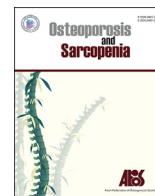




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Review article

School-based nutrition interventions can improve bone health in children and adolescents

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ABSTRACT

Objectives: Osteoporosis is a major global health problem, and optimizing bone health during childhood and adolescence with adequate calcium and vitamin D intake is a recommendation to prevent the disease. School milk programs may be a viable approach to help children and adolescents increase calcium and vitamin D intakes while improving their bone health.

Methods: A review of the literature was conducted on school milk programs, including examination of details regarding these studies and their participants, and assessments of their effects on bone health in children and adolescents.

Results: Nearly all studies reviewed showed significant increases in the bone health behaviors and outcomes that were measured, such as bone mineral density, milk consumption, and calcium and vitamin D intake.

Conclusions: School milk programs can be effective in improving bone health in children and adolescents, and public health policies should be considered to help support and fund effective programs that promote bone health and prevent osteoporosis in population health.

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1. Introduction

Osteoporosis is global health issue, and optimal approaches for preventing this disease include sufficient amounts of weight-bearing physical activity and adequate consumption of calcium and vitamin D throughout the lifespan, especially during childhood and adolescence when bone mineral density (BMD) is maximized, which helps prevent osteoporosis and fractures from occurring in older adulthood, as recommended by the World Health Organization [1] and the National Osteoporosis Foundation [2]. To increase these particular health behaviors in children and adolescents, school-based interventions are an ideal approach for promoting both weight-bearing physical activity and calcium and vitamin D consumption in this demographic age group. A review has shown that school-based exercise interventions are effective in promoting weight-bearing physical activity to increase BMD in children and adolescents [3]; however, a review on the effectiveness of school-based nutrition interventions in promoting calcium and vitamin

D for bone health has yet to be conducted.

Many populations throughout the world have below adequate calcium consumption [4], and nutrition interventions are needed to increase calcium and vitamin D consumption worldwide. The most common sources of calcium and vitamin D are milk and other dairy products, and school-based nutrition interventions can promote and/or offer these foods and drinks to improve bone health in children and adolescents. Thus, the purpose of this review is to determine if and how school-based nutrition interventions that promote milk and dairy products can improve bone health in children and adolescents, in order to recommend public health policies that can support these community health interventions that will prevent osteoporosis and fractures in population health.

2. Review of the literature

To assess the effects of school-based nutrition interventions serving milk and/or other dairy products on bone health, a review of the literature was recently conducted in January 2021 in PubMed with 2 separate advanced searches. The first advanced search for terms in “Title/Abstract” included “milk,” “bone,” and “school,” was conducted that resulted in 64 items. Also, to ensure inclusion of the

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possibility of school programs serving dairy products other than milk that can promote bone health, a second advanced search for terms in “Title/Abstract” included “dairy,” “bone,” and “school,” that resulted in 39 items. The combined results of the 2 advanced searches led to 103 total articles, but 24 articles were duplicates and immediately eliminated, resulting in 79 articles in consideration for the review. After a thorough examination of all 79 articles, 69 articles were not studies on the effects of school nutrition programs involving milk and/or dairy products on bone health, and they were excluded from the review. This resulted in 10 articles that were studies on school milk programs on bone health for children and/or adolescents as the focus of this review (Fig. 1).

Of the 10 articles, 3 were multi-year randomized control studies with 1 observational study that administered milk at school lunch [5–8], 1 was a multi-year intervention study that administered milk at school [9], 1 was a cross-sectional study measuring milk and dairy consumption differences between children who do and do not participate in a school milk program [10], 1 was a randomized control study that attempted to motivate increased calcium consumption [11], 1 was an intervention study of an online educational

program promoting bone health [12], and 2 were intervention studies investigating blood serum from the consumption of fortified vitamin D [13,14] (Table 1).

