Advantage of Dairy for Improving Aging Muscle

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The risk of sarcopenia increases with aging. Malnutrition in the elderly population is an important risk factor for sarcopenia. Calcium (Ca), phosphate (P), vitamin D and protein are key nutrients for the human body and affect muscle mass and quality. Dairy products are rich in these nutrients, which implicates that dairy products might be ideal for elderly population. This systematic review highlights the effects of dairy products on muscle mass, muscle strength and body performance in the elderly population in the perspective of Ca, P, vitamin D and protein.

Key words: Dairy products, Calcium, Phosphate, Vitamin D, Proteins, Muscle

INTRODUCTION

With the aging process, weakening of muscle strength and quality (sarcopenia) is predicted to be the cause of increased early mortality for the elderly.1 With the aging of the long baby-boomer generation, the prevalence of sarcopenia will increase.2 Now, there are 50 million patients with sarcopenia in the world and it is forecasted to be 500 million sarcopenia patients in 2050.3,4 Therefore, aging and sarcopenia have had a serious impact on public health in countries around the world. Moreover, in the elderly population, sarcopenia will undoubtedly become a growing financial burden for the health care system of developed countries.5

The muscle is under great pressure. The causes of muscle loss are unclear, but it is apparent that during the development and maintenance of muscle, muscle mass and strength of the aged are under the influence of environmental factors, exercise factors, nutritional factors etc. Among these, nutritional factors play pivotal roles. Appropriate nutritional supplements for the elderly are particularly important for preventing age-related muscle mass and muscle loss (sarcopenia).6 A lot of literature have proved that there is a lower basal rate of protein synthesis and/or an increased rate of protein breakdown, and lower sensitivity to insulin-induced stimulation of protein synthesis in the aged muscle,7,8 and that vitamin D can precisely improve insulin resistance and insulin secretion.9,10 Moreover, the main active form of vitamin D after its conversion in vivo is 1,25-dihydroxyvitamin D (1,25(OH)₂D), which is an important factor regulating the balance among calcium (Ca), phosphate (P) and muscle metabolism. Therefore, these factors can prevent from the age-related loss of muscle.11,12

Dairy products are one of the important supplying sources of Ca, P, vitamin D and protein in diet. Dairy products contain almost all the essential nutrients that promote growth and maintain the health of the elderly and have been confirmed in most studies.13,14 Therefore, the health effects of dairy consumption in elderly patients with sarcopenia should be given more attention. This paper explores literature and clinical evidence, and provides information...
for health professionals to help older people with sarcopenia make informed decisions about consumption of dairy products as a part of balanced diet.

**SKELETAL MUSCLE HEALTH**

**The changes in muscle with aging**

Muscle plays an essential role in the health of the elderly. Muscle mass corresponds to approximately 40% of body mass.\(^{15}\) The quality and strength of skeletal muscle usually peaks at the ages of 20 to 35 years.\(^{16}\) After that, there will be 3% to 8% muscle mass loss every 10 years and the loss usually accelerates after age of 60 years.\(^{17-20}\)

With aging, the quality and strength of skeletal muscles decline. It is reported that the incidence rate of sarcopenia among the elderly aged 60 years and above reaches 30%, and the elderly aged 80 years and above can reach more than 50%.\(^{19}\) Muscle strength decreases with aging. In the meantime, it has recently been reported to predict the onset of sarcopenia.\(^{21}\) It is caused by an imbalance between protein synthesis and degradation. There are several mechanisms causing the declination of age-related muscle mass and strength, including altered hormonal status, inflammatory processes, reduced physical activity, and undernutrition, most often resulting from undernutrition.\(^{22}\)

**Undernutrition in elderly and sarcopenia**

As early as the 1990s, Castaneda et al.\(^{23}\) found that older women had a decrease in lean body mass and decreased muscle function on a low-protein diet. Campbell et al.\(^{24}\) also found that skeletal muscle growth was significantly higher in people with high protein intake than in low protein intake. In the review by Wilson and Morley\(^{25}\) loss of appetite and malnutrition caused a decrease in muscle mass and an increase in fat mass. This is mainly because as the nutritional intake of the elderly is unbalanced, the protein consumption in the body increases. In addition, the relative synthesis is insufficient, resulting in a decrease in muscle mass. Most elderly people have decreased appetite and inadequate nutrient intake. In addition, the clinical development of many wasting diseases and most malignant tumors will consume different levels of protein in the body, which will lead to imbalance of protein synthesis, catabolism and muscle reduction.

