



Physical Activity and Bone Mineral Density in Healthy Young Adult Women: A Narrative Review

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Abstract. Bone Mineral Density (BMD) is a critical determinant of skeletal strength and osteoporosis risk. Young adulthood is a pivotal period for achieving peak bone mass; however, sedentary behavior threatens optimal bone development. Regular physical activity—particularly weight-bearing and resistance exercise—provides mechanical loading that stimulates bone remodeling and enhances BMD, supporting Sustainable Development Goal (SDG) 3. This narrative review summarizes current evidence (2020–2026) regarding physical activity and BMD in healthy young adult women aged 18–30 years, using literature from PubMed, Scopus, Web of Science, ScienceDirect, and Google Scholar. The findings consistently show that active women maintain higher BMD than sedentary peers. Weight-bearing exercises, resistance training, and sports participation foster greater bone mineral accrual, whereas prolonged sedentary time correlates with reduced BMD. Exercise parameters (intensity, frequency, duration), nutrition, and body composition further moderate bone health. In conclusion, regular physical activity is essential for optimizing peak bone mass in young women, aiding osteoporosis prevention and promoting lifelong health.

Keywords: Bone Mineral Density; Physical Activity; Sedentary Behavior; Young Adult Women; Peak Bone Mass; Narrative Review.

1 Introduction

Bone Mineral Density (BMD) is a fundamental indicator of skeletal strength and plays an essential role in maintaining musculoskeletal health throughout the life course. Low BMD is recognized as the principal determinant of osteoporosis and fragility fractures, conditions that contribute substantially to disability, reduced quality of life, and increased healthcare expenditure worldwide. According to the International Osteoporosis Foundation (IOF), osteoporosis affects more than 200 million people globally and is responsible for approximately 8.9 million fragility fractures annually, equivalent to one osteoporotic fracture every three seconds [2]. With increasing life expectancy and population ageing, the global burden of osteoporosis and other musculoskeletal disorders is expected to rise substantially over the coming decades, making bone health an important public health priority [5].

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Although osteoporosis is commonly diagnosed in older adults, its biological origins begin much earlier in life. Approximately 90–95% of peak bone mass is accumulated before the age of 30 years, making young adulthood a critical period for optimizing bone mineral accrual [3,8]. Achieving an adequate peak bone mass provides greater skeletal reserve and reduces the likelihood of accelerated bone loss during ageing and menopause. Conversely, failure to attain optimal peak bone mass during early adulthood increases the lifetime risk of osteopenia, osteoporosis, and fragility fractures [2]. Consequently, preventive strategies should emphasize bone health promotion before skeletal maturation is completed rather than focusing solely on treatment after bone loss has occurred.

Among the various determinants of bone health, physical activity is considered one of the most important modifiable lifestyle factors influencing Bone Mineral Density. Mechanical loading generated during weight-bearing activities, impact exercise, resistance training, and sports participation stimulates osteogenesis through activation of bone remodeling processes, leading to increased bone formation and improved bone strength [1,3,4]. In contrast, prolonged sedentary behavior reduces mechanical stimulation of bone tissue, potentially impairing bone mineral accrual during the years when peak bone mass should be achieved [7]. The osteogenic response to exercise is influenced by exercise intensity, loading magnitude, frequency, duration, nutritional status, hormonal factors, and body composition, indicating that different patterns of physical activity may produce varying effects on skeletal adaptation.

Insufficient physical activity has become a major global health concern, particularly among adolescents and young adults. The World Health Organization estimates that nearly one-third of adults worldwide fail to achieve the recommended level of physical activity, while sedentary lifestyles continue to increase because of technological advances, academic demands, and urbanization [10]. These behavioral changes may adversely affect musculoskeletal health during the period of peak bone mass acquisition. Promoting regular physical activity among young women therefore represents not only an effective strategy for improving Bone Mineral Density but also contributes to achieving the United Nations Sustainable Development Goal 3 (SDG 3: Good Health and Well-being), particularly Target 3.4, which aims to reduce premature mortality from non-communicable diseases through prevention, health promotion, and healthy lifestyles [9].

