Food Science & Applied Microbiology Reports
Vol. 2(2),2023; 68-77
ISSN (Online) 2958-0684
https://finessepublishing.com/fsamr

Adult Bone Health and Consumption of Dairy-based Products: A Review

Areej Saleem[a], Muhammad Adeel Javed[a*]

a. Department of Food Technology, Institute of Food & Nutritional Sciences, Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi, Pakistan

Abstract: Calcium is essential for bone health at all ages as it maintains bone strength and avoids the risk of fractures in older people. Milk is considered one of the best sources of calcium and other nutrients like magnesium and potassium. Clinical investigations have demonstrated a strong favorable correlation between dairy dietary consumption and the bone turnover indicators. Milk, cheese, and yogurt are examples of high-protein, high-calcium dairy foods that are recommended for bone health throughout the lifespan to lower the risk of low-trauma fractures. This review covers recent cross-sectional, case-controlled prospective cohort and clinical trials documenting the impact of products of dairy on fracture risk, bone mineral density, and/or bone mineral content. Moreover, it provides an overview of various studies examining the relationship between dairy consumption and bone health and discusses the strengths and limitations of these studies, emphasizing the importance of maintaining a balanced diet rich in dairy products to support overall bone health. However, to date, no randomized controlled trials have shown the anti-fracture effectiveness of dairy food consumption; instead, this has been assumed through cross-sectional and prospective studies.
Keywords: Dairy products; Adults; Bone health; Osteoporosis; Bone mineral density; Fracture risk

1. Introduction

Dairy foods including milk, yogurt, cheese, etc. are considered the main dietary source of calcium around the world. They are encapsulated as one of the five major food groups in most dietary guidelines (Wallace et al., 2021). Dairy products are the main sources of micro and macronutrients like calcium, phosphorous, vitamin D, magnesium, and protein with adequate consumption providing maximum bone health (Heaney, 2000). The risk of osteoporosis increases with low bone mineral density (Iuliano & Hill, 2019).

The calcium nutrient intake reference of the UK for adults over the age of 19 is 700mg/day. Exceeding 1500mg/day causes stomach pain and diarrhea (Flynn, 2003)—requirements for calcium intake increase during childhood, pregnancy, lactation, and adolescence.

Increased fracture frequency is related to removing cow's milk, calcium-rich foods, and calcium supplements from the diet. Avoiding milk and poor dairy intake leads to lower total body BMC, and bone area (Weaver et al., 2016). The association of dairy dietary intake is not with excessive fat and weight gain because it does not raise the saturated or total fat intake. Considering recent disputes about the effectiveness of dairy consumption for the prevention of osteoporosis and related fractures. This review covers recent cross-sectional, case-controlled prospective cohort and clinical trials documenting the impact of products of dairy on fracture risk, bone mineral density, and/or bone mineral content. Moreover, it provides an overview of various studies examining the relationship between dairy consumption and bone health and discusses the strengths and limitations of these studies, emphasizing the importance of maintaining a balanced diet rich in dairy products to support overall bone health. However, to date, no randomized controlled trials have shown the anti-fracture effectiveness of dairy food consumption; instead, this has been assumed through cross-sectional and prospective studies.

[Received] 11 Oct 2023; Accepted 13 Dec 2023; Published (online) 21 Dec 2023]
Finesse Publishing stays neutral about jurisdictional claims published maps
Attribution 4.0 International (CC BY 4.0)
Corresponding email: a.javed@uaar.edu.pk (Muhammad Adeel Javed)
DOI: 10.61363/1265gj29

2. Recommended calcium intake in adults

Calcium's role in the body is to give the stiffness needed for the skeleton and teeth. Calcium is necessary for the activation of nerve conduction and muscular contraction. Body fluids also contain calcium, which is involved in protein binding, a protein activator within cells, and acts as a signal transmitter. The body needs a lot of calcium at all stages of life (Heaney, 2006).

Table 1 Recommended Calcium Intake Guidelines for Different Age Groups and Gender in mg/day

Age (year)	Estimated Average Requirement	Recommended Dietary Allowance (USA (IOM))	Estimated Average Requirement (FAO/WHO)	Recommended Nutrient Intake	Estimated Average Requirement (UK (SACN))	Recommended Nutrient Intake
0.5-3	500	700	-	500	275	350
4-6	800	1000	440	600	350	450
7-10	800	1000		1300	425	550
Males						
11-14	1100	1300	1040	1300	750	1000
15-18	1100	1300	1040	1300	750	1000
19-24	800	1000	840	1000	525	700
25-50	800	1000	840	1000	525	700
50	800	1000	840	1000/1300	525	700
Females						
11-14	1100	1300	1040	1300	625	800
15-18	1100	1300	1040	1300	625	800
19-24	800	1000	840	1000	525	700
25-50	800	1000	840	1000	525	700
50	1000	1200	840	1000	525	700