Of the 3 that were multi-year randomized control studies of school milk programs, they were intervention studies conducted in China, with 1 observational study conducted in Japan. Of the 3 studies in China, all used the same intervention but with statistical analyses on different participants. The study in Japan by Kohri et al [5] was a 4-year intervention of a school milk program that was designed to provide 50% of the recommended dietary allowance for calcium for schoolchildren compared to control participants, which resulted in a significant increase in calcium intake ($P < 0.001$), and significant increases in bone area ratio for boys ($P < 0.01$) and girls ($P < 0.05$), and the 3 studies in China conducted by Zhu et al [6], Zhu et al [7], and Du et al [8] were 2-year interventions of school milk programs with 3 groups: 1 group receiving school milk supplying 560 mg of calcium per day (Ca milk), 1 group receiving school milk supplying 560 mg of calcium fortified with 5–8 μg of vitamin D per day (CaD milk), and 1 control group. All 3 studies found significant increases in calcium intake for the Ca milk and CaD milk groups in

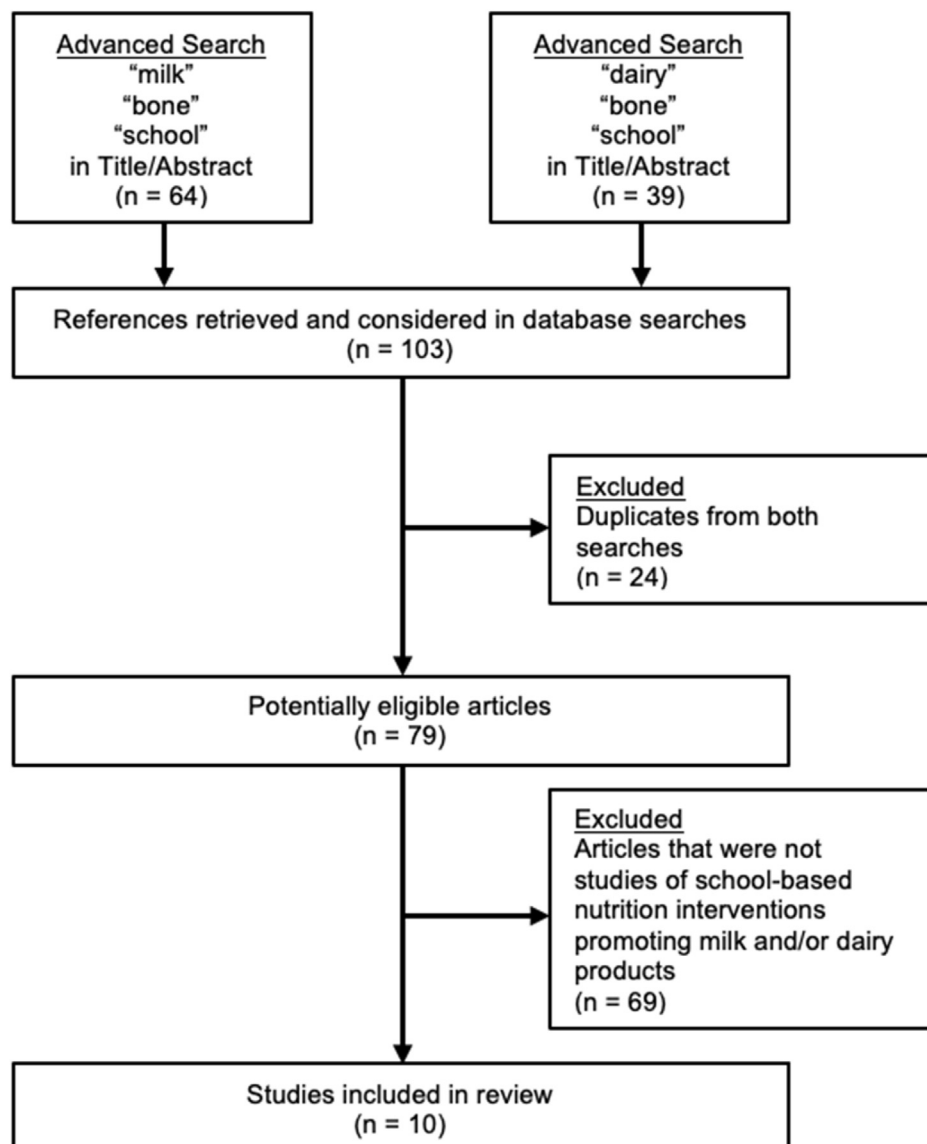


Fig. 1. Flowchart of studies included in review.

Table 1
Aspects of school milk programs on bone health.

