23 The Potential Role of Dairy Foods in Fracture Prevention in Elderly in Aged-Care

Sandra Iuliano

Abstract

The global population is both expanding and aging, resulting in a rise in the burden of fragility fractures. The highest fracture rates occur in the oldest old, or those greater than 80 years of age. The majority of institutionalised elderly are women aged 80 years and older, so a substantial fracture burden arises from the aged-care sector. Malnutrition, and more specifically deficiencies of protein, calcium and vitamin D contribute to fracture risk, and are common in elderly in aged-care. While drug therapy is not an option to reduce the public health burden of fractures, correction of these deficiencies may be a safe, accessible and cost saving approach to fracture prevention.

The nutritional benefits of oral nutritional supplements in relation to weight gain and fewer health complications have been demonstrated in the short term, but limited compliance and efficacy have been observed for interventions greater than 6 months. Significant improvements in bone metabolism in elderly aged-care residents have been observed with fortification of foods, especially dairy foods fortified with calcium and vitamin D. However, fortified products may not be available to all elderly. A food-based approach that warrants attention is improving the dairy content of the food supply in aged-care, as dairy is a good source of protein, calcium (and vitamin D) and this approach satisfies the requirements of safe, low cost and accessible. Feasibility studies of added dairy foods indicate significant improvements in nutritional status in elderly aged-care residents using this method. To advocate for a dairy-based approach to fracture prevention, quality studies demonstrating anti-fracture efficacy are required.

Keywords

Aged-care • Calcium • Dairy • Elderly • Fractures • Malnutrition • Protein

S. Iuliano, PhD
Department of Endocrinology, Level 2 Centaur Building, Heidelberg Repatriation Hospital, West Heidelberg 3081, Australia
e-mail: sandraib@unimelb.edu.au

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The Aging Population: A Global Phenomena

Globally, the population is expanding, and life expectancy lengthening resulting in the those older than 65 years becoming one of the fastest growing population groups [1]. Within the elderly population, the oldest old, or those over 80 years of age is expanding rapidly. By the year 2050, the number of people aged over 80 years is projected to be almost 380 million, or 4 % of the world's population. In developed countries one in ten people will be 80 years or older [1]. The trend of reduced mortality (deaths) and fertility (births) is leading to the population distribution shifting from a large base of younger people supporting a proportionally smaller number of elderly, to a more cylinder like shape; fewer children and younger productive people (aged 15–64 years) supporting a larger number of elderly (>65 years of age). It is projected that by 2047 the number of people aged >60 years will outnumber children [1]. It is often questioned if a longer lifespan is associated with more years of good health, or a longer period of morbidity and so prolonged disability and dependency. If the later ensues the sustainability of the aging population may be challenged. Falls, fractures and immobility combine to form one of the four non-communicable 'diseases' that will afflict the elderly and contribute to the health care costs of the aging population [1].

The Growing Fracture Burden

As the population ages, the burden of fractures also increases. Globally, nearly 9 million fragility fractures occur each year [2]. It is estimated that 1⁄3 of women and 1⁄5 of men aged 50 years and over will suffer a fragility fracture [3]. For hip fractures alone, it is projected that by 2050, the worldwide incidence of hip fractures, will increase by ~300 % in males, ~200 % in females, and will total over 6 million hip fractures annually [4]. The highest fracture risk is observed in women over the age of 80 years, and they will make up the majority of the oldest old in the population [1]. Hip fractures are common in the very old and are a major contributor to loss of mobility, and requirement for institutionalised care. To curb the contribution of the elderly to the total fracture burden, effective strategies to reduce fracture risk are needed.

The Role of Institutionalized Care for the Elderly

The aging of the population creates specific demands at all levels of society. While in developed countries, the majority of elderly people (>60 years of age) live independently with or without a spouse, approximately 10 % of elderly people live in some form of institutionalised care [5]. The level of dependency and need will determine the type of care required. Elderly that are semi-independent but require assistance with basic care needs are accommodated in 'hostels', or assisted (USA) or residential (UK) care facilities, while those with greater disability and more severe and chronic illnesses that require higher care, are accommodated in 'nursing homes'. Of those living in institutionalised care, which will be collectively termed 'aged-care', over three quarters are aged 80 years and over, and the majority are women. As women aged over 80 years have the highest fracture rates in the community, fracture rates in aged-care are about three times higher than for elderly living in the community [6].