IOM: USA Institute of Medicine. SACN: UK Scientific Advisory Committee on Nutrition

3. Method of data acquisition

Conduct comprehensive literature review on the impact of dairy foods on adult bone health. This involves identifying relevant scientific articles, clinical trials, systematic reviews, and meta-analyses. Search databases such as PubMed, ScienceDirect, and relevant journals using keywords such as "dairy products," "adults," "bone health," and "osteoporosis." Include studies that cover different age groups and populations. After removing duplicates, the exclusion criteria for animal studies, non-randomized trials, not dairy food-based interventions, and studies with non-English publications were applied. To ensure that all pertinent research was assessed, we cross-checked our list of included studies with the reference lists of relevant systematic reviews.

3.1. Osteoporosis

In osteoporosis, the increased risk of fracture is characterized by low bone mass, and a lot of factors are involved in increasing the risk of osteoporosis like sarcopenia, falls, reflexes, and inadequate soft tissue padding (Terrie, 2008). Maintaining a healthy diet and engaging in weight-bearing activities can lower the risk of osteoporosis by 50%. The common and main fractures are at the sites of the pelvis, humerus, and ribs while the major fractures of osteoporosis are at the vertebra, forearm, and hip. Osteoporosis is recognized as a pediatric disease with geriatric consequences that is why to promote optimal bone health adolescence is recognized as an awesome time to prevent osteoporosis (Akkawi & Zmerly, 2018). More than 90% of peak bone mass is achieved at the time of adolescence before 20 years (Langdahl, 2021). In terms of the prevention of fragility fractures, osteoporosis is an under-screened, underdiagnosed, and undertreated disorder (Rinonapoli et al., 2021).

3.2. Bone Composition and Nutrient Influence

Inorganic salts, mostly hydroxyapatite, and trace amounts of other minerals, including magnesium, sodium, potassium, and zinc, are found in bones, and are bonded to a protein-based natural lattice. Three different types of bone cells—osteoblast, osteoclast, and osteocytes—produce and maintain bone. (Prentice et al., 2003). There are two different forms of bone: trabecular, which is located (15-25% by volume) at the ends of long bones and within the vertebrae, and flat bones, and compact bone (80-90% by volume), which is a thick and dense layer of calcified tissue that makes the shaft and exterior surfaces of bone. (Prentice et al., 2003). Three endocrine calciotropic hormones, namely dihydroxy vitamin D, calcitonin, and parathyroid hormone regulate the amount of calcium in the serum. (Heaney, 2009). When the serum calcium level drops, the parathyroid gland's Ca2+ detecting receptors activate the release of PTH, which acts on the kidney to inhibit the excretion of calcium and on the bone to release calcium. Increases in 25 dihydroxyvitamin concentration operate on the intestine to boost intestinal calcium absorption and on the bone to release calcium even more. (Cashman & Flynn, 1999).

Table 2. Nutritional Composition of Calcium-Rich Foods (Per 100g Serving)

Calcium-rich foods	**K** (*mg*)	**Ca** (*mg*)	**Protein** (*mg*)	**P** (*mg*)
Milk skimmed	156	122	3.4	101
3.7% full-fat milk	151	118	3.3	93
Yogurt, plain low-fat	234	183	5.3	144
Cheddar cheese	98	721	24.9	512
Yogurt, fruit fat	216	169	4.9	133
Cottage cheese non-fat	137	86	10.3	190
Ice cream, soft serve, chocolate	177	131	4.1	116

The USDA National Nutrient Database provided the data for this standard reference

More nutrients (calcium, protein, magnesium, phosphorous, and zinc) are provided by dairy products per calorie than by any other food group in an adult's diet. (Skinner, Simpson, & Buchholz, 2011). Avoidance of milk and dairy products in children for the long term leads to more modest height and lower bone mineral mass. Before puberty risk of fracture increases because of low milk intake during childhood (Goulding et al., 2004). The higher lumbar BMC is linked to dietary milk protein but not dietary meat protein. (Esterle et al., 2009). In a 12-month postmenopausal study, women who consumed dairy products containing 1200 mg of calcium and 300 IU of vitamin D (7.5 mcg) showed extensively better improvements in spine, hip, and overall BMD as well as better changes in biochemical markers of bone metabolism and bone mineral thickness than those who only took calcium supplements (Manios et al., 2007). In studies of pre-pubertal girls and boys receiving calcium supplements for a year, calcium-enriched dietary options significantly increased the buildup of bone mass, and the effects persisted for 1-3 years after the calcium supplements were stopped (Chevalley et al., 2005).

