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ABSTRACT

The most recent scientific evidence supports the consumption of cow's milk and dairy products as part of a balanced diet. However, these days, the public and practicing physicans are exposed to a stream of inconsistent (and often misleading) information regarding the relationship between cow's milk intake and health in the lay press and in the media. The purpose of this article, in this context, is to facilitate doctor–patient communication on this topic, providing physicians with a series of structured answers to frequently asked patient questions. The answers range from milk and milk-derived products' nutritional function across the life span, to their relationship with diseases such as osteoporosis and cancer, to lactose intolerance and milk allergy, and have been prepared by a panel of experts from the Italian medical and nutritional scientific community.

When consumed according to appropriate national guidelines, milk and its derivatives contribute essential micro- and macronutrients to the diet, especially in infancy and childhood where bone mass growth is in a critical phase. Furthermore, preliminary evidence suggests potentially protective effects of milk against overweight, obesity, diabetes, and cardiovascular disease, while no clear data suggest a significant association between milk intake and cancer. Overall, current scientific literature suggests that an appropriate consumption of milk and its derivatives, according to available nutritional guidelines, may be beneficial across all age groups, with the exception of specific medical conditions such as lactose intolerance or milk protein allergy.

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Key teaching points:

- Milk and its derivatives contribute essential micro and macronutrients to the diet, when consumed according to appropriate national guidelines, especially in infancy and childhood where bone mass growth is in a critical phase.
- Preliminary evidence suggests potentially protective effects of milk against overweight, obesity, diabetes and cardiovascular disease
- No clear data are available about the association between milk intake and cancer.
- Current scientific literature suggests that an appropriate consumption of milk and its derivatives may be beneficial at all ages, with the exception of specific medical conditions such as lactose intolerance or milk protein allergy.

Introduction

Bovine milk and dairy products have been part of the human diet, from birth to old age, for millennia. However, beyond its nutritional role, milk is the subject of active research aimed at elucidating the relationship between its consumption and human health.

In order to summarize the current scientific evidence, NFI–Nutrition Foundation of Italy convened a panel of experts and representatives of Italian medical and nutritional scientific societies, who discussed the available scientific evidence concerning cow's milk nutrient composition, its technological and safety aspects, its nutritional role across age groups and in physiological conditions, and the possible relationship between milk consumption and specific diseases and disease risk factors. This article outlines the outcome of the meeting in a question-and-answer format, in order to facilitate the work of busy clinicians when answering commonly asked patient questions on this topic.

Which nutrients does milk provide?

Milk, that is, cow's milk, is composed of about 87% water; it also contains, on average, 3%–4% fat, 3.5% protein, about 5% lactose, and 1.2% minerals, with some variation depending on the breed considered (1). In milk marketed for direct consumption, the fat content is usually standardized to the levels required by law for the three types: whole (>3.5%), semi-skimmed (1.5%–1.8%), and skimmed (<0.5%) (2). Fat, mainly represented by triacylglycerols (98%), is present in milk as globules, ranging from 0.1 to 10 μm in diameter and surrounded by a membrane (MFGM, or milk fat globule membrane), composed of several layers of phospholipids and about 40 different proteins (3) endowed with multiple enzymatic activities and involved in various metabolic processes. The presence of MFGM, for example, is associated with a more favorable lipid and low-density lipoprotein (LDL) cholesterol response to milk consumption compared to butter oil, an MFGM-free dairy product devoid of phopholipids (4).

About 60% of total fatty acids in milk are saturated fatty acids, mainly represented by palmitic (16:0, about 30% of total fatty acids), followed by myristic and stearic acids (14:0 and 18:0, 10% and 12%, respectively, on average). About 10% of milk fatty acids are short-chain saturated (with 4, 6, 8, or 10 carbons), infrequently found in other commonly used foods (2). Among the unsaturated fatty acids, oleic acid (18:1, with one double bond) is noteworthy (up to 25%–30%); the essential fatty acids linoleic (18:2 of the n-6 series) and alpha-linolenic (18:3 n-3) are also present in cow's milk (2). Milk also contains small amounts of odd-chain saturated fatty acids (pentadecanoic, 15:0, and heptadecanoic acid, 17:0), produced in the cow's rumen, which are rather peculiar, and are hence used as biomarkers of dairy fat intake (5). Typically found in milk are also specific trans fatty acids, including conjugated linoleic acid (or CLA, 18:2 with two conjugated double bonds), produced by incomplete biohydrogenation of linoleic acid (18:2 n-6) in the rumen (2).