A considerable portion of the total fracture burden comes from elderly in aged-care [7, 8]. Thirty percent of all hip fractures and 25 % of all fragility fractures arise from elderly in aged-care [9, 10]. At a population level drug therapy is not an option to prevent fractures, so safe, accessible and cost effective strategies require investigation. Correcting nutrient deficiencies, especially for protein, calcium and vitamin D may be one approach. While fracture risk in an individual attributable to deficiencies of these nutrients may be small, the high prevalence of deficiencies in the elderly confers a high attributable risk, so shifting the elderly population to a higher level of intake may have a large net effect, similar to that seen with reducing sodium intake at a population level to lower blood pressure and risk of cardiovascular disease [11–14]. In aged-care malnutrition rates are high, with up to 89 % of residents being malnourished or at risk of malnutrition, and deficiencies of protein, calcium and vitamin D are common. For example in a sample of elderly aged-care residents in Australia, 30 % consumed below the estimate average requirement for protein, mean calcium intakes was approximate 600 mg/day and over half of residents had serum 25(OH)D levels below 50 nmol/L [15, 16]. Given these high rates of malnutrition, and the high fracture risk in aged-care residents this high-risk group is likely amenable to improved intakes of these (and other) nutrients as a strategy to reduce fracture risk. The cost-benefit analysis of a nutrition-based fracture prevention program in aged-care has not been reported but the cost-effectiveness of dairy consumption on fracture risk reduction in the community has been modelled [17]. However, in aged-care the cost of identifying, treating and monitoring malnutrition is estimated at €8,000 (~$9,000USD) per resident per year for those at risk of malnutrition, and €12,000 (~$13,000USD) per resident per year for malnourished residents, so reducing malnutrition alone will likely have cost-saving benefits as well as potentially reducing fracture risk.

Dietary Factors That Contribute to Fracture Risk in Elderly in Aged-Care

Malnutrition in Elderly Aged-Care Residents

Malnutrition results from an imbalance in the diet or to compromised absorption of nutrients. However, in the elderly, acute or chronic inflammation also contributes to malnutrition. Inflammation, associated with acute illness, injury or disease increases resting energy requirement, impairs protein utilization and increases nitrogen excretion, heightening nutrient requirements [18]. During this acute inflammatory phase, it has been suggested that nutritional support alone may not be sufficient to prevent a decline in lean mass reserves [18]. Jensen et al. (2010) defines the point at which lean mass declines and functional status is impaired as 'disease-related malnutrition' [19]. In the aged-care setting mild to moderate inflammation may be present in some residents due to chronic disease or illness. For example, Van Nie-Visser et al. (2014) observed in a sample of nearly 20,000 aged-care residents across three European countries that the mean number of diseases, and the presence of specific diseases (e.g. CVD, diabetes mellitus, respiratory disease) was associated with malnutrition [20]. However, malnutrition occurs with or without the presence of inflammation, so in part relates to insufficient intake and/or absorption relative to need. Insufficient nutrients in the absence of inflammation may be successfully treated with nutrition interventions.

Malnutrition in institutionalized elderly is endemic, with up to 89 % of residents reported to be malnourished or at risk of malnutrition [15]. However, inconsistencies in defining malnutrition contribute to a lack of consensus on the extent of malnutrition in institutionalised elderly. Amongst aged-care residents, age and sex (female) are recognised risk factors for malnutrition, however, the majority of residents are elderly women >80 years of age [5, 20–22]. Other contributors to malnutrition include cognitive impairment, poor dentition, level of dependency, stroke, immobility, swallowing difficulties, infrequent weight checks, consuming ≤ half of meals provided and not eating snacks [21–24].

Malnutrition is associated with increased falls, fractures, greater morbidity, impaired immunity, pressure ulcers, mortality and reduced quality of life [25–30]. Neyen et al. (2013) investigate the relationship between nutritionals status (assessed by BMI, nutrient intake and unintentional weight loss) and risk of falls over 30 days in a cohort of over 6700 aged-care residents. Malnourished residents were 1.7 times more likely to fall (95 % CI: 1.4–2.1, $p<0.01$), with a trend observed for greater falls risk for residents at risk of malnutrition (OR 1.2; 95 % CI: 1.0–1.4, $p=0.084$) compared to residents with normal nutritionals status. Over 90 % of fractures result from falls, so reducing falls will likely benefit fracture risk reduction [25].

Staff at aged-care facilities are pivotal in ensuring nutritional adequacy of residents. Low staff numbers is identified as a risk factor for malnutrition in elderly residents [31]. Simmons et al. (2006) observed that even with feeding assistance, nursing home residents did not achieve desired levels for energy intake. Staff assisted each resident with eating at meal times for approximately 6 min; which is less than the 30+ min estimated to ensure an adequate intake [32]. In a sample of 42 aged-care institutes in France, the risk of malnutrition was less in facilities where a higher number of staff were trained in nutrition screening (OR 0.54; 95 % CI: 0.32–0.91, $p<0.05$), managing malnutrition (OR 0.53; 95 % CI 0.31–0.92, $p<0.05$) and managing swallowing difficulties (OR 0.33; 95 % CI: 0.34–0.95, $p<0.05$) [33]. While malnutrition is common in elderly in aged-care, specific deficiencies of protein, calcium and vitamin D are also frequent, and contribute to fracture risk [34–37].

