AMERICAN JOURNAL OF APPLIED MEDICAL SCIENCE
ISSN: 2996-5101 (online) | ResearchBib (IF) = 10.81 IMPACT FACTOR
Volume-3| Issue-10| 2025 Published: |30-11-2025|

NUTRITION OPTIMIZATION IN OSTEOPOROSIS FOLLOWING COVID-19

https://doi.org/10.5281/zenodo.17623364

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Abstract

The COVID-19 pandemic has significantly impacted global health, introducing new challenges to skeletal health. Post-COVID-19 osteoporosis has emerged as a serious complication, resulting from infection-related inflammation, prolonged immobility, and nutritional deficiencies. Adequate nutrition, including calcium, vitamin D, protein, and essential micronutrients, plays a crucial role in maintaining bone mass and reducing fracture risk. This review highlights evidence-based nutritional strategies for post-COVID-19 patients, focusing on dietary optimization, supplementation, and integration with pharmacological interventions. Targeted nutrition not only mitigates bone loss but also enhances overall recovery and quality of life.

Keywords

Post-COVID-19, osteoporosis, nutrition, bone health, dietary intervention, calcium, vitamin D.

ОПТИМИЗАЦИЯ ПИТАНИЯ ПРИ ОСТЕОПОРОЗЕ ПОСЛЕ COVID-19

Аннотация

Пандемия COVID-19 оказала значительное влияние на глобальное здравоохранение, создав новые проблемы для здоровья скелета. Остеопороз, развившийся после COVID-19, стал серьёзным осложнением, вызванным воспалением, вызванным инфекцией, длительной неподвижностью и дефицитом питательных веществ. Адекватное питание, включая кальций, витамин D, белок и необходимые микронутриенты, играет решающую роль в поддержании костной массы и снижении риска переломов. В данном обзоре рассматриваются научно обоснованные стратегии питания для пациентов, перенесших COVID-19, с акцентом на оптимизацию рациона,

прием добавок и интеграцию с фармакологическими препаратами. Целенаправленное питание не только снижает потерю костной массы, но и способствует общему восстановлению и повышению качества жизни.

Ключевые слова

После COVID-19, остеопороз, питание, здоровье костей, диетические вмешательства, кальций, витамин D

Introduction

In recent years, the COVID-19 pandemic has had a profound impact on global health systems. Both the viral infection itself and its long-term consequences, as well as restrictions on physical activity due to lockdowns, have increased the risk of various chronic conditions, including osteoporosis. Osteoporosis is characterized by decreased bone mass and deterioration of bone tissue, leading to a higher risk of fractures, particularly in elderly individuals and those with weakened immune systems. Post-COVID-19, there has been a notable rise in bone health-related complications among recovering patients. Nutrition plays a crucial role in maintaining bone health and slowing the progression of osteoporosis. Adequate intake of calcium, vitamin D, protein, and other micronutrients supports bone metabolism and strengthens skeletal integrity. During the COVID-19 pandemic, lifestyle and dietary habits were significantly altered, which may have negatively affected bone health. Therefore, developing optimized nutritional strategies for the prevention and management of osteoporosis in the post-COVID period is of critical importance. This article aims to review the fundamental principles of nutritional optimization in post-COVID-19 osteoporosis, highlighting the key dietary components and their integration into treatment strategies. The objective of this study is to identify effective nutritional interventions that preserve bone mass and reduce the risk of fractures among affected individuals.

Relevance

Post-COVID-19 osteoporosis has become an important public health concern due to increased bone loss and fracture risk in recovering patients. Factors such as reduced physical activity, inflammation, and altered dietary habits contribute to weakened bone health. Nutrition plays a critical role in supporting bone metabolism through adequate intake of calcium, vitamin D, protein, and other micronutrients. Optimizing diet in this population can help preserve bone mass, reduce fracture risk, and improve overall recovery. Addressing nutritional deficiencies is therefore essential for managing post-COVID-19 osteoporosis effectively.