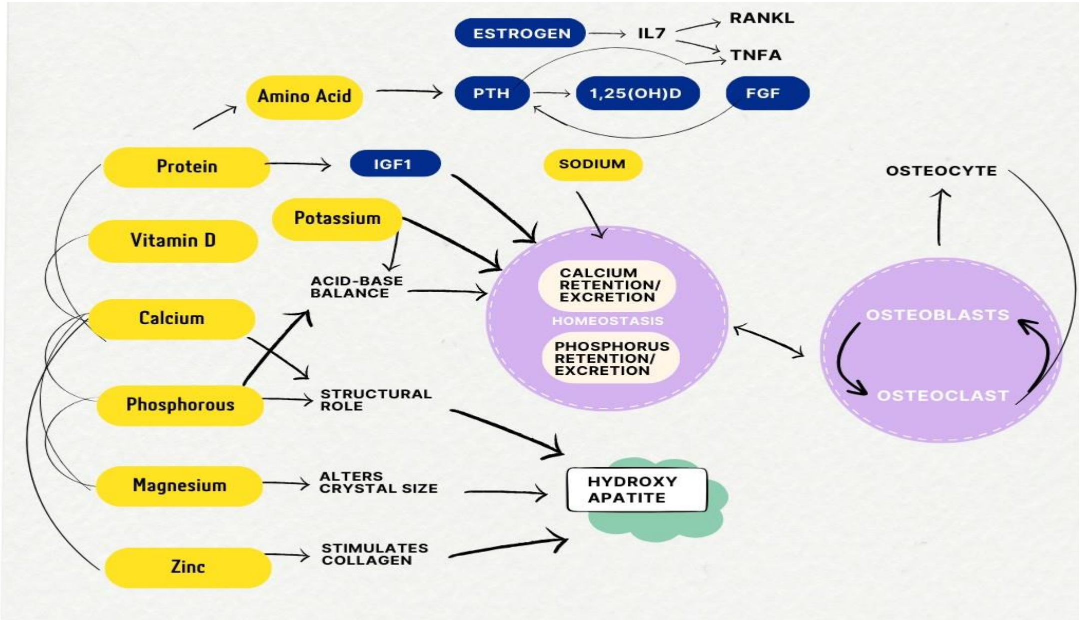

Figure 1. The Effect of Dairy Nutrients on Bone Health

3.3. Protein and Bone Health

For protein, the Recommended Dietary Allowance (RDA) is 0.8 grams per kilogram of body weight. Utilizing nitrogen balance and the factorial technique to predict nitrogen necessary losses, this level was established to give a standard of adequate protein to prevent deficiency and sickness. Experiments on young women varying their protein intake from 0.7 kg/body weight to 2.1 kg/body weight revealed that while low protein intake increased PTH and decreased calcium absorption, high intake of protein increased bone resorption and urinary excretion of calcium without corresponding increases in bone formation (Rizzoli, 2022).

3.4. Calcium Intake and Bone Health

Calcium recommendations were set at 1300 mg/d for adolescents, 1000 mg/d for adults, and 1200 mg/d for those 51 years of age and above. These amounts were linked to the creation of maximal peak bone mass during growth and the decrease of bone loss thereafter. These values were determined using the genetic potential for maximal calcium retention—that is, the intake that results in no further retention advantage (Marriott et al., 2020). Low calcium consumption is linked to low intakes of several other nutrients and has been linked to the development of premenstrual syndrome, colon cancer, and hypertension. Promoting a higher intake of foods high in calcium has the potential to be an affordable approach to lower the risk of fractures later in life, improve the nutritional quality, and improve the general health of patients. Although lactation is linked to a temporary loss of bone that cannot be stopped by calcium supplements, pregnancy, and lactation are not risk factors for skeletal fragility (Bristow et al., 2022). Intakes of several other nutrients are linked to low calcium, which has been linked to the development of premenstrual syndrome, colon cancer, and hypertension. In addition to improving patients' general health and diet quality, encouraging increased consumption of foods high in calcium may prove to be a financially advantageous method for lowering the incidence of fractures in later life (Shlisky et al., 2022).