Protein Deficiency and Fracture Risk in the Elderly

Epidemiological studies in community-based older adults indicate no clear relationship between protein intake and fracture risk, likely because few elderly in these studies are truly protein deficient [38–44]. Relative to recommended protein levels, protein deficiency is more common in institutionalised elderly in whom rates of malnutrition are high [6, 15, 45, 46]. In some cases the provision of food to residents do not meet recommended protein intake levels [16].

Protein deficiency is associated with accelerated bone resorption, impaired bone formation and sarcopenia, so may affect both falls and fracture risk [47, 48]. Wengreen et al. (2004) compared a cohort of 1167 female and male cases to 1334 controls and observed a reduced risk of hip fracture with increasing quartiles for protein intake; 1st quartile OR = 1.0 (reference), 2nd quartile (OR = 0.51; 95 % CI: 0.30–0.87), 3rd quartile (OR = 0.53; 95 % CI: 0.31–0.89), 4th quartile (OR = 0.35; 95 % CI: 0.21–0.59, $p<0.001$ for trend) for those aged 50–69 years, but not for those aged 70–89 years [40]. Protein deficiency reduces IGF-1 levels, and low IGF-1 levels were associated with increased fracture risk in postmenopausal women independent of BMD [49, 50]. The mechanisms for the effect of protein deficiency on bone have been explored using the animal model. In aging male rats, protein deficiency was associated with reduced bone formation, with minor reductions in bone resorption, while in aging female rats, bone resorption was elevated, with limited formation, resulting in cortical thinning and loss of bone strength. Reduced IGF-1 was also observed [51–53].

It has been suggested that an adequate protein intake increases IGF-1, promotes calcium absorption, and stimulate muscle protein synthesis, potentially slowing bone and muscle loss [54]. Recommended daily protein intakes in the elderly range between 0.75 and 1.0 g/kg body weight (BW) however, these recommendations were based on nitrogen balance studies in adults in whom protein needs may differ to the elderly [54, 55]. Some authors have suggested that daily protein intakes of between 1.0 and 1.3 g/kg BW are required to maintain nitrogen balance in the elderly, due to observed reductions in protein synthesis efficiency and insulin action in the elderly [56]. Recommendations by the PROT-AGE study group suggest for elderly people with acute or chronic diseases, daily protein intakes of 1.2–1.5 g/kg BW are well tolerated, expect for those with severe kidney disease or on dialysis [57].

Some authors have suggested that to maximise muscle protein synthesis and prevent sarcopenia, in addition to consuming sufficient protein, each meal throughout the day should also contain between 25 and 30 g of high quality protein, while others have indicated that muscle protein synthesis can also be enhanced when consuming up to 80 % of total protein intake in a single meal [58–60]. Increases in IGF-1, muscle protein synthesis and lean muscle mass have been observed in older women in some, but not all studies, when supplemented with the branch chain amino acid leucine, [61, 62]. A recent meta-analysis of the effects of leucine-rich protein supplements in the elderly reported beneficial effects on gains in weight (1.02 kg; 95 % CI: 0.19–1.85, p = 0.02) and lean mass (0.99 kg; 95 % CI: 0.43–1.55, p = 0.0005), but not muscle strength, and the benefits most evident in those with sarcopenia [63]. However the authors, and others have noted, that the differences in study design make direct comparisons between studies problematic. Dairy foods and various meats are good natural sources of leucine so investigating the benefits of a leucine-rich diet on muscle and bone is worthy of consideration.

Calcium Deficiency and Fracture Risk in the Elderly

No clear relationship between calcium intake (with or without supplementation) and fracture risk in the elderly has been observed [64, 65]. Nieves et al. (2008) observed no relationship between calcium intake and osteoporotic fractures over 3 years in over 70,000 postmenopausal women [65]. Analysis of the Swedish Mammography study cohort involving over 60,000 women followed for more than 19 years, indicated that after adjusting for various confounders, an increased risk of first fracture (RR = 1.18, 95 % CI: 1.12–1.25) or hip fracture (RR = 1.29, 95 % CI: 1.17–1.43) was observed for women in the lowest quintile for calcium intake (<751 mg/day) compared to the reference intake (882–996 mg/day). However, a 15–17 % increased risk of hip fracture was observed in the highest quintile for calcium intake (>1184 mg/day; dietary plus supplemental calcium) compared to the reference intake [66]. Bischoff-Ferrari et al. (2007) did not observe a relationship between dietary calcium intake and hip fracture risk in women (RR = 1.01, 95 % CI: 0.97–1.05) or men (RR = 0.92, 95 % CI: 0.82–1.03) or for non-vertebral fractures and calcium intake (+ supplementation) in women (RR = 0.92: 95 % CI: 0.81–1.05) [64]. Warenjo et al. (2011) observed an increased risk of hip fracture in women with high calcium intakes, when it included supplementary calcium (RR = 1.64, 95 % CI: 1.02–2.64) [64]. Whether the observed increase in fracture risk in women in the highest intakes for calcium is due to those with a propensity for fractures supplementing their intake or due to suppression of bone turnover delaying fatigue repair of bone is unclear [67].

