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Review Article

The rising global burden of osteoporosis: insights into prevalence, fracture rates, and future trends

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ABSTRACT

Osteoporosis is a global health concern, marked by reduced bone density and increased fracture of risk, which unfavorably impacts quality of life and results substantial burdens on healthcare systems. This condition often progresses asymptotically, with fractures, functional decline, and rise in mortality emerging in advanced stages. However, projections indicate that by 2050, over 50% of global osteoporotic fractures will occur in Asia, highlighting the urgency for targeted interventions. Early detection is very crucial for mitigating osteoporosis-associated morbidity. Screening programs enable timely identification of at-risk individuals, may facilitating interventions such as pharmacological therapy and lifestyle modifications that significantly lower the fracture incidence. Furthermore, community-based awareness campaigns may be playing a critical role in promoting bone health by encouraging sufficient intake of calcium and vitamin D supplement, in-addition regular to do physical activity. A life-course approach to bone health is essential. In postmenopausal women, pharmacological and non-pharmacological treatments, lifestyle strategies are imperative for decline bone loss and preventing bone fractures. To achieve optimal bone mineral density (BMD) and postpone the onset of disease, premenopausal women must receive early preventive measure care and proper education. However, substantial rise in the prevalence of osteoporosis worldwide suggests to improve awareness among the public, expand access to healthcare, and create all-encompassing prevention and management plans. In order to lessen the significant societal and economic effects of this silent epidemic, multidisciplinary collaboration and continuing public health initiatives are essential.

Keywords: Osteoporosis, Bone density, Fracture risk, Estrogen

INTRODUCTION

Osteoporosis is a pressing public health concern, predominantly affecting postmenopausal women, but often starting its course earlier in premenopausal women. This systemic skeletal disorder gradually impairs bone

quality, with declining bone mass density (BMD), weakened bone microarchitecture, and increased fragility, making fractures likely even after minor trauma. What makes osteoporosis particularly insidious is its silent progression-no symptoms until the disease has advanced

significantly, leading to late-stage manifestations such as vertebral fractures, back pain, and loss of height.¹

In South India, as in many parts of the world, osteoporosis is a significant cause of disability and hospitalization among the elderly population. The economic burden of managing osteoporosis-related fractures is steadily rising, not just globally but also in the Indian healthcare system. The escalating costs associated with osteoporosis management in India are a growing concern, with projections indicating an upward trend in the coming decades.

Worldwide, over 200 million people are affected by osteoporosis, with 8.9 million fractures occurring annually. In South India, the prevalence of osteoporosis is especially concerning due to widespread vitamin D deficiency and inadequate calcium intake, particularly among women. Studies show that southern states report alarmingly high rates of vitamin D deficiency, largely driven by inadequate sunlight exposure and poor nutritional habits.²

Osteoporosis is influenced by both (75%) genetic and environmental (25%) lifestyles factors such as, poor nutrition, tobacco use, and alcohol consumption may further accelerate bone loss in women, particularly during menopause. The critical need for early prevention is evident, with education about bone health, nutrition, and physical activity being essential in mitigating the onset of osteoporosis.³

Despite efforts, research highlights a significant gap in knowledge and awareness, especially among South Indian women, about the importance of maintaining bone health before menopause. Osteoporosis is influenced by both (75%) genetic and environmental (25%) lifestyles factors such as, poor nutrition, tobacco use, and alcohol consumption may further accelerate bone loss in women, particularly during menopause.⁴

Estrogen, a hormone crucial in maintaining bone health, diminishes after menopause, accelerating bone loss by 2-5% annually, with this loss continuing for a decade. Although lifestyle changes such as calcium and vitamin D supplementation, along with regular physical activity, can help slow the progression of osteoporosis, pharmacological treatments may also be necessary to prevent fractures and further bone degradation in high-risk individuals. Therefore, our study to assess the beliefs held by premenopausal women concerning osteoporosis and its implications for health.

LITERATURE REVIEW

Objective

The objective of this literature review is to synthesize current findings regarding health outcomes, interventions,

and management strategies in postmenopausal women from 2010 to the present.