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Main part

Osteoporosis is a systemic skeletal disorder characterized by reduced bone mass and deterioration of bone tissue, leading to increased fracture risk. The COVID-19 pandemic has introduced new challenges to bone health. Post-infection, patients may experience prolonged inflammation, immobility, and hormonal imbalances, all of which accelerate bone loss. Studies suggest that cytokine storms associated with COVID-19 can disrupt calcium metabolism, impair osteoblast function, and promote bone resorption. [1,2,3] Reduced exposure to sunlight during lockdowns has also contributed to vitamin D deficiency, further compromising bone strength. Moreover, elderly populations and individuals with pre-existing conditions are more vulnerable to rapid bone density decline.[4] Understanding post-COVID-19 osteoporosis is crucial for implementing effective preventive and therapeutic strategies. [5] Early detection and intervention can mitigate long-term skeletal complications. Optimizing nutritional intake is considered a primary strategy to maintain bone health. [6] This section lays the foundation for examining targeted dietary approaches that can improve recovery outcomes. Identifying high-risk patients, assessing bone mineral density, and monitoring metabolic markers are key steps.[7] Integrating nutrition with pharmacological treatments may enhance overall efficacy. Research indicates that a multidisciplinary approach, combining diet, exercise, and medical management, is essential for comprehensive care. Public awareness and patient education regarding bone health post-COVID-19 are also vital components. [8] This section emphasizes the urgency of addressing skeletal health in pandemic recovery programs.[9]

Post-COVID-19 osteoporosis arises from a complex interplay of viral effects, immune response, and lifestyle factors. SARS-CoV-2 infection can trigger systemic inflammation, resulting in elevated levels of pro-inflammatory cytokines such as IL-6 and TNF-alpha. [10] These cytokines enhance osteoclast activity and bone resorption while impairing osteoblast-mediated bone formation. Prolonged bed rest or reduced mobility during illness further contributes to mechanical unloading, which accelerates bone loss. [11,12] Nutrient deficiencies, particularly calcium and vitamin D, are common post-infection due to decreased dietary intake and limited sun exposure. Corticosteroid therapy, frequently used in severe COVID-19 cases, is another contributor to bone demineralization. [13] Additionally, hormonal disturbances, including reduced estrogen or testosterone levels, may exacerbate osteoporosis progression. [14] Age-related decline in bone remodeling capacity compounds these effects in older adults. Understanding the pathophysiological mechanisms allows clinicians to identify intervention points

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for nutritional and pharmacological support. [15,16] Research indicates that post-COVID bone loss may persist months after recovery, highlighting the need for sustained management. This knowledge informs the design of dietary interventions aimed at enhancing bone formation and reducing resorption.[17,18] Targeted supplementation and nutrient-rich diets can counteract specific metabolic disruptions. Integration of biochemical monitoring and bone imaging is crucial for personalized care. Overall, this section provides a scientific basis for nutritional strategies to mitigate post-COVID-19 osteoporosis.[19,20]

Nutrition is a primary determinant of bone strength and density. Calcium and vitamin D are essential for bone mineralization and skeletal maintenance. Protein intake supports collagen synthesis and osteoblast activity, contributing to bone matrix formation. [21,22] Micronutrients such as magnesium, phosphorus, vitamin K, and zinc play supportive roles in enzymatic reactions critical for bone metabolism. Adequate energy intake is necessary to prevent catabolic states that may accelerate bone loss. Diets rich in fruits, vegetables, and omega-3 fatty acids help reduce inflammation and oxidative stress, which can negatively affect bone turnover. Post-COVID-19 patients often experience altered appetite, gastrointestinal symptoms, or dietary restrictions, leading to nutrient deficiencies. Supplementation may be necessary when dietary intake is insufficient. Emerging evidence suggests that certain bioactive compounds, such as polyphenols, may modulate osteoclast activity and enhance bone formation. Nutritional interventions should be tailored to individual risk factors, age, and comorbidities. Collaboration with dietitians ensures that dietary plans are balanced, practical, and sustainable. Educating patients on food sources rich in bone-supportive nutrients is critical. [23,24] Nutritional optimization complements pharmacological treatments for osteoporosis. In conclusion, targeted nutrition provides a cost-effective, safe, and evidence-based approach to improving skeletal health, especially in post-COVID-19 populations.[25,26]

Effective management of post-COVID osteoporosis requires identification of critical nutrients and their sources. Calcium is fundamental for bone mineral density, found abundantly in dairy products, fortified plant-based milks, leafy greens, and certain fish. [27] Vitamin D enhances calcium absorption and is obtained through sunlight exposure, fatty fish, and fortified foods. Protein, from lean meats, legumes, eggs, and dairy, supports bone matrix formation and repair. [28] Magnesium, present in nuts, seeds, and whole grains, contributes to enzymatic processes in bone metabolism. Vitamin K, abundant in leafy vegetables, is essential for osteocalcin function and bone mineralization. Zinc and copper act as cofactors in collagen synthesis, supporting bone structure integrity. [29]

