MILK
Nutritious by nature

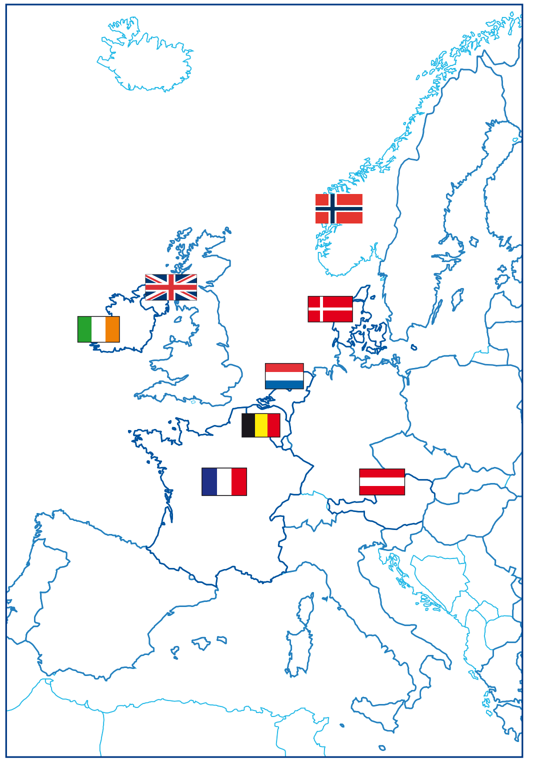
The science behind
the health and nutritional impact
of milk and dairy foods

“Milk, Nutritious by Nature” is a European information initiative addressing nutrition and health issues.

The initiative’s objective is to disseminate relevant information and create a dialogue with key stakeholders such as high level scientists, health professionals, policy makers and journalists in relation to the nutrient richness and health impact of milk and dairy products and how those nutrients and other components come together in the dairy matrix to exert their beneficial effects. The aim is to build a clearer understanding of the role of milk and dairy products in a healthy, balanced diet across Europe.

This brochure for nutrition and health professionals is the result of collaboration between the nutritionists from the EMF member organisations to review the latest science on the role of milk and dairy foods in nutrition and health.

EMF comprises dairy organisations in eight countries - Austria, Belgium, Denmark, France, Ireland, Northern Ireland (UK), Norway and The Netherlands.



September 2017

Milk, Nutritious by nature

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Milk and dairy foods have been an important part of the European diet and food culture for generations. They are naturally rich sources of a wide range of nutrients and make a significant contribution to nutrient intakes and diet quality.

Milk and dairy foods have also been linked to a variety of potential benefits in areas such as bone health, blood pressure and weight control, as well as type 2 diabetes, cardiovascular disease and colorectal cancer. They also have a role in sports nutrition and in helping to maintain muscle mass and function in older people.

This review summarises the scientific evidence of what makes Milk, Nutritious by Nature.

Nutrient richness

A unique package of essential nutrients

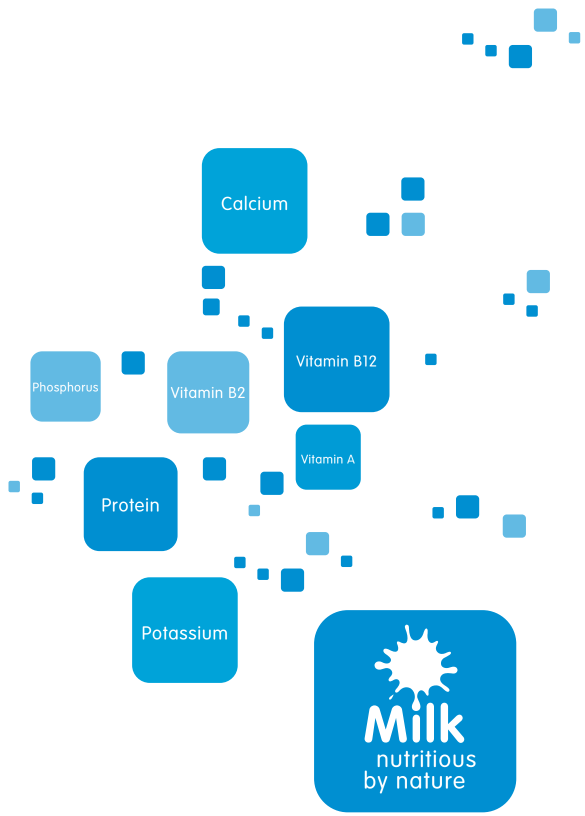
Milk and dairy foods are naturally rich sources of a wide range of essential nutrients. Many people associate milk and dairy with calcium and bone building but dairy foods offer much more extensive nutritional benefits.

Milk contains high quality protein, carbohydrate in the form of lactose, as well as many different fatty acids and a wide range of micronutrients including vitamins, minerals and trace elements.

Milk is a natural source of calcium, vitamin B12, riboflavin (vitamin B2), phosphorus and potassium. It also contains smaller amounts of other nutrients including vitamin A, niacin, folate, vitamin B6, vitamin D, magnesium, selenium and zinc. In some, but not all, European countries milk is also a good source of iodine. The variation in iodine content is mainly due to differences in cows' diets between countries. The cows' diet can also affect the content of other nutrients, for example fatty acids and selenium.

Products made from milk such as yogurt, fermented milks and cheese also contain many of the nutrients which are present in milk. Many yogurts and cheeses, for example, are natural sources of protein, calcium, phosphorus and vitamins B2 and B12. Hard cheeses, in addition, also have zinc and vitamin A.

The nutrients present in milk and dairy foods are involved in a number of important functions in the body[1]. These include the well-known benefits of calcium for bones and teeth, and protein for muscle. But dairy nutrients also play a part in nerve and muscle function, energy release, vision, blood clotting and red blood cell formation, digestion, blood pressure, skin health, the immune system, psychological function and in children's growth.



Contributing to diet quality in Europe

Given their rich nutrient content, it is not surprising that milk and dairy foods make an important contribution to the nutritional quality of the European diet. In many countries they are the main providers of calcium, contributing to 40% – 70% of the calcium intake in the European diet. Dairy also makes significant contributions to the intake of many other nutrients including high-quality protein, riboflavin, vitamin B12, phosphorus, vitamin A, iodine, zinc and potassium. For some countries and age groups, milk and dairy products also make worthwhile contributions to intakes of selenium, magnesium, niacin, folate and vitamin D.

Contribution (%) of dairy foods to nutrient intakes in adults in eight European countries

Nutrients	Austria	Belgium	Denmark	France	Ireland	Netherlands		Norway	UK
	18-65 years	3-64 years	Total population	18-79 years	18-90 years	31-50 years	51-69 years	18-70 years	19-64 years
Protein	-	19	24	16	13	23	24	22	14
Calcium	53	49	59	40	39	58	62	67	37
Phosphorus	-	-	33	23	-	32	34	-	22
Potassium	-	-	17	10	-	16	15	17	11
Iodine	-	16	30	21	44	16	16	60	35
Zinc	-	-	22	16	13	24	25	-	16
Selenium	-	-	16	7	-	14	14	-	6
Magnesium	-	-	14	9	11	14	15	14	10
Vitamin A	-	-	11	24	37	21	20	30	16
Vitamin B2	-	32	41	26	29	42	42	37	29
Vitamin B6	-	8	12	7		12	12	11	8
Vitamin B12	-	31	30	17	35	40	40	25	33
Folate	-	10	14	12	11	12	12	12	8
Niacin	-	-	17	2	-	-	-	-	7
Vitamin D	-	20	9	27	11	6	6	16	6
Total fat	14	18	17	17	13	18	20	26	14
Saturated fat	23	29	28	26	20	31	33	42	22
Calories	-	13	13	11	9	14	16	18	9

See page 42 for details of the sources of dietary data for individual countries.

The total amount of dairy foods consumed and the relative contribution of milk and other dairy products differs between countries, and, therefore, affects the contribution to nutrient intakes - for example, cheese makes a more important contribution to nutrient intake in France and Belgium than it does in the UK or Ireland where milk contributes proportionately more. Similarly, both the types and amounts of dairy consumed vary with age and so, therefore, do contributions to nutrient intakes. In general, milk contributes proportionally more to the diets of young children than to adults[2,3].

Some of the nutrients provided by dairy are not easily replaced by other foods without reducing the overall nutritional quality of the diet. For example, modelling dietary patterns to remove dairy and replace with non-dairy substitutes for calcium, resulted in lower amounts of several nutrients including protein, phosphorus, riboflavin, zinc and vitamin B12[4].

Inadequate intakes of certain nutrients in the European diet are partly a consequence of low dairy consumption. A study providing information about micronutrient intakes across Europe shows that in some countries including France, the UK and, to a lesser extent, Denmark, intake of some micronutrients is inadequate, particularly among adolescents and young women[5]. These include calcium, iron, potassium, iodine, magnesium, selenium, zinc and riboflavin. Low intakes of magnesium, potassium, selenium were also evident in people over 60. With the exception of iron, these nutrients are all found in dairy foods, and the inadequate intakes are likely to be partly a reflection of low dairy intakes. In relation to teenagers and young women, for example, in many countries, milk drinking tends to decline in the teenage years especially in girls, with adverse consequences for intake of 'dairy' nutrients, which can be particularly important at this life-stage[6].

The wide range of milk and dairy foods can suit different dietary needs. People with low energy requirements or those who are restricting their energy intake in order to lose weight, still need adequate amounts of protein, vitamins and minerals which low-fat dairy foods can provide. Others such as young children and the frail elderly may, in addition to their nutrient requirements, need to pay special attention to ensure their energy needs are met despite small or reduced appetites, and in this case whole milk and whole milk dairy products can be the most appropriate.

Nutrient density

It is increasingly recognised that a food's total nutrient content is important, rather than just the particular individual nutrients it contains. For example, in addition to specifying the quantities of nutrients needed in the diet, the latest Nordic Nutrition Recommendations emphasise the need to consider the particular foods that nutrients are obtained from and the quality of the food[7].

One approach which takes into account the overall nutritional package of a food is nutrient density. The nutrient density of a food is usually defined as the ratio of essential nutrients, compared with the energy (calories) provided by the food – in some definitions these are also corrected for the presence of nutrients 'to limit' such as fat and sodium. The contributions of milk and milk products, particularly low-fat dairy, to nutrient intakes are relatively high compared to their calorie and fat contribution, giving them a favourable nutrient density score[8].

