Bone health and dairy products:
from the latest scientific news on the matrix effect

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European Milk Forum

In Europe, osteoporosis affects over 22 million women aged over 50 (22% of the population) and 5.5 million men (7% of the population). It is responsible for more than 3 million fractures each year, including 620,000 hip fractures, and results in 2 million DALYs (disability adjusted life years). It is a serious public health problem that is of great concern to the medical and scientific communities.

Over 1,500 scientists and healthcare professionals therefore gathered at the opening ceremony of the World Congress on Osteoporosis, Osteoarthritis and Musculoskeletal Diseases (WCO-IOF-ESCEO1), which was held in Paris on 4 April.
During the opening session, the latest breakthroughs in the field of bone and muscle health were presented. Part of the session was devoted to the theme of nutritional prevention of osteoporosis, and Professor Arne Astrup spoke about the innovative "food matrix" concept using the example of dairy products.

Milk and dairy products associated with reduced risk of fracture

Two major studies, published in 2018, helped put an end to the debate on the relationship between dairy products and fractures linked to osteoporosis.

The American healthcare professionals and nurses cohorts

These two well known cohorts included over 80,000 women and 43,000 men aged over 50 and studied for 21 and 17.5 years, respectively [1]. During the study period, there were 2,138 hip fractures in the women and 694 in the men. The findings were clear – daily consumption of dairy products was associated with a reduced risk of fracture:

- 6% per serving of dairy productss
- 8% per serving of milk (240 ml)
- 9% per serving of cheese (28 g).

Meta-analysis of 10 cohorts

This meta-analysis of 10 cohort studies, conducted in North America, Europe and Asia[2], confirms this data. In total, over 360,000 subjects were studied from between 3 to 22 years, during which time there were 8,613 hip fractures. Dairy products, and particularly yoghurt and cheese, are associated with a significant reduction in the risk of fracture.

Risk of fracture according to the consumption of dairy products (high versus low consumption).

Yoghurt	**↘ 25 % ***
Milk	**↘ 9 %**
Cheese	**↘ 32 % ***

** P <0,01*

1 Feskanich D et al. Milk and other dairy foods and risk of hip fracture in men and women. Osteoporos Int 2018;29(2):385-396 2017.
2 Bian S et al. Dairy product consumption and risk of hip fracture: a systematic review and meta-analysis. BMC Public Health. 2018;18(1):165.

What are the mechanisms?

A well-known positive effect on bone mass…

It has long been known that adequate consumption of dairy products is essential throughout life and particularly during two key periods – it optimises the building of bone structure during growth and limits bone loss associated with ageing, from the time of menopause in women and slightly later in men.

… and bone architecture

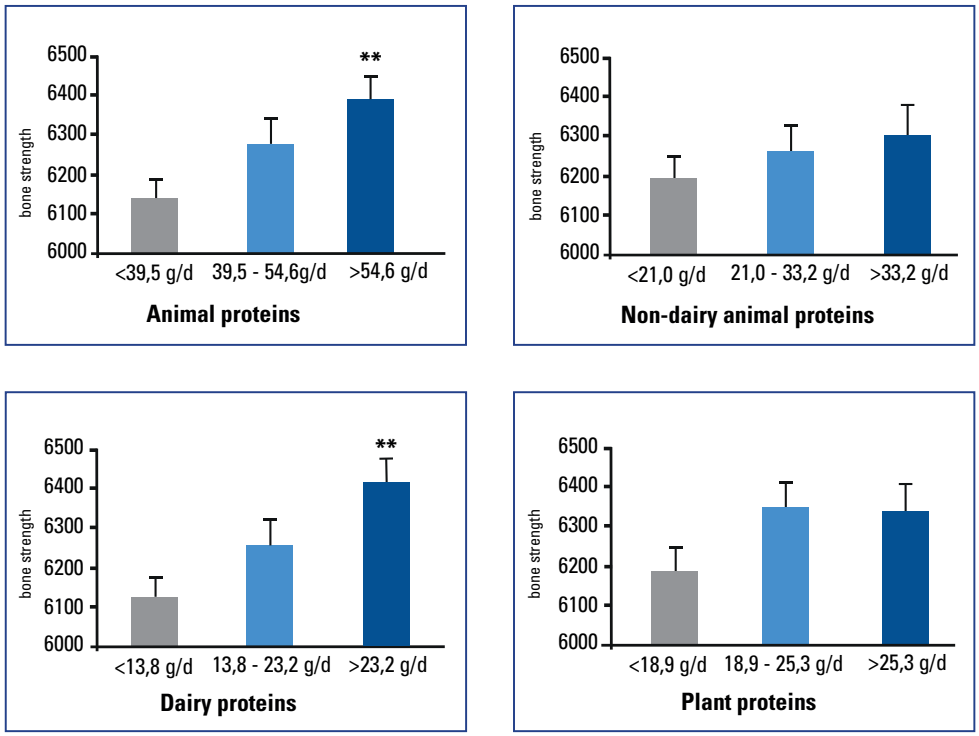
Bone fragility is not just linked to a reduction in bone mass, it also depends on bone geometry and micro-architecture, which influence the ability of the bone to resist pressure, torsion and consequently fracture. A very recent study shows that bone microarchitecture impairments – which we are now able to assess thanks to high resolution scanners – are a powerful marker for predicting future fracture risk, irrespective of bone mineral density[3].

