timed Up and Go (TUG) test, Berg Balance Scale (BBS), and performance-based stabilometry platforms were used. Aerobic capacity was measured using a cycle ergometer. Fall frequency was assessed using fall diaries.	After 1 year, there was a statistically significant difference in improvements achieved in the intervention and control groups in the TUG, BBS, and performance-based stabilometry tests ($p < 0.05$). The relative risk of falls was 0.534 over 1 year ($p = 0.17$). The 12-month balance training program significantly improved postural balance and increased aerobic capacity in women with established osteoporosis.
Su et al. (2020)	263	/	/	/	The aim was to determine whether swimming affects bone mineral density (BMD) of the spine and femoral neck in postmenopausal and premenopausal patients with osteoporosis.		Research has shown that swimming can improve cardiopulmonary function, reduce blood lipid levels, and enhance the body's antioxidant capacity, as well as delay aging. Swimming can improve BMD in postmenopausal women if the swimming time is between 3 and 6 hours, especially in long-term swimmers.
Albrecht et al. (2022)	1610	65–75	M F	/	The aim of this study was to investigate adherence of older adults to lifestyle recommendations promoting bone health, depending on their osteoporosis status.	Osteoporosis self-assessment and diagnostic tools were used to classify participants according to their osteoporosis status (low risk, high risk, diagnosis).	A total of 91 women (10.6%) and 15 men (2.0%) reported an osteoporosis diagnosis, 457 women (43.2%) and 311 men (41.4%) were classified as high risk, and 311 women (36.2%) and 425 men (56.6%) as low risk. Adherence to bone health recommendations was high for calcium intake (93.3–100.0%), vitamin D intake (77.8–93.3%), and sun exposure (86.7–97.7%). Lower adherence was observed for resistance/weight-bearing exercise (36.3–54.4%), physical activity (14.3–57.7%), and alcohol consumption (40.0–72.4%).

Hoffmann et al. (2023)				2	The aim of the study was to provide positive evidence for the effects of exercise on the number of osteoporotic fractures in adults, as well as to identify important predictors of the effect of exercise on osteoporotic fractures in adults.	The primary outcome of the study was the incidence ratio (IR) for major osteoporotic fractures. Subanalyses were conducted for intensity progression (yes vs. no) during the trial and study duration (≤ 12 months vs. > 12 months).	The results provided significant evidence for the beneficial effect of exercise on major osteoporotic fractures.

DISCUSSION

Aging is a biologically natural and inevitable process in human life. The aging process withventails the decline of a number of functions of organic systems, as well as the decline of morphological, motor,vcognitive and conative abilities and characteristics. Therefore, the elderly population canvexperience certain challenges in terms of physical and mental health. In many societies todayvolder people turn more to activities that improve their quality of life, which contributes to them preserving and improving health.

Osteoporosis is a disease of the skeletal system that leads to a significant reduction in bone density, causing decreased bone strength, which most often leads to fractures. In the United States, osteoporosis causes about 1.5 million fractures annually. Among people suffering from osteoporosis, the most common fractures are of the hip, vertebrae, and wrist (Hoffmann et al., 2023; Zhou et al., 2017). As a result, research indicates that physical activity plays an important role in the treatment of individuals with osteoporosis (Castrogiovanni et al., 2016; Dohrn et al., 2016; Liu-Ambrose et al., 2004). Therefore, it is important to focus physical activity on the most sensitive parts of the skeletal system (Kerr et al., 2017). The reduction in bone mineral density occurs due to physical inactivity and reduced loading of the skeletal system. For women, the post-menopausal period is a critical risk period (García-Gomáriz et al., 2018). Menopause is associated with low levels of physical activity, which consequently leads to reduced bone stimulation, decreased muscle strength, coordination, and balance. Castrogiovanni et al. (2016) highlight physical activity as an effective preventive measure that contributes to a healthy balance and increases bone and muscle mass. They also emphasize that for patients clinically diagnosed with osteoporosis, multicomponent training that includes aerobic activity and other types of exercises, including resistance and strength exercises, is the best combination for improving bone mass and health in older adults, especially women. Benedetti et al. (2018) investigated whether aerobic exercises such as walking, stair climbing, running, and Tai Chi positively affect osteoporosis. Walking did not improve bone mass, but it was able to limit progressive loss. Identical results were obtained by Bolamet et al. (2013) in a study aimed at examining the effects of different intervention treatments on osteoporosis in men. Similarly, in men, walking did not have positive effects on osteoporosis, but resistance and strength exercises proved to be the most effective program for men with osteoporosis. They recommend including swimming and cycling as effective programs. The implementation of water exercise programs leads to adaptive changes that limit the aging process and positively affect the prevention of osteoporosis (Vizitiu & Constantinescu, 2022). Su et al. (2020) in their research highlight that swimming for menopausal women can improve bone mineral density if swimming time ranges between three and six hours per week. Halvarsson et al. (2015) and Miko et al. (2018) recommend balance training as an effective program that improves self-efficacy regarding falls in individuals with osteoporosis. The most effective interventions included, in addition to balance training, increasing bone mineral density through diet and increasing estrogen hormones (Peraza-Delgado et al., 2020). McMillan et al. (2017) emphasize in their research that any physical activity significantly affects reducing bone density loss. Bjelić et al. (2017) and Ryan et al. (2011) in their research, besides the significant effects of physical activity,