Carbohydrates in milk are almost exclusively represented by lactose, a disaccharide, which must be cleaved into glucose and galactose by the intestinal enzyme lactase (or beta-galactosidase) to be absorbed (6).

Eighty percent of the protein fraction of cow's milk is caseins, which predominantly contain glutamic acid, proline, arginine, and branched amino acids (leucine, isoleucine, valine). Beta-casein, representing about 35% of total caseins, exists in two different forms (A1 and A2), with possibly different physiological effects (7). Soluble whey proteins rich in cysteine, lysine, leucine, and tryptophan account for the remaining 20% of milk proteins (8).

Milk proteins are of high biological value, both because they contain all the essential aminoacids required by the human body, and because of their high digestibility and bioavailability (high protein digestibility-corrected amino acid score [PDCAAS value]).

Finally, milk provides a variety of minerals, in particular calcium and phosphorus, but also potassium, magnesium, zinc, and selenium and both B-group water-soluble vitamins (riboflavin and B_{12}) and fat-soluble vitamins (e.g., A and E) in concentrations directly related to its lipid content (1). Safety and keeping quality of milk intended for direct consumption can be achieved by heat treatment under different conditions, which are summarized in Table 1 (1).

How is raw milk processed and how do such processes affect its nutritional quality?

Pasteurization and ultra-high temperature (UHT) sterilization destroy the most common pathogens of raw milk (*Listeria*, *Campylobacter*, pathogenic *Escherichia coli* strains

Table 1. Main Types of Commercially Available Milk for Direct Consumption.

	Heating conditions	Typical durability and storage conditions
Fresh pasteurized* milk:	72–78 °C for 15–20 seconds	6 days at 4–6 °C
"High quality" fresh* pasteurized milk:	72 °C for 15-–18 seconds (minimum required conditions)	6 days at 4–6 °C
Microfiltered pasteurized milk:	Microfiltration (removal of bacterial cells) and subsequent pasteurization	15–18 days at 4–6 °C
High-temperature pasteurized milk	90 °C for 20–30 seconds or 100–120 °C for 0.1–0.4 seconds	15–18 days at 4–6 °C
UHT (ultra-high-temperature) milk	135 to 150 °C for 4–8 seconds	3 months at least, room temperature.
Lactose-free milk	Pasteurization or UHT treatment with enzymatic hydrolysis of lactose	Dependent upon treatment
Powdered (dried) milk	Pasteurization, evaporation drying	Room temperature

*The terms "pasteurized fresh milk" and "high quality fresh milk" are defined by Italian law (Regulation 169/89 and Ministerial Decree 185/91).

[VTEC], *Salmonella*, coagulase-positive staphylococci). Pasteurization, which is carried out by heating raw milk to at least 72 °C for 15 seconds, is the mildest heat treatment; it destroys non-spore-forming pathogens and reduces the generic total flora, and the resulting product can be stored at 4–6 °C for a few days. Pasteurization is recommended for all milk for human consumption by many medical and scientific organizations, like as the Food and Agriculture Organization, the Centers for Disease Control and Prevention, the Food and Drug Administration (FDA), the American Academy of Pediatrics, and others.

With UHT sterilization, raw milk is heated to a temperature between 135 °C and 150 °C for 4–8 seconds and packaged under aseptic conditions, to ensure complete bacterial destruction and inactivation of heat-sensitive enzymes; sterilized milk can be stored at room temperature for at least 3 months. Both types of milk maintain the nutritional characteristics of the original product almost completely, while ensuring safety and health. Heat treatments only moderately reduce the concentrations of some vitamins (especially C, B_6, and B_1), but not of others (A, E and D, B_2) (1).

Bacteria can also be physically removed, for example, via microfiltration through porous membranes that retain bacterial and somatic cells and spores. Subsequently, complete safety is ensured via pasteurization.

Lactose-free or low-lactose milk (i.e., <0.01% and <0.1% lactose by weight), suitable for consumption by lactose-intolerant individuals, is obtained by adding beta-galactosidase to milk before heating, thus leading to the release of glucose and galactose.

Powdered milk, used as an ingredient in a number of industrial products, is produced by dehydration of fluid milk. During this process, the Maillard reaction produces specific derivatives (which are globally evaluated, for example, determining the "blocked lysine" levels), but the overall effect is similar to that observed with UHT processes (9). Once reconstituted, powdered milk presents the same composition and nutritional value as native milk, provided it is not stored for too long or exposed to light or humidity.

What about the safety of milk marketed for human consumption?