Study design

This review will employ a systematic literature review design, following PRISMA (Preferred reporting items for systematic reviews and meta-analyses) guidelines to ensure transparency and reproducibility.

Eligibility criteria

The inclusion criteria for the review consist of studies published from January 2010 to the present. Only peer-reviewed articles are considered, including randomized controlled trials, cohort studies, and qualitative research. The selected studies must focus on postmenopausal women aged 45 years and older and address topics such as hormone replacement therapy (HRT), osteoporosis, cardiovascular health, mental health, and quality of life. The exclusion criteria eliminate studies not published in English. Research involving premenopausal women or mixed-age populations without clearly specified data for postmenopausal women is excluded. Additionally, non-peer-reviewed articles, such as commentaries, editorials, and opinion pieces, are not considered.

Search strategy

A comprehensive search strategy will be employed to identify relevant literature across multiple databases, including PubMed, Scopus, the Cochrane Library, Web of Science, and Google Scholar. The search will utilize a combination of keywords such as postmenopausal women, hormone replacement therapy, osteoporosis, cardiovascular health, mental health, quality of life, and health interventions. Boolean operators (AND, OR) will be applied to refine the search results effectively. Additionally, specific filters, including publication date and study type, will be used to narrow down the results to the most relevant and high-quality studies.

Screening process

Two independent reviewers will screen titles and abstracts of all retrieved articles to identify studies that meet the predefined inclusion criteria. Full-text articles of potentially eligible studies will then be assessed for final inclusion. Any discrepancies or disagreements between the reviewers will be resolved through discussion, and if necessary, by involving 3rd reviewer to reach a consensus.

Data extraction

A standardized data extraction form will be utilized to systematically collect relevant information from the studies included in the review. Extracted data will comprise details such as author(s) and year of publication, study design, sample size, and participant demographics, including age and health status. Information on

intervention specifics (if applicable), key findings related to health outcomes and interventions, as well as the conclusions drawn by the authors, will also be recorded.

Quality assessment

The quality of included studies will be assessed using appropriate tools, such as the Cochrane risk of bias tool for randomized controlled trials and the Newcastle-Ottawa Scale for observational studies.

Data synthesis

A narrative synthesis will be conducted to summarize findings across studies, focusing on common themes and outcomes. If feasible, a meta-analysis will be performed to quantitatively analyze pooled data from similar studies, utilizing random-effects or fixed-effects models based on heterogeneity.

Limitations

Osteoporosis disproportionately affects women, particularly postmenopausal women, underscoring the need for gender-sensitive health policies and global initiatives to address this growing public health burden.^{5,6}

SILENT PROGRESSION AND LACK OF EARLY SYMPTOMS

Osteoporosis is often termed a “silent disease” due to its asymptomatic progression. The disease can advance over many years without any noticeable signs until a fracture occurs. By the time symptoms such as back pain, loss of

height, or a fracture become apparent, the disease may already be in an advanced stage, characterized by substantial bone loss. The absence of early symptoms makes timely detection challenging, resulting in the underdiagnosis and undertreatment of many individuals. This leaves a large portion of the population vulnerable to debilitating fractures. Early screening, particularly among high-risk groups such as postmenopausal women and the elderly, is essential to mitigate the serious consequences of osteoporosis and facilitate early intervention to slow disease progression. However, different phase of significance in postmenopausal and premenopausal Women in osteoporosis was depicted in Table 1.

Osteoporosis holds particular importance for women, both in the premenopausal and postmenopausal phases of life. Postmenopausal women are at increased risk due to the sharp decline in estrogen levels following menopause. Estrogen plays a pivotal role in maintaining bone density, and its deficiency leads to accelerated bone loss, heightening the risk of fractures. Women may lose up to 20% of their bone mass in the first five to seven years after menopause, rendering them highly susceptible to osteoporosis. However, premenopausal women are not exempt from the risks associated with the disease. During this phase, it is crucial to maintain bone health through adequate nutrition, physical activity, and healthy lifestyle choices to achieve optimal peak bone mass. This peak serves as a protective factor against osteoporosis later in life. Early education and preventive interventions targeting premenopausal women can significantly reduce the likelihood of developing osteoporosis after menopause, emphasizing the importance of a life-course approach to bone health.⁷

Table 1: Significance in postmenopausal and premenopausal women.