**The nutrient profile of dairy products**

Eating habits are influenced by diverse factors, even in some developed countries, like Republic of Korea. The eating habits are also affected by age, income, educational level and other factors. These factors lead to various personal nutrition consumption, even in undernutrition. Eating habits and various factors which consists of age, income level, educational level, personal nutrient consumption, etc. affect many countries of the world, like Republic of Korea.\(^{26,27}\)

Hence, dietary guidance needs to identify foods that are nutrient rich, affordable, and appealing.\(^{28}\) The analysis of the nutritional composition of the Korean diet in 2007 and Food and Agriculture Organization of the United Nations in 2013 showed that the micronutrients in dairy products were rich in content and high in content (Table 1), and the price was relatively low.\(^{27}\) In addition, according to other studies, the energy of dairy products is relatively low, and low-fat dairy products, high-Ca dairy products are essential for elderly people with sarcopenia.\(^{29}\) Therefore, it is instrumental and necessary to, first, determine which kind of nutrients play the significant role in muscle development and maintenance; second, identify how these essential nutrients interact in muscle development and maintenance; finally, develop appropriate and reasonable dietary methods to prevent the occurrence of diseases, for ex-

| Food name                        | Energy (kcal) | Total fat (g) | Carbohydrate (g) | Protein (g) | Calcium (mg) | Phosphorus (mg) |
|----------------------------------|--------------|---------------|------------------|-------------|--------------|----------------|
| Milk (3.7% milkfat)              | 64           | 3.7           | 4.7              | 3.3         | 119          | 93             |
| Milk (skimmed without added vitamin A and vitamin D) | 34          | 0.1           | 5.0              | 3.4         | 122          | 101            |
| Yoghurt (low fat)                | 63           | 1.6           | 7                | 5.3         | 183          | 144            |
| Yoghurt (fruit, low fat)         | 105          | 1.4           | 18.6             | 4.9         | 169          | 133            |
| Cheese (cheddar)                 | 403          | 33.1          | 1.3              | 10.3        | 721          | 512            |
| Cheese (non-fat)                 | 72           | 0.3           | 6.7              | 3.5         | 128          | 190            |
| Ice cream                        | 207          | 11.0          | 23.6             | 3.5         | 128          | 105            |
ample, sarcopenia is through food surveys which can provide relative dietary patterns.\textsuperscript{29,30}

**Influence of dairy products on muscle health**

The potential impact of dairy products on muscle building should be taken seriously. In the daily diet, the supplement of Ca, P, vitamin D, and protein can be achieved by drinking milk. The beneficial effect of Ca, P and protein can enhance muscle mass and function.\textsuperscript{31,32} Vitamin D levels in dairy products are variable and insufficient to meet body needs. After investigation, at least of 20 μg (800 IU) per day is needed in healthy adults, the demand was expected to be higher for the elderly.\textsuperscript{33,34} The 2002 review article from the Institute of Clinical Osteology, Germany illustrated that vitamin D plays a pivotal adjective role in Ca\textsuperscript{2+} transport and protein synthesis in muscle cells.\textsuperscript{35}

In developed countries, such as the United States and Canada, dairy products have become an important part of diet and dairy products in the market often strengthen Ca and vitamin D.\textsuperscript{37,38} In addition, skeletal muscle mass is determined by net balance between synthesis of new proteins and degradation of existing proteins. Daily turnover of skeletal muscle protein in healthy humans is around 1%–2% per day.\textsuperscript{39} Protein synthesis increases with increased diet while decreases during fasting. In the elderly population, the postprandial response of protein synthesis is decreased. However, this lower rate of muscle protein synthesis may be a key factor in aging sarcopenia.\textsuperscript{40} Studies have indicated that vitamin D deficiency can reduce the ability of the intestinal mucosa to fully absorb Ca and P, which is the strong evidence of significance of vitamin D. However, clinical data also explains how and when nutrients rich in dairy products improve muscle maintenance in adults.\textsuperscript{41}

As a result of aging, the muscle mass can reduce and lead to the imbalance of muscle reinforcement and decomposition. Theret-