Low calcium intake is reported to increase bone remodelling intensity, and result in an apparent reduction in BMD, and bone loss if balance in the basic multi-cellular unit (BMU) is negative i.e. more bone is resorbed than formed in the individual BMU [68]. Correction of calcium (and vitamin D) deficiency likely contributed to the fracture risk reduction reported by Chapuy et al. (1992) who randomised over 3000 elderly female aged-care residents to 1200 mg calcium and 800 IU vitamin D daily or placebo for 18 months. Overall 42 % fewer hip fractures (p = 0.043) and 32 % fewer non-vertebral fractures (p = 0.015) were observed in those receiving supplementation. PTH levels were significantly lower, and serum 25(OH)D more than doubled in the supplemented women [69]. Markers of bone turnover are lowered with calcium supplementation, but a reversal of skeletal benefits are observed after calcium (and vitamin D) supplementation is ceased likely resulting from remodelling intensity returning to pre-supplemented levels [70].

Calcium intakes below recommended levels are common in elderly in aged-care, with intakes of less than 600 mg/day observed in elderly women in aged-care [71–74]. The FAO/WHO report higher fracture risk is in those consuming <500 mg/day of calcium [75]. However, there is lack of agreement on the required calcium intake to reduce fracture risk [76]. Despite this the FAO/WHO recommended a calcium intake of 1300 mg/day for postmenopausal women and men >65 years of age [55]. While the evidence for post-menopausal women is based on calcium balance studies, less data are available for elderly males so recommendations for men were increased as a precaution [75].

Vitamin D Deficiency and Fracture Risk in the Elderly

An association between low 25(OH)D levels and increased fracture risk has been observed in some but not all studies, but the 25(OH)D level at which fracture risk increases in not well defined [35–37]. Case-controlled and prospective studies involving over 20,000 elderly men and women have observed increased fracture risk for those with serum 25(OH)D levels ranging from <42.2 nmol/L to <64 nmol/L [77–79]. De Koning et al. (2013) observed that hip fracture risk was only related to serum 25(OH)D when levels were <70 nmol/L [80]. While this observation may suggest that fracture risk reduction is no greater when serum 25(OH)D levels are >70 nmol/L, defining the 25(OH)D level at which fracture risk is increased requires further investigation.

Vitamin D deficiency may be exacerbated in institutionalized elderly due to reduced mobility and limiting time outdoors [81]. For example hours of sunlight exposure was positively correlated with serum 25(OH)D ($r = 0.61$, $p < 0.01$) in 133 Japanese nursing home residents however, mean levels remained low (29.9 ± 13.1 nmol/L) [82]. Mean serum 25(OH)D levels <50 nmol/L have been observed in up to 94 % of institutionalized elderly, and is observed in countries both with (e.g. Germany and the USA) and without (e.g. Spain, Greece and Australia) limited seasonal cutaneous production [83–86]. Vitamin D supplementation may be required to maintain vitamin D sufficiency in institutionalized elderly [87].

Dairy Intake and Fracture Risk in the Elderly

No consistent relationship between the intake of milk or dairy produce and fractures has been observed [88–91]. Various methodological issues add to the complexity of attempting to determine relationships between a particular food or food group and fracture outcomes, in the context of a mixed diet. For example, accuracy in measuring food intake may obscure results. Sahni et al. (2013) observed that in a validation study of a version of the FFQ used in their assessment of dairy intake, the correlation with dairy intake determined using a 7-day food record was between 0.57 and 0.94 [92]. Furthermore, fracture outcomes need to be relevant and clearly defined. Participants in the study cohort reported by Sahni et al. (2013) were aged 26–85 years; hip fractures increase with age, fragility fractures are uncommon in young adults, fractures were not exclusively validated by hospital radiology reports, and all fractures were included, so degree of trauma associated with fractures not reported [93].

Inconsistencies in the definition of dairy foods (i.e. some include ice-cream as a dairy food, which is not a substantial source of protein or calcium), the size of a standard serve, and the choice of foods for analysis further add to the difficulty of determining a relationship between dairy intake and fracture risk [89, 94]. For example, using data from the Swedish mammography study Michaelsson et al. (2014) observed a negative relationship between milk intake and hip fracture risk in women (HR 1.09; 95 % CI: 1.05–1.13) however, the opposite relationship was observed for intake of cheese and fermented milk products, so likely negating any relationship when dairy as a food group is analysed [89].

Strategies to Reduce Fracture Risk in Elderly Aged-Care Residents

Oral Nutritional Supplements and Fracture Risk Reduction in Elderly Aged-Care Residents

Most studies demonstrating benefits of oral nutritional supplements in the elderly are hospital-based, and report minor weight gain, improved health outcomes and reduced mortality, mostly in malnourished patients [47, 95]. Delmi et al. (1990) randomised 59 malnourished hip fracture patients (mean age 82 years) to protein supplementation (20 g protein) and observed more favourable outcomes (56 vs. 13 %), fewer complications and death during hospital stay (44 vs. 87 %) and at 6 months after discharge (40 vs. 74 %) and shorter hospital stay (24 vs. 40 days) compared to 32 controls consuming only hospital food [96].

