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COMMENTARY

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Calcium and vitamin D supplementation for fracture and fall prevention: A reappraisal from a mechanical loading perspective

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Calcium and vitamin D have traditionally been considered central to skeletal health. Calcium serves as a key substrate for bone mineralization, while vitamin D facilitates intestinal calcium absorption and supports calcium–phosphate homeostasis. On this basis, supplementation with calcium and vitamin D, alone or in combination, has long been embedded in clinical practice as a standard approach for preventing fractures and falls. Nevertheless, fracture and fall risk is driven by a complex interplay of physiological, environmental, and functional factors, which makes it unlikely that nutritional supplementation alone can substantially modify outcomes at a population level. The divergence between biological rationale, clinical practice, and trial evidence has prompted re-examination of whether routine supplementation remains justified as a broad preventive strategy in community-dwelling adults. This question becomes particularly relevant when supplementation extends beyond correction of deficiency and is used as a general preventive intervention.

In this context, a recent systematic review and meta-analysis by Massé et al., published in *The BMJ*, provides important evidence for reappraising current practice. The analysis included 69 randomized controlled trials involving 153,902 adults and examined the effects of calcium, vitamin D, and their combination on fracture and fall outcomes. For any fracture, moderate- to high-certainty evidence indicated a pooled risk ratio of 0.91 (95% CI, 0.81–1.01) for calcium alone, 1.00 (95% CI, 0.95–1.06) for vitamin D alone, and 0.91 (95% CI, 0.84–0.99) for combined supplementation. Although combined supplementation showed a statistically significant reduction in some analyses, the absolute benefit did not reach the predefined minimal clinically important difference. Overall, the authors reported little or no meaningful protection against fractures. Similar null or minimal effects were observed for other fracture- and fall-related outcomes.[1] Taken together, these findings suggest that, in most community-dwelling adults without overt deficiencies or high-risk conditions, routine calcium and vitamin D supplementation is unlikely to yield clinically relevant benefits for fracture or fall prevention. More broadly, these findings support a shift in fracture and fall prevention from a supplementation-centered approach to a mechanobiology-driven framework, mediated through muscle function and balance.

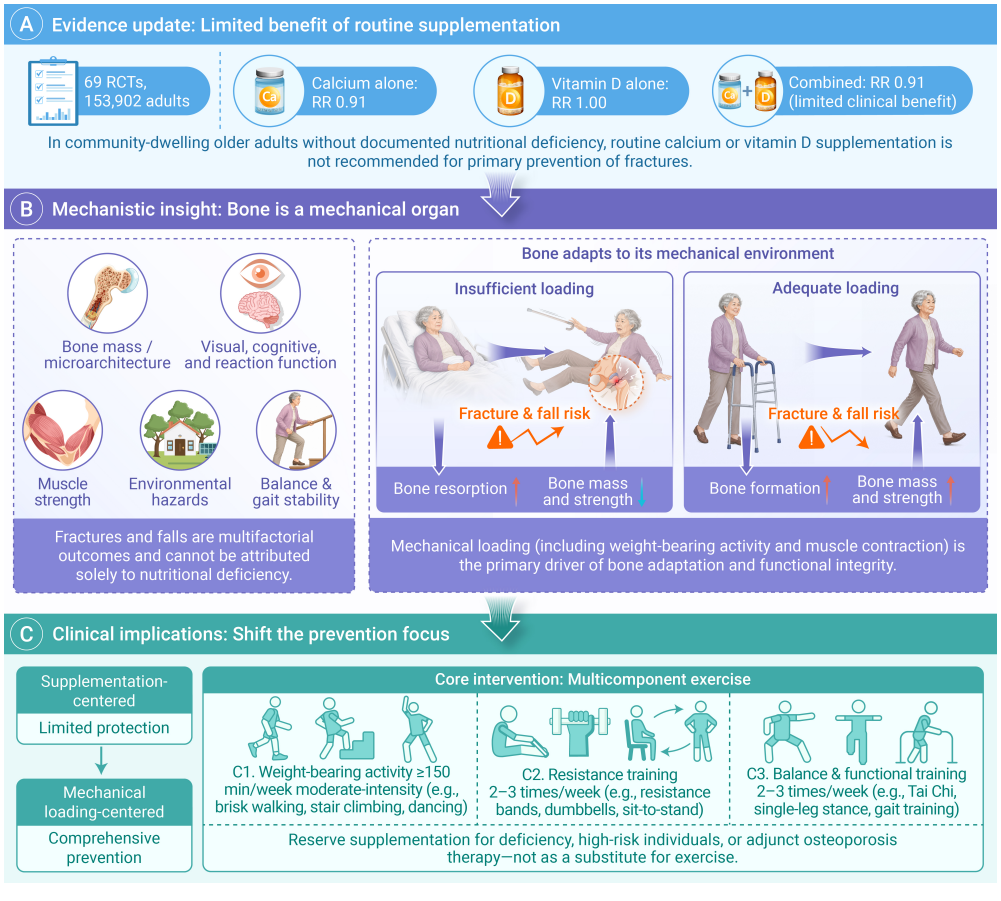

Figure 1. From nutritional supplementation to mechanical loading in fracture and fall prevention

The limited effectiveness of supplementation likely reflects the multifactorial nature of fractures and falls, which cannot be fully explained by nutritional status alone. Risk results from interacting skeletal, neuromuscular, environmental, cognitive, and psychological factors that extend beyond bone mineral metabolism and operate in a highly interdependent manner. Although calcium and vitamin D are essential for skeletal health, their effects are largely confined to bone-related pathways and do not directly address key contributors such as muscle strength, balance, gait stability, environmental hazards, or fear of falling. These non-skeletal determinants may interact with nutritional status through effects on mobility and physical activity, contributing to functional decline over time. Therefore, nutritional supplementation alone is unlikely to provide clinically meaningful protection against fractures and falls, particularly in community-dwelling older adults.