| Author (year) | Study population/age/place of study | Intervention | Treatment duration | Outcome measurement | Effect on outcome |
|---------------|------------------------------------|-------------|-------------------|-------------------|------------------|
| Bonjour et al. (2013)\textsuperscript{22} | 2,066 Men and women/range, 70–79 yr/USA | Daily protein intake (0.7 and 1.1 g/kg b.w.) | 3 yr | Appendicular lean mass | The group of daily protein intake (0.7 g/kg b.w.) is 40% less of appendicular lean mass than the group of daily protein intake (1.1 g/kg b.w.). |
| Björkman et al. (2011)\textsuperscript{62} | 47 Older people/over 69.5 yr/Helsinki, Finland | A whey protein enriched dairy product with high leucine content | 8 wk | Lower limb muscle mass | A 1.8% increase in lower limb muscle mass |
| Alemán-Mateo et al. (2014)\textsuperscript{49} | 132 Apparently healthy people/over 60 yr/ Mexico | A group habitual diet but add 210 g of ricotta cheese, while B group was instructed to consume only their habitual diet. | 12 wk | ASMM | The addition of 210 g of ricotta cheese improves ASMM and balance-test scores, while attenuating the loss of muscle strength. |
| Mojtahedi et al. (2011)\textsuperscript{60} | 31 Overweight or obese, postmenopausal women/mean ± SD, 65.2 ± 4.6 yr/USA | Prescribed a reduced calorie diet (1,400 kcal/day) and randomly assigned to 50 g/day whey protein (15 participants with protein and 16 participants without). | 6 mon | Muscle and weight | 15 Participants with protein maintain muscle relative weight loss. |
| Wilkinson et al. (2007)\textsuperscript{61} | 8 Healthy men/mean ± SD, 21.6 ± 0.3 yr/Canada | Milk beverage after a unilateral resistance exercise | 1 wk | Muscle mass | Milk resistance training promotes muscle mass maintenance and gains. |
| Zemel et al. (2005)\textsuperscript{65} | 38 Otherwise healthy obese adults/range, 18–50 yr/USA | On balanced deficit (500 kcal/day) diets and randomized to control (400–500 mg Ca/day) or yogurt (1,100 mg Ca/day) | 12 wk | Lean tissue and trunk fat | In the yoghurt diet, the decline of trunk fat significantly increased, while lean tissue was increased in the 400–500 mg Ca/day mode. Notably, dairy Ca markedly more effective than other Ca sources. |
| Melanson et al. (2005)\textsuperscript{66} | 10 Men and 9 women/range, 20–50 yr/USA | High-dairy (3 to 4 servings per day, 1,400 mg Ca\textsuperscript{2+}/day) energy balance diet | 1 wk | BMI and body mass | Increased consumption of dairy products in the short term may affect the reduction of BMI and the increase of body mass |
| Rozenberg et al. (2016)\textsuperscript{32} | 116 Healthy prepubertal boys/mean ± SD, 7.4 ± 0.4 yr/Switzerland | Providing 850 mg/day calcium | 1 yr | Weight, fat mass, waist circumference and lean body mass | A possible small weight reduction, with decreases in fat mass and waist circumference and increases in lean body mass |
| Schürch et al. (1998)\textsuperscript{67} | 82 Orthopedic ward patients/mean ± SD, 80.7 ± 7.4 yr/USA | Received calcium supplementation, 550 mg/day, and 1 dose of vitamin D, 200,000 IU | 6 mon | Biceps muscle strength | Found the incremental of biceps muscle strength. |

b.w., body weight; ASMM, appendicular skeletal muscle mass; SD, standard deviation; BMI, body mass index.
ter, the supplement of dairy products has been postulated to prevent further loss of lean mass and promote muscle accretion and enhanced function (Table 2).

The beneficial effects of nutrients on sarcopenia
The cause of sarcopenia is unclear for now, but it is obvious that many causes are associated with undernutrition in the elderly. Undernutrition results in decreased muscle synthesis and increased rate of decomposition. The nutrients that cause nutrients for muscle synthesis and decomposition includes Ca, P, vitamin D, and protein. Also, in the previous studies,7,48 they have proved that it is the key to cause muscle reduction. However, as other, no dietary factors are involved. Sarcopenia is considered to be a multifactorial disease. Regardless of its causes, nutritional supplements appear to play a significant role in preventing and reversing health and loss of muscle and function in the elderly.49,50 The ability to reverse this situation is to apply nutrient-rich dairy products as a dietary strategy to prevent sarcopenia, which is based on the multi-nutrient supplements in dairy products that can supplement muscle production and increase body lean body mass.