Some scoring systems (such as the US Nutrient Rich Foods Index), which rank foods on the basis of their nutrient content per calorie, also allow the calculation of nutrients in relation to the cost of the food[9]. This is intended to help people choose diets that are both affordable and nutrient dense. Using such scoring systems, dairy foods, especially milk, have been shown to provide good nutritional value in relation to both calories and cost. This has been shown in European studies, as well as in the US[10-12].

An important part of European dietary guidelines

The milk and dairy food group forms an important part of food-based dietary guidelines across Europe, and dairy is recognised as one of the components of a healthy dietary pattern.

Food-based dietary guidelines

Dairy forms part of food-based dietary guidelines throughout Europe. The specific recommendations vary between countries, but on average 2 to 3 servings of milk and dairy foods a day are recommended for adults; often more for children and adolescents (around 3 to 4 servings), and in some cases more for pregnant women and older people too.

In some countries, dairy consumption falls short of the recommendations. In Belgium, for example, only 2% of the population (aged 3 to 64 years) meets the recommended intake of milk and milk products (except for cheese)[13]. In Ireland, adults (18 to 64 years) consume on average just over two portions from the 'milk, yogurt and cheese' food group a day compared to the recommended three servings; only 13% of adults meet this target[14]. In older Irish adults (60 years plus) the figure is lower still, at 3.5%[15]. Moreover, in many countries, milk and dairy consumption is declining. In France, for example, data from the CCAF Survey (French eating behaviours and consumption) reported a decrease in milk intake between 2013 and 2016 of 10% in children (3 to 17 years) and 18% in adults[16].

Dietary patterns

Milk and dairy foods are recognised as part of a healthy dietary pattern. Increasingly, research is focusing on the effects of the whole diet on health and trying to distinguish the most favourable dietary patterns and habits. This is beginning to be translated into guidance for the public, including at national level. The 2012 Nordic Nutrition Recommendations, for example, have a stronger emphasis than previously on the whole diet, and describe a healthy dietary pattern as including plenty of vegetables, fruits and berries, pulses, regular intake of fish, vegetable oils, wholegrains, low-fat versions of dairy and meat, and limited intake of red and processed meat, sugar, salt and alcohol[11]. Similarly, in the 2015 Dutch Dietary Guidelines, the Health Council of the Netherlands sets out what constitutes a healthy dietary pattern for the population, including milk and dairy foods[17].

Dairy and health

Health impact of milk and dairy foods

Milk and dairy foods have been linked to a number of potential health benefits in areas such as blood pressure, bone health and weight control, as well as type 2 diabetes, cardiovascular disease and colorectal cancer. They also have a role in sports nutrition and in helping to maintain muscle mass and function in older people.

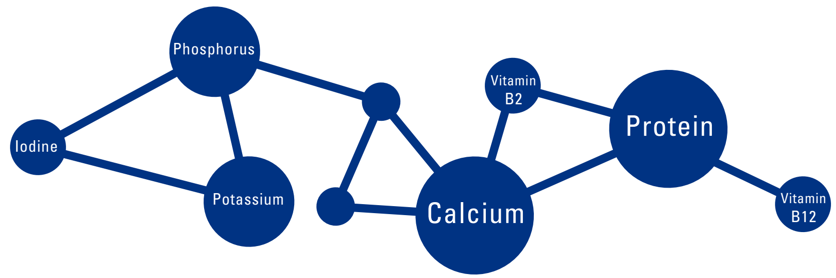
Ideally, the relationship between dairy foods and health would be measured by very large, very long-term intervention trials. In practice, however, the best available data are often from large, long-term observational studies. While not able to prove a cause and effect relationship, such prospective cohort studies and other types of observational data provide a 'real life' picture of a food in the diet and in a particular dietary pattern.

A number of analyses have pooled data from individual intervention or observational studies and the combined results increase statistical power and add weight to the results of single studies. Such meta-analyses provide the most robust evidence of the relationship between milk and dairy foods and health and, along with the recent reviews (both systematic and narrative), are discussed below. However, some individual studies conducted in European populations are also highlighted. These give an indication of the potential health effects of milk and dairy foods in relation to the particular amounts, types and patterns of consumption in Europe.

Intakes in European countries may be different to other parts of the world such as the United States or Asia where dairy consumption is often lower; they can also differ between European countries. In addition, the composition of milk and dairy products can vary between Europe and elsewhere depending, for instance, on animal feeding practices e.g. whether the cows are fed predominately on grain or fresh pasture. Fortification practices can also differ - e.g. vitamin D is routinely added to milk in the USA, and it is mandatory to do so in Canada. This is the case for low-fat milk in some Scandinavian countries including Norway but, on the whole, consumption of vitamin D-enriched milk is less commonplace in other parts of Europe. All of these factors may influence the results of research on the impact of dairy on health, and help explain differences between Europe and other parts of the world, and also within Europe.

Dairy matrix effects

It is increasingly recognised that the effects of milk and dairy foods on health extends beyond the individual nutrients they contain. Rather, the unique combination of nutrients and bioactive factors, and how they interact with each other in the dairy matrix, combine to produce the overall effect on health.



The food matrix

The 'food matrix' describes a food in terms of both its structure and its nutrient content, and how these interact together. Foods consist of a large number of different nutrients that are contained in a complex physical structure. The nature of the physical structure together with the mix of nutrients and bioactives can impact nutrient digestion, absorption and metabolism, affecting the overall nutritional and health properties of the food[1].

Whole foods or single nutrients

Nutrition research has traditionally focused on identifying the specific mechanisms and health impact of single nutrients – for example, saturated fatty acids in relation to blood lipids and cardiovascular disease (CVD). It has often then followed that nutrition policy is based on such associations - for example, recommendations to limit foods containing saturated fatty acids in order to reduce CVD risk.

More recently, however, nutrition research has shifted focus to examine the relationship of whole foods with health, including dairy foods (in both observational studies and intervention studies as discussed above). This is based on the premise that we do not eat nutrients in isolation but as foods, and meals, and part of dietary patterns. From this research, a different picture has emerged in some cases than might be predicted from the nutrient content of the foods investigated. Cheese is a good example: despite its saturated fat (and salt) content, the majority of epidemiological studies report that cheese consumption does not increase the risk of CVD and may, in fact, be beneficial[2]. Researchers have characterised this as a 'food matrix' effect[1]. This recognises that the health effects of a food are much more complex than that of a single nutrient it contains or even a few nutrients. Rather, they are a function of both a food's structure and its nutrient composition, and how these interact with each other.

Complex dairy matrices

Milk and dairy products are complex foods containing numerous nutrients and bioactive components. The rich dairy matrix of nutrients includes **protein, fat, lactose, calcium, phosphorus, potassium, vitamin B12, riboflavin (vitamin B2)** and many other vitamins and minerals. Dairy is also rich in bioactive components - for example, small peptides with biological effects are produced when milk protein is digested in the intestine or during the fermentation process in foods such as cheese and yogurt[3]. Fermented dairy products also contain bacteria with the potential to produce beneficial short-chain fatty acids (SCFAs) in the gut[4].

The nutritional and functional complexity in dairy food matrices is exemplified by milk fat, which has over 400 different fatty acids with different physiological properties[3,5]. Components of the membrane which encloses the fat droplets in milk (the milk fat globule membrane; MFGM) also have functional effects, for example in relation to lipid metabolism[6].

The matrix of different dairy foods will differ in the amounts and combinations of nutrients, including proportions of whey and casein proteins, fat and bioactives. Within a dairy food category, production methods and processes will also alter the composition of the matrix - for example, the length of ripening time for cheese affects the extent of protein breakdown and production of bioactive peptides[1].

In addition to their nutritional matrices, dairy foods also have complex physical matrices: from the solid matrix of cheese, gel-like structure of yogurt to liquid milk. Again, these differ within dairy categories - for instance, methods of production and ripening will influence the structure of the many different types of cheese.

The structure of a food matrix can have an impact on factors such as nutrient absorption and digestion and, therefore, the metabolic response after eating. For example, rates of gastric emptying can differ for liquid compared to solid or semi-solid structures and so affect satiety and appetite responses[7]. The matrix structure can also influence protein absorption and digestion, for example, between casein contained in the milk matrix and given as a supplement[8].

More than the sum of its nutrients

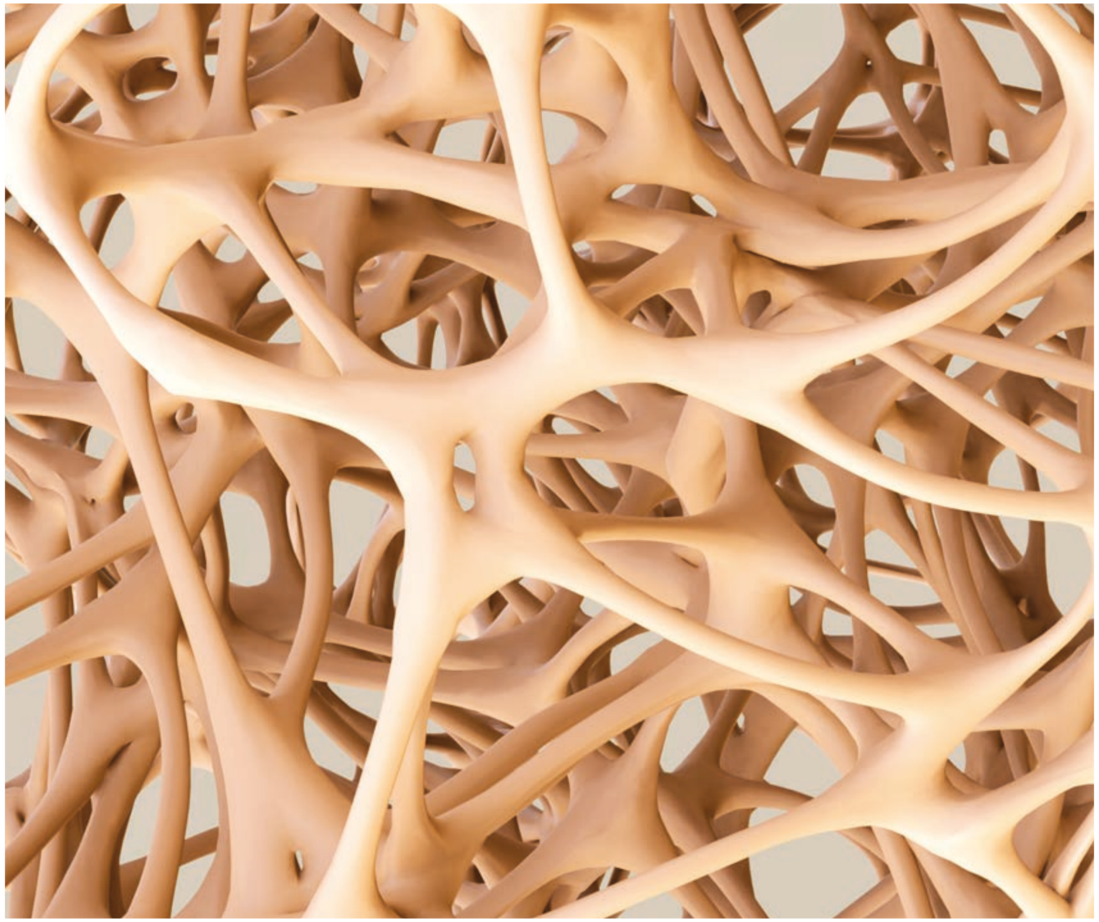
Given the complex nature of dairy matrices, it is perhaps not surprising that there is increasing evidence that the health effects of dairy foods extend beyond their constituent parts. Potential matrix effects are discussed in detail below. However, evidence to date suggests that milk and dairy matrices have specific beneficial effects on cardiometabolic disease risk, body weight and bone health[1].