Different phase of life	Significance of osteoporosis	Key points
Postmenopausal women	-Increased risk may leads to a sharp decline in estrogen after menopause. -Increased Estrogen deficiency leads to bone loss, increasing fracture risk.	-Loss of up to 20% bone mass in the first 5-7 years post-menopausal women. -High susceptibility to osteoporosis patients.
Premenopausal women	-Not exempt from osteoporosis risk; bone health maintenance is very crucial. -Important to achieve peak bone mass through proper nutrition, activity, and lifestyle choices for long-term protection.	-Optimal peak bone mass serves as a protective factor against osteoporosis later in life.
Preventive interventions	-Early education awareness and interventions targeting premenopausal women are very essential improve bone health. -A life-course approach to bone health strategies is an important key to reducing the risk of osteoporosis post-menopause.	-Emphasizes the importance of consistent bone health practices throughout life stages process in women.

GLOBAL PREVALENCE OF OSTEOPOROSIS

Worldwide osteoporosis statistics

Osteoporosis is a pervasive global health issue, affecting over 200 million individuals worldwide. This metabolic

bone disorder is particularly prevalent in older adults and postmenopausal women, as age-related bone density loss significantly elevates the risk of fractures. Osteoporosis accounts for millions of fractures annually, contributing to considerable morbidity, disability, and mortality. With global populations aging, the prevalence of osteoporosis

and its associated complications is projected to rise sharply, positioning osteoporosis as a critical public health concern in the coming decades.

Regional variations in osteoporosis prevalence (USA, Europe and Asia)

The prevalence of osteoporosis varies widely across different regions due to factors such as lifestyle, nutrition, and genetic predisposition. In the United States, an estimated 10 million individuals have osteoporosis, with an additional 44 million presenting with low bone mass, placing them at elevated risk for the disease. In Europe, approximately 22 million women and 5.5 million men are affected by osteoporosis, with higher prevalence observed in southern European countries, likely due to widespread vitamin D deficiency. In Asia, osteoporosis prevalence is increasing rapidly, particularly in countries such as China and India, driven by demographic shifts and lifestyle changes. Projections indicate that by 2050, over half of all osteoporotic fractures globally will occur in Asia, reflecting the growing burden of the disease in the region.⁸

Comparative fracture rates across continents

The prevalence of osteoporotic fractures varies significantly across continents, shaped by genetic predispositions and environmental factors such as diet and physical activity. North America and Europe consistently report some of the highest rates of hip fractures worldwide,

especially among postmenopausal women. Notably, countries like Sweden, Norway, and the United States rank among those with the highest hip fracture incidences per capita. In contrast, Asia and Africa have historically exhibited lower fracture rates. However, these regions are now experiencing a rapid rise in osteoporotic fractures, driven by factors such as urbanization, reduced physical activity, and inadequate calcium intake. In Asia, in particular, the aging population and increasingly sedentary lifestyles are expected to result in a significant increase in fracture rates in the coming years.⁹

Growth trends and global burden projections for osteoporosis

Global burden of osteoporosis is anticipated to rise dramatically in the coming decades, driven largely by the rapid aging of populations around the world. By 2050, osteoporotic fractures are expected to increase by over 300%, with Asia and Latin America projected to experience the greatest growth. This escalating burden will place immense strain on healthcare systems, as the costs of treating and rehabilitating osteoporotic fractures are substantial. Additionally, as life expectancy continues to increase, the prevalence of osteoporosis will further rise, exacerbating its impact on public health infrastructure. Addressing the global burden of osteoporosis will require a concerted effort, with an emphasis on prevention, early detection, and intervention to mitigate the disease's long-term societal and economic consequences (Figure 1).¹⁰