3.5. Vitamin D and Bone Health

The AI for vitamin D was determined by multiplying the amount of sunlight that individuals in the population group with limited but uncertain sun exposure and stores will need to maintain adequate serum 25-hydroxyvitamin D levels by 100%. This prevents seasonal fluctuations. These dosages were 200 mg/d for people under 50, 400 mg/d for those between 51 and 70, and 600 mg/d for those above 70 (Wilson-Barnes et al., 2022). Sunlight and food are two ways to get vitamin D. The primary dietary sources of vitamin D include fortified foods, dairy products, and fatty fish. The ability of vitamin D to promote calcium absorption, and therefore maintain blood levels of phosphorus and calcium is its most well-known activity (Charoenngam, Shirvani, & Holick., 2019). Vitamin D is essential for sufficient intestinal calcium absorption and improves calcium absorption by inducing active transport in the gut. Furthermore, vitamin D and PTH cooperate to improve renal calcium reabsorption. PTH is released when serum calcium levels fall, and it works with the kidneys to boost 25-hydroxyvitamin D's 1-hydroxylation and transform it into its active form. Additionally, vitamin D directly affects bone. It has been demonstrated that vitamin D increases the mRNA for insulin-like growth factor binding protein (IGFBP)5 and stimulates the synthesis of IGF-II (Bhattarai et al., 2020).

3.6. Vitamin K and Bone Health

A variety of indicators have been used to assess the status of vitamin K; nonetheless, because of a lack of information and an inadequate comprehension of the physiological relevance, they do not offer a sufficient foundation for estimating vitamin K requirements. Consequently, data on the consumption levels of healthy persons were used to determine the recommended dietary amounts of vitamin K. Compared to values linked to vitamin K and bone health, these values are lower. Men should take 120 mcg/d and women 90 mcg/d (Booth et al., 2003). According to recent findings, women who consumed vitamin K at the lowest quartile (<109 mcg/d) had higher fracture risks and lower bone mineral density (BMD) than those who consumed the top quartiles (Tsugawa & Shiraki, 2020).

3.7. Vitamin B12 and Bone Health

Vitamin B12 is required to produce developing bone, the synthesis of collagen, and the lowering of homocysteine levels, all of which support the general upkeep of bone health. To further highlight its role in supporting skeletal health, its effects on nerve function and muscular coordination also serve as an indirect means of preventing falls and fractures (Butola et al., 2020). Because it functions as a cofactor on proteins associated to osteoblasts, like osteocalcin and bone alkaline phosphatase, vitamin B12 is essential for osteoblast activity. In addition to its involvement in bone production, vitamin B12 also plays a role in iron metabolism. Through its impact on osteoblast proliferation and/or its role in homocysteine metabolism, vitamin B12 may play a role in bone health (Ilesanmi-Oyelere & Kruger, 2023).

3.8. Sodium and Bone Health

Not only is sodium necessary for many physiological activities, but it also has a complex interaction with calcium homeostasis, dietary consumption, and general metabolic processes that affect bone health. Excessive sodium intake has been linked to decreased bone density, mostly because of altered acid-base balance and increased excretion of calcium (EFSA Panel on Nutrition et al., 2019). A complex balance of many nutrients is required to maintain optimal bone health, of which salt is only one component. It is imperative to maintain bone density and reduce the risk of osteoporosis and fractures by eating an adequate amount of calcium, magnesium, potassium, and vitamin D, along with moderate salt intake.

3.9. Potassium and Bone Health

Potassium recommendations are 3800 mg/d for children ages 4–8, 4500 mg/d for children ages 9–18, and 4700 mg/d for children ages 19 and up. The study revealed that patients consuming the highest quartile of potassium consumption, approximately 3494–3999 mg/d, had significantly better trochanter BMD in both men and women compared to the lower quartiles, these amounts would be beneficial for bone. Through urinary calcium losses, potassium influences calcium, homeostasis. Elevated urine calcium is a result of a low-potassium diet, but the opposite is also true. It's feasible that a diet strong in potassium will counteract the effects of a high salt diet on bone resorption (Palacios, 2006).

3.10. Calcium intervention in young adults

Dairy consumption has considerable advantages for bone health during development. Pregnant women who take calcium and other micronutrient supplements during their pregnancy are more likely to have children who have higher skeletal growth and bone mass/thickness. A low-dairy diet significantly reduced lumbar spine bone mineral density, but not lumbar spine bone mineral content, hip bone mineral density, or hip bone mineral content, according to a 15-16 week randomized control trial conducted on females between the ages of 19 and 45. Several studies of calcium supplementation in younger adults showed increased BMD in response to weight loss (Labouesse et al., 2014). Adults are given calcium supplements in a variety of salt forms, including calcium carbonate, calcium citrate, calcium lactate, and calcium gluconate. (Straub, 2007). Age-related BMD loss is halted in several places, including the femoral neck and around 33% of the radius, but not on the lumbar spine, by consuming milk fortified with reduced-fat calcium and vitamin D3 (Daly et al., 2008). An increase in skim milk, dairy, and overall milk consumption was linked to a decreased comparative danger of a high-stress rate among females (average age 21 years), according to a cohort study with a two-year follow-up. A lower incidence of stress fractures and more pronounced bone growth have been related to calcium, vitamin D, and protein, which are essential components of milk. Additionally, more significant increases in hip and total BMD were associated with potassium intake (Nieves et al., 2010). Women in a randomized control study between the ages of 25 and 45 received one of the following complementary therapies in addition to 500 kcal energy-restricted diet: three servings of 250 mL of low-fat milk or 250 mL of low-fat milk with micronutrients every day. The findings indicated that the consumption of micronutrients and reduced-fat milk raised the efficacy of an energy-limited diet for the treatment of obesity, but that it did not impact blood glucose levels, C-responsive protein, blood lipid levels, or pulse rates (Rosado et al., 2011). Sufficient vitamin D consumption is linked with a decreased rate of osteoporotic hip cracks in ladies who have undergone menopause, according to 18-year prospective cohort research. A high-calcium diet and milk don't appear to reduce risk. Given that most women don't get the recommended amount of vitamin D (Feskanich, Willett, & Colditz, 2003). In premenopausal women aged 20-35 years effect of fortified milk supplementation showed that it decreased bone turnover significantly but in this short study phylloquinone does not show an obvious impact on bone turnover (Kruger et al. 2016).