Study Reference (n = 10)	Participant Descriptions	Study Details	Bone Health Findings
Kohri et al., 2016 [5]	Intervention Group: n = 329, 153 boys and 176 girls; mean age: 9.3 ± 0.4 years for boys, 9.3 ± 0.4 years for girls. Control Group: n = 484, 262 boys and 222 girls; mean age: 9.2 ± 0.4 years for boys, 9.2 ± 0.4 years for girls.	4-year observational study: School lunch with milk designed to provide 50% of the recommended dietary allowance for calcium. (Kinki region, Japan)	Significant increase in calcium intake for intervention group compared to control group ($P < 0.001$), and significant increase in bone area ratio in intervention group compared to control group ($P < 0.01$ for boys, $P < 0.05$ for girls).
Zhu et al., 2008 [6]	Intervention Groups: n = 110 girls in calcium (Ca) milk group, n = 112 girls in calcium fortified with vitamin D (CaD) milk group; mean age: 10.1 ± 0.4 years at baseline for Ca milk group, 10.1 ± 0.4 years at baseline for CaD milk group. Control Group: n = 123 girls; mean age: 10.1 ± 0.3 years at baseline.	2-year randomized control study: Ca milk group received school milk supplying 560 mg calcium per school day, and CaD milk group received milk supplying 560 mg calcium fortified with 5–8 mcg vitamin D per school day. (Beijing, China)	Significant increase in calcium intake for both intervention groups (Ca milk and CaD milk) groups compared to control group ($P < 0.001$), significant increase in vitamin D intake in CaD milk group compared to Ca milk group and control group ($P < 0.001$), and significant increase in bone mineral density (BMD) for both intervention groups compared to control group for the total body ($P < 0.05$) and legs ($P < 0.05$).
Zhu et al., 2005 [7]	Intervention Groups: n = 177 girls in calcium (Ca) milk group, n = 210 girls in calcium fortified with vitamin D (CaD) milk group; mean age: 10.1 ± 0.4 years at baseline for Ca milk group, 10.1 ± 0.3 years at baseline for CaD milk group. Control Group: n = 219 girls; mean age: 10.0 ± 0.3 years at baseline.	2-year randomized control study: Ca milk group received school milk supplying 560 mg calcium per school day, and CaD milk group received milk supplying 560 mg calcium fortified with 5–8 mcg vitamin D per school day for 2 years. (Beijing, China)	Significant increase in calcium intake for both intervention groups (Ca milk and CaD milk) groups compared to control group ($P < 0.001$). Bone mineral measures significantly increased for both intervention groups compared to control group in periosteal diameter, cortical thickness, and medullary diameter ($P < 0.05$). And bone metabolism measures significantly improved for the CaD group compared to control group with a significant decrease in bone alkaline phosphatase (BAP) at 1 year and in parathyroid hormone (PTH) at 1 and 2 years ($P < 0.05$).
Du et al., 2004 [8]	Intervention Groups: n = 207 girls in calcium (Ca) milk group, n = 240 girls in calcium fortified with vitamin D (CaD) milk group; mean age: 10.1 ± 0.4 years at baseline for Ca milk group, 10.1 ± 0.3 years at baseline for CaD milk group. Control Group: n = 234 girls; mean age: 10.0 ± 0.3 years at baseline.	2-year randomized control study: Ca milk group received school milk supplying 560 mg calcium per school day, and CaD milk group received milk supplying 560 mg calcium fortified with 5–8 mcg vitamin D per school day for 2 years. (Beijing, China)	Significant increase in calcium intake for both intervention groups (Ca milk and CaD milk) groups compared to control group ($P < 0.01$), significant increase in vitamin D intake in CaD milk group compared to Ca milk group and control group ($P < 0.01$). And significant increases in bone growth with anthropometric and bone mineral measures for both intervention groups compared to control group in height, sitting height, weight, body weight ($P < 0.0005$), and in total body bone mineral content (BMC) ($P < 0.05$) and bone mineral density (BMD) ($P < 0.0005$), with those in the CaD milk group being significantly higher than Ca milk group ($P < 0.01$).
Marsh et al., 2018 [9]	Participants: n = 511, 244 boys and 266 girls (1 unidentified); mean age: 8.5 ± 0.61 years for all participants at baseline.	2-year intervention study: Assessment of participants of the “Milk for Schools Program” measured at baseline, 1-year follow-up, and 2-year follow-up. (Auckland, New Zealand)	Portion of children meeting guidelines for milk and milk product consumption significantly increased from baseline (72%) to 2-year follow-up (94%) ($P < 0.001$).
Lee et al., 2019 [10]	Participant Group: n = 346, 167 boys and 179 girls; mean age: 14.1 ± 0.1 years for boys, 13.9 ± 0.1 years for girls. Non-Participant Group: n = 346, 153 boys and 193 girls; mean age: 13.8 ± 0.0 years for boys, 13.5 ± 0.0 years for girls.	Cross-Sectional Study: Questionnaires were administered to boys and girls who did or did not participate in school milk programs. (Incheon City and Daejeon City, South Korea)	Boys and girls who participated in school milk programs had significantly higher milk and dairy product consumption ($P < 0.001$).
Lee et al., 2018 [11]	Intervention Group: n = 274 girls; mean age: 13.2 ± 0.47 years at end of study. Control Group: n = 164 girls; mean age: 13.3 ± 0.45 years at end of study.	18-month randomized control study: The “Adequate Calcium Today (ACT)” intervention consisted of six (6) lessons of 50 min each 2 weeks apart, consisting of videos and games to motivate increased consumption of calcium-rich foods using the “No Bones About It” program, with measures at baseline, 12-month follow-up, and 18-month follow-up. (United States)	No significant differences between the intervention and control groups at the end of study.
Pampaloni et al., 2015 [12]	Participants: n = 156, 74 boys and 82 girls at end of study; age 9–10 years at baseline.	7-month intervention study: An educational program featuring “Mister Bone®” on a website encompassing online games educating and promoting bone health. (Florence, Italy)	Significant increase in calcium and vitamin D ($P < 0.05$) and milk consumption ($P < 0.05$) for both boys and girls and end of study.
Keshtkar et al., 2015 [13]	Participants: n = 468, age 15–19 year old boys and girls.	30-day intervention study: Each school was randomly assigned to administer 200 mL of either: 1) whole milk, 2) milk fortified with 600 IU vitamin D per 1,000 mL, or 3) milk fortified with 1,000 IU vitamin D per 1,000 mL. Blood samples taken at baseline and at end of study to measure bone biomarkers. (Tehran, Iran)	None provided.
Neyestani et al., 2014 [14]	Participants: n = 410, age 9–12 years old boys and girls.	12-week randomized control study: Each school was randomly assigned to administer either: 1) 200 mL of milk fortified with 500 mg calcium and	Significant increase in serum vitamin D ($P < 0.001$) between intervention groups receiving fortified or