Minimizing possible health risks associated with milk consumption requires a continuous system of preventive measures starting from animal feed suppliers, farmers, and milk processors to good hygiene practices and food safety management throughout the production chain, as defined, for example, in the Pasteurized Milk Ordinance (PMO) published in 2009 by the FDA, in the Canadian National Dairy Code or in the European Regulations 853/2004, 1881/2006, 2073/2005, and 37/2010.

The regulation on milk and milk products addresses animal health, hygiene of milk production, storage, packaging, and specific criteria related to production and distribution of raw milk, that is, unpasteurized milk. As an example, acceptable upper limits have been fixed for total bacterial count and somatic cells (possible markers of breast inflammation) to be fulfilled in raw milk, and may be different from one country to another. The aim behind this approach is to prevent heating abuse when sanitizing low-quality raw milk. The presence of aflatoxins (from feed contamination), contaminants, and pathogens is also kept under control.

Moreover, milk marketed for human consumption should not present any antibiotic residue.

Finally, the use of hormones for fattening purposes (known as "feeding hormones") in livestock production or to stimulate lactation was banned many years ago in the European Union, Canada, Australia, New Zealand, and Japan, which share a common view of the animal and human health concerns.

Milk consumption: recommendations of nutritional guidelines

Despite the cross-country variability of recommendations for milk and dairy products, all international guidelines recommend daily consumption of milk (and yogurt) (1).

The main differences among countries relate to the consideration of milk (and yogurt) alone or their inclusion in the category of dairy products: in Finland and Denmark, for example, the recommendations refer to 500 ml of milk per day; in Italy, the United Kingdom, Spain, and the Netherlands the reference intakes are based on serving number (about 2–3 milk servings per day, with 1 daily cheese serving in the Netherlands and 2–3 weekly servings of cheese in Italy); the United States, Canada, and Australia share recommendations of about 2–3 servings per day (according to age and requirements) of fat-free or low-fat dairy products (selected from 1 cup of milk or yogurt and 1 and ½ oz cheese). Moreover, the standard milk serving size differs considerably across countries: from 125 ml in Italy to 150 ml in the Netherlands, 200 in the United Kingdom, and about 250 ml in Spain, the United States, Canada, and Australia.

What nutritional role does milk play in the first years of life?

Whole cow's milk should not be used as the main dietary component during the first 12 months of life, in order to provide optimal nutritient supply to the infant, to avoid an excessively high protein intake, as well as of energy and fat during complementary feeding and to reduce the risk of subsequent overweight or obesity (especially in predisposed individuals) (10,11).

In observational studies, a high intake of total animal and dairy protein in toddlers (i.e., 1–3 years of age) has also been associated with increased body mass index (BMI) at later ages (12,13). However, the effect of cow's milk after the first year of life is less well understood, due to the lack of data from randomized clinical trials. It has been suggested that there be a limit on the consumption of cow's milk to 200–400 ml/d, in order to maintain the overall diet protein content below 15% of total calories (14,15).

Taking into account the available evidence, all the national/international guidelines recommend, starting from the second year of life, milk and/or yogurt consumption on a daily basis, especially for its digestible protein and calcium content, essential for growth. Milk has also been placed at the bottom of the food pyramid defined by the Italian Society of Pediatrics, among the foods for which a daily consumption is suggested. Other international guidelines such as those of the American Academy of Pediatrics, or the European Society for Paediatric Gastroenterology Hepatology and Nutrition and the Food and Agriculture Organization, agree upon the role of cow's milk as a component of a balanced diet for children (16).

Are there relevant reasons to exclude cow's milk from the diet of healthy children?

The replacement of cow's milk with other types of milk (such as donkey milk, for which the low fat content makes it unsuitable for pediatric diets) or with plant-based drinks (which can no longer be labeled as "milk" in Europe, according to Regulation [EU] 1234/2007) to gain supposed health effects, in the absence of diagnosis for specific diseases, is becoming a widespread practice. However, such an approach is not supported by adequate scientific evidence, and has no proved benefits for the general healthy population, including children. Specifically, the content of selected micronutrients in vegetable alternatives to cow's milk (which often contain less protein and calories) is variable and strictly dependent upon the degree of enrichment (e.g., as concerns calcium and phosphorus).

In addition, no association has been ascertained between cow's milk consumption and autism, despite this issue being occasionally raised by the media. On the contrary, cow's milk is a well-recognized marker of the proper habit of having breakfast, which is an important factor affecting the nutritional quality of the diet at pediatric ages (17,18). Therefore, children should not use any alternative to cow's milk in the absence of a specific indication provided by the pediatrician. Both doctors and families must also address incorrect nutritional children's habits, including the progressive reduction in milk consumption from school age to adolescence.