Table 3. Summary of Selected Research Studies on Dairy Consumption and Bone Health

Study characteristics	Strength	Limitations	References
samples present 51 female students, ages 19 to 45 length: 15 weeks To see if consuming enough dairy slows down weight reduction. decreased bone density Intervention: milk, yogurt, and cheese three to four times per week (1339 mg of calcium daily)	Following weight loss and a decrease in serum osteocalcin concentration, an adequate dairy diet led to noticeably raised lumbar spine BMD (p 0.004).	Small population size Short term study There must be additional factors at work because BMD alone could explain just 19.6% of the entire variance.	(Labouesse et al., 2014)
Postmenopausal women n = 66 Dairy foods/placebo Duration: 30 months	In comparison to the control group, the intervention produced positive changes in the arms, entire spine, and total body BMD. DG noticed a considerable rise in lumbar spine BMD, however, there was no discernible difference from the control group.	The study had a relatively small sample size (n = 66) and focused on postmenopausal women aged 55-65, limiting generalizability to other populations The long-term effects of this intervention beyond 30 months were not assessed	(Moschonis et al., 2010)
Eighty-two women aged 20 to 35 were randomly allocated into three groups Interventions: Two groups received high-calcium skim milk (1000 mg/d extra calcium) with or without added phylloquinone (80 µg/d), while a control group	Demonstrated significant reductions in bone turnover in premenopausal women with fortified milk supplementation Significant decreases in bone turnover markers (cross-linked C-telopeptide of type I collagen, total	Short-term study duration (16 weeks) may not capture long-term effects Limited information about the potential additive effects of vitamin K supplementation over the bone turnover	(Kruger et al. 2006)

received no supplementation	osteocalcin, and type I N-terminal procollagen peptide) in supplemented groups compared to control		
Investigated the impact of milk supplementation on bone mineral density (BMD) in Chinese women aged 20–35, a population with low dairy consumption	Both groups showed an increase in BMD and a decrease in bone turnover markers over time, indicating the natural process of reaching peak bone mass	Lack of a placebo or control group not receiving any supplement makes it difficult to distinguish the specific effects of milk supplementation	(Woo et al., 2007)
441 community-living women from Hong Kong and Beijing, China, were randomized to receive milk supplements or nothing	Utilized intention-to-treat and per-protocol analyses to assess the impact of milk supplementation		

3.11 Calcium intervention in older adults

A 12-month randomized control study conducted by Moschonis and his colleagues revealed that adding three fortified dairy products—calcium-vitamin D, calcium-vitamin D plus phylloquinone, and calcium-vitamin menaquinone—raised total BMD. In postmenopausal women in the stage of life 55–65 years, the nutrient phylloquinone and menaquinone-fortified dairy groups showed an extra significant rise in L2-L4 lumbar spine bone mineral density compared to the control (Moschonis et al, 2011). In a cross-sectional study of white men and women between the ages of 50 and 80, milk consumption is positively connected with BMD at the femoral neck, spine, and trochanter. Soft cheese is substantially related to women but not to men, while hard cheese is associated with the femoral, spine, and trochanter in men but not in women. Yoghurt did not substantially correlate with women's trochanter or their spine, femoral neck, or trochanter BMD, but it did significantly correlate with their femoral neck and spine. However, neither the spine, femoral neck, or trochanter BMD in men nor the spine, or the trochanter BMD in women, demonstrated a significant relationship with milk. The spine, femoral neck, or trochanter BMD of men and women were not significantly impacted by other milk products (Lunt et al., 2001). Higher consumptions of yogurt, milk, and cheese were protective against trochanter BMD loss among vitamin D supplement users but not among nonusers (n = 628), according to the findings of a prospective cohort study of older persons (aged 67 to 93) with a follow-up duration of 4 years. No association was seen between the consumption of dairy products and femoral neck BMD (Sahni et al., 2017).