Neelemaat et al. (2012) randomised 210 elderly malnourished patients (mean age 74 years) to intervention or normal care (control) and reported a significant reduction in patients who fell within 3 months after discharge in those in the intervention group [97]. Intervention patients were provided a protein-energy enriched diet during hospital stay, oral nutritional supplements plus vitamin D and calcium supplementation post discharge, and support by telephone counselling by dieticians. Both protein intake (+11 g/day, $p<0.05$) and serum 25(OH)D (+11 nmol/L, $p<0.01$) were increased with intervention compared to controls. The basis for the benefits is unclear as neither fat free mass, hand-grip strength or physical performance were improved with supplementation. No benefit of a protein-based ONS on falls risk was observed over 16-weeks in 253 malnourished elderly patients (mean age 82 years), despite improved hand-grip strength in supplemented patients. Adherence to supplementation was <40 %, and no post-discharge counselling or support was provided [98].

As the majority of studies of oral nutritional supplements focussed on weight gain (to prevent or overcome malnutrition) with supplements admitted during hospitalization, the sustainability of oral nutritional supplement use in the elderly outside of the acute hospital setting is uncertain. Compliance with, and acceptance of oral nutritional supplements by elderly people is often poor, especially in longer-term trials (>6 months), and gastro-intestinal disturbances are frequently reported, so raising doubt about the long-term use of ONS as a strategy for falls and fracture prevention [98, 99].

Despite frequent prescription of ONS for elderly in aged-care, limited data are available to support the use of ONS as a strategy for fracture risk reduction [99]. Meta-analyses indicate weight gains of ~2.5 % (95 % CI: 1.7–2.7 %), but few studies demonstrate favourable changes to lean mass and physical function, both of which may influence falls and fracture risk [99]. Bonneyfoy et al. (2003) did not observe improvements in lean mass assessed from total body water, in retirement home residents (mean age >80 years) over a 9-month period when consuming two oral nutritional supplements daily that provided 400 kcal energy and 30 g protein. Compliance was 54 % so effectively half of that prescribed [100]. Fiatarone et al. (1994) observed no change to muscle strength, gait velocity and stair climb power in nursing home residents (mean age 87 years) when supplemented with a 240 ml ONS daily that provided 360 kcal of energy and 18 g of protein. The supplement was administered by nursing staff, and compliance was 99 % [101]. Gains of ~0.8 kg in fat free mass were observed in elderly Alzheimer disease patients when randomised to receive a choice of oral nutritional supplements (soups, desserts & drinks; protein content 10–12 g) over a 3-month period. Supplement administration and monitoring was performed by care-givers [102].

In the aged-care setting oral nutritional supplements are often not delivered according to treatment plans and significant waste is observed [103, 104]. Kayser-Jones et al. (1998) reported that less than 1/3 of nursing home residents were provided with the correct type and dosage of oral nutritional supplements and mean intake was approximately 55 % [105]. Moreover elderly with limited appetites may have difficulties consuming supplements in addition to regular meals so normal intake may be compromised. Fiatarone et al. (1994) observed during a 10-week exercise and nutrition supplementation trial in frail nursing home residents, that habitual dietary intake decreased by ~250 kcal/day in the supplement arm, so no change to total energy intake was observed. Manders et al. (2006) observed during a 24-week randomised double-blind placebo-controlled study of oral nutritional supplements in 176 nursing home residents that mean food intake in the supplemented group declined by ~0.5 MJ/day resulting in no difference in change to energy intake between intervention and controls [106]. Given the reported effectiveness of ONS in the short, but not long-term, investigating alternative strategies to reduce fracture risk in the aged-care setting are warranted.

Fortification of Dairy Produce and Fracture Risk Reduction in Elderly Aged-Care Residents

Fortification of the food supply represents one approach that may ensure nutritional adequacy for particular nutrients in certain at risk populations. For example in Australia bread-making flour is fortified with folic acid to reduce the risk of neural tube defects in new born babies, and iodised salt is used in bread due to the re-emergence of iodine deficiency in the population [107]. Countries such the United States of American and Canada fortify dairy foods with vitamin D, which may be effective in reducing the prevalence of vitamin D deficiency. For example, Shakur et al. (2014) used the food intake (24 h recall) in over 34,000 Canadians as part of the 2004 Canadian Community Health Survey 2.2 and observed that vitamin D fortification of milk, cheese and yoghurt a 270 IU/serving effectively doubled vitamin D intake and the proportion with inadequate intake was reduced from >80 to <50 %, with no intakes approaching the upper limit for vitamin D intake [108]. However, some authors have argued that fortification of only dairy produce may be insufficient to reduce the incidence of vitamin D insufficiency, and other food staples such as wheat flour, may also require fortification with vitamin D [109, 110]. For the elderly fortification may also serve to increase nutrient density, so even with limited appetite, nutrient adequacy may be achieved.