conclude that smoking is an independent risk factor for osteoporosis, especially in postmenopausal women. Additionally, Zhu & Prince (2015) add that, besides smoking, alcohol consumption is a risk factor for osteoporosis. Bone mass is influenced by various factors, including diet, smoking, alcohol intake, lack of vitamin D and vitamin K, and protein deficiency (Ishimi, 2015; Ryan et al., 2011). LPinheiro et al. (2020) emphasize that higher doses of adapted physical activity and programs that include multiple types of exercises are the most effective. The effects of physical activity on bone mineral density are greater on the lumbar spine than the hip (Muir et al., 2013; Varahra et al., 2018; Warming et al., 2002). Recommended physical activities that achieve significant results are more than 60 minutes, two to three times a week. Many studies suggest a positive correlation between long-term and planned physical activity on bone health (Albrecht et al., 2022; Hoffmann et al., 2023; Papadopoulou et al., 2021; Pinheiro et al., 2020; Stief et al., 2016).

CONCSLUSION

Changes in the skeletal system with aging are reflected in the structural changes in bones, joints, and periarticular tissue. Initially, there is a loss of bone mass, making the bones fragile. This process, known as osteoporosis, is generalized and affects the entire skeletal system, with the greatest impact on the bones of the spine and pelvis. Epidemiological data show a significant prevalence of osteoporosis in the elderly population. Osteoporosis is a major health problem, as its effects increase the risk of fractures and reduce quality of life. Hormonal imbalances and metabolic changes caused by aging contribute to the development of this disease. In conclusion, physical activity, regardless of the type of training adopted, always has a beneficial effect on patients with osteoporosis, not only on bone homeostasis but also on the entire skeletal muscle system.

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EFEKTI PRILAGOĐENIH FIZIČKIH AKTIVNOSTI U PREVENCIJI OSTEOPOROZE KOD STARIJIH OSOBA

Marković Ina, Durlević Slavka, Delibašić Ivana, Durlević Marija

***Sažetak**: Danas jedna on najčešćih bolesti koja zahvata stariju populaciju, češće žensku nego mušku, jeste osteoporoza. Osteoporoza je bolest koju karakteriše gubitak koštanog tkiva i jedna je od najčešćih komplikacija starenja. Uzroci nasanka osteoporoze su mnogobrojni, a jedni od njih su nedostaci vitamina i menerala u ishrani, hormonski disbalans i nedostatak fizičke aktivnosti. Prilagođena fizička aktivnost predstavlja fizičku aktivnost individualno isplaniranu i sastavljenju aktivnost prema psihosomatskim mogućnostima osobe i cilju koji se želi postići. Shodno tome, cilj ovog istraživanja bio je sistemski pregled prethodno objavljenih istraživanja koja su se bavila efektima prilagođenih fizičkih aktivnosti u prevenciji osteoporoze kod starijih osoba. Prilikom prikupljanja dosadašnjih istraživanja korišćeni su internet pretraživači „Google Scholar", „PubMed" i akademska mreža „ResearchGate". U ovoj studiji primenjen je sistematski pristup koji usvaja PRISMA. Prilagođena fizička aktivnost u mladom dobu ima za cilj što bolju izgradnju kostiju, u odraslom ima za cilj očuvanje koštane mase, dok kod osoba u starijoj dobi sprečeva gubitak gustine kostiju, smanjenje rizika od pada kao i rizika za nastanak preloma. Prilagođene fizičke aktivnosti kod starije populacije doprinose očuvanje koštane mase i poboljšavaju kvaliteta života.*
***Ključne reči**: efekat, prilagođene fizičke aktivnosti, prevencija, osteoporoza, starije osobe*