For example, the effects of milk and dairy foods on bone health may be due in part to positive interactions of calcium, protein and phosphorus with each other and with lactose and bioactive peptides in the dairy matrices, rather than simply a 'calcium effect' as is often assumed. Similarly, the blood pressure lowering effect of milk may be the result of interactions between calcium, potassium, phosphorus and bioactive dairy peptides in the milk matrix. In relation to cheese, the explanation for the potential beneficial rather than harmful effects on CVD may again lie in interactions of the components of the cheese matrix including calcium, phosphorus, the milk fat globule membrane and starter cultures, which modify saturated fatty acid-induced increases in blood lipids.

More research is underway to investigate the health effects of the dairy matrix and to unravel the mechanisms and pathways through which the different components work together. However, the matrix concept underlines the importance of considering the health effects of milk and dairy as whole foods, alongside the individual components they contain. This is particularly important in relation to public health policy, and there is a growing recognition that dietary guidance should be based on evaluation of the health impact of whole foods, including dairy, rather than on single nutrients.

Bone health

The role of calcium in building and maintaining healthy bones is well established, and dairy foods are recognised as important sources of calcium, supplying up to two thirds of intake in the European diet. However, milk and dairy foods also contain other nutrients needed for bone health including protein, phosphorus and potassium (and vitamin D in the case of fortified dairy). Increasingly, the science indicates that nutrients in the dairy matrix work together to help maintain healthy bones. For example, there is some evidence that milk's calcium may offer longer lasting skeletal benefits than supplements due to its favourable calcium-phosphorus ratio, and that the calcium and protein in dairy have positive interactions on bone health.



Dairy and bone health in children and adolescents

Both observational and intervention studies provide evidence linking dairy consumption with bone health, especially in children and adolescents[1-3]. In children, a meta-analysis of studies investigating the effect of dairy products and dietary calcium (predominantly from dairy) on bone mineral content (BMC) reported that total body and lumbar spine BMC were significantly greater in children with higher intakes[4]. Dairy as part of an overall healthy dietary pattern has also been associated with beneficial effects on bone development[5]. Intervention studies which have specifically used milk or dairy foods are limited compared with those for calcium supplements, but positive effects have been reported; including in French, Finnish and British children[6-8]. For example, significant improvements in bone mineral acquisition compared to control subjects were observed in adolescent British girls who were given 568ml (one pint) of milk a day for 18 months[8]. The corollary is that milk avoidance in children has been associated with increased risk of fracture and poorer bone health[10,11]. In a 2016 position statement on lifestyle choices that promote maximal bone health from childhood through adolescence, the National Osteoporosis Foundation concludes that there is 'good evidence' for a role for dairy consumption (the 'best evidence' is for the positive effects of calcium intake and physical activity)[12]. A number of retrospective studies, although not all, have found that milk consumption in childhood and adolescence is related to better bone health and / or reduced risk of fracture later in life[13]. There are limitations to such studies, however, including accurate recall of childhood milk and dairy intake.

Dairy and bone health in adults

For adults, the majority of observational studies report either a positive association between milk and milk products and BMC or bone mineral density (BMD) or a neutral outcome[1,2]. Again, randomised controlled trials using milk and dairy foods are limited compared with calcium supplementation ones, and longer-term trials and meta-analyses are needed. In such studies the outcome will depend on factors such as the age of the subject, relation to the menopause for women, initial dairy intakes and so on[13]. Intervention studies have, however, reported positive associations between increase in dairy food intake and BMC or BMD, and reductions in bone turnover markers[14,15]. On the whole, there is support for favourable effects of dairy on measures of bone health in adults[3].

Fracture risk

With respect to fracture risk, the effects of dairy are less clear. This may be due to heterogeneity in the study designs, duration, participants' age, and other confounding factors such as vitamin D status and physical activity. A meta-analysis of prospective cohort studies published in 2011, found no overall association between adult milk intake and hip fracture risk in women; insufficient data was available in men[16]. However, the data on women were disproportionately influenced by one study from Sweden; when the authors excluded this study from the analysis there was a marginally significant 5% lower hip fracture risk for each glass of milk consumed per day. A subsequent publication in 2014 utilising data from the same Swedish cohort of 61,000 women but with a longer follow up (around 20 years) found fermented milk products (yogurt and other soured milk products) and cheese consumption were associated with a significant decrease in fracture incidence[17]. However, high intakes of milk (three or more glasses/day; more than 600 ml/day) were associated with increased fracture rate. It is worth noting that when the dietary questionnaires were performed (1987–90 and 1997) milk in Sweden was fortified with high dose of vitamin A: such levels of vitamin A intake have been linked to an increased risk of fracture. A study of Finnish women has reported that milk avoidance (because of lactose intolerance) was associated with increased fracture risk[18].

No dairy intervention trials on fracture risk are available because of the feasibility of carrying out such a study; however, calcium supplementation trials do exist. A meta-analysis of 17 randomised trials concluded that calcium supplementation (with or without vitamin D) decreases fracture risk by 12% in people aged 50 years and older[19]. The fracture risk reduction was greater (24%) in trials when compliance was high; also in participants older than 70 years and whose daily calcium intake was initially low.

Potential dairy matrix mechanisms

The importance of calcium in bone development and maintenance is well established[1,13]. Milk and milk products make the largest contribution to calcium intake in the European diet. Few other foods naturally contain as much calcium, and dairy sources are some of the most bioavailable[20]. While it is sometimes assumed that supplementation with the same amount of calcium from different sources - e.g. milk, foods fortified with calcium and calcium supplements – have comparable effects on bone health, there is some evidence of a beneficial 'dairy matrix effect'[21]. Dairy foods may have greater benefits than the equivalent calcium in the form of supplements. In adolescent girls, for example, it has been estimated that bone mineral density increases by up to 10% when 700mg extra calcium is provided as dairy foods, compared with an increase of 1% to 5% when the same quantity of calcium is given as a supplement[22]. Similarly, using cheese to increase calcium intake in 10- to 12-year-old Finnish girls resulted in a greater increase in bone mineral density compared to either a calcium supplement or a calcium plus vitamin D supplement[7]. Another randomised controlled trial investigating the effect of dairy products providing 1,200mg calcium a day or an equivalent calcium supplement on markers of bone metabolism and BMD found that after 12 months, the dairy intervention group had greater improvements in pelvis, spine and total BMD than the calcium supplement group[14].

The greater benefits of dairy may be due to the presence of other nutrients in the dairy matrix which are important for bone health such as protein and phosphorus, and their interactions with calcium. Protein is essential for bone development in children and is needed for the maintenance of normal bones in adults since amino acids are required for the synthesis of intracellular and extracellular bone proteins. Older adults consuming a protein-restricted diet are at higher risk for bone loss and fractures, and sufficient protein intake is recommended in guidelines for maintaining skeletal health[23-26]. There has been some controversy around the adverse effects of high protein intakes, but it is now established that although a high-protein diet increases urinary calcium excretion this does not result in a negative skeletal calcium balance, or bone loss[24-28]. Indeed, recent research suggests higher protein intakes are beneficial to bone health, especially when calcium intake is also adequate[29]. For example, in the US Osteoporotic Fractures in Men study, greater intakes of dairy protein were associated with a decreased risk of hip fracture[30]. Similarly, in healthy postmenopausal women, dairy protein intakes were positively associated with measures of bone strength and microstructure[31]. The potential mechanisms for this include protein enhancing calcium balance by stimulating intestinal calcium absorption, both directly and indirectly via an IGF1-vitamin D link. Part of the explanation of the greater effectiveness of dairy calcium versus supplements may also be due to better absorption of calcium because of the presence of lactose and / or casein phosphopeptides in the dairy matrix[7]. Fermented dairy products may additionally enhance calcium absorption through positive alterations in the gut microbiota[32].

In addition to potentially larger effects, it has been suggested that the skeletal benefits of dairy calcium may persist longer than from calcium supplements[25]. In a study of 8-year-old French girls, the benefits of milk-extracted calcium phosphate on bone mass remained 3.5 years post supplementation[4]. This has not been the case after supplementation with calcium salts (such as citrate malate or carbonate). Part of the explanation may lie in the favourable calcium to phosphorus ratio in milk. Phosphorus (as inorganic phosphate) is an important structural component of bone and an adequate intake is necessary for bone growth and development, and the maintenance of normal bones in later life[24]. Although a high intake, if accompanied by low calcium (in a ratio of about 4:1) may be deleterious to bone, the phosphorus to calcium ratio of milk (0.8:1) can enhance calcium balance by stimulating renal tubular reabsorption of calcium and lead to positive effects on bone[33].

Other nutrients in milk and dairy foods are also involved in bone health including magnesium, potassium, vitamin K2 and zinc, as well as vitamin D in fortified dairy[1]. Increasingly, the science indicates that the nutrients in the dairy matrix may work together to help maintain healthy bones. Simply in terms of the quantities of 'bone' nutrients in dairy, however, it has been suggested that it is difficult to devise a diet that is 'bone healthy' without including three servings of dairy a day[1].