Using bread as the vehicle for nutrient delivery, Monacu et al. (2009) undertook a 1-year intervention providing daily buns fortified with vitamin D (5000 IU/day) and calcium (320 mg/day) to 45 elderly nursing home residents. Serum 25(OH)D levels increased from 29 ± 11 nmol/L to 126 ± 38 nmol/L; serum PTH levels more than halved from a baseline value of 59.3 ± 38.3 pg/ml to 19.0 ± 16.0 pg/ml ($p < 0.001$). Osteocalcin levels were lowered by ~27 % (20.1 ± 10.3 ng/ml to 14.7 ± 9.0 ng/ml, $p < 0.001$) but no significant difference was observed for serum C-telopeptide. BMD at both the total hip and lumbar spine significantly increased [111].

Dairy foods are a good source of protein, so fortification can improve nutrient density (e.g. calcium), or serves as a vehicle to provide bone-related nutrients (e.g. vitamin D). In the aged-care setting malnutrition is common, so providing fortified dairy products may improve nutrient intake and could potentially reduce fracture risk.

Etjahad et al. (2105) developed a hypothetical model of vitamin D fortification of milk (42 IU/100 g) and yoghurt (89 IU/100 g), based on vitamin D intakes of over 5000 adults in a population at high-risk of vitamin D deficiency, and observed that nearly 80 % of the population could achieve the RDA for vitamin D, without any exceeding the upper limit of intake [112]. As aged-care residents are at high risk for vitamin D deficiency this may be an effective strategy to improve bone health.

Bonjour et al. (2009) observed a 12.3 % decrease in PTH and a 16.9 % increase in IGF-1 in elderly institutionalised women (mean age 85 years) after 1-month of supplementation using calcium (151 g/100 g) and vitamin D (50 IU/100 g) fortified soft cheese [113]. Bonjour et al. (2013) also compared the efficacy of vitamin D- (400 IU) and calcium-fortified (800 mg) yoghurt to regular yoghurt (calcium content 280 mg) over 56 days in 60 vitamin D deficient elderly institutionalised women, and observed 25(OH)D was approximately 20 nmol/L higher ($p < 0.0001$) and PTH and CTX, 20 % ($p < 0.001$) and 8 % ($p < 0.05$) lower with fortification [114]. Residents consumed two 125 g serves daily, with two flavours provided. Products were rated as satisfactory, so long term adherence was uncertain. In a similar design, Bonjour et al. (2015) undertook a subsequent randomised study comparing fortified to regular yoghurt involving 48 women (mean age 73 years) in a community home and observed after 84 days of intervention a significant increase in serum 25(OH)D in both the fortified (34.3 ± 2.4–56.3 ± 2.4 nmol/L) and non-fortified yoghurt groups (35.0 ± 2.5–41.3 ± 3.0 nmol/L), while reductions in PTH (63.5 ± 4.6–60.7 ± 4.2 ng/L, $p < 0.01$), and bone resorption ($p < 0.05$) were observed in the fortified yoghurt consumers [115].

Iuliano-Burns et al. (2012) conducted a 2-year randomised cluster intervention using a dairy-based protein, calcium and vitamin D supplement in 813 ambulant elderly in aged-care (mean age 85.5 years). Supplementation reduced the number of residents who fell by 42 % (OR = 0.58, 95 % CI: 0.44–0.78, $p < 0.001$), slowed bone loss at the proximal femur, which declined in the control group by 2.5% ($p<0.05$), maintained serum 25(OH)D, which declined in the control group by 22% ($p<0.001$) and reduced PTH by 16% ($p<0.05$). Falls reduction was observed for those who did not fall in the prior year, or fell once or twice, but no benefit of supplementation was observed for frequent fallers (Fig. 23.1) [116].

Issue observed in the aged-care setting that hinder the implementation of nutrition-based interventions, are high staff turnover, and limited time and resources for staff to support these initiatives. In the previously mentioned study, Iuliano et al. (2013) reported that food service staff had difficulties mixing the supplement into the foods, with the problem being resolved only when the foods products were provided pre-fortified [116]. Staffing issues were also identified as a limitation to implementation by Grieger et al. (2009) who tested the provision of calcium and vitamin D fortified milk to elderly in aged-care. The authors observed that without supervision and guidance, food service staff did not make sufficient modifications to the menu to increase milk intake, so no changes were observed for PTH, bone turnover markers, physical function or bone ultrasound measures and mean serum 25(OH)D levels remained below 50 nmol/L [117]. A dietary approach to fracture prevention, using the established dietary guidelines as the foundations, relies less on staff involvement in preparing specialised food products, so may be an approach that may fulfil the requirements of being a safe, accessible and cost effective approach to fracture prevention.