This limited clinical effectiveness is further supported by substantial heterogeneity across trials, which may reflect underlying differences in baseline nutritional status as a key effect-modifying factor. Most randomized controlled trials have enrolled participants without clinically confirmed calcium or vitamin D deficiency, which may have attenuated the detectable benefit of supplementation and partly explains the inconsistent findings across studies. In contrast, individuals with true deficiency or impaired absorption may demonstrate greater responsiveness, suggesting that treatment effects are context-dependent and vary across population subgroups. These observations also highlight the limited generalizability of existing evidence to deficient or high-risk populations.

Moreover, bone is not merely a mineral reservoir but a dynamic tissue highly responsive to its mechanical environment. Skeletal remodeling is strongly regulated by mechanical loading, whereby increased loading promotes bone formation and structural reinforcement, whereas reduced loading accelerates bone resorption and leads to declines in bone mass and strength.[2] In astronauts exposed to microgravity, substantial bone loss occurs despite carefully controlled nutritional intake. Disuse osteoporosis is likewise common in patients undergoing prolonged bed rest, immobilization, or severe functional impairment. In these contexts, the primary driver of bone loss is sustained absence of effective mechanical loading rather than inadequate nutrition. Evidence from International Space Station astronauts further indicates that prolonged unloading is associated with marked skeletal deterioration, and recovery may remain incomplete in certain bone compartments even after return to Earth.[3] Collectively, these observations highlight that although nutritional supplementation may provide substrates for bone mineralization, it cannot substitute for the mechanical stimuli generated by weight-bearing activity and muscle contraction. Figure 1 summarizes the interplay between clinical evidence, skeletal mechanobiology, and implications for fracture and fall prevention.

The central clinical implication of *the BMJ* systematic review by Massé et al. is a shift in emphasis: skeletal and functional health should be maintained primarily through mechanical loading and physical activity, rather than routine supplementation alone. In ambulatory, community-dwelling older adults, fracture and fall prevention should prioritize structured, progressive multicomponent exercise that combines weight-bearing activity, resistance training, and balance or functional exercises. These interventions can be supervised or home based and should be tailored to baseline functional status, with progression as tolerated. Practical targets for resistance, weight-bearing aerobic, and balance training are summarized in Figure 1. By improving bone density, muscle strength, and balance, these interventions target both reduced bone strength and increased fall risk. This approach is consistent with the 2024 US Preventive Services Task Force (USPSTF) recommendation supporting exercise interventions for fall prevention.[4] In contrast, calcium and vitamin D supplementation alone has limited effects on neuromuscular function, balance, and other non-skeletal contributors to fracture and fall risk. The USPSTF further recommends against vitamin D supplementation, with or without calcium, for the primary prevention of fractures and falls in older adults.[5]

Taken together, these findings suggest that the clinical role of calcium and vitamin D supplementation should be more narrowly defined. In community-dwelling older adults with adequate dietary intake and sufficient outdoor activity, routine supplementation for primary prevention is not recommended. In contrast, for individuals with limited sunlight exposure, insufficient dietary calcium, malabsorption disorders, long-term use of medications affecting bone metabolism, confirmed vitamin D deficiency, previous fragility fractures, or ongoing osteoporosis treatment, supplementation may remain an important component of care. In these settings, supplementation should be viewed as an adjunctive measure to correct deficiencies and support bone metabolism, rather than as a substitute for weight-bearing activity, muscle contraction, or balance training.

For frail, bedbound, or non-ambulatory older adults, prevention strategies require particular caution. These individuals are at particularly high risk of bone loss and fractures due to profound reductions in mechanical loading and physical function, yet remain underrepresented in randomized controlled trials. Current evidence is insufficient to determine whether calcium and vitamin D supplementation alone prevents fractures in this group. Nevertheless, after assessment of renal function, serum calcium, dietary intake, and concomitant medications, supplementation may be appropriate to prevent or correct deficiencies and support skeletal health. Preventive should primarily focus on preserving mobility and function through bedside rehabilitation, passive mobilization, sit-to-stand and transfer training, muscle strength maintenance, and environmental safety measures. Future research should determine whether passive mechanical stimulation, assisted standing, neuromuscular electrical stimulation, or vibration-based interventions can partially compensate for the lack of active loading and improve bone mass, muscle strength, and fracture outcomes.

Clinical guidelines and health policies for older adults should evolve as new evidence emerges. Current USPSTF recommendations reflect a shift away from routine calcium and vitamin D supplementation for the primary prevention of fractures and falls and toward exercise-based strategies. This underscores the importance of distinguishing between the treatment of nutritional deficiency and population-level preventive strategies. Further research should focus on frail, institutionalized, and nutritionally deficient older adults and clarify whether baseline nutritional status modifies the effects of combined nutritional, mechanical, and neuromuscular interventions.

In summary, although calcium and vitamin D remain fundamental for skeletal health, they should not be regarded as the cornerstone of fracture and fall prevention in older adults. Skeletal health depends not only on nutritional adequacy but also on mechanical loading, muscle function, and the preservation of physical performance. Future strategies should move beyond a supplementation-centered paradigm and prioritize multicomponent interventions, including weight-bearing activity, resistance training, and balance exercises.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this work, the authors used ChatGPT by OpenAI to improve language and readability. The authors reviewed and edited the content as needed and take full responsibility for the published work.

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DECLARATION OF INTERESTS

The authors declare no competing interests.