Indonesia is also experiencing an epidemiological transition characterized by an increasing prevalence of non-communicable diseases and a rapidly ageing population. National surveys indicate that insufficient physical activity remains common among Indonesian adults, including university students and young women [6]. Furthermore, inadequate calcium intake, limited vitamin D exposure, prolonged sedentary behavior, and low participation in structured exercise programs may compromise bone health during early adulthood [6]. Considering that interventions during this period are more effective than those initiated after menopause, promoting active lifestyles among healthy young women should become an important component of osteoporosis prevention strategies in Indonesia.

Although numerous studies have investigated the relationship between physical activity and Bone Mineral Density, the available evidence remains

heterogeneous. Previous reviews have generally focused on postmenopausal women, older adults, athletes, or patients with osteoporosis, whereas evidence specifically involving healthy women aged 18–30 years has received comparatively less attention [1,3]. Moreover, differences in exercise modality, intensity, duration, and participant characteristics make it difficult to draw consistent conclusions regarding the most beneficial forms of physical activity for optimizing peak bone mass [1,4].

Therefore, this narrative review aims to critically summarize current evidence regarding the relationship between physical activity and Bone Mineral Density in healthy young adult women aged 18–30 years. This review discusses the biological mechanisms underlying exercise-induced skeletal adaptation, compares Bone Mineral Density between sedentary and physically active women, identifies factors influencing bone health during early adulthood, and highlights future research directions. The findings are expected to provide an evidence-based foundation for developing effective physical activity strategies to optimize peak bone mass, prevent osteoporosis, and support the achievement of sustainable public health goals [9].

2 Methods

A comprehensive narrative review was conducted to synthesize current empirical literature regarding the effects of physical activity and sedentary lifestyles on Bone Mineral Density (BMD) among healthy young adult females. Electronic database searches were executed across PubMed, Scopus, Web of Science, ScienceDirect, and Google Scholar to retrieve peer-reviewed articles published between January 2020 and 2026. The search architecture utilized combinations of Medical Subject Headings (MeSH) terms and high-precision keywords, including: "Bone Mineral Density" OR "BMD" AND "physical activity" OR "exercise" OR "resistance training" AND "sedentary behavior" OR "screen time" AND "young adult women" OR "females".

The inclusion criteria were strictly restricted to: (1) human studies involving healthy young adult women aged 18–30 years; (2) studies evaluating BMD using Dual-energy X-ray Absorptiometry (DXA); and (3) investigations assessing distinct modalities, intensities, or durations of physical activity and sedentary patterns. Studies focusing on postmenopausal cohorts, competitive elite athletes, populations with pre-existing metabolic bone diseases, or those published outside the 2020–2026 window were systematically excluded. Two reviewers independently screened titles and abstracts, followed by a critical full-text evaluation of eligible papers to extract and narratively synthesize data regarding structural bone adaptations.

3 Results and Discussion

3.1 Biological Mechanisms of Exercise-Induced Bone Remodeling

The skeletal adaptation to physical activity is fundamentally governed by mechanotransduction, a biological process where mechanical forces are converted into biochemical signals to modulate bone remodeling[8]. When healthy young women engage in physical exercise, the skeleton experiences mechanical deformation or strain. Osteocytes, the resident mechanosensor cells embedded within the mineralized bone matrix, detect this fluid shear stress through their primary cilia and canalicular networks[8].

Upon activation, osteocytes downregulate the expression of sclerostin, a potent inhibitor of the Wnt/ β -catenin signaling pathway[8]. The subsequent activation of the Wnt pathway promotes osteoblast differentiation and survival, leading to accelerated bone formation and mineralization. Concurrently, mechanical loading increases the ratio of osteoprotegerin (OPG) to receptor activator of nuclear factor- κ B ligand (RANKL), effectively suppressing osteoclastogenesis and diminishing bone resorption[8]. This synergistic biological interplay ensures that net bone mineral accrual occurs during the critical window of peak bone mass development (ages 18–30)[3,8].