Blood pressure

Observational and clinical studies suggest that milk and dairy intake, particularly low-fat dairy, could have a beneficial effect on blood pressure and contribute to the prevention of hypertension. The DASH (Dietary Approaches to Stop Hypertension) diet, which focuses on fruit and vegetables and low-fat dairy foods, has been found to be an effective way to lower blood pressure.

Milk and dairy foods contain several nutrients and other bioactive components in the dairy matrix including calcium, potassium, phosphorus and bioactive peptides, which may be involved, individually or in combination, in the beneficial effects on blood pressure.

Observational studies

A number of observational studies have noted an association between milk and dairy intake and lower blood pressure, including in European populations. For example, in Welsh men, milk intake predicted systolic blood pressure: in the group with the highest milk intake (around a pint / 586ml of whole milk per day), systolic blood pressure was 10.4 mmHg lower than those who drank little or no milk after a 23-year follow-up[1]. Similarly, for older people (over 55 years) in the Rotterdam Study, the risk of hypertension decreased with increasing low-fat dairy consumption; although no relationship between dairy and blood pressure was seen in a wider age range of the Dutch population (20–65 years)[2,3]. In the French DESIR cohort, dairy (milk or yogurt) and cheese consumption were associated with lower diastolic blood pressure after the 9-year follow-up[4]. Cross-sectional data from the French cohort of the MONICA study also showed higher dairy intake was associated with lower systolic blood pressure[5]. A recent analysis of the National Adult Nutrition Survey in Ireland also reports an association between higher total dairy, and specifically milk, intake and lower systolic and diastolic blood pressure[6].

In a meta-analysis of five cohort studies, consumption of dairy foods was associated with a 13% reduced risk of elevated blood pressure[7]. Further analysis suggested that the effect may be driven by low-fat dairy and 'fluid' dairy (defined as milk and yogurt); cheese and full-fat dairy foods had no association with risk of high blood pressure. In another meta-analysis, of nine prospective cohort studies in 2012, dairy consumption was also associated with a reduced risk of hypertension[8]. Again, the effects were specific for low-fat dairy and milk (3% reduction per 200g/day) whereas there was no association for cheese, full-fat dairy, total fermented dairy and, in this case, for yogurt. Both meta-analyses suggest that milk and low-fat dairy could contribute to the prevention of hypertension. This concurred with the US Dietary Guidelines Advisory Committee's assessment of the science in 2010 which concluded that there was a moderate body of evidence that high intake of milk and milk products is associated with lower blood pressure[9]; subsequent studies have strengthened this conclusion. A systematic review published in 2016 of the association between dairy product consumption and risk of various cardiovascular-related clinical outcomes reports favourable associations between intakes of total dairy, low-fat dairy and milk and the risk of hypertension[10].

The DASH diet

The best known intervention involving dairy, the DASH (Dietary Approaches to Stop Hypertension) diet, has proved an effective way to lower blood pressure in those with and without hypertension[11-13]. The DASH eating plan, which emphasises fruit, vegetables, wholegrains and low-fat dairy products (around 3 servings a day), has been widely promoted in the USA for the prevention and treatment of high blood pressure[14]. Although this intervention was first conducted as a feeding trial, further studies have found that DASH dietary advice can also be effective at lowering blood pressure in free-living populations[15,16]. European guidelines on the management of hypertension now also include a 'DASH diet' approach recommending increased consumption of vegetables, fruits, and low-fat dairy products[17]. Observational studies have suggested that in children too, a 'DASH' dietary pattern may have beneficial effects on blood pressure[18,19]. A recent trial has also indicated that when higher-fat dairy foods are incorporated into the DASH pattern, blood pressure lowering effects are still evident[20]. In addition, three controlled trials which examined the impact of dairy products per se on blood pressure (rather than as part of a dietary pattern such as DASH) reported beneficial effects[21-23]. These included an intervention using full-fat hard cheese (two months of 30g/day of Grana Padano) compared with a placebo consisting of flavoured bread mixed with fats and salts in the same concentrations as the cheese[23].

Potential dairy matrix mechanisms

Milk and dairy foods contain several nutrients and other bioactive components which have been associated with blood pressure control. Recent research has focused on the importance of **bioactive peptides** in the regulation of blood pressure, including those from dairy. For example, a group of peptides (lactotripeptides), released from milk and dairy products during digestion of casein proteins in the gut or by fermentation, have been shown to have anti-hypertensive properties and to regulate blood pressure by inhibiting ACE-1, a potent vasoconstrictor[24-26]. Similarly, in a recent clinical trial, whey protein also lowered blood pressure and improved endothelial function in adults with pre-hypertension and mild hypertension[27].

Blood pressure-lowering effects of the B vitamin riboflavin, of which milk is a good source, have also been reported[28]. This reflects the role of riboflavin in regulation of homocysteine levels in those with a genetic defect in homocysteine metabolism (about 10% of the European population); an elevated level of homocysteine has been associated with hypertension[29].

The minerals in milk including calcium, potassium and magnesium are also linked to blood pressure regulation through their effects on intracellular mechanisms and production of vasodilators[30,31]. **Calcium**, for example, may have a direct impact on blood pressure through effects on vascular smooth muscle, as well as through parathyroid hormone (PTH) and vitamin D secretion, and increased sodium excretion[31]. **Phosphorus** in the dairy matrix may be involved too[31]. It has been reported that phosphorus from dairy products, but not from other sources, is associated with lower baseline blood pressure and reduced risk of hypertension[32]. This may indicate that the benefits of phosphorus are dependent on interactions with other dairy components. Indeed, it is likely that the blood pressure lowering effects of milk and dairy products are the results of interactions between the constituents of the dairy matrix[33].

The weight of the evidence to date suggests that milk and dairy foods, particularly low-fat dairy, can help lower blood pressure and contribute to the prevention of hypertension. This is important given that high blood pressure is a major risk factor for cardiovascular disease, particularly stroke, and even values at the high end of the normal range increase the risk. Around 30% to 45% of the European population has hypertension, with a steep increase with ageing, so even small reductions in prevalence could have public health benefit[17].

Weight control

Contrary to the popular perception that dairy foods are 'fattening', a growing body of research suggests that milk and dairy foods may have a positive role in weight control in both adults and children. A number of observational studies have reported that dairy-rich diets are associated with lower body weight, less body fat, less abdominal obesity and less fat gain over time. Overall, results from intervention studies suggest that including dairy foods in a weight-reducing diet may enhance weight loss.
Dairy's calcium and protein are likely to be involved in its effects on energy balance, including through influences on appetite and satiety, fat absorption and energy use. From the available evidence it seems likely that for those trying to lose weight, avoiding dairy or having a low dairy intake may be counterproductive.

Observational studies

Scientific evidence is accumulating to suggest that milk and dairy foods may have a positive role in weight control in both children and adults. A relationship between calcium and weight was first noticed in a cross-sectional analysis more than 30 years ago[1]. However, it was not until the late 1990s, when a possible mechanism linking calcium and weight was proposed, that research in this area gathered pace[2]. Since then, a number of other cross-sectional studies have noted a similar negative relationship between calcium and/or dairy foods and weight, body fat and abdominal obesity including some in European populations[3-10].

For example, in a study of early-postmenopausal Italian women, those in the highest quartile of dairy intake had a lower BMI than those who ate the least dairy foods[8]. Similarly, data from the 'Observation of Cardiovascular Risk Factors in Luxembourg' survey found dairy intake was associated with a reduced likelihood of both overall obesity and abdominal obesity[9]. A recent analysis of the National Adult Nutrition Survey in Ireland also reports that higher total dairy intake, as well as higher milk and yogurt intake, were associated with lower measures of body fatness, including waist-to-hip ratio, % body fat and waist circumference[10].

Some prospective studies too suggest a modest protective effect of dairy product consumption on the amount of weight gained over time[11]. For example, a Swedish study which examined the association between dairy intake and weight change in 19,000 peri-menopausal women over nine years, found that regularly eating one or more servings a day of cheese or whole / fermented milk (3% fat) was associated with lower weight gains in normal weight women[12]. In overweight French men, milk and yogurt intake were related to lower gains in weight and waist circumference over six years[13].

A narrative review in 2011, concluded that data from observational studies, although not completely consistent, were suggestive of a protective effect of dairy consumption on the risk of overweight and obesity in adults[6]. A systematic review of prospective studies in the same year reached a similar conclusion with regard to dairy and the risk of weight gain[11]. A more recent analysis also reports that dairy consumption was not adversely related to changes in body weight; yogurt, in particular, showed a beneficial effect, where higher intakes were associated with a reduced risk of obesity, changes in body weight and waist circumference[14]. Another systematic analysis, which assessed the relationship between the intake of dairy fat and high-fat dairy foods with obesity, found no evidence that dairy fat intake adversely affects weight or obesity risk[15]. In fact, in the majority of observational studies (11 out of 16 studies), a dietary pattern with a high-fat dairy intake was associated with lower weight and other measures of adiposity.

Studies in children and adolescents

For children and adolescents there are fewer observational studies available, but on the whole these too indicate either a beneficial or neutral effect of dairy consumption on body weight or body composition[11,16]. In UK children, for example, higher dairy consumption during preadolescence (10 years old) was not associated with excess fat gain during early adolescence (up to 13 years) and, in fact, appeared to have a protective effect[17]. A recent meta-analysis looking at the long-term association between dairy consumption and risk of childhood obesity concludes that dairy is protective[18].

Intervention studies

Results from intervention studies strengthen the observational data. A meta-analysis of randomised control trials in 2012 found that inclusion of dairy products in calorie-restricted diets led to a significantly greater reduction in body weight, waist circumference, and fat mass, while maintaining lean body mass, compared with low-dairy weight-loss diets[19]. A more recent meta-analysis in 2016 reached the same conclusion: increased dairy intake as part of energy-restricted diets resulted in greater loss of body weight and fat while helping to reduce the amount of lean mass lost[20]. Other meta-analyses also report dairy consumption, in the short-term, coupled with calorie-restriction, has a beneficial impact on body fat reduction[21,22]. Increasing dairy intake without calorie-restriction had no effect on weight[19,21,22]. It is an important point that, in contrast to the popular perception, extra milk and milk products did not result in weight gain, and, when coupled with calorie restriction, enhanced weight loss.