Is it true that consuming milk in early life increases the risk of overweight and obesity in adulthood?

In the early years of life, as previously mentioned, attention should be paid to protein intake (and hence to the intake of all protein sources, including cow's milk) because an intake exceeding 15% of total energy has been associated with the risk of overweight and obesity later in life (19). Some observations suggest that excessive protein intake increases the synthesis of insulin-like growth factor 1 (IGF-1), which is involved in overweight and obesity programing (20).

Based on studies carried out in northern Europe, where circulating levels of IGF-1 increase along with milk consumption, it was hypothesized that milk proteins (casein directly and whey protein indirectly) were responsible for accelerated weight growth and adipogenic activity (14). However, IGF-1-mediated adiposity is a rather complex process, which has been demonstrated only in infants who received protein intakes with infant formulas markedly exceeding needs, and it has not been confirmed in older children (14,15). For example, among 99 children from the Framingham Children Study, those in the lowest tertile of milk consumption (less than 1.25 servings for females and less than 1.7 servings for males) at preschool age exhibited increased accumulation of subcutaneous fat during adolescence, in comparison with children in the highest tertile (21). Moreover, higher consumption of milk and yogurt by adolescents was associated with lower accumulation of body fat and lower cardiometabolic risk in the European multicenter study HELENA (22).

How does cow's milk contribute to calcium intake?

Milk products are important sources of protein, vitamins (e.g., retinol, vitamins B_2 and B_{12}), phosphorus, and zinc, as well as of calcium, for both adolescents and adults (23). In fact, based on the EPIC data, milk and its derived food products account for about 50% of the daily calcium intake in this European cohort (24). Diets including small amounts of milk and yogurt, followed by specific populations (e.g., Italian females), are—on average—inadequate in terms of calcium supply (25,26). Obviously, other foods, namely, plant-based ones (legumes, almonds, parsley, and sage), also contain considerable concentrations of calcium. However, if the calcium content, the energy value per serving, and the relative cost of each food item are taken into consideration, it is possible to conclude that cow's milk remains the more advantageous calcium dietary source, supplying energy, high-quality protein, calcium, and also essential fatty acids, at a fairly low price. The benefit of products belonging to the milk group has been confirmed also after the assessment of costs in terms of energy, euros, and nutrients to limit (saturated fatty acids, added sugar and sodium) associated with calcium supply equivalent to 15% of the European Union (EU) daily reference value (120 mg) (27). Furthermore, calcium in milk and dairy products is highly bioavailable (28).

What nutritional role can cow's milk play for pregnant or breastfeeding women?

During pregnancy the nutritional phenotype changes remarkably, and modifications involve not only the woman's body, but also the placenta and the fetus, which grow as effective organs with active metabolisms, in turn affecting maternal metabolism (in the second trimester of pregnancy, about 50% of nutrients are used by the placenta) (29). However, the energy requirement during pregnancy is only modestly increased (+100–300 kcal/d from the first to the third trimester), compared to the significant increase in micronutrient (vitamins and minerals) requirements (30). As a result, during pregnancy, the diet should be qualitatively improved rather than calorically increased. Many studies show that nonoptimal dietary patterns (different from the Mediterranean or the "prudent" ones) increase the risk of both short- and long-term adverse effects such as infertility, spontaneous abortion, diseases in late pregnancy, or risk factors for the newborn's health (31).

Nowadays, increasing importance is given to epigenetic modifications, modulated by the maternal nutritional status at conception, but also reflecting the energy and micronutrient intake in the periconceptional period (32).

During pregnancy, both deficiency and excess (e.g., protein intake falling outside 10%–15% of total calories), may adversely affect the infant's weight at birth. In this context, food sources of proteins with high biological value, such as milk and derivatives, play an important role (33). Research carried out in northern Europe showed significant correlations between intakes of dairy products in pregnancy and birth weight (34), height of the offspring measured at 20 years (35), reduction of the risk of developing milk allergy (36), and protection from the risk of postpartum depression (37). In 2012, the European Food Safety Authority (EFSA) Panel on Dietetic Products, Nutrition and Allergies proposed an additional intake of 1, 9, and 28 g/d of proteins, respectively, in the first, second, and third trimesters of pregnancy, over the reference intake (PRI) defined for nonpregnant women (30). A protein intake of 19 g/d and 13 g/d is also proposed in addition to the PRI during the first 6 months and after 6 months of breastfeeding, respectively.