Food-Based Approaches to Improving Nutrient Intake in Elderly in Aged-Care

Feeding Assistance

Of the methods explored to enhance nutritional intake in institutionalized elderly such as enhancing food flavours, provision of snacks, staff education, and altering dining environment, the greatest improvements are observed when residents are assisted with eating [118]. Feeding assistance is particularly pertinent for residents with dementia, who are also at high risk for falls, so ensuring an adequate nutrient intake in this group has even greater importance [119]. Simmons et al. (2008) undertook a 24-week cross over intervention in nursing home residents at risk of malnutrition who were assisted with feeding at meals and snacks. Sixty residents completed the trial. Energy intake increased by approximately 300 kcal/day, and weight was maintained or increased during the intervention, but lost during the control period. Staff assisted each resident for 42 min during meals and 13 min during snacks compared to the usual care of 5 min per resident for meals and less than 1 min per resident for snacks [120]. Whether these changes to

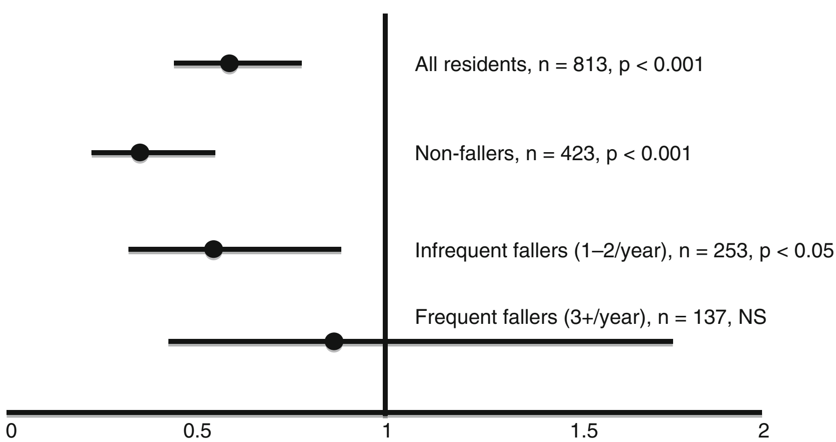

Fig. 23.1 Odds ratio (95% CI) for elderly aged-care residents receiving 8 months of dairy-based supplementation relative to non-supplemented control residents [116]

food intake translate to falls and fracture risk reduction require further investigation.

Are Residents Provided with Enough Food?

Institutionalized elderly are predominantly reliant on aged-care providers to meet their nutritional needs, with most meals and snacks prepared and provided through the facility's food service. Nutritional guidelines have been established to guide menu planning in aged-care to ensure nutrient needs of residents are met. Despite these guidelines, it has been observed in some cases that the actual foods provided in aged-care do not meet nutritional requirements [16, 121]. Protein and/or calcium intakes are frequently below recommended [122–125]. For example, in relation to calcium intake, Baric et al. (2006) observed from a random sample of 44 nursing home meals that women, but not men consumed sufficient energy (106 % vs. 88 % of the RDI), protein intake was adequate (>100 % of RDI for both), but calcium intake was well below recommended levels at 64 % of the RDI [126]. Food policies differ between aged-care providers with some prohibiting food prepared by others outside of the facility to be brought into facilities. However, it was observed that receiving additional meals provided by family members was negatively associated with malnutrition, which may indicate that some of the shortfall in food provision was being made up by this additional food [127].

Are Elderly in Aged-Care Provided the Right Types of Foods?

The cornerstone of the dietary guidelines is to choose a variety of foods from each of the food groups, which assists towards obtaining all required nutrients. Mila et al. (2012) used the double weighed method to record food intake over 21 days in 62 Spanish nursing home residents from various facilities. The authors observed that the highest intake was for milk (median intake 376 g/day), meat and meat alternatives were consumed in sufficient amounts (median intake ~ 150 g/day), but the consumption of cereals, fruit and vegetables were below recommended. With the high consumption of dairy (376 g of milk and 130 g of other dairy products) and meats, protein needs were met [128].

In contrast, Iuliano et al. (2013) observed in a sample of 199 elderly from 18 aged-care facilities, inadequate serving of dairy, vegetables and grain foods were consumed, and discretionary foods such as cakes and biscuits were consumed in excess of recommended, resulting in inadequate intakes of protein (61 % of residents below RDI) and calcium (98 % of residents below RDI). Meats and meat alternatives and fruit were consumed in recommended quantities [73]. In countries that do not have mandatory vitamin D fortification of foods, dietary intake of vitamin D is also marginal, amd supplementation may be necessary [73].