Again, there are fewer intervention studies in children and adolescents and no meta-analysis of results, however, the majority of the research indicates that the effect of milk and dairy intake on body weight and body composition in children and adolescents is beneficial or neutral[16].

Potential dairy matrix mechanisms

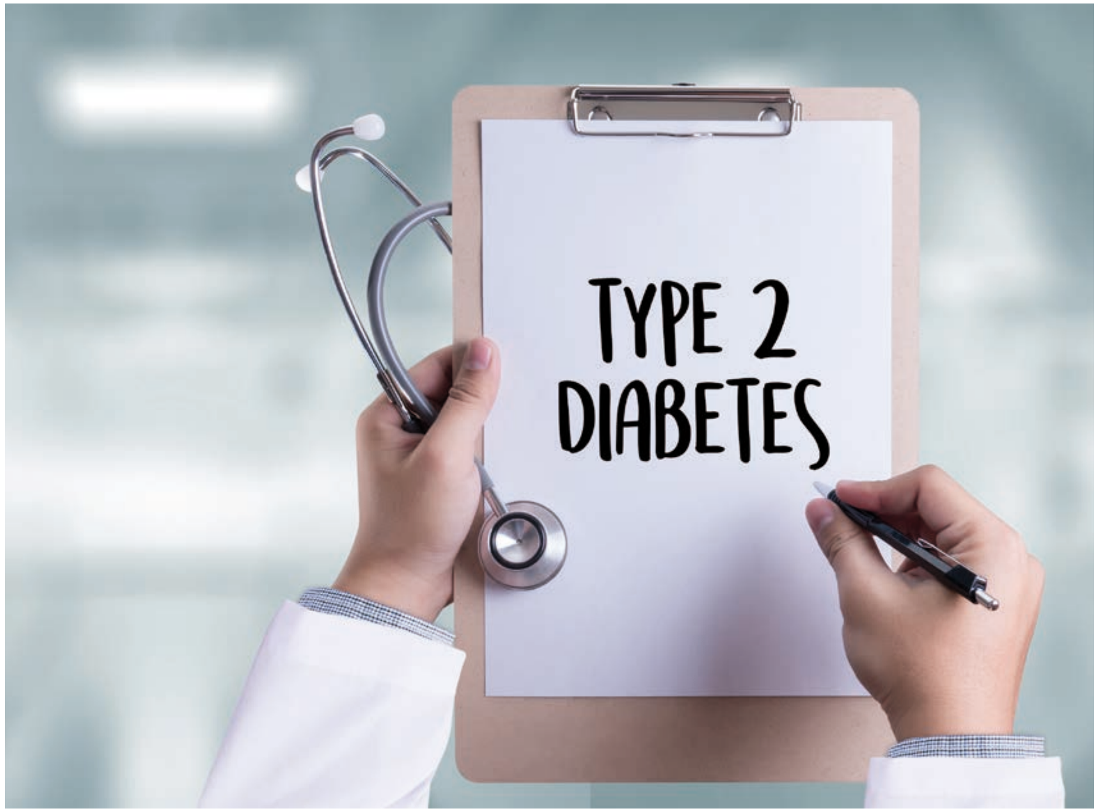
Possible mechanisms to explain the effects of dairy on weight control initially centred on calcium and particularly the hypothesis that calcium may alter fat cell function and fat oxidation: stimulating lipolysis (fat breakdown), reducing lipogenesis (fat synthesis) and increasing fat oxidation[2,23,24]. More recently it has been suggested that calcium may also work by binding fat in the intestine and increasing its excretion from the body and so decreasing fat (and therefore calorie) absorption[25]. Calcium in the dairy food matrix may be more effective in this respect than other forms of calcium[26]. Calcium-driven effects on appetite have also been postulated: a low calcium intake may trigger hunger and impair weight loss on energy restricted diets[27]. These potential effects of calcium are not mutually exclusive and multiple mechanisms may be involved.

Other components of the dairy matrix are also likely to be involved in dairy's beneficial effects[28]. Studies have reported that the weight-loss effects of milk and yogurt, for example, are greater than for the equivalent calcium supplement[2,29]. A probable candidate is dairy's **protein**. Several investigations indicate a role of protein in weight loss and weight maintenance including the European DIOGENES study[30]. Dairy protein may have positive effects on satiety, as well as benefits on 'muscle sparing' helping to maintain lean body mass during energy restriction[6,31]. Branched-chain amino acids, of which dairy foods, and particularly whey protein, are rich sources may be important in this respect[31]. Given associations between dairy fat and lower body weight, it has also been suggested that some fatty acids, principally **medium-chain fatty acids**, may have anti-obesity effects, including through lipogenesis and satiety[32,33]. Moreover, there is preliminary evidence that short-chain fatty acid production in the gut, which is favoured by fermented dairy foods such as cheese, may have positive effects on appetite regulation[34].

Further research will help to fully elucidate the relationship between dairy consumption and body weight including amounts and types of dairy foods and possible threshold effects. Nevertheless, from the available data, it seems likely that those trying to maintain a healthy weight, and particularly for those trying to lose weight, a low dairy intake is likely to be counterproductive. Indeed, recent guidelines on the 'Dietary Treatment of Obesity' from the Swedish Council on Health Technology Assessment, advise that a higher intake of dairy products (mainly milk) during energy restriction can lead to weight loss for both adults and children[35].

Type 2 diabetes

Evidence is building that dairy foods may help reduce the risk of type 2 diabetes. Protective associations have been reported for total dairy consumption as well as for both low-fat and regular-fat dairy, and are particularly pronounced for fermented products such as yogurt and cheese.
Several components of dairy foods could potentially be involved in the reduced risk including protein, calcium, magnesium and dairy fatty acids, along with mechanisms related to fermentation. These are not mutually exclusive and may well interact in the dairy matrix to produce the beneficial effects. Since the number of people with type 2 diabetes is rising in European populations, even a small protective effect of dairy as part of a healthy diet could have important public health implications.



Observational studies

A number of epidemiological studies have reported that intake of milk and dairy food is associated with a reduced risk of developing type 2 diabetes. An overview of four prospective cohort studies in 2007 showed a reduction of about 15% in the risk of diabetes in the highest dairy consumers (3 to 5 compared with less than 1.5 servings/day)[1]. Similar reductions were reported in overviews in 2010 and 2011 based on five and seven cohorts respectively[2,3]. In the latter meta-analysis, the protective effect of dairy was largely attributable to low-fat dairy foods, and a further dose-response analysis (involving three of the studies) suggested a 10% reduction in type 2 diabetes for every additional serving of low-fat dairy a day.

Since these overviews, several more prospective studies looking at the relationship between dairy consumption and type 2 diabetes have been published, including for European populations. The EPIC-InterAct Study (an investigation in eight European countries to identify the genes and lifestyle factors that influence risk of type 2 diabetes) found that both cheese consumption and fermented dairy product intake (cheese, yogurt, and thick fermented milk combined) were associated with a reduced risk of diabetes[4]. Similarly, in another EPIC cohort, this time in the UK and using 7-day food diaries, low-fat fermented dairy intake, largely driven by yogurt, was associated with a decreased risk of type 2 diabetes: 24% less between the highest and lowest consumers[5]. The PREDIMED study in an elderly Mediterranean population at high cardiovascular risk also reports that a healthy dietary pattern incorporating dairy products and, again, particularly yogurt, was protective against type 2 diabetes[6]. In the French DESIR cohort (Data from the Epidemiological Study on the Insulin Resistance Syndrome), those who consumed more than three servings of milk or yogurt a day had a lower risk of type 2 diabetes compared with those who consumed less than one serving a day[7]. Two other recent studies, in Danish and British cohorts, found no relationship between dairy intake and diabetes[8,9]. The Danish data did suggest a beneficial effect of cheese and fermented dairy on glucose regulation measures but these did not translate into a significant association with type 2 diabetes[8]. Another Danish study looking specifically at milk intake found no relationship with diabetes risk[10]. In the Dutch Maastricht Study, a high intake of full-fat products was positively related to diabetes risk[11]. However, individuals with a high total dairy consumption had lower risk of type 2 diabetes, and those with a high consumption of skimmed and fermented products had lower risk of impaired glucose metabolism[11].

A systematic review and dose-response meta-analyses published in 2013 utilised the available data to investigate in more detail the relation between the intake of individual dairy foods and diabetes risk, as well as between regular- and low-fat dairy[12]. Seventeen cohort studies were included in the overall meta-analysis and a significant reduction in the risk of type 2 diabetes was reported with increasing intakes of total dairy products and low-fat dairy products (up to 300g - 400g per day) and with increasing intake of cheese (up to around 50g per day). Another meta-analysis published in 2013 also found that total dairy product consumption, low-fat dairy products and cheese were associated with a reduced risk of diabetes, and additionally in this overview, so was yogurt[13]. In this case, total dairy and low-fat dairy intake were associated with 6% and 12% respectively, lower risk of type 2 diabetes per 200g a day consumption, with most of the risk reduction occurring with intakes up to about 200g per day for total dairy, and 300g per day for low-fat dairy.

A more recent analysis of cohort studies to inform the 2015 Dutch Dietary Guidelines concluded that there is convincing evidence that yogurt consumption is associated with a lower risk of type 2 diabetes; yogurt intake of more than 60g a day was associated with a 15% reduction in diabetes risk, compared with intakes less than 10g per day[14]. Similarly, a meta-analysis in 2016 which summarised the evidence from 22 prospective cohort studies found yogurt consumption was associated with a reduced risk of type 2 diabetes at 80g/day, but not with higher intakes[15]. In this analysis, total dairy food consumption was also associated with a lower risk, mainly attributable to low-fat dairy foods; there were no associations with either milk or cheese intake. The same conclusion was reached from a systematic review published in 2016; namely, that there is high-quality evidence to support favourable associations between yogurt and low-fat dairy intake and reduced risk of type 2 diabetes[16].

Intervention studies

Randomised control trials are needed to further confirm the results of the cohort studies. One recent small-scale trial found that consumption of four servings of low-fat milk and yogurt a day for six months improved plasma insulin and insulin resistance without negatively impacting on body weight or blood lipids[17]. Similarly, a six-week trial of three servings of low-fat dairy a day resulted in improvements in fasting glucose in men[18].

