Effects of physical activity on the musculoskeletal system in the aging process: gerocynesiological perspective and adaptation mechanisms

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Abstract

The multidisciplinary field of gerokinesiology studies how physical exercise affects aging on a biological, psychological, and social level. Understanding the effects of aging on human physiology and creating plans to improve people's quality of life are the main goals of this area. The musculoskeletal system experiences the most notable alterations as people age. Reduced bone mineral density (osteopenia and osteoporosis), decreased muscle mass (sarcopenia), and decreased connective tissue flexibility are important markers of the physical impacts of aging. Mobility and the capacity to live independently may be negatively impacted by these changes. This article offers a thorough analysis of how aging affects the musculoskeletal system, the molecular processes that underlie these changes, and the significance of consistent exercise in the adaptation processes. By maintaining muscular strength and flexibility, physical exercise can help halt the course of diseases like osteoporosis and sarcopenia. Additionally, by fortifying bones and connective tissues, it can reduce the likelihood of falls and accidents. In addition to its medical impacts, exercise is considered an essential strategy for promoting older individuals' psychological and social well-being. According to the body of scientific research, regular exercise has the ability to improve quality of

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life, preserve functional independence, and slow down the aging process. These assessments highlight the value of gerokinesiology as a framework for encouraging and enforcing physical exercise among senior citizens. As a result, the article also provides suggestions for leading a healthy life as one ages.

Key Words: *Gerokinesiology, Physical Activity, Aging Process, Elderly Population. Inception-ResNet-V2*

Yaşlanma sürecinde kas-iskelet sistemi üzerine fiziksel aktivitenin etkileri: gerokinesiyolojik perspektif ve adaptasyon mekanizmaları

Öz

Gerokinesiyoloji, yaşlanma sürecinde fiziksel aktivitenin biyolojik, psikolojik ve sosyal boyutlardaki etkilerini inceleyen disiplinler arası bir bilim dalıdır. Bu alan, özellikle yaşlanmanın insan fizyolojisi üzerindeki etkilerini anlamaya ve bireylerin yaşam kalitesini artırmaya yönelik stratejiler geliştirmeye odaklanmaktadır. Yaşlanma sürecinde en belirgin değişiklikler kas-iskelet sistemi üzerinde görülmektedir. Kas kütlesindeki azalma (sarkopeni), kemik mineral yoğunluğunun düşmesi (osteopeni ve osteoporoz) ve bağ dokularında esnekliğin kaybolması, yaşlanmanın fiziksel etkilerinin başlıca göstergeleridir. Bu süreçler, bireylerin hareket kabiliyeti ve bağımsız yaşam becerilerini olumsuz yönde etkileyebilir. Makale, yaşlanmanın kas-iskelet sistemi üzerindeki etkilerini detaylı bir şekilde incelerken, bu etkilerin altında yatan biyolojik mekanizmaları ve düzenli fiziksel aktivitenin adaptasyon süreçlerindeki rolünü de ele almaktadır. Fiziksel aktivite, kas gücünü ve esnekliği koruyarak sarkopeni ve osteoporoz gibi durumların ilerlemesini yavaşlatabilir. Ayrıca, kemik ve bağ dokularının dayanıklılığını artırarak düşme ve yaralanma risklerini azaltabilir. Egzersiz, yalnızca biyolojik etkileriyle değil, aynı zamanda yaşlı bireylerin psikolojik ve sosyal sağlıklarını destekleyen önemli bir araç olarak da değerlendirilmiştir. Düzenli fiziksel aktivitenin yaşlanma sürecini yavaşlatma, fonksiyonel bağımsızlığı sürdürme ve bireylerin yaşam kalitesini artırmadaki potansiyeli, mevcut bilimsel literatür ışığında analiz edilmiştir. Bu değerlendirmeler, gerokinesiyolojinin yaşlı bireylerde fiziksel aktivitenin teşvik edilmesi ve uygulanması için önemli bir rehber olduğunu göstermektedir. Makale, bu bulgular doğrultusunda, yaşlılıkta

sağlıklı bir yaşamın sürdürülmesine yönelik önerilere de yer vermektedir.