Table 4. Summary of Selected Research Studies on Bone Health and Risk Factors in Postmenopausal Women

Study characteristics	Strength	Limitations	References
Participants: 1,215 postmenopausal women (average age 64.3 years) with dietary intake assessed using a validated food frequency questionnaire	Identifies dietary factors associated with osteoporosis in postmenopausal women.	The study's findings may not be generalizable to populations with different dietary habits or demographics	(Lanyan et al., 2020)
Evaluate associations between nutrients, dietary patterns, and adherence to Swiss dietary guidelines with bone health among postmenopausal women	Comprehensive assessment of dietary intake and its relationship to bone health	Dietary assessment relies on self-report, which may have recall and reporting biases	

from the CoLaus/OsteoLaus cohort			
To report low-energy fracture incidence in postmenopausal women aged 70 years and explore associated risk factors	Large-scale study with a significant sample size of 68,783 postmenopausal women aged 70 years	The study is based on observational data, which cannot establish causation	(Zhu et al., 2019)
Assess factors associated with bone health in Malaysians aged ≥40 years Data collected from 786 Malaysians in Klang Valley, assessing demography, medical history, dietary, and lifestyle practices, and using DXA for bone health assessment	Provides valuable insights into bone health risk factors in Malaysia, addressing a gap in osteoporosis research in the region The inclusion of both men and women (51.4% women) provides a comprehensive overview of bone health factors	Cross-sectional design limits the ability to establish causation and only shows associations between variables Potential recall bias in self-reported data, as participants provided information on dietary and lifestyle practices	(Chan et al., 2020)
Postmenopausal women (n = 141) were assigned to control (n = 72) or calcium supplementation (n = 69) groups.	Shows a significant reduction in bone loss at the lumbar spine and less height loss in the calcium supplementation group.	No significant difference at the hip site and weight gain was not significant.	(Chen et al., 2015)

4. Conclusion

Osteoporosis is an ailment with numerous risk factors. Despite the significant influence that heredity has on the likelihood of developing osteoporosis, several naturally occurring variables may be changed to reduce risk, including diet and activity. Medical professionals should emphasize the need to eat enough veggies, organic foods, and low-fat dairy for the best disease prevention. Even though adults' risk of osteoporotic fracture increases with age, a person's diet throughout a lifetime can have an impact on bone health. Adults can get 25 to 87 percent of the daily necessary quantities of calcium, potassium, vitamin A, vitamin D, protein, iron, and magnesium from three to four servings of low-fat milk. The natural building blocks for bone development are found in dairy products, but other lifestyle factors also affect how bones form and are maintained. Physical activity has a greater positive impact on bone thickness and strength when dairy consumption contains enough dietary calcium. Dairy product consumption does not appear to enhance the risk of breaks or cracks. Consuming low- or nonfat dairy products on a regular basis as part of a balanced diet may improve BMD overall and, in certain cases, reduce the number of cracks in adults. Dairy consumption and markers of bone turnover, bone mineral density, and bone content have been positively correlated in clinical studies. The connection between dairy consumption and fracture rate is poorly understood, and more research and studies are required to completely comprehend the association.

5. References

Akkawi, I., & Zmerly, H. (2018). Osteoporosis: current concepts. Joints, 6(02), 122-127. Bhattarai, H. K., Shrestha, S., Rokka, K., & Shakya, R. (2020). Vitamin D, calcium, parathyroid hormone, and sex steroids in bone health and effects of aging. Journal of Osteoporosis, 2020.

Bristow, S. M., Bolland, M. J., Gamble, G. D., Leung, W., & Reid, I. R. (2022). Dietary calcium intake and change in bone mineral density in older adults: a systematic review of longitudinal cohort studies. European Journal of Clinical Nutrition, 76(2), 196-205.

Butola, L. K., Kute, P. K., Anjankar, A., Dhok, A., Gusain, N., & Vagga, A. (2020). Vitamin B12-do you know everything. Journal of Evolution of Medical and Dental Sciences, 9(42), 3139-3147.

Cashman, K. D., & Flynn, A. (1999). Optimal nutrition: calcium, magnesium, and phosphorus. Proceedings of the Nutrition Society, 58(2), 477-487.

Chan, C. Y., Subramaniam, S., Mohamed, N., Ima-Nirwana, S., Muhammad, N., Fairus, A., . . . Chin, K.-Y. (2020). Determinants of bone health status in a multi-ethnic population in Klang Valley, Malaysia. International Journal of Environmental Research and Public health, 17(2), 384.