Potential dairy matrix mechanisms

Several components of the dairy matrix could potentially be involved in the protective relationship between dairy and type 2 diabetes. These are not mutually exclusive and a combination of mechanisms may well produce beneficial effects on glycaemic control and other risk factors. These include dairy minerals such as **calcium and magnesium**: both have a role in regulating insulin-mediated intracellular processes[1,19,20]. **Protein** in dairy has also been shown to have beneficial effects on insulin secretion and blood glucose control[21-24]. The **bioactive peptides** that may be involved result from digestion of milk protein in the gut and from the fermentation process in foods such as cheese, yogurt and fermented milk. Similarly, a form of **vitamin K** (vitamin K2; part of the menaquinone family) which is associated with fermented dairy foods has been linked to reduced risk of type 2 diabetes[25].

In addition, dairy fatty acids may play a role. Certainly, evidence from cohort studies suggests that the positive effect of dairy on diabetes risk is not restricted to low-fat dairy foods but also includes higher fat ones such as cheese. Data from the Malmö Diet and Cancer cohort, for example, indicated a decreased risk of type 2 diabetes with high intakes of regular-fat dairy foods but not with low-fat dairy[26]. A number of recent studies have found that the dairy-derived fatty acid trans-palmitoleate is associated with a substantially lower incidence of diabetes (60% less in one study)[27-29]. Other fatty acids in dairy have also been associated with reduce diabetes risk including odd-chain saturated fatty acids pentadecanoic acid (C15:0) and heptadecanoic acid (C17:0) and short-chain fatty acids (SCFA) including buyrate (C4:0); the branched-chain dairy fatty acid phytanic acid has been reported to have anti-diabetic effects including increasing insulin sensitivity[30-32].

Dairy may indirectly modify diabetes risk through beneficial effects on weight, body fat and central adiposity, and on muscle mass and function. Additional research will help to differentiate the effects of individual dairy foods and components of the dairy matrix for diabetes risk particularly the relevance of fermented dairy products such as yogurt. Randomised control trials to confirm the results of cohort studies would also be useful. However, the protective effect of dairy suggested by evidence to date, has important public health implications given that there are already around 60 million people with diabetes in the European Region, and these numbers are increasing[33].

Cardiovascular disease

The focus on dairy foods and cardiovascular disease (CVD) is often in relation to saturated fat. There is an assumption that because some dairy foods contain saturated fatty acids and dairy in general contributes to saturated fat intake in the diet, that it also increases the risk of cardiovascular disease. Yet the majority of epidemiological studies have shown no adverse effects of regularly consuming milk and dairy foods such as yogurt and cheese on cardiovascular health, irrespective of fat content. In fact, in some cases a cardio-protective effect has been observed.

The explanation for this may lie in the complex composition of milk and dairy foods which, in addition to saturated fat, contain other nutrients and bioactive components such as calcium, potassium and bioactive peptides in the dairy matrix which may be beneficial to cardiovascular health. In addition, the overall fatty acid profile of milk and dairy may not have the detrimental effect on blood lipids or other cardiovascular parameters that has been assumed.

Observational studies

In the absence of long-term intervention trials, the best available data on the relationship between dairy foods and cardiovascular disease are from large, long-term observational studies. There are several studies of this type in European populations. For example, a prospective cohort study from the UK reports that men who drank the most milk (around a pint / 586ml of whole milk a day) had fewer heart attacks and fewer strokes than those who had little or no milk in their diets[1]. The very large Netherlands Cohort Study, consisting of over 120,000 men and women, showed no association between total milk product consumption and stroke mortality, although butter and dairy fat was associated with a small (7%) increased risk of all-cause and heart disease mortality among women[2]. Recent data from the smaller Dutch Hoorn Study also found that overall dairy intake was not associated with CVD mortality but the intake of high-fat dairy products was[3]. In contrast, the Rotterdam Study reports that in an older Dutch population, high-fat dairy was associated with a reduced risk of fatal stroke; total dairy consumption or the intake of specific dairy products was not related to CVD events[4].

In another Dutch prospective cohort, there was again no evidence that dairy products increased risk of heart disease or stroke[5]. In fact, high intakes of total and low-fat dairy were associated with a lower coronary heart disease (CHD) risk in participants without hypertension. Low-fat dairy consumption was also associated with reduced risk of stroke in cohorts of Swedish men and women[6]. In the same cohorts, a high intake of fermented milk (yogurt and cultured sour milk) was found to reduce CVD risk[7]. Fermented milk and cheese were also associated with reduced cardiovascular disease mortality[8]. There was, however, an increased CVD mortality risk reported in this study in those drinking three or more glasses of (non-fermented) milk a day compared with less than one glass. The reason for this discrepancy in the same cohort is not clear and the authors urge a cautious interpretation of the results. Moreover, when these data were re-examined, milk consumption was associated with a lower risk of CVD mortality[9]. In line with the majority of epidemiological studies, a recent Danish investigation reports no adverse effects of dairy on cardiovascular health[10]. The French MONICA project conducted over 14 years, found that dairy consumption (particularly milk intake) as part of a diverse, healthy diet was associated with the lowest mortality rate mostly due to reduced cardiovascular deaths[11].

Meta-analyses for milk

A number of analyses have pooled the data from individual prospective studies such as these and their results strengthen the evidence that regularly consuming milk and other dairy products does not increase risk of cardiovascular disease and may even have a protective effect[1,13-20]. In relation to milk, an overview conducted in 2010 concluded that milk drinking is not harmful and may be associated with a small but worthwhile reduction in risk of coronary heart disease (8%) and a more substantial reduction in stroke risk (21%) for those who drank the most milk compared with those who drank the least[13]. The pooled results of seventeen studies in 2011 also found milk intake was associated with a small potential reduction in overall cardiovascular risk of 6% for each 200ml of milk consumed a day[14]. This analysis found no association between high intakes of either regular-fat or low-fat dairy products and increased risk of death from cardiovascular disease. Similarly, systematic reviews in 2015 and 2017 examining milk consumption and cardiovascular disease mortality observed no consistent association[15,16]. This was also the conclusion for milk and CVD risk in a meta-analysis published in 2016; milk intake was found to be neutral with respect to risk of stroke and coronary artery disease[17].

Meta-analyses for dairy products

Meta-analyses also support neutral or beneficial effects of other dairy foods on cardiovascular disease. Twenty two prospective cohort studies were included in an analysis published in 2015 which examined stroke and CHD incidence in relation to intake of individual dairy foods, and to low- and regular-fat dairy[18]. Cheese consumption was associated with a 16% decreased heart disease risk, and both cheese and low-fat dairy foods were associated with reduced risk of stroke (9% and 7% respectively). An earlier meta-analysis in 2014 looking specifically at stroke also reported similar reductions in risk with low-fat dairy (9%) and cheese intake (6%) and, in addition, with total dairy (12%) and fermented milk (20%)[19]. Similarly, in another meta-analysis including 18 studies which had examined dairy intake and stroke risk, milk and cheese consumption were associated with reduced risk of stroke; risk reductions were maximal around 125g/day for milk (16%) and from 25 g/day upwards for cheese (9%)[20]. Cheese was also associated with a lower risk of stroke (13%) in a meta-analysis published in 2016, as was total dairy intake (9%)[21]. In addition, cheese intake was associated with an 18% reduced risk of coronary heart disease. A beneficial effect of cheese was also supported by a meta-analysis of prospective cohort studies published in 2017 in which cheese intake was associated with 10%, 14% and 10% reduced risks of total CVD, CHD and stroke respectively[22]. A recent systematic review of the association between dairy product consumption and risk of various cardiovascular-related clinical outcomes also reports favourable associations between intakes of total dairy, low-fat dairy, cheese, and fermented dairy and the risk of stroke[17]. Similarly, a dose-response meta-analysis in 2017 combining data from 29 prospective cohort studies demonstrated neutral associations between dairy products and cardiovascular mortality[16].

Potential dairy matrix mechanisms

The explanation for the finding that dairy foods, even those containing fat and saturated fat such as cheese, have a neutral or even a beneficial effect on CVD is likely to lie in the complex composition of the dairy matrix[23].

Although some dairy foods contain saturated fatty acids, they are also rich in nutrients and bioactive components such as **calcium, potassium, phosphorus and bioactive peptides** that may modify CVD risk through, for example, positive effects on blood pressure, weight and diabetes. In addition, dairy constituents such as bioactive peptides may have direct effects on cardiovascular parameters including blood clotting, arterial stiffness endothelial function and inflammation[24]. This may help counter any negative effects of saturated fat in dairy on blood lipids and CVD risk. However, it is also increasingly recognised that individual **saturated fatty acids** have different effects on blood lipids; several of those in milk fat do not have an adverse effect on LDL ('bad') cholesterol or other markers of CVD risk including HDL ('good') cholesterol and the ratio of total to HDL cholesterol[25]. Moreover, components of the dairy matrix have been shown to modify blood lipid levels[23].

There is evidence that **calcium** in dairy foods, through its effects on binding fat and decreasing its absorption in the gut, may reduce the potential rise in LDL cholesterol following saturated fat consumption[26-28]. For example, cheese does not increase LDL cholesterol compared with butter of equal fat content[27]. Similarly, compared with a low-calcium control diet, milk- and cheese-based diets lessened saturated fatty acid-induced increases in total and LDL cholesterol[29] It may be important for this beneficial effect that fat and calcium are embedded in the same food matrix, as is the case for milk and cheese[23]. **Phosphorus** in the dairy matrix may also interact with calcium to influence blood lipids; calcium phosphate binds bile acids and fatty acids, and increases their excretion[30]. It has been suggested too that the membrane which encloses milk fat (the **milk fat globule membrane**; MFGM) and which is rich in bioactive phospholipids and proteins may have a beneficial role in modulating blood lipids[31]. Fermented dairy foods may also modify blood lipids through favouring gut bacteria which produce short-chain fatty acids (SCFA), and which in turn have a positive effect on lipids[32].

In addition, the total fatty acid profile of a food, not just its saturated fatty acid content, is important. Milk fat includes a number of fatty acids which may have beneficial effects on CVD risk factors such as blood lipids and markers of inflammation. These include conjugated linoleic acid (cis-9, trans-11 CLA) and trans palmitoleic acid (trans-C16:1)[33-35]. A recent study reported that higher levels of a biomarker of dairy fat in the diet were associated with a lower incidence of CVD and CVD risk factors[36].