Anahtar Kelimeler: *Gerokinezyoloji, Fiziksel Aktivite, Yaşlanma Süreci, Yaşlı Nüfus.*

Introduction

Similar to global trends, Turkey's old population is progressively growing. The number of people 65 and over, who are referred to as the elderly population, increased by 21.4% from 7,186,204 in 2018 to 8,722,806 in 2023, according to TUIK data (TUIK, 2023). The impacts of aging on individuals, society, and the economy have become increasingly noticeable as a result of this growth. Maintaining a decent quality of life has grown more crucial as people get older. Aging is a complicated process that affects people's social and psychological well-being in addition to their physical health. The quality of aging is greatly influenced by a number of factors, including lifestyle decisions, genetic predisposition, and environmental effects (Christensen et al., 2009). According to Jones and Rose (2005), aging is "a specialized field of study that focuses on how physical activity affects all aspects of health and well-being in the older adult population and the aging process in general." This definition emphasizes how important exercise is for encouraging good aging. A sizable segment of the population rejects the conventional "rocking chair" picture of old age in favor of an active attitude to aging. Through a variety of social and physical activities, these people aim to improve their quality of life (Chodzko-Zajko et al., 2009). Sheehan (1978), however, emphasized social biases by characterizing aging as "a process where everything goes downhill from the moment you become a spectator." Prejudices like this can have a detrimental effect on older people's self-esteem and social positions. In light of this, gerokinesiology has become a vital discipline devoted to promoting healthy aging. The multidisciplinary field of gerokinesiology studies the social, psychological, and physical aspects of aging (Rejeski & Mihalko, 2001). By examining the beneficial impacts of physical activity on older people's wellbeing, it seeks to encourage healthy aging. According to Colcombe and Kramer (2003), physical activity has a major impact on social relationships, cognitive abilities, and physical health. For example, a research conducted by Yaffe et al. (2001) discovered that frequent walking significantly improved cognitive function in older adults. Similarly, in older people who are sedentary,

aerobic activities have been associated with improved executive skills and a lower risk of dementia (Erickson et al., 2011). Numerous studies have demonstrated the advantages of physical exercise as people age. Both mental and physical health are enhanced by aerobic exercise. According to a Cochrane Foundation comprehensive review, physical activity improves older individuals' motor function, cognitive speed, and attention (Forbes et al., 2015). It is yet unknown, though, if these advantages apply only to aerobic exercise or to other types of physical activity. Individual quality of life has changed significantly as a result of the aging population, as have fields including urban planning, social policy, health, and education. Physical exercise and the necessity for certified trainers in this area have increased in Turkey due to the country's aging population (Aydoğan and Emrah, 2015). Universities are now focusing on multidisciplinary subjects like gerokinesiology as a result of this changing environment, which has led to the creation of new job prospects (Figure 1).

The purpose of this study is to investigate how gerokinesiological practices can help older people age in a healthy manner. In light of demographic shifts, it also aims to assess how physical exercise affects quality of life and offer suggestions for community-based activities.

Musculoskeletal system effects and adaptations

Slower biological processes and a decreased ability of the organism to adjust to external stimuli are two characteristics of aging (Owsley, 2011). The musculoskeletal system is significantly impacted by this process. For elderly people to preserve their independence and enhance their quality of life, the musculoskeletal system must remain functioning (Cruz-Jentoft et al., 2019). Both muscle mass and strength significantly decline with aging. Muscle atrophy, loss of motor units, reduced muscle protein synthesis, and decreased production of anabolic hormones (such as growth hormone and testosterone) are all symptoms of this illness, which is known as "sarcopenia" (Mitchell et al., 2012). Additionally, aging is frequently associated with changes in muscle fiber width and the loss of type II fast muscle fibers (Lexell, 1995). Furthermore, bone mineral density declines with age, with postmenopausal women seeing a more noticeable decline (Johnell & Kanis, 2006). In older people, sarcopenia is a major cause of frailty and a decline in quality of life. However, by promoting muscle protein synthesis, resistance exercise can halt or reduce this process. Activating mechanotransduction pathways, especially the mTOR (mammalian target