Both meat and meat alternatives (eg eggs) and dairy produce (milk, cheese, yoghurt) are sources of quality protein so adequate intakes may help ensure an adequate protein intake. In a sample of 215 aged-care residents (70 % females, mean age 85.8 ± 7.5 years) from 21 aged-care facilities both meat and dairy servings were not consumed in sufficient amounts, and 68 % were malnourished, or at risk of malnutrition based on mini nutrition assessment (MNA) scores. Protein intake was 87 ± 28 % of recommended and mean calcium (622 ± 263 mg/day) was well below recommended (1300 mg/day). Residents consumed on average 0.9 ± 0.5 servings of meat daily and 1.1 ± 0.7 servings/day of dairy. Using multivariate analysis, number of dairy and meat servings were related to proportion of recommended protein intake; one more dairy serve would contribute ~14 % to recommended protein intake levels, so on average, residents would meet protein needs (100 % of RDI), while an additional meat serving would contribute ~10 % to protein requirement. Number of dairy ($p < 0.001$) but not meat ($p = 0.4$) serving contributed to MNA score; one additional dairy serving would contribute four points on the MNA, so on average residents would achieve normal nutrition status (minimum MNA score of 24) with the addition of one dairy serving daily. The provision of at least one additional serving of dairy daily could ensure protein intake meets requirements and reduce malnutrition in residents (Iuliano et al. unpublished).

Provision of Dairy Produce as a Food-Based Approach to Fracture Prevention

For an anti-fracture intervention to have widespread application it needs to be safe, effective and easily accessible. Food fortification laws differs between countries so fortified products may not be readily available to all. In some cases fortified foods are considered nutritional supplements, so would not be regarded or administered as part of the food supply. An important feature of a food-based approach is it can be implemented unimpeded through the food supply so is available to all residents. Using a dairy-based approach, Iuliano et al. (2013) undertook a feasibility study to determine if improving dairy intake from the two serving per day currently consumed, to the recommended four serving per day could be a potential anti-fracture strategy in institutionalised elderly [129]. 130 residents (mean age 86.5 years) in four aged-care facilities participated in the 4-week trial. Two facilities underwent intervention while two facilities served as controls so residents consumed from their normal menu. Following the intervention, daily increases in mean energy intake (900 kJ, $p<0.001$), protein intake (+25 g, $p<0.0001$), proportion of energy from protein (+4 %, $p<0.0001$) and proportion of estimated energy requirements (EER) (+18 %, $p<0.0001$) were observed, while proportion of energy from fat decreased (−3 %, $p<0.0001$). In residents in control facilities mean energy intake remained below the EER, and protein intake remained unchanged. Increases in mean daily intakes of calcium (+679 mg, $p<0.0001$), vitamin D (+1.4 μg, $p<0.0001$), phosphorus (+550 mg, $p<0.0001$), and zinc (+2.8 mg, $p<0.0001$) were observed with intervention, which remained unchanged in controls. Calcium and zinc intakes achieved recommended levels with intervention, but remained below recommended levels in controls. Mean sodium intakes remained unchanged.

The mean increase in protein intake of 25 g/day was greater than that reported in other studies which used supplements (6 g/day) or food fortification/snacks (12 g/day) [106, 130, 131]. In addition, this level of protein supplementation is similar to amounts suggested to maximize muscle protein synthesis and prevent sarcopenia [58]. Moreover intake of leucine in dairy foods has been shown to increase IGF-1 expression, lean muscle mass and muscle protein synthesis in older women, so is a potential strategy to improve muscle as well as functioning to reduce fracture risk, and most likely beneficial in those with protein intakes below recommended [61, 62].

Why Target Anti-fracture Interventions at Elderly People in Aged Care?

Targeting institutionalised elderly is likely cost effective given that falls and fracture risk is highest in this group, so fewer require treatment to prevent a fracture, and many of the factors that compromise study design are overcome [7, 69, 132, 133]. Most notably in aged-care, rates of nutritional deficiency are high, so residents are more likely to benefit from treatment, food intake (compliance) can be closely monitored and outcome measures more readily quantified as the setting is well controlled. The demand on institutionalised care will increase as the aging population grows, so reducing fractures in this high-risk group will help reduce care and medical costs in this setting.

With the availability of more sensitive imaging techniques (e.g. High resolution micro pQCT), closer examination of bone structure and its response to nutrition interventions is achievable. If bone deterioration is too advanced in the very old, but in whom fracture rates are the highest, then other components of dairy may exert a benefit, such as protein influencing IGF-1, and so benefit both muscle and bone. The same scientific rigour applied to clinical trials also needs to be applied to food-based intervention, to quantify the improvements achievable with enhanced dairy intake. The findings from these trials will help provide the evidence to shape future policies to ensure nutritional adequacy in elderly in aged-care, and the best time to intervene to achieve the optimal musculoskeletal benefits from consuming sufficient dairy foods. Such a large randomised controlled trial is warranted to evaluate the effectiveness of a dairy-based intervention on fracture prevention in high-risk elderly in aged-care. With the aging of the population, the sustainability of institutionalised care to cater for the growing number of elderly may depend on the efficacy and cost-benefit of such a food-based approach.

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