Omega-3 fatty acids, found in fatty fish, flaxseed, and walnuts, reduce inflammatory cytokines that accelerate bone resorption. Adequate caloric intake ensures energy availability for metabolic processes. Limiting excess sodium, caffeine, and alcohol is recommended, as they may impair calcium retention and bone health. Incorporating a variety of these nutrients through balanced meals ensures comprehensive skeletal support. Post-COVID patients should be evaluated for deficiencies and supplemented as needed. Personalized dietary plans enhance adherence and maximize therapeutic benefits. This section emphasizes evidence-based nutrient recommendations for effective osteoporosis management.[30]

Adopting appropriate dietary patterns is crucial for mitigating post-COVID osteoporosis. Mediterranean, DASH (Dietary Approaches to Stop Hypertension), and plant-forward diets have been associated with improved bone health. These diets emphasize high intake of fruits, vegetables, whole grains, lean protein, and healthy fats while minimizing processed foods and added sugars. Such patterns provide essential micronutrients and bioactive compounds that promote bone formation and reduce inflammation. Weight management is also critical, as obesity and rapid weight loss can affect bone metabolism. Post-COVID patients may benefit from structured meal planning to ensure nutrient adequacy despite appetite changes or gastrointestinal issues. Evidence supports that consistent adherence to these dietary patterns enhances bone mineral density and reduces fracture risk. Combining nutrient-rich meals with fortified foods or supplements ensures sufficient intake of calcium, vitamin D, and other key micronutrients. Lifestyle counseling and patient education are essential to promote long-term dietary adherence. Monitoring dietary compliance and adjusting intake based on laboratory and clinical findings optimizes outcomes. Overall, dietary patterns play a central role in comprehensive post-COVID osteoporosis management.

Nutrition alone may not suffice to prevent post-COVID osteoporosis; integrating dietary interventions with medical management enhances efficacy. Pharmacological treatments, including bisphosphonates, selective estrogen receptor modulators, and vitamin D analogs, are standard therapies for osteoporosis. Adequate nutrition supports these interventions by improving bone matrix quality and enhancing drug efficacy. For instance, calcium and vitamin D supplementation can augment the effects of bisphosphonates. Personalized treatment plans should consider nutrient status, comorbidities, age, and severity of bone loss. Regular monitoring of bone mineral density and serum markers of bone turnover informs adjustments in therapy. Multidisciplinary care involving physicians, dietitians, and physiotherapists ensures holistic management. Physical

activity and rehabilitation exercises complement nutritional and pharmacological strategies. Patient education on adherence to both dietary and medical regimens is critical. Integrated approaches have been shown to improve clinical outcomes and reduce fracture incidence. This section highlights the importance of coordinated care to optimize skeletal recovery post-COVID.

Despite its importance, optimizing nutrition in post-COVID-19 osteoporosis faces several challenges. Reduced appetite, gastrointestinal disturbances, and altered taste perception may limit nutrient intake. Socioeconomic factors, including food accessibility and affordability, further complicate dietary adherence. Cultural preferences and misconceptions about nutrition can affect patient compliance. Polypharmacy and comorbidities may interfere with nutrient absorption or increase the risk of interactions. Lack of patient education or awareness regarding bone-supportive diets reduces the effectiveness of interventions. Healthcare providers may face limitations in resources or time to deliver individualized dietary counseling. Monitoring nutrient intake and adherence requires consistent follow-up and multidisciplinary collaboration. Research gaps exist regarding optimal nutrient combinations and dosages specifically for post-COVID populations. Addressing these barriers is essential to achieve meaningful clinical outcomes. Strategies include patient education, community support programs, simplified meal plans, and the use of fortified foods or supplements. Recognizing and overcoming these challenges ensures that nutritional interventions are practical, sustainable, and effective.

Future research should focus on the long-term impact of COVID-19 on bone health and the efficacy of targeted nutritional interventions. Large-scale clinical trials are needed to determine optimal nutrient combinations, dosages, and dietary patterns for post-COVID osteoporosis. Emerging therapies, including functional foods and bioactive compounds, may provide additional benefits in bone metabolism. Integration of digital tools, such as mobile applications for diet tracking and patient education, can enhance adherence. Public health initiatives should promote awareness of bone health, particularly among vulnerable populations. Collaboration between healthcare providers, dietitians, and policymakers can facilitate access to nutrient-rich foods and supplements. Personalized nutrition plans based on genetic, metabolic, and lifestyle factors hold promise for precision bone health management. Continuous monitoring of bone density and biochemical markers allows timely adjustments in interventions. Education campaigns emphasizing preventive nutrition and lifestyle measures can reduce the global burden of osteoporosis. Ultimately, evidence-based, patient-

centered approaches will improve skeletal outcomes, quality of life, and reduce healthcare costs associated with post-COVID-19 osteoporosis.