of rapamycin) signaling pathway, can stimulate the production of muscle proteins (Goodman CA, 2019). It has been demonstrated that resistance training (PRT) is a progressive strategy that involves a steady increase in exercise load or intensity. An eight-week PRT program raised thigh muscular cross-sectional area by 11.4% in fragile old persons, according to a research by Fiatarone et al. (1994), demonstrating its efficiency in preventing sarcopenia. Given the impacts of aging on the musculoskeletal system, it is evident that resistance training is essential for preserving muscle mass and enhancing the quality of life for senior citizens. Loss of bone raises the risk of fracture and causes osteoporosis or osteopenia. The interaction between osteoclast and osteoblast activity determines the equilibrium of bone metabolism. Age-related increases in osteoclast activity and decreases in osteoblast activity upset this equilibrium (Raisz, 2005). Furthermore, as people age, their tendons and ligaments lose their flexibility, their joints' cartilage degrades, and their production of synovial fluid declines (Loeser, 2010). All of these modifications might result in range-of-motion restrictions and make people more vulnerable to joint conditions like osteoarthritis. Regular exercise and physical activity, however, can reduce and even reverse these adaptations in spite of these musculoskeletal system modifications. Resistance training enhances neuromuscular function and encourages muscle development. Elderly people can gain more muscular strength through increased protein synthesis and the reactivation of latent motor units (Frontera et al., 1988). High-impact activities and weight-bearing workouts support osteoblast activity and bone mineral density maintenance. Specifically, mechanical stress reinforces the bone matrix and is essential for bone remodeling (Kohrt et al.2004). Stretching and low-impact aerobic activities (like swimming and walking) preserve range of motion by making connective tissues more elastic. Additionally, it promotes the generation of synovial fluid, which benefits joint health (Chighizola et al., 2014). In summary, older adults who engage in physical exercise had better musculoskeletal adaptations and overall health (Figure 1).

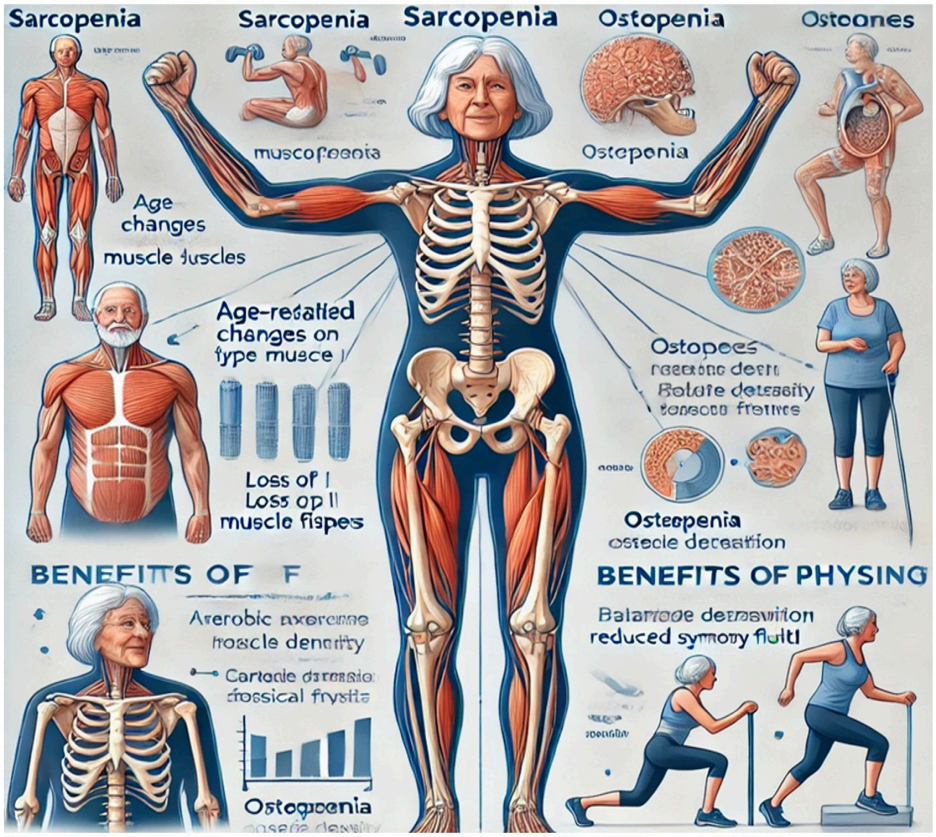

Figure 1. *The advantages of physical exercise and the impact of aging on the musculoskeletal system are depicted in this image, which illustrates age-related changes and the processes that counteract them through exercise. This visual was created using the DALL-E 3 software, a powerful tool for generating images based on detailed text descriptions.*