(continued on next page)

Table 1 (continued)

Study Reference (n = 10)	Participant Descriptions	Study Details	Bone Health Findings
		100IU vitamin D, 2) 200 mL of plain milk with 240 mg calcium and no detectable vitamin D, 3) 200 mL of orange juice fortified with 500 mg calcium and 100 IU vitamin D, 4) 200 mL of plain orange juice with 180 mg naturally-occurring calcium and no detectable vitamin D, 5) supplement tablet of 500 mg calcium and 200 IU vitamin D, or 6) placebo tablet of 500 mg starch. Blood samples taken at baseline and at end of study to measure bone biomarkers. (Tehran, Iran)	supplemental vitamin D compared to control groups receiving placebo counterparts.

comparison to controls [6–8], as well as significant increases in vitamin D intake in the CaD milk group compared to the Ca milk group in the studies by Zhu et al [6] ($P < 0.001$) and Du et al [8] ($P < 0.01$). In addition to calcium and vitamin D intake, bone health measures were recorded for each study [6–8]. Zhu et al [6] found significant increases in bone mineral density (BMD) for the total body ($P < 0.05$) and legs ($P < 0.05$) for both the Ca milk and CaD milk groups in comparison to the control group. Zhu et al [7] found significant increases for bone mineral measures in periosteal diameter, cortical thickness, and medullary diameter ($P < 0.05$), as well as improved bone metabolism measures with significant decreases in bone alkaline phosphatase at 1 year ($P < 0.05$) and parathyroid hormone ($P < 0.05$) at 1 and 2 years. Also, Du et al [8] found significant increases in bone mineral content ($P < 0.05$) and BMD ($P < 0.0005$), with those in the CaD milk group being significantly higher than the Ca milk group ($P < 0.01$).

Additional studies that were not randomized control or observational studies also investigated school milk programs. One multi-year intervention study that administered milk at school but did not include a control group [9], and found that the percentage of children participating in a “Milk for Schools Program” significantly increased their milk and milk product consumption from 72% up to 94% in 2 years ($P < 0.001$), and 1 cross-sectional study between children who do and do not participate in a school milk program found that participants had significantly higher milk and dairy product consumption compared to non-participants ($P < 0.001$) [10].