It is evident that in terms of the effects of milk and dairy foods on cardiovascular health, the whole food, and the dietary pattern, rather than an individual component such as saturated fat should be taken into account. In this respect, the weight of epidemiological evidence suggests no adverse effects of regularly consuming milk and dairy foods on cardiovascular health and rather, in some studies, a cardio-protective effect has been observed.

Cancer

Based on a comprehensive review of the scientific literature, the World Cancer Research Fund report on diet and cancer concludes there is strong evidence that dairy foods are likely to protect against colorectal cancer. There is also limited evidence that consuming dairy foods might decrease the risk of premenopausal breast cancer. Although a protective effect of milk and milk products on bladder cancer and postmenopausal breast cancer has been indicated, the evidence is inconclusive. The evidence suggesting an increased risk of prostate cancer with higher consumption of dairy products is limited.
Several plausible mechanisms exist whereby constituents of the dairy matrix, either individually or in combination, may be involved in protective effects including calcium, lactoferrin, conjugated linoleic acid (CLA), sphingolipids, vitamin K2, probiotics and vitamin D (in fortified dairy).

Both protective and negative associations with dairy foods and cancer have been suggested by epidemiological studies. The relationship between diet and cancer risk is complex and pooled analysis of data is necessary before a reliable picture emerges. Even then, most common cancers are multifactorial, generally resulting from several causative factors and the impact of individual foods or food groups, either positive or negative, may be relatively small. The World Cancer Research Fund (WCRF) together with the American Institute for Cancer Research (AICR) systematically analyses the worldwide scientific literature on the relationship between food, nutrition, physical activity and cancer. The reports produced include an assessment of the strength of the evidence and the mechanisms which may be involved.

Colorectal Cancer

There is strong evidence that consuming dairy products decreases the risk of colorectal cancer (cancer of the colon and rectum, sometimes referred to as bowel cancer). Meta-analyses consistently report a reduced risk with higher intakes of milk and dairy foods. The latest WCRF/AICR Report (2017) concludes that consumption of dairy foods probably protects against colorectal cancer, and rates the level of evidence as 'strong'[1]. The report estimates a 13% decreased risk of colorectal cancer per 400g of dairy consumed a day. A significant dose-response relationship was also noted with milk: a 6% decreased risk of colorectal cancer per 200g of milk consumed a day.

The protective association is observed in European populations, as well as North American. For example, results from the European Prospective Investigation into Cancer and Nutrition (EPIC) which included data from over 477,000 men and women from ten European countries showed that higher intakes of milk, cheese, yogurt and total dairy products (and dietary calcium from dairy sources) were all associated with reduced colorectal cancer risk[2].

Bladder Cancer

It has been suggested that milk intake may have a protective effect on bladder cancer. However, according to the 2015 WCRF report, evidence for an association is inconsistent and no conclusions could be drawn[3]. A meta-analysis in 2011 showed a decreased risk of bladder cancer with a high intake of milk, while another in the same year found no association between dairy intake and bladder cancer risk[4, 5].

Breast cancer

The most recent WCRF/AICR report (2017) concludes that there is limited, but generally consistent, evidence that consumption of dairy products may decrease the risk of premenopausal breast cancer[6]. A dose response meta-analysis conducted as part of the report estimated a 5% reduced risk of breast cancer per 400g of dairy foods consumed a day. Evidence for an association between dairy intake and risk of postmenopausal breast cancer was inconclusive.

Prostate cancer

The 2014 WCRF report concluded that the evidence of an association between dairy intake and increased risk of prostate cancer is limited[7,8]. The evidence for total dairy product intake showed an increased risk per 400g a day, but the relationship was unclear and not significant when stratified by prostate cancer type. For diets high in calcium, WCRF also concludes that the evidence suggesting an increased risk of prostate cancer is limited7. On this basis, dairy is not part of the WCRF dietary recommendations concerning prostate cancer risk[7].

Other cancers

In relation to other cancer types including ovarian, endometrial, lung and pancreatic cancers, WCRF reports and recent meta-analyses suggest no association with dairy intake[9]. In Europe and the United States, there is some suggestion that total dairy product intake may reduce the risk of gastric cancer[10].

Potential dairy matrix mechanisms

Dairy foods contain several components which may have anti-cancer properties. The effect of milk, or other dairy foods, in reducing colorectal cancer risk is likely to be mediated, at least in part, by their **calcium** content. Plausible mechanisms include calcium's ability to bind secondary bile acids and free fatty acids in the gut lumen which can otherwise have a toxic effect on the cells of the colon, and to reduce abnormal proliferation of colonic epithelial cells[11]. Similarly, animal studies have shown that a high calcium intake also inhibits hyper-proliferation of mammary glands and has inhibitory effects on breast cancer cells[12]. Indeed, a 2016 meta-analysis reports a dose-response relationship between calcium intake and reduced breast cancer risk[13].

There is evidence too that other components of the dairy matrix may be involved along with calcium in protective effects. For example, the relation between dietary calcium and a lower risk of colorectal cancer in the EPIC study was evident for dairy sources of calcium only[14]. Similarly, in a prospective cohort of Swedish men, control for total calcium intake in the analysis lessened but did not eliminate the beneficial effect of milk[15].

Other constituents of milk and milk products which may have anti-carcinogenic properties include **vitamin D** (in fortified dairy), **lactoferrin** (a protein in cows' milk), **menaquinones** (a class of **vitamin K** compounds of which cheese is an important dietary source) and **probiotic** bacteria in fermented products such as yogurt[16-20]. In addition, the fatty acids **conjugated linoleic acid** (CLA) and **butyric acid**, and components of the membrane which encloses the fat droplets in milk (milk fat globule membrane; MFGM) such as **sphingolipids** and particularly sphingomyelin, are thought to have anti-cancer effects[16, 20-22]. With respect to CLA, data from the Swedish Mammography Cohort found intakes of CLA could partly explain the relation between high-fat dairy food and lower colorectal cancer incidence observed in this study[23]. However, in relation to other cancers, including breast cancer, although promising from in vitro and animal work, the evidence for CLA from human studies is limited[24]. The mechanisms by which dairy constituents may reduce cancer risk are not mutually exclusive and there may be interaction within the dairy matrix to produce the beneficial effects.

Research on the role of specific dairy products and dairy constituents, and possible interactions between them in the matrix will help clarify our understanding of the relationship between dairy and cancer risk. Nevertheless, from the available data there is good evidence that milk reduces the risk of colon cancer. In addition, milk and milk products may also be associated with a reduced risk of premenopausal breast cancer and possibly bladder cancer. Consumption of milk and dairy foods as part of a healthy dietary pattern fits with guidance on cancer prevention[25].

Muscle mass maintenance in older people

There is evidence to suggest a potential role for milk and dairy foods in helping to maintain muscle mass and function in older people. A number of studies point to the benefits of milk protein for increasing muscle protein synthesis in the elderly, and that supplementation, in combination with physical activity, can improve muscle mass and function. There is some evidence too, that older people with higher intakes of milk, cheese and yogurt have greater muscle mass and better functional capacity. In addition to high-quality protein for muscle health, the rich mix of other nutrients in milk and dairy foods make them a valuable part of the diets of older people.

Sarcopenia

Ageing is accompanied by a progressive loss of skeletal muscle mass and strength – sarcopenia - which leads to the loss of functional capacity and a greater risk of developing metabolic disease such as diabetes[1]. Although some degree of sarcopenia is inevitable, the extent to which it can be minimised, and possibly reversed, has important implications as loss of physical function predicts loss of independence, falls, and even mortality. With an ageing population in Europe, strategies for prevention are increasingly important.

Muscle protein synthesis

Both food intake and resistance exercise stimulate protein synthesis in muscles. Recent studies suggest that older people's muscles are less responsive to the stimulating effects of protein than their younger counterparts[2]. Consequently, research has focused on whether higher intakes of protein can overcome this 'anabolic resistance' and can enhance the effects of exercise. Although there is not yet consensus, it has been argued that to help older people maintain and regain lean body mass and function, higher protein intakes than currently recommended (0.8 g/kg/day) are required: in the range of at least 1.0 to 1.2 g/kg/day and up to 1.5g/kg/day[3-6]. Roughly equal distribution of protein intake at meals across the day is suggested to be the most effective way to achieve this which, assuming three meals a day, equates to 0.4 to 0.5 g/kg per meal[2,7]. Currently, protein intakes at breakfast time are often low, and increasing protein intake before bed may also represent an opportunity for overnight muscle protein synthesis[8,9].

The quality of protein intake is also important. Protein that has a high concentration of essential amino acids, most importantly leucine, has been shown to best stimulate muscle protein synthesis[9]. This points to milk protein, particularly whey, and a number of studies have confirmed beneficial effects on muscle protein synthesis[10,11]. It is likely that the effects of whey on muscle gain in older people extend beyond its leucine or essential amino acid content since comparable amino acid 'mixes' do not have the same effect[11]. Factors such as rate of absorption, influenced by the dairy food matrix, may be important[12-14]. In this respect, more research is needed on the effects of milk per se and of other whole dairy foods on muscle protein synthesis in older people.

Dairy protein supplementation

A meta-analysis in 2012 of longer term studies examining the effects of diet and exercise in older people found that protein supplementation increased muscle mass and strength gains during resistance exercise programmes: 38% more fat free mass and a 33% increase in strength[15]. All six studies in the meta-analysis used a dairy-based protein; five exclusively dairy (milk, whey or casein) and the sixth a combination of egg, meat and dairy. A subsequent six-month clinical trial from the Netherlands also found that a milk protein drink combined with a resistance exercise programme significantly increased skeletal muscle mass in frail elderly adults[16]. Another long-term study by the same research group found that although increasing milk protein without exercise did not increase muscle mass, it enhanced physical performance in the frail elderly subjects including improvements in balance, walking speed and ability to 'get up and go' from a chair[17]. The milk drink used in these two studies provided around 30g of protein a day, equivalent to 3 to 4 servings of dairy. In another dairy intervention, adding 210g of ricotta cheese a day to the usual diets of older people (without sarcopenia) for 12 weeks improved skeletal muscle mass and balance-test scores[18].