Aerobic, resistance, and balance exercises and their ımpact on physical, cognitive, and social functions in the aging process

Natural physiological changes that accompany them may have an impact on social, cognitive, and physical functioning. Nonetheless, via focused treatments, older persons without cognitive impairment represent a group with substantial potential to preserve and even enhance their functional performance (Colcombe & Kramer, 2003). According to recent studies, physical activity and organized exercise are crucial for enhancing this population's cognitive and physical performance (Erickson et al., 2011). Similarly, exercise is a powerful defense against the physiological changes

that come with age. The cardiovascular, musculoskeletal, and neurological systems all benefit greatly from well designed exercise programs for the elderly (Nelson et al., 2007). Combining various forms of physical activity provides a more efficient way to manage the complex impacts of aging (Sherrington et al., 2017). Aerobic Workouts: A crucial strategy for boosting cardiovascular endurance and promoting metabolic health is aerobic exercise. By improving the heart, lungs, and vascular system's efficiency, moderate to high-intensity aerobic exercises lower the cardiovascular risks linked to aging (Hagberg et al., 1985). Studies consistently demonstrate that aerobic exercise increases VO_2 max, a crucial measure of cardiovascular efficiency (Hagberg et al., 1985). Age-related declines in cardiac output, lung function, and muscle oxidative capability cause VO_2 max to naturally decline. Regular aerobic exercise, on the other hand, slows this loss by enhancing the efficiency of oxygen use in skeletal muscles and raising stroke volume, or the volume of blood the heart pumps out each beat (Figure 2). Regular aerobic exercise for six months has been demonstrated to raise VO_2 max levels by 10-15% (Hagberg et al., 1985). Reduced vascular elasticity with age is frequently linked to increased arterial stiffness and high blood pressure (Tanaka et al., 2000). By enhancing endothelial function-the capacity of blood vessels to expand in response to increased blood flow-regular aerobic exercise mitigates these effects. Increased synthesis of the vasodilator molecule nitric oxide mediates this effect (Green et al., 2004). According to studies, aerobic exercise lowers pulse wave velocity and raises arterial compliance, two markers of better vascular health (Tanaka et al., 2000). Furthermore, it has been shown that aerobic exercise considerably reduces hypertension patients' systolic and diastolic blood pressure (Cornelissen & Smart, 2013). Aerobic exercise programs lasting at least four weeks decreased the risk of heart disease and stroke by reducing systolic blood pressure by an average of 4-6 mmHg, according to a meta-analysis by Cornelissen and Smart (2013). Aerobic exercise improves psychological health and functional ability in addition to cardiovascular health. According to Nelson et al. (2007), increased endurance makes it easier for senior citizens to carry out everyday tasks, encouraging independence and lowering reliance on caregivers. Additionally, aerobic exercise's production of endorphins is associated with a decrease in anxiety and depressive symptoms, which enhances quality of life (Reiner et al., 2013). Furthermore, aerobic exercise is essential for preserving and enhancing cardiovascular health in the elderly. In addition to promoting physical health, it lowers the risk of