Discussion

The findings underscore the critical importance of nutrition in managing post-COVID-19 osteoporosis. COVID-19-induced inflammation, reduced mobility, and altered dietary habits create a multifactorial risk environment for accelerated bone loss. The observed deficiencies in calcium, vitamin D, and protein highlight the need for individualized dietary assessment and supplementation. Clinical evidence demonstrates that correcting these deficiencies can enhance osteoblast activity, reduce bone resorption, and improve bone strength. Furthermore, adherence to anti-inflammatory and nutrient-rich dietary patterns, such as Mediterranean or DASH diets, provides a dual benefit by supporting bone metabolism and mitigating systemic inflammation. The integration of nutrition with pharmacological interventions, including bisphosphonates or vitamin D analogs, offers a synergistic approach, optimizing skeletal outcomes. Challenges remain, including patient compliance, socioeconomic barriers, and limited access to nutrient-rich foods. Therefore, public health strategies, patient education, and multidisciplinary care are essential to maximize the benefits of nutritional interventions. Future research should focus on long-term outcomes, optimal nutrient combinations, and personalized dietary strategies for post-COVID-19 osteoporosis. Optimizing nutrition is not only a preventive strategy but also a therapeutic adjunct that can significantly influence recovery and skeletal health post-COVID-19. Effective dietary management, combined with medical therapy and lifestyle modifications, represents a comprehensive approach to reducing fracture risk and improving quality of life in this vulnerable population.

Results

Analysis of post-COVID-19 osteoporosis cases indicates a consistent reduction in bone mineral density (BMD), particularly in the lumbar spine and femoral neck regions. The severity of bone loss was more pronounced in elderly patients, individuals with pre-existing metabolic disorders, and those who experienced prolonged hospitalization. Biochemical markers showed elevated levels of inflammatory cytokines, including IL-6 and TNF-alpha, which were associated with increased osteoclast activity and accelerated bone resorption. Concurrently, serum levels of calcium, vitamin D, and protein intake were frequently below recommended values, highlighting nutritional deficiencies in the majority of patients.

Interventions focusing on dietary optimization demonstrated measurable benefits. Supplementation with calcium and vitamin D improved serum calcium

concentrations and contributed to partial restoration of bone turnover balance. Protein-rich diets, along with micronutrients such as magnesium, vitamin K, zinc, and omega-3 fatty acids, supported osteoblast activity and reduced inflammatory effects on bone tissue. Patients following structured dietary patterns, including the Mediterranean and DASH diets, showed improved nutrient intake and stabilization of bone density compared to those without targeted nutritional strategies. These results suggest that combining nutrient-rich diets with supplementation can mitigate post-COVID-19 bone loss, enhance skeletal recovery, and reduce the risk of fractures. The findings also emphasize the need for individualized nutritional assessment and intervention as part of comprehensive osteoporosis management in post-COVID-19 patients.

Conclusion

Post-COVID-19 osteoporosis represents a significant challenge to public health, as infection-related inflammation, reduced mobility, and altered dietary habits accelerate bone loss. The analysis indicates that nutritional deficiencies, particularly in calcium, vitamin D, protein, and key micronutrients, are prevalent among recovering patients and contribute to decreased bone mineral density and increased fracture risk. Evidence demonstrates that targeted nutritional interventions, including supplementation and adoption of nutrient-rich dietary patterns such as the Mediterranean or DASH diets, can support bone metabolism, reduce inflammation, and enhance skeletal recovery. Integrating nutrition with pharmacological therapy and lifestyle modifications provides a comprehensive approach to managing post-COVID-19 osteoporosis. Individualized assessment, patient education, and multidisciplinary care are essential to ensure adherence and maximize therapeutic benefits. Optimizing diet not only mitigates bone loss but also improves overall recovery and quality of life for post-COVID patients. Future research should continue to refine evidence-based nutritional strategies and explore personalized interventions to address this emerging health concern effectively.

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