Two studies investigated educational programs promoting bone health behaviors. The “Adequate Calcium Today (ACT)” intervention consisted of six 5-min lessons 2 weeks apart, consisting of videos and games to motivate increase consumption of calcium-rich foods using the “No Bones About It” program, but did not show significant differences in bone health behaviors between intervention and control groups at the end of the study [11]. However, an educational intervention featuring “Mister Bone®” on a website encompassing online games educating and promoting bone health did significantly increase consumption of milk ($P < 0.05$) and calcium and vitamin D ($P < 0.05$) among participants [12].

In addition, 2 studies investigated blood serum from consumption of vitamin D fortification in school meals [13,14]. One was a short 30-day intervention study measuring serum vitamin D differences among participants who drank at school 200 mL of either whole milk, milk fortified with 600 IU of vitamin D per 1,000 mL, or milk fortified with 1000 IU of vitamin per 1000 mL; however, no outcomes were reported in the article [13]. But a longer 12-week randomized control study measured blood biomarkers among participants who consumed at school either 200 mL of milk fortified with 500 mg of calcium and 100 IU of vitamin D, 200 mL of plain milk with 240 mg of calcium without fortified vitamin D, 200 mL of orange juice fortified with 500 mg of

calcium and 100 IU of vitamin D, 200 mL of orange juice with 180 mg naturally-occurring calcium and without fortified vitamin D, a supplement tablet of 500 mg of calcium and 200 IU of vitamin D, or a placebo tablet of 500 mg of starch. This study did report increased serum vitamin D ($P < 0.001$) between the intervention groups that received fortified vitamin D compared to the control groups receiving a placebo counterpart [14].

3. Discussion

For the studies that provided milk during and at school, results showed that participants had increased milk and calcium consumption, with improved bone health when measured. Educational programs promoting bone health may or may not be effective in increasing bone health behaviors, though children may respond better to innovative interventions that involve online gaming rather than traditional interventions at school. In addition to increasing calcium intake from milk and dairy products, fortification and supplementation may be an effective approach in increasing the consumption of both calcium and vitamin D.

Numerous studies from across the world have shown that most school-age children consume low amounts of calcium and/or vitamin D per day that are well below dietary recommendations [15–19], and this review has found that school milk programs can help children and adolescents increase their calcium and vitamin D intake, in order to maximize their bone health to prevent osteoporosis. Children who consume more school milk over the long-term have been shown to have higher bone mineral density [20], and the studies in this review support that school milk programs can be responsible for that. Bone mineral density is significantly higher in school-age children who previously and/or currently consume milk on a daily basis compared to school-age children who consume little to no milk at all [21,22]. Consuming at least 4 servings of milk and/or dairy products per day have been shown to have positive effects on bone density in school-age children [23], and school milk programs can help children and adolescents reach that daily amount. While school milk programs are effective in improving bone health, withdrawal from them may eliminate long-term increased calcium consumption and bone health benefits [24]. Not only do most school-age children not meet daily dietary recommendations for calcium, they also continue to consume even less calcium as they grow older [25,26], which further supports the need for public health policies to incorporate and sustain school milk programs to help promote and improve bone health in children and adolescents.

This literature review did have limitations. After a search of the literature, relatively few intervention studies were found of school milk programs and their effects on bone health. In addition, the longest duration of these studies lasted for only a few years, without long-term findings on how bone health improvements

may continue into older adulthood to prevent osteoporosis and bone fractures when they are more likely to occur. Therefore, additional research is recommended to investigate different interventions for school milk programs, perhaps those supplying different amounts of calcium and vitamin D to determine their effects on bone health for school-aged children. In addition, these research studies can also track participants in school milk programs over their lifetimes in order to determine their effects on preventing osteoporosis and bone fractures later in life. But in spite of these limitations, the studies in this review support the effectiveness of school milk programs to significantly increase calcium and vitamin D intake. Furthermore, nearly all of the studies in this review showed improved bone health outcomes during childhood and/or adolescence, which is the key time of the lifespan for maximizing bone mass, and this theoretically results in lower risks for osteoporosis and bone fractures later in life during adulthood and the elderly years.

4. Conclusions

School milk programs can be effective in promoting and improving bone health in children and adolescents. Public health policies should be considered in order to support and fund effective, evidence-based programs in schools in order to prevent osteoporosis and bone fractures later in life to improve population health.

Conflicts of interest

The author declares no competing interests.

Acknowledgments

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