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Literature Review

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The role of calcium-fortified milk in preventing osteoporosis in the elderly: A Literature Review

Peran susu yang diperkaya kalsium dalam mencegah osteoporosis pada lansia: Tinjauan Pustaka

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Abstract

Osteoporosis is a common degenerative disease among the elderly that increases fracture risk and ranks among the top 10 global degenerative conditions according to WHO. This study reviews evidence on the effectiveness of calcium-rich milk and dairy products in preventing osteoporosis in older adults. This is a review was conducted using purposive sampling of journal articles from 2008 to 2022 from Google Scholar. Studies were evaluated based on Elwood's framework, focusing on evidence description, internal and external validity, and biological plausibility. As a result, all articles confirmed calcium's role in bone formation and maintenance. Two review articles highlighted the importance of calcium and vitamin D for bone health, particularly in specific groups like long-term corticosteroid users and older adults with mineral imbalances; however, they lacked empirical data and statistical analysis. Two cross-sectional studies showed associations between calcium intake and improved bone mineral density or reduced osteoporosis risk, but limitations such as uncontrolled confounders and incomplete statistics reduce confidence in these findings. No longitudinal or randomized controlled trials were identified to establish causality or dose-response relationships. Although calcium is essential for bone health, current evidence is insufficient to conclusively support calcium-fortified milk as an effective intervention to prevent osteoporosis in the elderly. Further longitudinal and randomized controlled studies are necessary to provide robust data to inform public health policies. As an immediate step, health practitioners should promote a balanced diet rich in calcium and vitamin D alongside lifestyle modifications such as regular weight-bearing exercise to support bone health in older adults.
Keywords: Osteoporosis, Calcium, Elderly

Abstrak

Osteoporosis adalah penyakit degeneratif umum di kalangan lansia yang meningkatkan risiko patah tulang. Review studi ini meninjau bukti tentang efektivitas susu dan produk susu yang kaya kalsium dalam mencegah osteoporosis pada orang dewasa. Artikel yang direview terbit dari tahun 2008 hingga 2022 dari Google Scholar. Studi dievaluasi berdasarkan kerangka kerja Elwood, dengan fokus pada deskripsi bukti, validitas internal dan eksternal, dan kemungkinan biologis. Hasil review mengungkapkan bahwa semua artikel mengkonfirmasi peran kalsium dalam pembentukan dan pemeliharaan tulang. Dua artikel review menyoroti pentingnya kalsium dan vitamin D untuk kesehatan tulang, terutama pada kelompok tertentu seperti pengguna kortikosteroid jangka panjang dan orang dewasa yang lebih tua dengan ketidakseimbangan mineral; namun, mereka kekurangan data empiris dan analisis statistik. Dua studi cross-sectional menunjukkan hubungan antara asupan kalsium dan peningkatan kepadatan mineral tulang atau penurunan risiko osteoporosis, tetapi keterbatasan seperti faktor perancu tidak dikendalikan. Meskipun kalsium sangat penting untuk kesehatan tulang, bukti saat ini tidak cukup untuk secara meyakinkan mendukung susu yang diperkaya kalsium sebagai intervensi yang efektif untuk mencegah osteoporosis pada orang tua. Sehingga studi longitudinal lebih lanjut diperlukan untuk memberikan data yang kuat sehingga dapat dipergunakan sebagai landasan kebijakan kesehatan masyarakat. Sebagai langkah pencegahan awal, para tenaga kesehatan dan pemerhati kesehatan harus mempromosikan diet seimbang yang kaya kalsium dan vitamin D di samping modifikasi gaya hidup seperti olahraga beban secara teratur untuk mendukung kesehatan tulang pada kelompok usia dewasa.
Kata kunci: Osteoporosis, Kalsium, Lansia

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Introduction

Calcium plays a fundamental role in the bone remodeling process, which is also influenced by nutrition, physical activity, estrogen, endogenous hormones, vitamin D, parathyroid hormone, tumor necrosis factor (TNF), and insulin-like growth factors I and II. Bone remodeling ceases and maintains its mass once linear growth and maximum bone volume are achieved. Bone mass is determined by the dynamic balance between bone formation and resorption processes.[1,2,3]

Bone tissue comprises three main cell types: osteoblasts, osteocytes, and osteoclasts. Osteoblasts are responsible for bone formation, mineralization, and parathyroid hormone receptor expression. Osteoclasts are multinucleated bone cells derived from hematopoietic precursors and contain lysosomal enzymes. Osteocytes, the most abundant bone cells, are small and flattened, embedded in the bone matrix, and responsible for translating mechanical stimuli into signals that induce remodeling aligned with mechanical load. Osteocytes are interconnected via canaliculi networks and undergo apoptosis or phagocytosis during osteoclastic resorption. Bone is composed of extracellular matrix and bone cells. The extracellular matrix consists primarily of organic components and a smaller portion of inorganic elements. The organic matrix includes type I collagen, proteoglycans, non-collagenous proteins (osteocalcin, osteonectin, osteopontin), thrombospondin, growth factors, and cytokines. The inorganic matrix primarily comprises calcium hydroxyapatite, which serves as a reservoir for calcium and phosphate ions.[4,5]