Dairy proteins are associated with stronger bones

- In women

A team from Geneva Cantonal Hospital recruited 746 healthy 65-year-old women, who exercised regularly and had a balanced diet, and assessed the bone microstructure in their wrists and ankles[4].The analysis shows that consumption of animal proteins, and particularly dairy proteins, is significantly linked to bone strength, which is not the case of plant and non-dairy proteins. In other words, dairy proteins are associated with stronger bones.

Bone strength (tibia) according to protein consumption

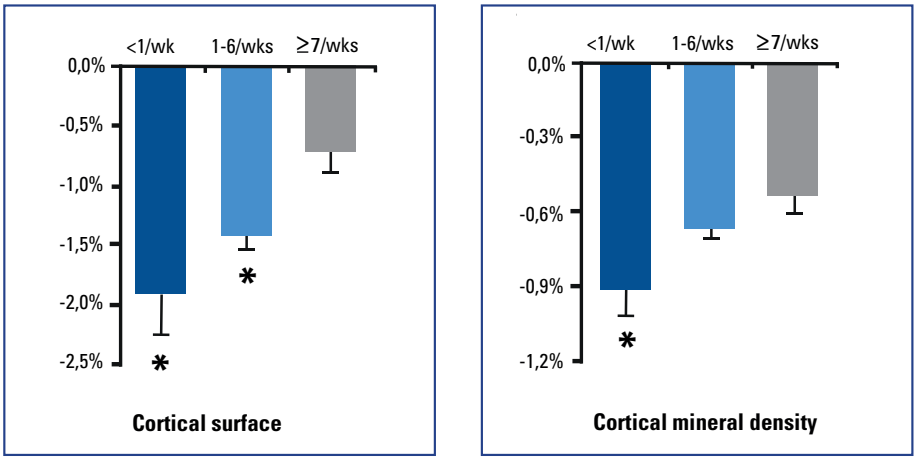


3 Samelson EJ et al. Cortical and trabecular bone microarchitecture as an independent predictor of incident fracture risk in older women and men in the Bone Microarchitecture International Consortium (BoMIC): a prospective study. Lancet Diabetes Endocrinol. 2019 ;7(1):34-43.

4 Durosier-Izart C et al. Peripheral skeleton bone strength is positively correlated with total and dairy protein intakes in healthy postmenopausal women. Am J Clin Nutr 2017;105(2):513-525

This positive effect becomes apparent over time as the same Swiss research team has just shown by measuring the development of bone mineral density and microarchitecture over 3.5 years in 482 woman, according to their consumption of fermented dairy products[5]. Bone loss linked to age was, of course, observed in all the women but much less significantly so in the radius of women who regularly consumed fermented dairy products (at least one daily serving).

Development of radial bone mass (%/year) according to the consumption of fermented dairy products (servings/week)



This mitigation of bone loss has been confirmed by bone resorption markers and does not depend on vitamin D status, or calcium and protein intakes; suggesting fermented products have a special effect which goes beyond the individual nutrients they contain.