Charoenngam, N., Shirvani, A., & Holick, M. F. (2019). Vitamin D for skeletal and non-skeletal health: What we should know. Journal of Clinical Orthopaedics and Trauma, 10(6), 1082-1093.

Chen, Y., Zhang, Q., Wang, Y., Xiao, Y., Fu, R., Bao, H., & Liu, M. (2015). Estimating the causal effect of milk powder supplementation on bone mineral density: a randomized controlled trial with both non-compliance and loss to follow-up. European Journal of Clinical Nutrition, 69(7), 824-830.

Chevalley, T., Bonjour, J.-P., Ferrari, S., Hans, D., & Rizzoli, R. (2005). Skeletal site selectivity in the effects of calcium supplementation on areal bone mineral density gain: a randomized, double-blind, placebo-controlled trial in prepubertal boys. The Journal of Clinical Endocrinology & Metabolism, 90(6), 3342-3349.

Daly, R. M., Petrass, N., Bass, S., & Nowson, C. A. (2008). The skeletal benefits of calcium-and vitamin D3 fortified milk are sustained in older men after withdrawal of supplementation: an 18-mo follow-up study. The American Journal of Clinical Nutrition, 87(3), 771-777.

EFSA Panel on Nutrition, N. F., Allergens, F., Turck, D., Castenmiller, J., de Henauw, S., Hirsch-Ernst, K. I., . . McArdle, H. J. (2019). Dietary reference values for sodium. EFSA Journal, 17(9), e05778.

Esterle, L., Sabatier, J.-P., Guillon-Metz, F., Walrant-Debray, O., Guaydier-Souquières, G., Jehan, F., & Garabédian, M. (2009). Milk, rather than other foods, is associated with vertebral bone mass and circulating IGF-1 in female adolescents. Osteoporosis International, 20, 567-575.

Feskanich, D., Willett, W. C., & Colditz, G. A. (2003). Calcium, vitamin D, milk consumption, and hip fractures: a prospective study among postmenopausal women. The American Journal of Clinical Nutrition, 77(2), 504-511.

Flynn, A. (2003). The role of dietary calcium in bone health. Proceedings of the Nutrition Society, 62(4), 851-858.

Goulding, A., Rockwell, J. E., Black, R. E., Grant, A. M., Jones, I. E., & Williams, S. M. (2004). Children who avoid drinking cow's milk are at increased risk for prepubertal bone fractures. Journal of the American Dietetic Association, 104(2), 250-253.

Heaney, R. P. (2000). Calcium, dairy products and osteoporosis. Journal of the American College of Nutrition, 19(sup2), 83S-99S.

Heaney, R. P. (2006). Absorbability and utility of calcium in mineral waters–. The American Journal of Clinical Nutrition, 84(2), 371-374.

Heaney, R. P. (2009). Dairy and bone health. Journal of the American College of Nutrition, 28(sup1), 82S-90S.
Ilesanmi-Oyelere, B. L., & Kruger, M. C. (2023). B vitamins and homocysteine as determinants of bone health: A literature review of human studies. Journal of Human Nutrition and Dietetics, 36(3), 1031-1044.

Iuliano, S., & Hill, T. R. (2019). Dairy foods and bone health throughout the lifespan: a critical appraisal of the evidence. British Journal of Nutrition, 121(7), 763-772.

Labouesse, M. A., Gertz, E. R., Piccolo, B. D., Souza, E. C., Schuster, G. U., Witbracht, M. G., . . . Van Loan, M. D. (2014). Associations among endocrine, inflammatory, and bone markers, body composition, and weight loss induced bone loss. Bone, 64, 138-146.

Langdahl, B. L. (2021). Overview of treatment approaches to osteoporosis. British Journal of Pharmacology, 178(9), 1891-1906.

Lanyan, A., Marques-Vidal, P., Gonzalez-Rodriguez, E., Hans, D., & Lamy, O. (2020). Postmenopausal women with osteoporosis consume high amounts of vegetables but insufficient dairy products and calcium to benefit from their virtues: the CoLaus/OsteoLaus cohort. Osteoporosis International, 31, 875-886.

Lunt, M., Masaryk, P., Scheidt-Nave, C., Nijs, J., Poor, G., Pols, H., . . . Benevolenskaya, L. (2001). The effects of lifestyle, dietary dairy intake, and diabetes on bone density and vertebral deformity prevalence: the EVOS study. Osteoporosis International, 12, 688-698.

Manios, Y., Moschonis, G., Trovas, G., & Lyritis, G. P. (2007). Changes in biochemical indexes of bone metabolism and bone mineral density after a 12-mo dietary intervention program: the Postmenopausal Health Study. The American Journal of Clinical Nutrition, 86(3), 781-789.