The most solid data concern the contribution of milk-derived products to calcium intake. Calcium is essential for the formation of bones and for the health of the skeleton of mothers and children, but calcium supplementation throughout pregnancy also reduces the risk of developing hypertension and pre-eclampsia, especially in women with low mineral intakes (38). Supplementation with 1.5–2 g of calcium per day is in fact recommended by the World Health Organization (WHO) for pregnant women with inadequate dietary intakes.

Particular attention should also be paid to the maternal status of vitamin D—largely dependent on the consumption of animal foods, including milk—which has multiple roles in pregnancy: not only to support bone growth and fetal and maternal health, but also to promote immunological development and the prevention of both pre-eclampsia and infant allergies. Dietary intake of vitamin D often falls below the recommendations in all high-income countries (39).

Finally, ongoing studies reveal associations between positive outcomes of pregnancy and overall quality of the maternal diet, especially if it includes—in addition to fish, whole grains, and red fruits—milk and its derivatives.

What is the nutritional role of milk in the elderly? Is there any specific reason to limit the consumption of cow's milk in old age?

An adequate intake of high-quality protein, such as that contained in cow's milk, along with appropriate physical activity, is essential to counteract the progressive loss of muscle mass and strength which typically begins during the fourth decade of life (40). This decline accelerates past the age of 65 years, potentially leading to sarcopenia (41).

According to the ESPEN Group, individuals over 65 years of age should consume at least 1.0–1.2 g per kg body weight per day, and as much as 1.2–1.5 g/kg/d in the presence of acute or chronic diseases (42). Recent evidence suggests that consumption of milk protein in combination with resistance training is more effective at improving muscle strength compared to vegetable protein (43).

Other nutrients contained in milk, such as calcium, phosphorus, and vitamin D, are of great importance in the elderly as they play both structural and functional roles in bone and muscle, thereby reducing the risk of falls and fractures (44,45).

Recent studies also suggest that another milk trace component, nicotinamide riboside, a niacin-derived substance (vitamin B_3), may act on NAD metabolism and sirtuins, which in turn possess anti-aging properties (46).

Are there specific indications or contraindications regarding the consumption of milk by [professional or amateur] athletes?

Milk may play an important role in supporting competitive and amateur sports activities as a source of protein and minerals during recovery after exercise. The simple carbohydrate (lactose) content in milk (50 g/l) is similar to that of many drinks specifically formulated for sports, containing glucose or maltodextrin, which are quickly absorbed from the gut. Milk also presents a high concentration of electrolytes, which can replace those lost with sweat during exercise: The rehydrating capacity of skim milk after training is comparable to that of hydrosaline sports drinks (47). Furthermore, a recent study in physically active men demonstrated that skim milk performed better than other drinks (milk, water, sports drinks) in restoring and maintaining water balance after exercise and loss of fluids due to heat exposure (48).

In addition, the consumption of 250–500 ml of milk in the first hour after training may promote muscle recovery and contribute to increasing muscle mass. Subjects who ingested 500 ml of skim milk immediately after resistance training maintained anabolic activity, resulting in increased protein synthesis in muscles (49). Similar results were also obtained by other authors, who propose low-fat milk as a safe and effective "sports drink" (50).

What is the relationship between milk consumption and bone mass, osteoporosis, and risk of fracture?

Protein, calcium, phosphorus, magnesium, manganese, zinc, and vitamin K, provided in good amounts by cow's milk and dairy products, are necessary to build a solid skeletal system in infancy and adolescence and to maintain bone structure during adulthood (51).

According to the results of a meta-analysis, consumption of milk and derived products (with or without vitamin D supplementation) increases calcium concentrations in both the bloodstream and the lumbar spine in children with low basal milk intake (but not in children with high milk consumption) (52). Moreover, the inadequate supply of calcium and phosphorus associated with low milk consumption during childhood and adolescence has been linked with an increased incidence of osteoporotic fractures among older women (53).

Furthermore, magnesium, which is also provided by cow's milk, may be more important than calcium for bone development in children and adolescents (except for those with a very low calcium intake) (54).

In adults, consumption of diets providing adequate amounts of protein, calcium, phosphorus, and vitamin D reduces bone resorption, slowing down age-related bone loss (44).

Most likely due to the complex interactions regulating bone metabolism and the availability of nutrients with different food sources, the published evidence of a clear relationship between milk consumption in adulthood and the risk of osteoporosis and risk fractures in later years is not entirely consistent (55). However, according to a systematic review of the literature, both milk and calcium are positive determinants of bone health in adults (56). Furthermore, the available data are mostly in favor of a positive role of milk and calcium in bone mass maintenance and of selected dairy sources of calcium in the reduction of the risk of hip fractures (57,58). On the contrary, there is no evidence of plasma acidification following milk consumption (a concept rather widespread on the Web and among the "no milk" movement), or of the release of calcium by the bone matrix aimed at buffering such purported plasma acidification (59).