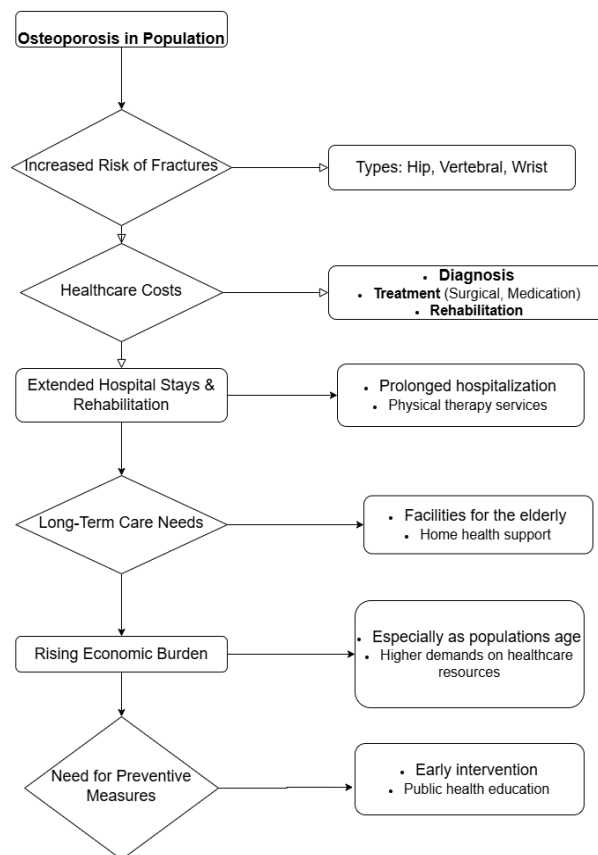


Figure 1: Financial impact of osteoporosis on healthcare systems globally.

RISING COSTS OF OSTEOPOROSIS MANAGEMENT (EXAMPLES FROM THE USA, EUROPE, AND OTHER REGIONS)

Osteoporosis-related fractures impose a substantial and growing economic burden worldwide. In the United States, annual healthcare costs linked to osteoporosis are projected to exceed \$57 billion by 2030, driven by rising disease prevalence and healthcare expenses. Europe faces similar challenges, with costs estimated at €37 billion annually and expected to nearly double to €76.7 billion by 2050, particularly affecting countries like the UK, France, and Germany. In Asia, rising osteoporosis rates in countries such as China, Japan, and India, coupled with limited healthcare resources, are increasing the financial strain. The Middle East also experiences growing costs, exemplified by Saudi Arabia's estimated 2.359 billion Riyals spent annually on fracture treatment. These expenses encompass hospitalizations, surgeries, rehabilitation, long-term care, lost productivity, and caregiver needs. Osteoporotic fractures, especially hip fractures, contribute to long-term disability through reduced mobility, chronic pain, and increased dependence, further amplifying the social and economic impact. Addressing this escalating burden requires proactive

strategies, including early screening, effective prevention, and personalized treatment to improve outcomes and reduce costs globally.¹¹

OSTEOPOROSIS PREVALENCE IN LOW- AND MIDDLE-INCOME COUNTRIES

Osteoporosis is increasingly recognized as a significant public health issue in low- and middle-income countries (LMICs). As populations age and urbanization rises, the prevalence of osteoporosis and related fractures is projected to grow substantially. Studies have indicated that osteoporosis affects millions of individuals in these regions, yet the true extent of the problem is likely underreported due to limited research and data collection. Factors contributing to the high prevalence of osteoporosis in LMICs include nutritional deficiencies, particularly low dietary calcium and vitamin D intake, along with lifestyle changes such as reduced physical activity. Additionally, cultural practices and socio-economic factors may further increase susceptibility to osteoporosis among these populations, necessitating targeted public health strategies to address this emerging health crisis.¹² Meanwhile various aspect of diagnostic limitations was identified and reported in Table 2.

Table 2: Challenges in diagnosis, treatment, and management.