chronic illness by addressing age-related reductions in VO_2 max, vascular flexibility, and blood pressure management. Low-intensity aerobic exercises, on the other hand, have been shown to raise HDL cholesterol and decrease LDL cholesterol. According to Nelson et al. (2007), aerobic workouts improve cardiovascular endurance, which in turn enhances total functional ability. According to Reiner et al. (2013), it has psychological advantages and lessens disorders like anxiety and sadness. Regular exercise offers an efficient defense mechanism against the major structural and functional changes that the aging process brings about in the musculoskeletal system. Additionally, by improving insulin sensitivity, aerobic exercise lowers the incidence of type 2 diabetes. Church et al. (2007) shown that aerobic exercise lowers visceral fat levels and enhances glycaemic management in elderly people. Another type of exercise that is essential for boosting bone health, preventing sarcopenia, and building muscle strength in older persons is resistance training. By encouraging the synthesis of muscle proteins, progressive resistance training helps to prevent the loss of muscle mass (Fiatarone et al., 1994). Once more, resistance training increases muscle mass, which lessens the symptoms of sarcopenia. According to Fiatarone et al. (1994), senior citizens' muscular strength rose by 174% after 10 weeks of high-intensity resistance training. Osteoporosis risk is decreased by resistance training that increases bone density. By increasing osteoblast activity, mechanical stress encourages bone mineralization (Kohrt, et al., 2004). As people age, their bone mineral density declines, increasing their risk of osteoporosis and fracture. Resistance exercise enhances bone density, encourages bone remodeling, and activates osteoblasts. According to a comprehensive study by Wolff et al. (1999), older individuals' bone mineral density is considerably increased by resistance workouts, particularly those that involve weight-bearing activities. These adaptations lower the incidence of fractures and are especially noticeable in weight-bearing regions like the wrists, hips, and spine. By enlarging individual muscle fibers, especially type II fibers, which are disproportionately impacted by aging, resistance exercise results in muscular hypertrophy. By enlarging individual muscle fibers, especially type II fibers, which are disproportionately impacted by aging, resistance exercise results in muscular hypertrophy. Training increases the recruitment and firing rates of motor units, which enhances muscle efficiency and coordination. By inducing the release of anabolic hormones including growth hormone (GH) and insulin-like growth factor-1 (IGF-1), resistance

training aids in muscle development and repair. Peterson et al. (2010) conducted a meta-analysis to investigate how resistance training affected older individuals' muscular strength and functional outcomes. According to the data, resistance training increased upper limb strength by 25% and lower limb strength by 30%. Mobility, balance, and general quality of life all significantly improved as a result of these advances. Additionally, resistance training has been shown to be beneficial at different intensities, with progressive programs yielding the most notable outcomes. For older individuals, resistance exercise is crucial for preserving and enhancing physical attributes including muscle mass, functional strength, and balance. Peterson et al. (2010) conducted a meta-analysis to investigate how resistance training affected older individuals' muscular strength and functional outcomes. According to the data, resistance training increased upper limb strength by 25% and lower limb strength by 30%. Mobility, balance, and general quality of life all significantly improved as a result of these advances. Additionally, resistance training has been shown to be beneficial at different intensities, with progressive programs yielding the most notable outcomes. For older individuals, resistance exercise is crucial for preserving and enhancing physical attributes including muscle mass, functional strength, and balance. Resistance training should be done at least two to three times a week for older persons, according to the American College of Sports Medicine (ACSM). The ideal range for exercise intensity is 60-80% of one repetition maximum (1RM). Beginners may benefit from lower intensities (40-50% 1RM), while more seasoned people may benefit from higher intensities (70-85% 1RM) in terms of building muscle and strength. It is advised that each workout set focus on the major muscle groups and range from 8 to 12 repetitions. When choosing exercises, a mix of isolation and multi-joint exercises should be employed. Multi-joint workouts improve coordination and strength by simultaneously working many muscle groups. Exercises that are suggested include: strengthens the lower body, which facilitates everyday tasks like sitting up and walking. Enhances dynamic balance and lessens unilateral movement asymmetry. Improves leg and waist strength, which aids in postural control. Smaller muscle group isolation exercises, such as triceps extension, biceps curls, and calf raises, can also be utilized in rehabilitation procedures and be useful in boosting muscular endurance. Resistance training must be planned using the progressive overload concept in order to be successful. This idea entails progressively raising the resistance, repeat count, or