Osteoporosis is a systemic skeletal disorder characterized by low bone mass and microarchitectural deterioration, leading to bone fragility and increased fracture risk. It is most prevalent in the elderly. According to WHO, osteoporosis ranks among the top 10 global degenerative diseases. Contributing factors include aging, prior fracture history, family history of low bone mass, menopause, and prolonged corticosteroid use.[6,7] Calcium deficiency during bone growth is a major risk factor. Individuals with osteoporosis face a 18% higher total fracture risk and 43% pelvic fracture, adversely affecting mobility and quality of life.[8]

Calcium, a micronutrient, is essential in small amounts for human health. It contributes to hormone and enzyme synthesis involved in metabolism and digestion. Preventing osteoporosis involves adequate calcium intake throughout life, regular physical activity, non-smoking habits, and hormonal balance. Calcium's direct role strengthens bone growth via absorption, while indirectly preventing rickets due to vitamin D deficiency or calcium-phosphorus imbalance that disrupts bone mineralization. Achieving peak bone mass during growth phases is vital to preventing bone loss in adulthood.[8,9] Adequate calcium intake is essential for building optimal bone mass in the first three decades of life. In infants, children, and adolescents, calcium supports bone formation alongside dietary intake and protein sufficiency. Evidence shows that adult and elderly bone loss is influenced by peak bone mass achieved in earlier life stages.[10] Therefore, high calcium intake during growth is critical.

Calcium-rich foods and proteins are necessary to achieve optimal peak bone mass and prevent osteoporosis. Dairy products, particularly milk, are the most common calcium sources consumed by the elderly. They are widely believed to reduce osteoporosis risk. This review aims to examine the benefits of consuming milk and dairy products in preventing osteoporosis among older adults.

Methods

This study employed a review to examine peer-reviewed journal articles published between 2008 and 2022 that discuss the association between calcium intake, particularly from milk and its derivatives and osteoporosis in the elderly. The articles were selected using purposive sampling through Google Scholar, based on relevance to the research objectives. Data collection was performed by identifying eligible articles that fulfilled criteria such as focus on calcium consumption, relevance to bone health or osteoporosis, study population including older adults, and publication in a scientific journal. The primary instrument used for analysis was a review matrix adapted from J. Mark Elwood's *Critical Appraisal of Epidemiological Studies and Clinical Trials*[11] which facilitated systematic appraisal.

The review considered several dimensions: (1) description of evidence including exposure, outcome, study design, population, and main findings; (2) assessment of internal (3) external validity.

Result And Discussion

A total of four journal articles were included in the final analysis. Two were literature-based reviews and two were cross-sectional empirical studies. The synthesis focused on evaluating methodological strengths and limitations, the plausibility of biological mechanisms, and the consistency of findings across studies. The summary of reviewed as detailed in Table 1.

Tabel 1. Summary of reviewed articles on calcium-rich milk consumption and osteoporosis prevention in the elderly

Author(s), Country, Year	Study Design	Exposure & Outcome Description	Study Population	Main Findings
Setiorini et al., Indonesia, 2009[12]	Literature Review	Exposure: Calcium and vitamin D supplementation; Outcome: Osteoporosis prevention in long-term corticosteroid users	Children on long-term corticosteroid therapy	Calcium and vitamin D supplementation are needed to prevent bone mass loss in this group
Polzonetti et al., Italy, 2020[13]	Literature Review	Exposure: Intake of dairy, vitamin D, and selected minerals; Outcome: Fracture risk in older adults	Elderly individuals	Imbalance of calcium-phosphorus (calcium paradox) may increase fracture risk; highlights role of mineral homeostasis
Hayati & Herwana, Indonesia, 2018[14]	Cross-sectional	Exposure: Dietary calcium intake; Outcome: Bone mineral density (BMD)	Postmenopausal women	Increased calcium intake is associated with less BMD reduction
Al-Daghri et al., Saudi Arabia, 2023[8]	Cross-sectional	Exposure: Calcium intake from milk, fish, tea; Outcome: Risk of osteoporosis	Adults >30 years attending a hospital	Higher dietary calcium intake associated with lower osteoporosis risk; intake was below recommended levels
Al-Hazzaa et al., (2022)[10]	Polandia	1.248	Cross-sectional	Overweight

The results showed that although calcium has an important biological role in the formation and maintenance of bone structure, the currently available scientific evidence is still not strong enough to conclude that consumption of calcium-rich milk in particular can prevent osteoporosis in old age. The first two articles using a literature review approach emphasize the importance of calcium and vitamin D in maintaining bone strength and mineralization.[12] The articles theoretically support that calcium and vitamin D deficiencies can interfere with bone homeostasis.[15,16] which in turn may increase the risk of osteoporosis, especially in vulnerable populations such as long-term corticosteroid users and the elderly with impaired mineral metabolism.[17] However, because it is not supported by empirical data or statistical tests, the conclusions produced are conceptual and cannot be generalized. The arguments of both are based more on basic physiological and biological principles than on quantitatively testable causal evidence.