• And also in men

Overall, male osteoporosis is subject to fewer studies but men are nevertheless affected by fractures, even though they are less frequent and occur later than in women. And, in men too, research focusing on 1,000 men, aged on average 85 years, has shown that the consumption of dairy proteins is positively correlated with mechanical strength in both the radius and tibia, but plant proteins have no positive effects[6].

Not forgetting the effects on muscle

Spontaneous fractures are rare. In most cases, fractures are the result of a fall and sarcopenia, i.e. loss of muscle mass and strength due to age. But we can slow sarcopenia, and the most effective strategy involves combining exercise with sufficient protein consumption (both in terms of quantity and quality). Thanks to the quality of their proteins - the presence of rapidly-absorbed whey proteins, and their high level of leucine, an amino acid that is a strong stimulant of muscle protein synthesis - dairy products have proven their effectiveness and so are recommended[7].

A recent meta-analysis of 22 intervention trials comparing the effect of physical resistance exercise combined with protein supplementation (mostly in the form of dairy proteins) or a placebo, which lasted 6 to 24 weeks, shows a muscle mass accrual of 0.8 kg in the under 50 age group and 0.5 kg in the over 50s together with improved muscle strength[8].

5 Biver E et col. Fermented dairy products consumption is associated with attenuated cortical bone loss independently of total calcium,protein, and energy intakes in healthy postmenopausal women. Osteoporos Int 2018 ; 29 (8) : 1771-82.
6 Langsetmo L et al. High Dairy Protein Intake is Associated with Greater Bone Strength Parameters at the Distal Radius and Tibia in Older Men: A Cross-sectional Study. Osteoporos Int 2018; 29(1) : 69-77.
7 Phillips SM et Martinson W. Nutrient-rich, high-quality, protein-containing dairy foods in combination with exercise in aging persons to mitigate sarcopenia.NutrRev. 2019; 77(4):216-229.
8 Cermak NM et al. Protein supplementation augments the adaptive response of skeletal muscle to resistance-type exercise training: a metaanalysis. Am J Clin Nutr. 2012; 96(6):1454-64

Beyond nutrients: the matrix effect

Many of the nutrients contained in milk and dairy foods, including calcium, protein and vitamin D, have a positive effect on bone health. However, studies suggest the protective effects of dairy foods cannot necessarily be explained by their individual components alone.

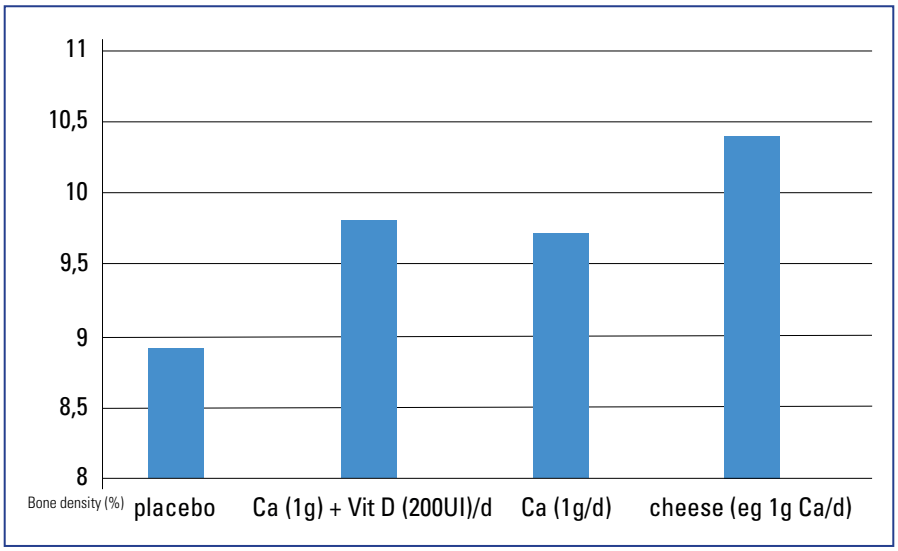
This demonstrates the importance of the food matrix. The matrix concept reflects the complexity of foods and takes into account that the sum of the nutrients may not be sufficient to explain all the physiological and health effects[9]. The presence in foods of, for example, protein, fibre, micro-nutrients and probiotics within a complex matrix can lead to interactions between the nutrients and other components. This means that different foods with the same amount of a particular nutrient will not necessarily be equivalent in terms of nutrition or health effects.

