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THE IMPACT OF PHYSICAL ACTIVITY ON THE DEVELOPMENT OF OSTEOPOROSIS: A SYSTEMATIC REVIEW

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ABSTRACT

Introduction: Osteoporosis prevention includes methods aimed at maintaining normal bone mineral density (BMD), increasing bone strength, and reducing the risk of fractures. Adequate intake of calcium and vitamin D, maintaining a healthy body weight, and regular physical activity play an important role. An important component of prevention is weight-bearing exercise and resistance training, which may have beneficial effects on BMD and bone tissue remodeling. In addition, walking, aquatic exercises, Tai Chi, and whole-body vibration (WBV) may serve as complementary interventions, although their effectiveness requires further research.
Aim of the study: The aim of this study is to review the literature on the role of physical activity and exercise in osteoporosis prevention and management. Particular attention is given to resistance and weight-bearing exercises, walking, aquatic exercises, Tai Chi, and whole-body vibration, focusing on their effects on bone mineral density, muscle strength, and fracture risk.
Methods and materials: We reviewed the literature available in the PubMed database using the following keywords: "Osteoporosis"; "Physical activity"; "Resistance training"; "Weight-bearing exercise"; "Walking"; "Aquatic exercise"; "Tai Chi"; "Whole body vibration"; "Postmenopausal women";
Conclusion: Comprehensive osteoporosis prevention includes regular physical activity, which supports bone health and reduces fracture risk. Resistance and weight-bearing exercises have the greatest benefits for bone mineral density, particularly in postmenopausal women. Walking, aquatic exercises, and Tai Chi may provide additional benefits, although their effects on BMD are less established. Whole-body vibration may improve muscle strength and reduce fall risk, but its impact on BMD remains uncertain. Therefore, individualized and appropriately selected exercise programs should be considered an important component of osteoporosis prevention.

KEYWORDS

Osteoporosis, Physical Activity, Bone Mineral Density, Postmenopausal Women

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1. Introduction

Osteoporosis is a systemic disease of the skeletal system in which bone mineral density decreases along with deterioration of bone structure. As bone strength decreases, bones become more susceptible to fractures, which are typically low-energy fractures (Brown, 2021). The disease involves impaired function of osteoblasts and osteoclasts, followed by disturbances in bone remodeling, which is considered a major cause of osteoporosis (Gao, Patil, & Jia, 2021). Protective factors include adequate intake of calcium and vitamin D, maintaining a healthy body weight, breastfeeding, the use of estrogen replacement therapy, and moderate physical activity. In the prevention of complications of osteoporosis, physical activity contributes to increasing peak bone mass at a young age, limiting bone loss during the postmenopausal period, and reducing the risk of fractures and their consequences (Kelsey, 1989). The effects of physical exercise were summarized in a review describing how an appropriate physical activity program consisting of multicomponent training may have a positive effect on bone mass. Resistance training and weight-bearing exercises provide the best results, walking has a limited effect on the skeletal system, whereas whole-body vibration, despite promising effects, requires further long-term studies (Gómez-Cabello, Ara, González-Agüero, Casajús, & Vicente-Rodríguez, 2012).

2. Description of the State of Knowledge

Exercise

Despite the questionable direct effect of physical exercise on bone tissue, physical exercise is a commonly recommended factor for reducing the risk of osteoporosis. The positive effect of exercise on increasing bone mass is noticeable in young people, whereas the available information in older people is inconclusive (Benedetti, Furlini, Zati, & Letizia Mauro, 2018). The main effect observed in older adults who exercise is an increase in bone tissue density and a lower rate of bone loss at the endosteal surface (Kohrt et al., 2004). Exercise, particularly involving the lower limbs, may limit the loss of cortical and trabecular volumetric BMD during a 12-month training period. Although studies involving longer intervention periods and larger groups of women are needed, exercise resulted in a small but statistically significant improvement (Polidoulis, Beyene, & Cheung, 2012). A prospective cohort study involving 2,855 men and 6,442 women demonstrated a beneficial effect of physical activity on increasing bone mineral density of the lumbar spine in women, with no demonstrated effect on changes in hip BMD or other aspects of health (Langsetmo et al., 2012). The most effective forms of physical activity that act through gravitational forces and the loading generated by muscle activity can be divided into weight-bearing aerobic exercises and resistance exercises (Hingorjo, Zehra, Saleem, & Qureshi, 2018).

Walking

A systematic review and meta-analysis of eight studies was conducted to assess the effect of regular walking on bone mineral density of the total hip, lumbar spine, and femoral neck in postmenopausal women. The results showed a beneficial effect on femoral neck BMD, with no significant effect observed in the lumbar spine. Based on Jadad scale scores ranging from 1 to 3, the quality of the included studies was low, and therefore walking alone may be insufficient to effectively prevent bone loss in postmenopausal women (Martyn-St James, & Carroll, 2008). A positive effect of walking on bone mineral density was also observed in a systematic review and meta-analysis, which found a beneficial effect of this form of physical activity on femoral neck BMD after at least six months of regular training (Ma, Wu, & He, 2013).