Further studies should establish the actual effectiveness of vitamin D-enriched dairy products in increasing the protective effect of vitamin D on the risk of fractures.

An additional benefit at the skeletal level could be provided by milk proteins (in particular whey proteins), by stimulating the release of IGF-1 and by promoting GH metabolism in bones, also in old age (60).

Milk allergy and lactose intolerance: how can we frame the problem and what are the most appropriate strategies for mitigating its effects?

Lactose intolerance and milk allergy are often confused by the lay public, despite their different pathophysiology and clinical consequences.

Milk allergy is especially common in infancy and represents one of the most common allergies, together with egg allergy; its prevalence is about 2%–3% of children in the first year of life and then decreases with age (61). One or more cow's milk proteins (casein or serum albumin) usually trigger milk allergy. The reaction is often shared by milk of other animal species, with the risk of cross-reactivity (62).

The allergic reactions are mediated by immunoglobulin (Ig) E in about half/two-thirds of cases and by non-IgE-mediated mechanisms in the remaining cases. In IgE-mediated allergies, symptomatology can range from skin reactions of varying intensity to potentially fatal, but rare, anaphylactic shock (63). Non-IgE-mediated reactions, to the contrary, usually cause gastrointestinal disorders, often difficult to interpret (64).

Lactose intolerance, on the other hand, is caused by the absence, or the reduction, of lactase (beta-galactosidase) activity, necessary to hydrolyze lactose and subsequently promote monosaccharide absorption (6). Lactase deficiency (also defined as lactase nonpersistence) affects about 70% of the world's adult population and often emerges in adolescence or during adulthood. The reduced digestion of lactose due to lactase absence/deficiency is therefore very frequent, except in northern Europe or North America, where lactase persistence is most common (65). If not digested, lactose remains in the lower intestine, where it calls for water by osmosis and is metabolized by the local microbial flora, with formation of water and gas (CO_2 and hydrogen) in quantities related to the amount of lactose consumed and to the extent of lactase deficiency. This results in cramping, abdominal pain, bloating, and diarrhea (66). When it is deemed necessary by the clinician, lactose malabsorption can be diagnosed by administering 20 or 50 g of lactose in the fasted state: High levels of breath hydrogen, caused by the bacterial fermentation of undigested lactose, confirm the lactase deficiency. However, an increase in breath hydrogen merely indicates lactose malabsorption, whereas for diagnostic purposes, specific symptoms associated with bacterial fermentation of undigested lactose must be observed (67). Many patients, on the other hand, report symptoms even in the absence of markers of malabsorption (the peak of exhaled hydrogen).

Individuals with a diagnosis of lactose malabsorption will not necessarily develop symptoms when consuming lactose containing food. In fact, symptom appearance may be affected by the absolute amount of lactose ingested, the residual activity of intestinal lactase, and the gastric emptying speed, the intake of lactose containing foods, the lactose fermentation rate by intestinal microbiota, and the individual sensitivity to lactose fermentation products.

Available data, reviewed by, indicates that adults and adolescents with lactose malabsorption can generally ingest up to 12 g of lactose administered in a single dose (equivalent to the lactose content of a cup of milk) without unpleasant effects or with mild ones; however, sensitivity may greatly vary across individuals. Tolerance is generally greater if lactose is consumed with meals and in smaller doses (68). Frequent lactose ingestion may increase the amount of lactose tolerable by adults and adolescents, but the data remain highly controversial.

The use of lactose-free milk and/or lactose-free dairy products, or even of lactase before meals, allows lactose-intolerant individuals to consume milk and milk derivatives without gastrointestinal symptoms. In general, ripened cheeses contain minimal amounts of lactose, and lactase produced by yogurt lactobacilli can contribute to the digestion of lactose consumed in yogurt (a so-called "post-biotic" effect).

Is there any relationship between cow's milk consumption and risk of overweight, obesity, and type 2 diabetes in adults?

Bioavailable calcium, branched chain amino acids, conjugated linoleic acid, proteins, and to some extent vitamin D, present in milk, have been correlated to a reduced risk of obesity (69,70). Several studies suggest that calcium can regulate body weight and fat mass, by reducing de novo lipogenesis, increasing lipolysis, or interfering with the absorption of dietary fat via the formation of insoluble soaps in the intestine (71). Milk proteins, on the other hand, may regulate weight by stimulating thermogenesis, increasing satiety, and preserving or increasing lean body mass (72).