intensity. For instance, a 5-10% weight increase spread out over a few weeks promotes muscle tissue adaptability and avoids plateaus. For older adults, gradual loading reduces muscle fatigue and guarantees a sustainable exercise regimen. Elderly people are less likely to have injuries while resistance training if they take safety precautions. Prior to activity, dynamic stretching and mild aerobic exercises raise muscle temperature and lower the chance of injury. Following exercise, static stretching aids in muscle healing. Exercise form is essential for avoiding injury to the muscles and joints. When learning workout motions, both verbal and visual assistance are crucial. Resistance training requires close supervision from a qualified teacher, particularly for novices or those with medical conditions. Numerous issues related to aging are addressed by resistance exercise. It is a successful strategy for combating sarcopenia. It makes it easier to carry out everyday tasks. Helps people live independently by lowering their risk of falling. Makes bones healthier and lowers the chance of osteoporosis. Resistance training should be combined with other therapies, such aerobic exercise and food optimization, in future research. Particularly for older people, more information is required about the long-term impacts of varying exercise intensities and the planning of specific programs (Nelson et al., 2007). Designing programs to enhance older folks' physical health and quality of life requires a comprehensive approach. Daily tasks like standing and sitting may be completed more readily when the muscles in the lower body are strengthened. It was demonstrated by Liu & Latham (2004) that resistance training improves functional independence. In order to combat sarcopenia, the age-related loss of muscular mass and strength, strength and resistance training are crucial elements of physical fitness for older persons (Cruz-Jentoft et al., 2019). Major muscle groups are the focus of resistance training, which enhances muscle strength, balance, and coordination-all of which are critical for lowering the risk of falls and preserving independence in senior citizens. The physiological mechanics of resistance training in older adults are explained in this section. Exercises for flexibility and balance, which are crucial for older people, are frequently utilized to improve mobility and lower the risk of falls. Activities like yoga and tai chi, in example, have been shown to improve mental health in addition to physical balance (Wolf et al., 1996). By enhancing postural control, tai chi has been demonstrated to lower the risk of falls in older adults by 47% (Wolf et al., 1996). Controlled movement transitions that improve neuromuscular coordination are linked to these benefits. In elderly

people, yoga increases muscular flexibility, which enhances joint range of motion. According to Greendale et al. (2012), people who practiced yoga showed a considerable increase in their mobility and functional flexibility. In order to reduce falls, one of the main causes of injury and mortality among older persons, resistance training enhances neuromuscular coordination and postural control (Liu & Latham, 2009). Balance and stability are enhanced by strengthening the lower limbs, particularly the calf, hamstring, and quadriceps muscles. Resistance training lowers the risk of falls by enhancing proprioceptive feedback and dynamic stability, according to research by Liu and Latham (2009). Fall prevention efforts are further improved by combining weight training with balance training techniques like tandem stance or standing on one leg (Sherrington et al., 2017). By boosting self-confidence, balance and flexibility exercises help people feel less afraid of falling (Chen et al., 2023). Yoga and Tai Chi's meditation elements are beneficial for anxiety and depression (Greendale et al., 2012). By enhancing balance and coordination, it lowers the chance of falls (Sherrington et al., 2017). Gerokinesiological techniques make it possible to create exercise regimens that are tailored to the specific requirements of senior citizens. These programs have to be assessed by a multidisciplinary team and tailored to each person's physical capabilities and health. Healthy aging management enables people to lead higher-quality lives on both a physical and mental level. Combining various forms of exercise offers older adults a variety of health advantages. Programs that incorporate strength, balance, flexibility, and aerobic exercises help maximize mental and physical well-being. For instance, multimodal fitness programs decreased the risk of falls by 23%, according to Sherrington et al. (2017). The benefits of such programs include increased cardiovascular endurance and improved muscular strength and balance. Aerobic exercise lowers the risk of chronic diseases including type 2 diabetes and metabolic syndrome in addition to improving cardiovascular parameters. By increasing insulin sensitivity, decreasing visceral fat, and modifying inflammatory markers, aerobic exercise helps to improve metabolic regulation (Church et al., 2007). The protective role of physical activity in preventing and managing chronic diseases was highlighted in a study by Church et al. (2007), which found that older adults who participated in a structured walking program saw significant reductions in both fasting glucose levels and HOMA-IR (homeostatic model assessment for insulin resistance).