Aquatic exercise program

Aquatic exercises, such as swimming, require further research to demonstrate their positive effect on BMD. A systematic review analyzed the effects of swimming on bone metabolism, structure, and bone mass. It was observed that swimmers had lower BMD compared with athletes participating in activities involving high mechanical loading. Therefore, swimming is characterized by lower osteogenic potential and does not lead to deterioration of bone health (Gómez-Bruton, Gónzalez-Agüero, Gómez-Cabello, Casajús, & Vicente-Rodríguez, 2013). A cross-sectional observational study with a control group included 43 female swimmers and 44 women in the control group. The results showed that even 1.45 hours of swimming training throughout life did not increase BMD in women and did not lead to deterioration of bone mineral status (Greenway, Walkley, & Rich, 2012). However, a review of eight studies found that most studies demonstrated a beneficial effect of aquatic exercise on maintaining BMD, which may provide an effective alternative for individuals whose physical conditions limit their ability to participate in land-based activities (McMahon, 2017).

Resistance Training

A review of studies published between 1990 and 2005 was conducted to investigate the effect of resistance training on BMD in postmenopausal women. Evidence was provided for an increase in bone mineral density, which required the use of high loads and was dependent on the anatomical site. The exercises should be performed at an intensity corresponding to 70–90% of the maximum weight that a person can lift for one repetition, divided into 2–3 sets of 8–12 repetitions, for a period of approximately one year. Long-term adherence to such a program may contribute to an increase in BMD of the spine and hip in women (Zehnacker, & Bemis-Dougherty, 2007). A systematic review of randomized controlled trials was also conducted to analyze the effects of resistance and weight-bearing exercises on bone mineral density in middle-aged and older men. Eight studies included various forms of resistance and aerobic training. Seventy-five percent of these studies showed that resistance training performed alone or in combination with exercises generating impact loading produced the best results. Due to the limited quality of some previous studies, further high-quality randomized controlled trials are needed to determine the optimal exercise program, although regular physical activity of this type may constitute an important component of osteoporosis prevention (Bolam, van Uffelen, & Taaffe, 2013). A study evaluating the prevention of bone loss and fractures in postmenopausal women collected combined data from 43 studies involving 4,320 participants. The systematic review and meta-analysis of randomized controlled trials showed the greatest effect on BMD, particularly in the case of progressive resistance training of the lower limbs and high-intensity resistance exercises. Despite the low methodological quality of the studies analyzed, the best results for the spine were obtained with programs combining different types of exercise, including resistance exercises combined with various types of aerobic exercise (Howe et al., 2011). Physical exercise is an effective way to maintain bone health in girls and women; therefore, physical activity should be initiated at a young age through high-intensity plyometric exercises involving impact loading, which may allow young girls to achieve peak bone mass. For improving bone mineral density in adult women, weight-bearing exercises combined with resistance training appear to be the most effective (Xu, Lombardi, Jiao, & Banfi, 2016). In a study involving 101 postmenopausal women, it was observed that combining resistance training with impact exercises performed twice a week for eight months improved lumbar spine BMD by 2.9% and femoral neck BMD by 0.3%, while a decrease in these parameters was observed in the control group (Watson et al., 2018). In a study involving 33 postmenopausal women, markers of bone remodeling and quality of life were assessed at three time points: at baseline, after one month, and after three months of training. The results showed that three months of resistance training combined with weight-bearing exercises resulted in an increase in the concentration of N-terminal propeptide of type I procollagen and in the number of osteoclasts, which are markers of bone formation and remodeling. At the same time, improvements were observed in physical functioning, psychological functioning, and quality of life in terms of pain perception (Pasqualini et al., 2019).

Tai Chi

The effect of Tai Chi on bone mineral density in women was analyzed based on 10 studies. Compared with patients who did not receive treatment, the meta-analysis demonstrated a significant positive effect of the exercises on changes in spinal BMD; however, no advantage was observed for combining Tai Chi with calcium supplementation over treatment with calcium alone. Unfortunately, due to the low methodological quality of the studies and the small treatment effect, the reliability of the results is limited (Sun et al., 2016). A review including 9 studies and 1,222 participants showed a reduction in BMD loss, particularly in the proximal femur and lumbar spine. To achieve these effects, the exercise period should last at least 12 months, as reported in 5 studies (Chow et al., 2017).

Whole-Body Vibration (WBV)

The therapy aims to increase muscle mass and bone mineral density by transmitting mechanical vibrations. The effectiveness of the therapy is influenced by factors such as the frequency and amplitude of the vibrations and body position during the treatment. Further research determining the appropriate level of stimulation is needed to assess the benefits of this therapy (Fratini, Bonci, & Bull, 2016). Although studies indicate improvements in muscle strength, particularly in the knee extensors, as well as positive effects on jump height and the ability to rise from a seated position during therapy, no effect on BMD was observed in postmenopausal women (Lau et al., 2011). A systematic review and meta-analysis of randomized controlled trials also demonstrated a reduction in the frequency of falls in adults, which may contribute to a reduction in the incidence of fractures in this group of patients. However, based on the 14 studies included, no beneficial effect on bone structure or bone mineral density was observed (Jepsen et el., 2017).

3. Conclusions

Osteoporosis leads to a reduction in bone mineral density, deterioration of bone structure, and an increased risk of fractures; therefore, its prevention should be tailored to the patient's age, health status, and physical capabilities. Regular physical activity is an important element of prevention, while resistance training and weight-bearing exercises have been shown to have the most beneficial effects on BMD and the maintenance of bone health, particularly in postmenopausal women. Walking, exercise in an aquatic environment, and Tai Chi may support the maintenance of bone mineral density; however, their effectiveness is less conclusive. Whole body vibration may improve muscle strength and functional performance and reduce the risk of falls; however, its effect on BMD remains unconfirmed. Therefore, an appropriately selected, regular, and individualized physical activity program, primarily comprising resistance and weight-bearing exercises, should constitute the basis for osteoporosis prevention and the reduction of its complications.

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