Variables	Challenges identified in an therapy	Clinical implications
Diagnostic limitations	Scarcity of dual-energy X-ray absorptiometry (DXA) machines in a health care centre	Leads to widespread underdiagnosis of osteoporosis in a community.
	Insufficiently trained health care personnel for accurate diagnosis in a hospital.	Delayed or missed identification of osteoporosis cases, reducing opportunities for early intervention of a disease.
Treatment barriers	High costs of essential current medications and therapies	Limits patient access to treatment, increasing the prevalence of untreated osteoporosis.
	Limited drug availability of advanced osteoporosis treatments.	Results in poor clinical outcomes, higher risk of bone fractures, and disability.
Comorbidity challenges	High prevalence rate of co-morbid conditions such as diabetes, cardiovascular diseases, and malnutrition.	Complicates drug treatment regimens and diminishes adherence to therapy.
	Inadequate management strategies for addressing multiple conditions concurrently.	Exacerbates health inequalities and disparities in care outcomes.
Healthcare infrastructure	Lack of diagnostic DEXA Scan and osteoporosis-focused facilities in many healthcare centers.	Hinders timely management and delivery of appropriate care, resulting in poor fracture prevention in a patients.
	Insufficient funds in osteoporosis-specific programs and public health awareness initiatives.	Limits sources of understanding risk factors and preventive measures, contributing to higher rates of bone fractures and associated healthcare costs.

PATHOPHYSIOLOGY OF OSTEOPOROSIS IN POSTMENOPAUSAL WOMEN

Osteoporosis is a complex condition primarily affecting postmenopausal women, characterized by decreased bone

density was calculated DEXA scan Figure (2) and an elevated risk of fractures. The pathophysiology can be understood as a series of interrelated steps involving hormonal changes, cellular mechanisms, and structural alterations in bone.



Figure 2: A young woman undergoing a dual-energy X-ray absorptiometry (DEXA) scan, a non-invasive imaging procedure commonly used to assess BMD for diagnosing osteoporosis and monitoring bone health. The scan is performed with the patient lying flat on the table while a specialized machine passes over the lower body, providing precise bone density measurements.

HORMONAL CHANGES

Estrogen decline

Menopause triggers a marked decline in estrogen production, which plays a vital role in maintaining bone density by promoting osteoblast activity and inhibiting osteoclast-mediated bone resorption. The loss of estrogen disrupts this balance, resulting in accelerated bone loss.

Increased osteoclastogenesis

Reduced estrogen levels enhance osteoclast differentiation and activation from hematopoietic stem cells, primarily through upregulated RANKL signaling. This increase in osteoclast activity accelerates bone resorption, leading to a progressive loss of bone mass.

Elevated bone turnover rate

The imbalance caused by reduced osteoblast activity and sustained osteoclast activity leads to negative bone remodeling. Clinically, this increased bone turnover results in accelerated bone loss, particularly during the initial years following menopause.

Cellular mechanisms

Estrogen deficiency significantly disrupts bone remodeling by enhancing osteoclast activation and

prolonging their lifespan, leading to increased bone resorption, especially in the metabolically active trabecular bone. At the same time, the lack of estrogen impairs osteoblast signaling pathways, reducing their proliferation and differentiation, and may also promote osteoblast apoptosis, thereby decreasing bone formation. Additionally, estrogen plays a crucial role in regulating the Wnt/ β -catenin pathway, which is essential for osteoblast function. Its absence disrupts this pathway, further reducing osteoblast activity and new bone formation, ultimately contributing to progressive bone loss.¹³

MECHANICAL AND STRUCTURAL CHANGES

Deterioration of bone microarchitecture

Effects of bone loss: The ongoing imbalance between resorption and formation leads to significant structural changes in bone.

Consequences: Trabecular bone becomes less dense and more porous, compromising bone integrity and increasing the risk of fractures.

Increased skeletal fragility

Cumulative effects: The interplay of hormonal changes, osteoclast activation, and osteoblast dysfunction culminates in skeletal fragility.

Clinical implications: This fragility predisposes postmenopausal women to fractures, particularly in weight-bearing sites such as the hip, spine, and wrist.¹⁴

CARDIOVASCULAR SYSTEM EFFECTS

Increased cardiovascular risk

Estrogen plays a protective role in cardiovascular health by maintaining vascular function and favorable lipid profiles. Its decline after menopause leads to altered blood lipids, increased arterial stiffness, and endothelial dysfunction, placing postmenopausal women at greater risk for cardiovascular diseases such as hypertension, coronary artery disease, and stroke.