However, evidence provided by epidemiological and intervention studies does not support this purported protective role of milk consumption in obesity: Controversial results have been obtained in the available studies, likely due to the variability of experimental designs, the different parameters evaluated, and the volume of milk servings considered (73). Additionally, in studies where a protective effect on weight is observed, this is modest and not clinically significant.

The absence of a correlation between milk intake and body mass index (BMI) has been confirmed by two recent prospective studies (74,75).

The results of meta-analyses are ambiguous. According to the analysis of 16 observational studies, both prospective and cross-sectional—on children and adults—milk consumption may reduce the risk of obesity by 13% in children and 23% in adults (76). However, when cross-sectional and prospective studies were analyzed separately, the protective effect of milk consumption on obesity risk remained significant for cross-sectional studies only. On the other hand, a reduction of both fat mass and risk of becoming obese has been raised by another meta-analysis of 10 studies on children and adolescents (77). It can be concluded that milk consumption within adequate diets does not negatively affect body weight, and associations with a reduction in body weight were only found in cross-sectional studies, but not in prospective ones.

With regard to the risk of developing type 2 diabetes, a reduction of about 10% was found in subjects who consumed the highest amounts of milk (either total or low fat) compared to those with the lowest consumption levels (78). These results are confirmed by another meta-analysis reporting that the relative risk of type 2 diabetes was reduced by 11% in subjects who consumed 200 g/d of low-fat milk (79). The effect was attributed to low-fat milk, however, not to the same amount of whole milk and total milk consumption (80). In a report and meta-analysis including a large cohort of healthy men and women participating in the Health Professionals Follow-up Study and Nurses' Health Study I and II, whole milk consumption did not modify the risk of type 2 diabetes, which was reduced by 17% by a 1-serving increase of yogurt (81). Finally, a meta-analysis of prospective studies, which analyzed about 580,000 subjects, reported a slight reduction in the incidence of type 2 diabetes associated with the consumption of total dairy products and, especially, of yogurt and low-fat milk (in two studies, however, that were not adjusted for confounding variables) and no significant association with other types of milk (82).

According to these findings, the protective effects of milk appear to be more relevant to the development of type 2 diabetes. Current evidence excludes an unfavorable effect of milk consumption on the risk of developing and type 2 diabetes.

Is there any correlation between cow's milk consumption and the risk of developing cardiovascular or cerebrovascular diseases?

Both within the general population and medical community there is a widespread belief that consumption of milk (namely, whole milk) is associated with an increase in cardiovascular or coronary risk. This is probably due to the high proportion of saturated fatty acids in milk (about 70% of the total lipid fraction), which are known to increase LDL cholesterol levels, a recognized risk factor for coronary heart disease (2).

Yet the most recent meta-analyses and reviews seem to exclude an effect of milk consumption on cardiovascular risk. Coronary risk is generally unchanged or not significantly increased by milk intake, while the risk of cerebrovascular events (e.g., stroke) is generally reduced. For example, two meta-analyses by Soedamah-Muthu and colleagues observed a reduction of cerebrovascular events, and no effect on coronary risk, in association with milk intake (83).

A reduction in stroke risk (−9%) and a neutral effect on coronary events also emerge from another meta-analysis, which evaluated the effect of milk and dairy products (mainly cheese and yogurt) (84). However, a more recent meta-analysis by Larsson and colleagues did not report a clear association between milk consumption and the risk of cardiovascular events, possibly because of the high heterogeneity observed among the studies considered (85). However, even the presence of a gene encoding for lactase persistence inducing higher milk consumption (about 400/500 ml per week) was not associated with any change in coronary risk in a recently published Mendelian randomization study (86).

The absence of effects on coronary risk of milk intake, despite its saturated fat content, fits with the lack of effects by saturates on coronary risk, as evidenced by the most recent meta-analysis on the subject, confirming that milk fatty acids (including some conjugated linoleic acid isomers, CLA), originating in the rumen, do not seem to affect coronary risk or all-cause mortality (87). Short-chain saturated fatty acids (from 4 to 10 carbons), which are also typical of milk, would also have a moderately protective effect on coronary risk, according to a European study (88).

Plasma levels of odd carbon atoms fatty acids (biomarkers of milk consumption) are associated with a reduction in the risk of stroke and myocardial infarction in American and Swedish cohorts (88,89).

In addition, it has been suggested that some milk components (calcium and tripeptides that can be cleaved from casein and/or whey proteins) lower systolic and diastolic blood pressure (90). A significant effect of milk intake on blood pressure, on the other hand, has not been confirmed by a recent Mendelian randomization (91).