The process of bone remodeling that lasts a lifetime is greatly influenced by calcium intake. Calcium deficiency during growth can inhibit the achievement of peak bone mass, increasing the risk of osteoporosis in old age.[8,18,19] Vitamin D plays an important role in the absorption of calcium in the intestines and the regulation of calcium-phosphate levels in the blood.[20] An imbalance between calcium, phosphate, and vitamin D can lead to bone remodeling disorders.[11,21,22] However, the role of milk as a source of calcium in the prevention of osteoporosis is still not effective, especially in the elderly group. The nutritional content of milk is rich in calcium, its also effectiveness in increasing bone mineral density (BMD) in the elderly and lowering risk of bone fracture[23].

Two other articles using cross-sectional study designs reported an association between calcium intake and bone mineral density or reduced risk of osteoporosis.[14,24] These results are indeed in line with the biological theory that calcium supports bone integrity.[25,26] However, the limitations of the study design are an important issue that needs to be examined. Both articles did not mention control for confounding factors such as vitamin D levels,

physical activity levels, and hormonal status, all of which play an important role in bone metabolism. In addition, not all important statistical parameters such as p-values and *confidence intervals* are reported, so the strength of the relationship between variables cannot be accurately assessed. Cross-sectional studies have also not been able to explain the cause-and-effect relationship, so the results found are not strong enough to be used as a basis for designing public health interventions.

In terms of external validity, both studies have limitations because they were conducted in very specific populations, such as postmenopausal women or hospital patients. This population cannot be representative of the elderly group in general. None of the articles examined the temporal relationship between calcium consumption from milk and the incidence of osteoporosis longitudinally, or evaluated the dose-response relationship required in the effectiveness of the intervention. Therefore, although all four articles support the theoretical importance of calcium, the limitations of the design and methods of analysis confirm that the claim of benefits of calcium milk to the prevention of osteoporosis in the elderly still requires further scientific proof. Longitudinal studies and *randomized controlled trials (RCTs)* that consider the duration of interventions, optimal doses, and control of confounding factors are needed to produce strong and generalizable evidence. With this approach, a new calcium-based intervention can be seriously considered as a public health strategy for the prevention of osteoporosis in elderly.

The findings of this review suggest that although there is a strong theoretical relationship between calcium intake and bone health, empirical evidence supporting the effectiveness of calcium milk consumption in preventing osteoporosis in the elderly is weak. The reviewed literature analyzed mostly concluded the benefits of calcium and vitamin D in maintaining bone strength, but the conclusions were based more on physiological principles and general epidemiological data.[12,13] None of the articles presented longitudinal data or clinical trial results evaluating the specific impact of calcium milk consumption on the incidence of osteoporosis. In addition, variations in milk types, nutritional content, and other lifestyle factors were not controlled or analyzed in the reviewed studies. Therefore, while biologically plausible, the claim of milk benefits as a preventive intervention is still speculative and requires confirmation through more controlled and representative studies.

In addition, this review also highlights the importance of considering contextual factors that affect the effectiveness of calcium milk-based interventions.[14,24] For example, low vitamin D status can inhibit calcium absorption, so the consumption of high-calcium milk alone may not be sufficient without vitamin D supplementation. In the context of the elderly, factors such as malabsorption, decreased physical activity, as well as the use of drugs that affect bone metabolism need to be taken into account in the evaluation of the benefits of milk consumption. These findings emphasize the need for a more integrated and evidence-based approach in developing nutrition policies or recommendations for the prevention of osteoporosis in older age groups.

Conclusion

Although calcium has an important biological role in bone formation and maintenance, empirical evidence supporting the effectiveness of calcium milk consumption in particular in the prevention of osteoporosis in the elderly remains strong and consistent. Existing studies suggest a potential link between calcium intake and bone health, but the limitations of the study design and lack of strong empirical data hamper definitive claims. Therefore, it is recommended to conduct further research with longitudinal designs or randomized controlled trials that can control confounding variables and evaluate dose-effect relationships appropriately. This approach is important to produce strong and valid scientific evidence so that the consumption of calcium milk can be officially recommended as an osteoporosis prevention intervention for elderly.

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