The protein in dairy products, especially casein and whey, is the highest quality protein. In 2007, Wilkinson et al.45 found that milk can promote better muscle protein increase compared to plant protein after exercise. In addition, Du et al.51 also proved that animal protein can effectively increase muscle mass in healthy young males. Another study shows that nutrient-rich dairy protein, which is abundant with protein, can increase protein synthesis in muscle.52 Moreover, in the elderly population, conducted studies with dairy products (such as ricotta and milk) used for clinical intervention studies of muscle mass and strength turned out to be unsuccessful.42,53,54 Nevertheless, it is worth noting that the study mentions that the use of milk protein concentrating on supplement proteins for the elderly has a potential for the future development.55 Protein can promote muscle formation. Increasing dietary protein intake is the basis for inhibiting muscle loss. Leucine intake promotes muscle protein synthesis and inhibits protein degradation.56 Moreover, amino acids are essential for the synthesis of intracellular and extracellular proteins. Furthermore, proteins can also indirectly affect Ca balance and muscle metabolism. The results of current research indicate that adequate intake of protein-source foods during the mid-

dle-adult years may play a salient role in the maintenance of skeletal muscle mass into the older-adult years.56 In other studies, protein, particularly from animal sources, has been linked with limb muscle mass and total body muscle in older adults.57-60

Also, a protein-mediated not only increases the incremental of insulin-like growth factors-1, but also produces 1,25(OH)2D3, which also affects the absorption of Ca and P in the intestine.61 Increase of Ca and P in the body cells has a positive effect on the muscles.67 In addition, studies by Zemel and the colleagues66,62,63 indicated that increasing dietary Ca and protein intake causes a decrease in circulating 1,25(OH)2D3 concentration resulting in creation of environment that promotes lipolysis and inhibits lipogenesis, and promotes muscle synthesis.

There is plenty of Ca in the dairy products. In the study of Waters et al.64 the high intake of Ca, and in the study of Seo et al.65 the low intake of Ca (< 415 mg/day), all revealed the linkage between Ca and muscle mass while the results of these two studies also illustrated that lower Ca intake can play a better role in the prevention and treatment of sarcopenia in the elderly. The results of other studies also further confirmed that the reduced Ca absorption and changes in Ca homeostasis are associated with sarcopenia in the elderly.66,67 In vivo absorption of Ca may require the assistance of vitamin D, but other animal studies have shown that Ca uptake is also possible through passive absorption.68 A study by Waters et al.64 found that vitamin D intake was significantly lower in elderly people with sarcopenia, but it did not provide serum 25(OH)D levels. However, most dairy products on the market have already strengthened Ca and vitamin D, which can be conducted to meet the needs of the elderly. Ca and vitamin D play key roles in regulating body muscles. Among the elderly population, the high incidence of sarcopenia usually coexists with insufficient intake of Ca and vitamin D. There are some empirical studies showing that for the elderly in France (average 84 years), with the supplement of vitamin D and Ca for 18 months, the muscle quality improved significantly.69 Another study has replicated these results in the United States.70 Although these two researches have both mentioned that the function to improve muscle, the elaboration for the starting stage to get better was not revealed. However, it has verified that oral vitamin D appears to reduce the risk of muscle mass loss only when Ca supplementation is added.
Ultimately, P stimulates the nerves and muscles, causing the heart and muscles to contract regularly. P helps cell division, proliferation, and protein synthesis, passing genetic characteristics from the previous generation to the next generation. P ions are essential for the metabolism of carbohydrates, lipids and proteins. They act as co-factors on a wide range of enzyme systems and also in high energy P compounds. Organic P, adenosine triphosphate, creating P, etc. have the effect of storing and transferring energy. The balance of Ca and P contributes to the utilization of inorganic salts during bone development and maturation. P can regulate the metabolism of vitamin D and maintain the stability of Ca. Moreover, elevated serum P levels were independently associated with increased mortality risk among sarcopenia patients with chronic kidney disease.71,72

In conclusion, this study synthesized and determined the importance of adding dairy products to the diet. The role of maintaining a healthy diet for muscle synthesis, muscle strength and even in old age is significant. The findings of this study are capable of providing evidence of the development of potential dietary strategies, such as improving the intake of dairy products in the elderly and improving muscle health in the elderly.

CONCLUSION

Dairy products provide nutrients for the elderly, maintain muscle health, prevent multiple physiological mechanisms, and interact with skeletal muscle mass and function to help prevent sarcopenia. Therefore, the risk of sarcopenia can be alleviated by appropriate nutrition measures in the elderly. In particular, increase in the intake of nutrient-rich dairy products improves muscles, reduces the loss of muscle strength, does not increase the incidence of metabolic diseases and chronic diseases, and has no side effects of increased fat and kidney function. Therefore, results of this study suggest that adding dairy products to a habitual diet may be a promising dietary improvement strategy. Ultimately, this dietary strategy may prevent muscle reduction in the elderly population.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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AUTHOR CONTRIBUTIONS

Study concept and design: all authors; acquisition of data: YD; analysis and interpretation of data: YD; drafting of the manuscript: YD; critical revision of the manuscript: all authors; statistical analysis: YD; obtained funding: JN; administrative, technical, or material support: JN; and study supervision: all authors.

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