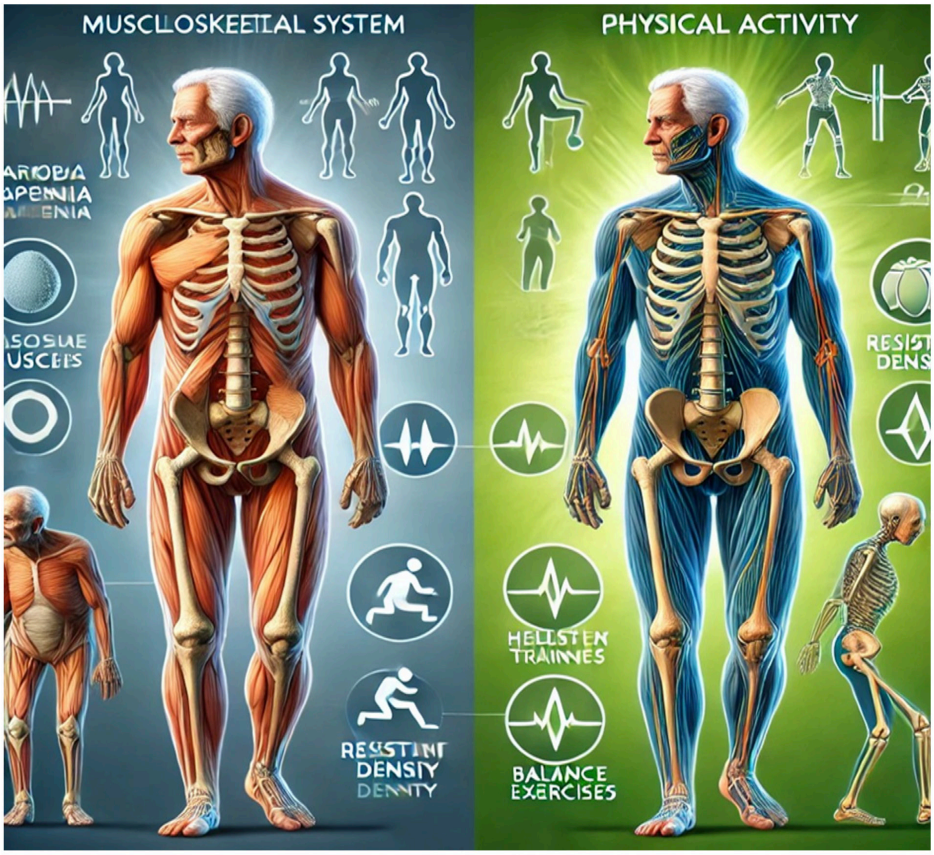

Figure 2. *This illustration shows how exercise impacts the musculoskeletal system as people age. On the left, aging-related changes like muscle loss, decreased bone density, and stiff joints are depicted, while the right side highlights the benefits of regular exercise, including more muscle mass, stronger bones, and improved joint flexibility. The graphic also includes icons representing the advantages of resistance training, aerobic exercise, and balance exercises. This visual was created using the DALL-E 3 software, showcasing age-related changes, the benefits of exercise, and the processes that reverse these effects.*

Conclusion

One of the most successful elements of lifestyle interventions to promote older adults' healthy aging is exercise. Combining various forms of exercise enhances older adults' quality of life by maximizing their physical and mental well-being. Combining aerobic, resistance, balance, and flexibility

exercises, multimodal exercise programs offer a useful way to manage the complex impacts of aging. According to Sherrington et al. (2017), these programs can enhance functional ability, promote independent living, and lower the risk of falls by 23%. Resistance training boosts bone density and muscle strength, aerobic training increases cardiovascular endurance, and balance and flexibility training improves neuromuscular control, which is essential for preventing falls. In addition to improving physical health, these holistic methods also improve psychological and cognitive well-being. By enhancing social contacts, exercise's beneficial benefits on psychological disorders like anxiety and depression may help older adults feel less alone. Future studies should concentrate on how exercise regimens may be tailored to each person's demands and combined with lifestyle variables. Dietary optimization, in particular, has a significant chance to boost the efficacy of fitness regimens. Exercise and dietary supplements are known to promote muscle protein synthesis and prevent sarcopenia more effectively (Koopman & van Loon, 2009). Furthermore, additional longitudinal research is required to comprehend the long-term impacts of varying exercise durations and intensities. Additionally, personalized workout regimens may be created based on each person's demands with the assistance of digital health technology. For instance, by monitoring individual performance, smartphone applications and portable sensors can give feedback and improve older persons' exercise adherence. In summary, encouraging physical activity among the elderly might lessen the strain on healthcare systems while also improving individual health outcomes. These programs help older people live active, independent, and fulfilling lives while also mitigating the negative impacts of aging.

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