Is there a correlation between the consumption of cow's milk and cancer?

A supposed association between cow's milk (and its derivatives) consumption and the incidence of specific cancers is often emphasized by public opinion. Different mechanisms of action have been hypothesized to explain these possible associations (both protective and unfavorable); however, there is no clear epidemiological evidence in this regard.

According to one theory, calcium would interfere with vitamin D metabolism and, in association with IGF-1, would increase the risk of cancer in specific anatomical sites, such as the prostate (92). According to another hypothesis, calcium could reduce cell proliferation and stimulate differentiation and apoptosis of cells in the gastrointestinal mucosa and breast; moreover, it could eventually bind to bile acids and fatty acids produced by bacterial fermentation in the colon, limiting its contact with the colon wall (93). The suggested specific toxicity of galactose to ovarian epithelial cells and role of this sugar in promoting neoplastic proliferation in these cells has been suggested, but has not been confirmed by a large population-based case-control study assessing possible relationships between milk component intakes and cancer risk (94).

As a matter of fact, the results of epidemiological studies are quite clear. One of the most relevant publications on the topic—based on the results of an Italian multicenter study that included 8,000 cases matched to controls—did not observe significant associations between milk consumption and total tumor incidence (95). Similarly, a recent meta-analysis of four prospective studies did not report this association (85,96).

Other studies have examined the correlation between milk consumption and the incidence of tumors in anatomic sites or specific organs. Specifically, a meta-analysis of 32 prospective studies reported a modest excess of prostate cancer risk associated with an increased consumption of 200 g/d of total and skimmed milk (risk ratio [RR] = 1.03, 95% confidence interval [CI] 1.00–1.07) (97). Another meta-analysis of 19 cohort studies by the same authors reported a modest reduction in colorectal cancer risk, again associated with a milk consumption of 200 g/d (RR = 0.91, 95% CI 0.85–0.94) (98). A protective association between consumption of total dairy products, milk, cheese, and dietary calcium intakes and the incidence of colorectal cancer has been established in 2017 by the World Cancer Research Fund International, within the Continuous Update Project, an ongoing program to analyze global research on how diet affects cancer risk and survival. A modest direct association with prostate cancer and an equally modest inverse association with colorectal cancer were also identified in the aforementioned Italian study.

Regarding breast cancer, the consumption of dairy products does not appear to be associated (either positively or negatively) with significant variations in the risk of this type of tumor, as evidenced by two meta-analyses, one of more than 20 studies involving over 350,000 women with an average follow-up of 15 years (99) and another taking into account 18 cohort studies, involving 1,063,471 participants and 24,187 cancer cases (100). Only in the most recent meta-analysis was a reduction in the risk of cancer associated with low-fat dairy product consumption (excluding milk), especially in premenopausal women. Furthermore, no evidence is available justifying that milk consumption modifies the prognosis of breast cancer patients (101).

As far as ovarian cancer is concerned, an analysis of the original data from 12 cohort studies did not report significant association with milk for a consumption of 500 g/d (RR =1.11, 95% CI 0.87–1.41) (102). Moreover, a recent Mendelian randomization study did not identify differences in the risk of ovarian cancer in relation to lactase persistence (the ability to release galactose from lactose) or absence (where galactose is not released from lactose) (103).

In conclusion, the available data suggest that milk consumption is not associated with either risks or protective effects on cancer incidence. A modest direct association between milk consumption and incidence of prostate cancer and an inverse correlation with colorectal cancer have been reported. Milk consumption does not appear to affect the risk of developing breast cancer or the evolution of the disease in affected women.

Conclusions

Cow's milk (and dairy products), due to their composition, can facilitate the appropriate intake of some important macro- and micronutrients throughout life.

The available evidence from the scientific literature suggests that the vast majority of associations between milk consumption and health are favorable. This especially applies to the early stages of life, where the relationship between milk and dairy products consumption and bone mass is evident.

There are neutral or favorable associations between milk consumption and the risk of overweight, obesity, diabetes, or cardiovascular disease (with a possible protective effect on stroke risk).

Cancer risk does not appear to be affected by milk consumption, with small effects—in opposite directions—for colon and prostate cancers.

Milk, if consumed according to guidelines and within a balanced diet, can continue to be part of human diet.

Conflicts of interest

All the authors have subscribed to a conflict of interest declaration on the topic of this article. Andrea Poli and Franca Marangoni are respectively president and responsible for research of NFI, a nonprofit organization partially supported by 18 food companies.

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