3.2 Comparative Effects: Physical Activity vs. Sedentary Behavior

The synthesized evidence from recent 2020–2026 literature consistently highlights a stark contrast in localized BMD profiles between physically active and sedentary young adult women [1,3,7]. Cross-sectional and longitudinal data confirm that young women who regularly accumulate moderate-to-vigorous physical activity possess significantly higher BMD at weight-bearing skeletal sites—specifically the lumbar spine (L_1 – L_4) and the femoral neck—than their sedentary peers [1,3].

Conversely, prolonged sedentary behavior (characterized by extended sitting times and high digital device dependency) serves as a state of mechanical unloading [7]. Under these conditions, the absence of skeletal strain triggers localized bone resorption [7,8]. Prolonged sitting acts as an independent risk factor for suboptimal peak bone mass development; even in young women who meet minimum public health exercise guidelines, excessive daily sedentary time can partially blunt the positive osteogenic benefits derived from structured exercise [7,10].

3.3 Impact of Distinct Exercise Modalities on BMD

Not all forms of physical exertion yield equal skeletal adaptations. Recent clinical trials demonstrate that the osteogenic potential of an activity depends on the magnitude and rate of the mechanical strain applied [3,4].

- **Weight-Bearing and High-Impact Activities:** Exercises that involve high-impact mechanical loading (such as jumping, plyometrics, volleyball, and gymnastics) induce the most profound increases in site-specific BMD. The

rapid, multidirectional impacts deform the bone matrix at a high rate, eliciting a robust osteoblast response at the hip and femoral neck [3].

- **Progressive Resistance Training:** Structured resistance exercises (e.g., squats, deadlifts, and targeted weight training) create localized mechanical pulls at muscular insertion points. Resistance training yields highly significant increases in lumbar spine BMD due to the targeted axial loading imposed on the vertebral bodies [1].
- **Non-Weight-Bearing Activities:** Conversely, activities like swimming or cycling, despite providing exceptional cardiovascular benefits, exert negligible direct impacts on bone mineral accrual. Because water buoyancy and smooth pedaling cycles minimize impact and gravity-mediated loading, these modalities fail to reach the mechanical strain threshold required to stimulate osteogenesis [4].

3.4 Confounding Determinants: Nutrition, Body Composition, and Public Health Linkages

While mechanical loading is the primary driver of bone development, its efficiency is profoundly modulated by systemic factors, particularly nutritional status and body composition [6,8]. Adequate dietary calcium intake and optimal serum 25-hydroxyvitamin D levels are mandatory substrates for translating mechanical strains into structural bone minerals [6]. Furthermore, adequate energy availability is vital; a low energy availability state (common in young women undergoing restrictive dieting) can disrupt the hypothalamic-pituitary-gonadal axis, leading to subclinical estrogen deficiencies that accelerate bone resorption regardless of activity levels. Regarding body composition, lean mass acts as a powerful local mechanical stimulus via muscular contractions, showing a stronger positive correlation with regional BMD than absolute fat mass.

From a broader public health framework, promoting target-specific physical activity during this narrow chronological window (18–30 years) directly aligns with United Nations Sustainable Development Goal 3 (SDG 3: Good Health and Well-being) [9]. By establishing a superior structural skeletal reserve prior to the inevitable age- and menopause-related bone loss, young women can effectively prevent the premature onset of osteopenia and osteoporosis, substantially reducing the long-term socioeconomic and clinical burdens of fragility fractures [2,5,9].

4 Conclusion

Regular physical activity serves as a foundational lifestyle determinant for optimizing Bone Mineral Density and maximizing peak bone mass acquisition in healthy young adult women aged 18–30 years [1,3]. High-impact mechanical loading and progressive resistance training demonstrate clear superiority in driving site-specific osteogenesis compared to non-weight-bearing exercises [1,4]. In contrast, prolonged sedentary

behaviors disrupt skeletal mechanosensitivity and impair bone mineral accrual [7]. Public health interventions in Indonesia and globally must shift from generic active-living guidelines toward structured, impact-bearing, and strength-building exercise regimens combined with adequate nutritional support [6,10]. Implementing these targeted musculoskeletal strategies during early adulthood represents a crucial preventive window to mitigate the lifelong risk of osteoporosis, thereby advancing sustainable public health and well-being [2,9].

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Disclosure of Interests. None declared.

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