A single nutrient does not make a food

Traditionally, milk and dairy products = calcium. And it is true that dairy products are rich in calcium and are the leading source of calcium in the European diet. But, in terms of health, dairy products are not just about calcium. This is reflected in studies comparing the effect of the same amount of calcium considered separately and within a dairy product.

It is also shown in this two-year intervention trial in 195 girls aged from 10 to 12[10]. The aim was to compare the effect of calcium on bone mass accrual – assessed by bone mineral density – according to its source. The girls were divided into four groups: placebo, calcium supplement (1g), calcium (1g) + vitamin D, and cheese providing the equivalent of 1g of calcium.

Although calcium intake was the same in both groups, regular consumption of cheese led to greater bone mass accrual than with calcium supplements whether associated with vitamin D or not.



9 Lecerf JM. Les effets des nutriments dépendent-ils des aliments qui les portent? L'effet matrice. CahNutrDiét2015 ; 50 (3) : 158-64
10 Cheng S et all. Effects of calcium, dairy product, and vitamin D supplementation on bone mass accrual and body composition in 10-12-y-old girls: a 2-y randomized trial. Am J Clin Nutr. 2005;82(5):1115-26

There are different kinds of matrices

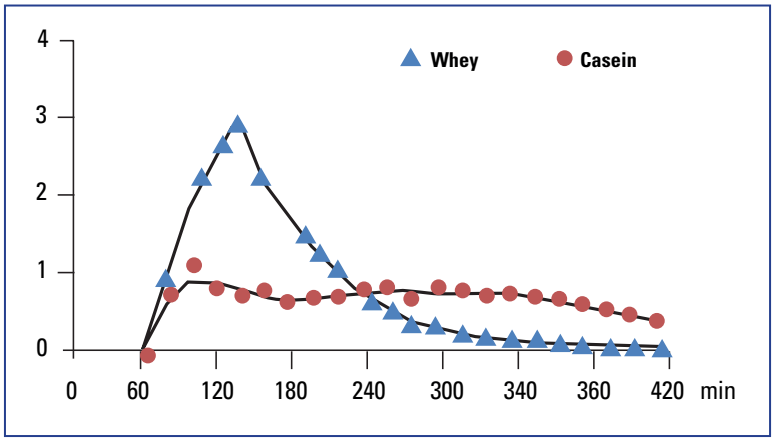
For metabolism and utilisation

- **of calcium**

The most well-known example is calcium, for which intestinal uptake is higher when it is provided by dairy products in comparison to most plant products. For calcium, it is better to drink milk than eat spinach, simply because the dairy matrix contains other nutrients, such as phosphopeptides and lactose, which potentiate calcium uptake whereas spinach contains oxalates which inhibit calcium uptake.

- **of proteins**[11]

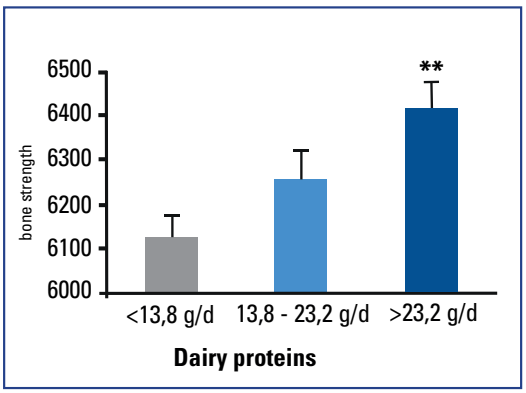
There are two types of protein in the dairy matrix: casein protein and whey protein, which mainly differ in digestion rate. The "fast" proteins of the whey lead to an early spike of amino acids in the blood, which is very effective in inducing protein synthesis. The "slow" casein proteins have a weaker effect but over an extended period. This perfect complementarity within the dairy matrix goes some way to explaining the greater effect of milk on protein synthesis in the elderly as compared to soya.