Metabolic changes

Hormonal changes during menopause, especially decreased estrogen levels, cause shifts in body fat distribution, leading to increased abdominal fat. This change contributes to metabolic syndrome, insulin resistance, and a higher risk of developing type 2 diabetes.¹⁵

UROGENITAL CHANGES

Urogenital atrophy

The decline in estrogen during menopause causes atrophy in the urogenital tract, resulting in vaginal dryness, reduced elasticity, and thinning of vaginal and urethral tissues. These changes can lead to symptoms such as painful intercourse, urinary incontinence, and recurrent urinary tract infections.¹⁶

PSYCHOLOGICAL AND COGNITIVE EFFECTS

Mood changes and cognitive function

Hormonal fluctuations during menopause can impact neurotransmitter systems, resulting in mood disturbances, anxiety, and depression. Additionally, some women experience cognitive difficulties such as impaired concentration and memory, though research on this aspect is still evolving (Kovács et al).

Limited awareness and resources for osteoporosis prevention in LMICs

Awareness of osteoporosis and its risk factors is alarmingly low in many LMIC. Public knowledge about the disease, its prevention, and the importance of bone health is often insufficient, which limits the adoption of preventive measures. Educational initiatives focused on osteoporosis are generally minimal or non-existent, and there is a lack of targeted outreach programs to inform individuals about the importance of adequate nutrition and physical activity for bone health.¹⁷

The growing burden of osteoporosis in aging populations within developing nations

The burden of osteoporosis is expected to grow significantly in aging populations within developing nations. As life expectancy increases and birth rates decline, the proportion of older adults is rising, leading to a greater incidence of age-related diseases, including osteoporosis. This demographic shift is particularly concerning in LMICs, where healthcare systems may already be strained by other pressing health challenges. The increased prevalence of osteoporosis among the elderly not only poses a risk for individual health outcomes but also places considerable stress on public health resources. Osteoporotic fractures can lead to long-term disability, decreased quality of life, and increased mortality among older adults, further complicating their care. As these countries face the dual challenges of managing an aging population and limited healthcare infrastructure, it becomes imperative to develop comprehensive strategies that encompass prevention, early diagnosis, and effective management of osteoporosis to alleviate the burden on individuals and healthcare systems alike.¹⁸. however, contributing factors and risk assessment of osteoporosis was shown in Table 3.

Table 3: Genetic and environmental risk factors for osteoporosis.

Main factor	Sub-factor	Description
Genetic	Family history of osteoporosis	Increases individual risk due to hereditary traits
	Genetic markers (related to bone density)	Specific markers linked to BMD
Environmental	UV-exposure level	Affects vitamin D synthesis in the body
	Vitamin D and calcium absorption level	Crucial for calcium absorption and bone health issue ²²
Socio-economic and healthcare system	Income level	Impacts access to nutrition and healthcare system
	Education level	Influences lifestyle choices for bone health
	Preventive care	Early interventions and health education
	Treatment access	Availability of medical resources for the osteoporosis

Lifestyle factors contributing to osteoporosis globally

Lifestyle choices are central to the development and progression of osteoporosis worldwide. Key dietary habits, such as low intake of calcium and vitamin D, are critical; populations with diets lacking dairy and leafy greens are more prone to osteoporosis. Regular physical activity is vital for maintaining bone density, while sedentary lifestyles contribute to bone loss. Moreover, harmful habits like smoking and excessive alcohol consumption increase osteoporosis risk by affecting bone density and disrupting calcium absorption. These factors collectively underscore the importance of targeted interventions to promote healthier lifestyle choices.

Regional differences in risk factor prevalence

Regional variations in osteoporosis risk factors can significantly influence disease incidence. For example, in the Middle East, vitamin D deficiency is common due to limited sun exposure and dietary insufficiencies, exacerbating osteoporosis rates. Conversely, many Asian countries struggle with dietary calcium insufficiency, as traditional diets often lack sufficient calcium-rich foods. These differences necessitate culturally sensitive prevention strategies that address specific nutritional needs. Additionally, while obesity can be associated with greater bone mass, it may also lead to metabolic issues that negatively impact bone health.