Observational studies

There is some evidence that older people with higher intakes of dairy have greater muscle mass and better muscle function. In a prospective cohort study of older Spanish adults (60 years plus), higher consumption of low-fat milk and yogurt was associated with lower risk of frailty and, specifically, of slow walking speed and weight loss[19]. Similarly, a recent study of almost 4,000 older people in Ireland (over 60 years), found higher daily yogurt intake was associated with better physical function scores[20]. A cross-sectional study in 70 to 85-year-old Australian women also reports that those with the highest milk, cheese and yogurt consumption (2.2 or more servings a day) had significantly greater lean body and skeletal muscle mass, greater hand-grip strength and better 'up and go' performance than women who consumed the least (less than 1.5 servings)[20]. The authors highlight the bioactive compounds present in dairy such as high-quality proteins and interactions with other components of the dairy matrix such as calcium which may be responsible for the beneficial effects.

Ensuring adequate protein intake, including with milk protein, alongside physical activity, appears a promising approach to maintaining and improving muscle mass and functional performance in older people. Given the consequences of sarcopenia for health and quality of life, and with an ageing population, such strategies are increasingly important. In addition to protein, milk and dairy foods offer older people other valuable nutrients in a palatable, convenient and affordable way.

Recovery after exercise

Although this is a relatively new area of dairy research, milk shows promise in the sports nutrition arena. The nutritional composition of milk makes it particularly well suited to support recovery after exercise. There is evidence that milk can be an effective post-exercise rehydration drink due to its fluid and electrolyte content. The protein in milk also helps promote muscle protein synthesis after exercise, and milk has been shown to reduce exercise-induced muscle damage and soreness. Practically, milk is convenient, inexpensive and accessible.

The nutritional composition of the milk matrix, including its protein, carbohydrate and electrolyte content suggests that it would be useful as a sports drink. A number of studies have confirmed a potential role for milk in sports and exercise nutrition, particularly in relation to recovery after exercise[1].

Rehydration

During exercise, fluid is lost from the body as sweat and needs to be replaced. The main factors that influence the process of post-exercise rehydration are the volume and composition of the fluid consumed, particularly the electrolyte concentration. The **sodium** and **potassium** content of milk make it a good candidate for effective post-exercise rehydration, and several studies have now shown that low-fat milk can restore and maintain hydration status equally as well as, or better than, a commercially-available sports drink[2-5]. The rehydration potential has been demonstrated in children and teens as well as adults[6]. In addition to the electrolyte content, there is some evidence that the **protein** in milk may also enhance rehydration, possibly through slowed gastric emptying[7]. Again, this has been shown in children as well as adults[8]. A recent trial to assess the potential of 12 different drinks to affect hydration status reports that milk (skimmed and whole milk) and an oral rehydration solution were the most effective at maintaining fluid balance[9].

Muscle recovery and repair

Following exercise, protein is important for recovery and repair. Resistance exercise stimulates muscle protein synthesis but a net gain in muscle mass is only possible if adequate protein or essential amino acids are also consumed. Milk is rich in high quality protein (80% casein and 20% whey) and contains all the essential amino acids; it is a good source of branched chain amino acids including leucine which are integral to muscle metabolism and produces a sustained increase in blood amino acids. Studies support a beneficial effect of milk and of dairy proteins in recovery from resistance exercise. Milk can stimulate protein synthesis and support muscle development following bouts of resistance exercise, in men and women, and in the short and longer term[10-13] and may have advantages for muscle metabolism over other protein sources such as soy[10,12]. Studies of individual milk proteins, particularly whey, also support beneficial effects on skeletal muscle amino acid uptake, protein synthesis and muscle mass[14]. In relation to muscle repair after exercise, studies have shown that drinking milk immediately following resistance exercise (500ml) can help to alleviate muscle soreness and drops in muscle performance[15-18].

Glycogen re-synthesis

Carbohydrate is key to supporting glycogen re-synthesis after exercise. Milk contains carbohydrate as the naturally present sugar lactose (glucose and galactose) and so can contribute to glycogen re-synthesis. Studies in this area have largely focused on flavoured milk, particularly chocolate milk, which has greater amounts of carbohydrate and has been shown to be effective for post-exercise muscle glycogen recovery[1,19].

Calcium balance

A further area where milk and dairy foods may be of benefit in sports nutrition is in relation to calcium balance. It has been hypothesised that calcium loss through prolonged or excessive sweating may have a detrimental effect on bone[20]. Although more research is needed, a recent study in competitive female cyclists found that a dairy-based meal before exercise was able to counteract the loss of calcium in sweat and reduce bone breakdown[21].

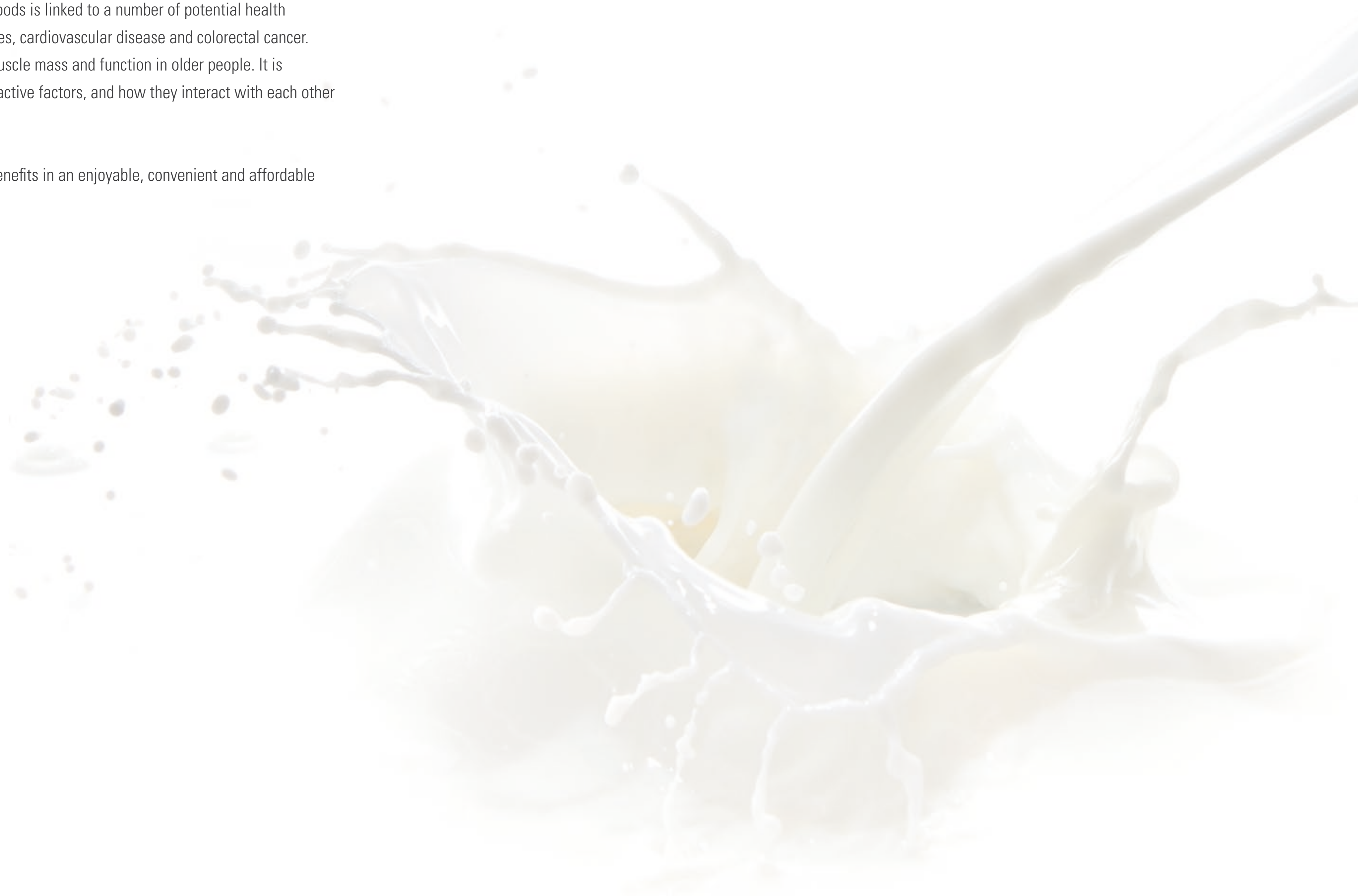
It is well established that milk can be effective for rehydration, and for muscle recovery and repair after exercise and sport. Preliminary data suggests it may also be of value pre-exercise as a calcium provider. Practically, milk is convenient, inexpensive and accessible. While chocolate milk and whey proteins also have a role in sports nutrition, the potential of other dairy products such as yogurt and cheese in this context has yet to be fully elucidated. The rich nutrient content of these dairy foods, however, mean they make a valuable contribution to a healthy, balanced diet for sports people.

Conclusion

Milk and dairy foods are naturally rich sources of a wide range of nutrients and make a significant contribution to nutrient intakes and diet quality in Europe. The milk and dairy food group forms an important part of food-based dietary guidelines across Europe, and dairy is, with good reason, recognised as one of the components of a healthy dietary pattern. The specific recommendations vary between countries, but on average 2 to 3 servings of milk and dairy foods a day are recommended for adults; often more for children and adolescents (3 to 4 servings), and in some cases more for pregnant women and older people too.

As this review of the research indicates, consumption of milk and dairy foods is linked to a number of potential health benefits including for bone, blood pressure, weight control, type 2 diabetes, cardiovascular disease and colorectal cancer. They also have a role in sports nutrition and in the helping to maintain muscle mass and function in older people. It is increasingly recognised that the unique combination of nutrients and bioactive factors, and how they interact with each other in the dairy matrix, combine to produce these positive effects on health.

Milk and dairy foods are versatile and offer a wide range of nutritional benefits in an enjoyable, convenient and affordable way.



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Food Consumption Survey, Belgium 2014-2015
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Total dairy = cheese, milk, yogurt, milk deserts (e.g. pudding), milk drinks, curd (~ fresh white cheese), soy drinks, soy deserts De Ridder K, Bel S, Brocatus L, Lebacq T, Moyersoen I, Ost C & Teppers E. De consumptie van voedings¬middelen en de inname van voedingsstoffen. In: Bel S, Tafforeau J (ed.). Voedselconsumptiepeiling 2014-2015. Rapport 4. WIV-ISP, Brussels, 2016

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September 2017 ref 2383