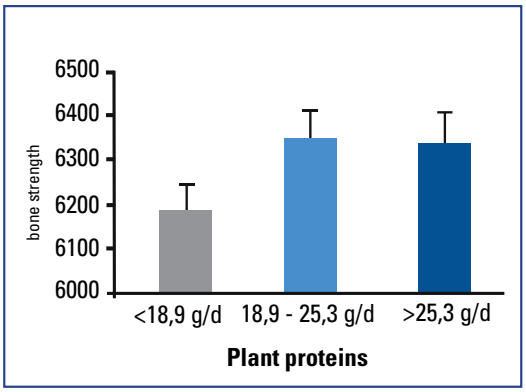


For the effects on fracture risk factors

- **bone strength**

In the above study[4], bone strength is associated with dairy protein and not plant proteins. However, similar amounts are consumed. For an identical quantity of protein, the effect is therefore different depending on the dietary source of protein. This proves that it is the foodstuff in its entirety that needs to be taken into account.





11 DanginM et col. Influence of the protein digestion rate on protein turn-over in young and elderly subjects. J Nutr2002; 132:3228S-33S

• sarcopenia

The "Framingham Offspring" cohort studied the relationship between the consumption of different sources of dietary protein, physical activity, muscle mass and functional decline over a 9-year follow-up period in over 2,500 elderly people[12].

In very active subjects, as long as there was enough protein, the source was not important. However, in the case of moderate physical activity, plant-based protein sources had no effect. Only animal-based protein sources were associated with higher muscle mass and reduced cognitive decline. Among the latter, the most "effective" were poultry and dairy products.

And, in contrast, vegan diets

Focusing on subjects who do not consume dairy products, vegans for example, is another way of providing possible answers, as has been shown by a recent systematic review[13]. The authors compiled the results of 20 prospective studies, totalling 37,000 participants, to compare bone mineral density (BMD) in the lumbar spine and hip, and the fracture risk for subjects according to their eating habits (vegans who exclude all animal products, vegetarians who exclude meat and fish but not dairy products, and omnivores).

Overall, vegetarians and vegans have a lower BMD score and a higher risk of fracture than omnivores. But while vegetarians are not markedly different from omnivores, vegans have a low BMD score and, above all, a much higher fracture risk (44%). Not surprisingly, this risk is greater after 50 years old.

Effect of vegetarian and vegan (compared with omnivore) diets on bone mineral density and fracture risk: meta-analysis of 20 studies

	Vegetarians + Vegans	Vegans
Bone density **• Femur** **• Whole body**	 **-3,7% *** **-4,8% ***	 **-5,5% *** **-5,9% ***
Fracture risk	**+32% ***	**+44% ***

** P <0,01*

The article does not give details about the subjects' dietary intake, and it is possible that the vegans have a nutritionally inadequate diet overall. But we know that people following a vegan diet are very concerned with their diet, often have thorough knowledge of nutrition and take supplements. So this may be an example of a matrix effect; one cannot just pile up nutrients to make the equivalent of a foodstuff such as dairy.

12 Bradlee ML et col. High-Protein Foods and Physical Activity Protect Against Age-Related Muscle Loss and Functional Decline. J Gerontol A Biol Sci Med Sci. 2017;73(1):88-94.
13 Iguacel I et al. Veganism, vegetarianism, bone mineral density, and fracture risk: a systematic review and meta-analysis. NutrRev. 2019 ;77(1):1-18

The matrix effect: a new paradigm revolutionising nutrition

For over half a century, the study of the relationship between diet and health has focused on nutrients taken in isolation: fats, carbohydrates, proteins and micro-nutrients. This reductionist approach linking a nutrient to a health effect is perfectly legitimate in the case of deficiency diseases, scurvy for example is linked to vitamin C deficiency and is cured by eating citrus fruit.

However, it is unsuitable for the multi-factorial and chronic pathologies affecting the health of populations today. The nutritional value of a food is not limited to the sum of its nutrients, but varies according to the structure of the food, the nutrients, the matrix and interactions with other components in the food. We eat foodstuffs, not just nutrients. The way in which the latter are interlinked has a real impact on their metabolic effects and, ultimately, their effects on long-term health. So dairy products may have a more positive effect on bone health than the sum of their nutrients.

The matrix effect helps to explain, at least in part, the greater effects of dairy products – compared with calcium alone – on bone and muscle health, and the prevention of osteoporosis, falls and fractures demonstrated by an accumulating body of scientific evidence. In addition, the matrix concept provides a new approach to nutrition, combining food science and human nutrition, which is more holistic and in keeping with "real" life.

More information
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