Impact of aging populations on osteoporosis incidence

The increasing proportion of older adults in the global population is significantly impacting the incidence of osteoporosis. As life expectancy rises and birth rates decline, the prevalence of osteoporosis continues to grow. Hormonal changes, particularly the reduction in estrogen levels during postmenopause, play a key role in accelerating bone loss. Additionally, older adults often face decreased levels of physical activity and inadequate nutritional intake, further elevating their risk for osteoporosis. This demographic shift underscores the importance of adopting proactive strategies for osteoporosis prevention and management. Key focus areas include early detection, nutritional interventions, and promoting regular physical activity to enhance bone health in older individuals. Our study identified a notable improvement in the "Walking" variable, which is both clinically significant and indicative of enhanced physical well-being and mobility among the participants. This finding highlights the potential benefits of targeted interventions in improving overall health outcomes for individuals at risk of or living with osteoporosis.¹⁹

PREVENTION AND MANAGEMENT STRATEGIES

Global recommendations for osteoporosis prevention

Osteoporosis prevention necessitates a comprehensive approach that prioritizes the adequate intake of essential

nutrients, particularly calcium and vitamin D, combined with regular physical activity. According to global health authorities such as the world health organization (WHO) and the international osteoporosis foundation (IOF), adults should aim for a dietary calcium intake of approximately 1,000 to 1,200 mg per day, with variations based on age and sex. Vitamin D is equally critical for calcium absorption and maintaining bone health, with recommended daily intakes ranging from 600 to 800 IU; supplementation is particularly advised for populations with limited sun exposure. Furthermore, participation in weight-bearing and resistance exercises is crucial for enhancing bone density and overall musculoskeletal health. Educational initiatives that raise awareness about bone health and its associated risk factors are essential to encourage preventive measures across various populations.²⁰

Regional differences in osteoporosis prevention programs

Osteoporosis prevention programs reveal substantial regional disparities influenced by local dietary habits, cultural practices, and healthcare resources. In North America and Europe, robust public health initiatives typically encompass nutritional guidelines, community programs aimed at promoting physical activity, and broad access to screening services. In contrast, LMIC often face significant challenges in osteoporosis prevention due to economic constraints and inadequate healthcare infrastructure. For example, areas with high vitamin D deficiency rates, such as certain regions of the Middle East, could greatly benefit from targeted public health campaigns promoting sun exposure and dietary intake of vitamin D-rich foods. In Asia, where dietary calcium insufficiency is a pressing concern, efforts may concentrate on improving access to calcium-rich foods and fortifying staple items with essential nutrients. These regional differences highlight the necessity for tailored prevention strategies that consider cultural, economic, and geographic factors.

Pharmacological treatments (global and regional access)

Our findings revealed a notable improvement in BMD when using a combination therapy of calcium (500 mg) and vitamin D3 (250 IU) daily. This combination plays a significant role in the current treatment guidelines for osteoporosis. However, among individuals with established osteoporosis, smoking and alcohol consumption emerged as the most prevalent risk factors. Raising calcium levels in bone mass through proper medication was observed in 21.6% of the subjects.

The study highlights that regular supplementation of calcium and vitamin D significantly enhances BMD and lowers the risk of osteoporosis. Pharmacological treatments for osteoporosis, such as bisphosphonates, selective estrogen receptor modulators (SERMs), and monoclonal antibodies, are critical for managing the

disease, particularly in individuals at high risk for fractures. Access to these therapies, however, varies widely between regions. In developed countries, a broader range of medications is available, supported by robust healthcare systems and insurance coverage. Conversely, LMIC face significant challenges, including high treatment costs, limited availability of medications, and insufficient awareness among healthcare professionals. Economic disparities further complicate the affordability and accessibility of these treatments, creating significant treatment gaps that exacerbate the burden of osteoporosis in underserved populations.^{21,22}