Marriott, B. P., Birt, D. F., Stalling, V. A., & Yates, A. A. (2020). Present Knowledge in Nutrition: Basic Nutrition

and Metabolism: Academic Press.
Moschonis, G., Kanellakis, S., Papaioannou, N., Schaafsma, A., & Manios, Y. (2011). Possible site-specific effect of an intervention combining nutrition and lifestyle counseling with consumption of fortified dairy products on bone mass: the Postmenopausal Health Study II. Journal of Bone and Mineral Metabolism, 29, 501-506.
Moschonis, G., Katsaroli, I., Lyritis, G. P., & Manios, Y. (2010). The effects of a 30-month dietary intervention on bone mineral density: the Postmenopausal Health Study. British Journal of Nutrition, 104(1), 100-107.
Nieves, J. W., Melsop, K., Curtis, M., Kelsey, J. L., Bachrach, L. K., Greendale, G., . . . Sainani, K. L. (2010). Nutritional factors that influence change in bone density and stress fracture risk among young female cross-country runners. Pm&r, 2(8), 740-750.
Palacios, C. (2006). The role of nutrients in bone health, from A to Z. Critical Reviews in Food Science and Nutrition, 46(8), 621-628.
Prentice, A., Bonjour, J.-P., Branca, F., Cooper, C., Flynn, A., Garabedian, M., . . . Weber, P. (2003). PASSCLAIM Bone health and osteoporosis. European Journal of Nutrition, 42, i28-i49.
Rinonapoli, G., Ruggiero, C., Meccariello, L., Bisaccia, M., Ceccarini, P., & Caraffa, A. (2021). Osteoporosis in men: a review of an underestimated bone condition. International Journal of Molecular Sciences, 22(4), 2105.
Rizzoli, R. (2022). Dairy products and bone health. Aging Clinical and Experimental Research, 1-16.
Rosado, J. L., Garcia, O. P., Ronquillo, D., Hervert-Hernández, D., Caamaño, M. d. C., Martínez, G., . . . García, S. (2011). Intake of milk with added micronutrients increases the effectiveness of an energy-restricted diet to reduce body weight: a randomized controlled clinical trial in Mexican women. Journal of the American Dietetic Association, 111(10), 1507-1516.
Sahni, S., Mangano, K. M., Kiel, D. P., Tucker, K. L., & Hannan, M. T. (2017). Dairy intake is protective against bone loss in older vitamin D supplement users: the Framingham Study. The Journal of Nutrition, 147(4), 645-652.
Shlisky, J., Mandlik, R., Askari, S., Abrams, S., Belizan, J. M., Bourassa, M. W., . . . Khadilkar, A. (2022). Calcium deficiency worldwide: Prevalence of Inadequate Intakes and Associated Health Outcomes (0077-8923).
Skinner, M. L., Simpson, J. A. R., & Buchholz, A. C. (2011). Dietary and total calcium intakes are associated with a lower percentage of total body and truncal fat in young, healthy adults. Journal of the American College of Nutrition, 30(6), 484-490.
Straub, D. A. (2007). Calcium supplementation in clinical practice: a review of forms, doses, and indications. Nutrition in clinical practice, 22(3), 286-296.
Terrie, Y. C. (2008). Early Preventive Care Reduces Risk of Osteoporosis—Pharmacy Times.
Tsugawa, N., & Shiraki, M. (2020). Vitamin K nutrition and bone health. Nutrients, 12(7), 1909.
Wallace, T. C., Bailey, R. L., Lappe, J., O'Brien, K. O., Wang, D. D., Sahni, S., & Weaver, C. M. (2021). Dairy intake and bone health across the lifespan: a systematic review and expert narrative. Critical Reviews in Food Science and Nutrition, 61(21), 3661-3707.
Weaver, C. M., Gordon, C. M., Janz, K. F., Kalkwarf, H., Lappe, J. M., Lewis, R., . . . Zemel, B. (2016). The National Osteoporosis Foundation's position statement on peak bone mass development and lifestyle factors: a systematic review and implementation recommendations. Osteoporosis International, 27, 1281-1386.
Woo, J., Lau, W., Xu, L., Lam, C. W. K., Zhao, X., Yu, W., . . . Pocock, N. (2007). Milk supplementation and bone health in young adult Chinese women. Journal of Women's Health, 16(5), 692-702.
Zhu, Y., Liu, S., Chen, W., Liu, B., Lv, H., Zhang, X., & Zhang, Y. (2019). Epidemiology of low-energy fracture in Chinese postmenopausal women: changing trend of incidence since menopause and associated risk factors, a national population-based survey. Menopause, 26(3), 286-292.