Challenges in osteoporosis management in developing countries

The management of osteoporosis in developing countries is hindered by numerous challenges that impede effective care delivery. A lack of robust healthcare infrastructure often results in insufficient diagnostic facilities, such as those required for BMD testing, leading to widespread underdiagnosis of the condition. Additionally, there is a scarcity of healthcare professionals trained in osteoporosis management, which complicates treatment efforts. Economic limitations restrict access to essential medications, with many individuals unable to afford ongoing treatment or follow-up care. Furthermore, cultural beliefs and practices can significantly influence health-seeking behaviors and attitudes toward preventive measures, potentially discouraging individuals from pursuing osteoporosis management. Addressing these multifaceted challenges requires targeted interventions and policy initiatives aimed at enhancing osteoporosis awareness, bolstering healthcare capacity, and ensuring equitable access to preventive and therapeutic resources in developing countries.²³

Research gaps and global initiatives

Osteoporosis is a growing global public health concern, yet significant research gaps remain, particularly regarding its prevalence and incidence in LMIC. Limited data hinders the development of targeted prevention and treatment strategies, and few studies explore the socioeconomic and cultural factors influencing osteoporosis across diverse populations. Additionally, the long-term safety and efficacy of newer therapies require further evaluation in specific groups such as men, postmenopausal women, and ethnic minorities. In response, the WHO and international organizations have actively promoted osteoporosis awareness through educational programs, clinical guidelines, and public campaigns. Despite these efforts, knowledge about osteoporosis remains low among both healthcare providers and the general public, often influenced by lifestyle factors like smoking, diet, hormonal therapy, and physical inactivity. Many individuals rely on informal sources for information, highlighting the need for targeted educational initiatives to improve awareness and disease management. The WHO's global strategy on diet, physical activity, and health

underscores the importance of healthy lifestyles in preventing osteoporosis, with public health events like world osteoporosis day serving as vital platforms to disseminate evidence-based information and encourage early detection and intervention.²⁴⁻²⁶

Global initiatives and campaigns to promote bone health

Numerous global initiatives and campaigns have been established to promote bone health and mitigate the impact of osteoporosis. The international osteoporosis foundation (IOF), for example, coordinates efforts to advocate for increased research funding, public education, and enhanced access to osteoporosis care. These campaigns frequently urge governments to implement national bone health policies and invest in preventive measures, including community-based screening programs and nutritional interventions. Collaboration among healthcare professionals, policymakers, and community stakeholders is crucial for fostering awareness and driving meaningful change, ultimately aiming to reduce incidence of osteoporosis-related fractures globally.²⁷

Importance of education and early detection in different regions

The significance of education and early detection in the battle against osteoporosis varies considerably across regions. In high-income countries, where healthcare resources are more readily available, educational initiatives can emphasize the importance of routine bone density screenings and lifestyle modifications. In contrast, LMICs may require tailored educational programs focusing on nutritional interventions and community engagement, which address specific cultural beliefs and practices that influence health behaviors. Early detection through screening and awareness campaigns can facilitate timely interventions, improving health outcomes and reducing fracture risk. The effectiveness of these initiatives relies heavily on understanding the unique challenges faced by different populations, allowing for a more targeted and effective approach.²⁸

FUTURE DIRECTIONS

Recent advances in pharmacotherapy, including new bisphosphonates and biologic agents, alongside non-pharmacological measures like nutrition and lifestyle changes, offer promising avenues for improving outcomes. Technological innovations such as telemedicine and mobile health tools further support patient monitoring and engagement. Effective osteoporosis management requires strong international collaboration to share knowledge and resources, and policy efforts should prioritize funding, education, and standardized care guidelines. Moreover, interventions must be tailored to regional risk factors and healthcare capacities-addressing local dietary patterns, cultural practices, vitamin D deficiencies, and access barriers-to ensure equitable and effective prevention and treatment globally.²⁹⁻³⁰

CONCLUSION

A multifaceted strategy that highlights early detection, effective management, and wide public awareness will be necessary to address the global burden of osteoporosis. In order to reduce the risk of fractures and enhance the wellness of bones, screening programs that identify high-risk individuals enable prompt interventions, such as prescription drugs and lifestyle changes. Public education campaigns that highlight the value of preventive measures, like ensuring adequate intake of both vitamin D and calcium and integrating regular physical activity into every day activities, are equally significant. Together, these tactics can lessen the incidence and effects of osteoporosis on people and healthcare systems around the world by raising awareness and promoting preventative health practices.

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