

MILK CONSUMPTION IN 5-11-YEAR- OLD CHILDREN AND THE ASSOCIATED HEALTH BENEFITS

Introduction

By Dr Benjamin P. Green & Dr Penny L.S Rumbold

Childhood is a significant phase in human life. During the ages of 5-11 years (primary school-age), children grow and mature at a rapid rate preceding the onset of puberty. Good nutrition for the childhood period is therefore particularly necessary to support proper growth and maturation and is also the foundation for immediate and lasting health, well-being and disease prevention. This may be achieved by consuming a balanced and varied diet that provides all the nutrients needed.

Milk is seen as a food of great value. It is naturally nutrient rich and is a major source of many essential nutrients. Including milk as a staple component of a healthy balanced diet has therefore been long recognised and recommended. Because of its large contribution to nutritional intakes, milk is often described as nature's perfect food. It is a readily available, accessible and an affordable means of providing high-quality nutrients. At present, there are many public misconceptions about the benefits of milk.

Scientific evidence has reported that adequate milk consumption may help in the protection against the development osteoporosis, hypertension, obesity, as well as cardiovascular disease. Emerging data also shows that milk may have a role in overall dietary quality, appetite control, hydration and cognitive function.

The overarching aim of this resource is therefore to review and summarise the scientific literature to provide an accurate, evidence-informed evaluation of the potential nutritional and health-related benefits of milk consumption in children aged 5-11-years old. In particular, the resource will focus on key areas related to nutrition and health, reporting on the variety of benefits milk purportedly offers including nutritional status, cognitive function, hydration, dental and bone health, physical stature, body composition, metabolic syndrome and appetite control. Throughout the resource, current gaps and future research directions will be alluded to.

To identify relevant original research articles concerning the associated health benefits of milk consumption in children (5-11 years), a systematic search of literature was performed. The search was performed using an online repository (PubMed) that archives publicly accessible full-text scholarly articles. Electronic data base searches were conducted in May 2016 using various combinations of keywords relevant to the scope of the review. Following an initial search, a total of $n = 2444$ abstracts were located and reviewed. Of these, 2203 were excluded following initial screening due to issues associated with methodological approaches, duplication and language. Two hundred and forty-one full text articles were

assessed further for eligibility. From this, a total of 80 published articles met criteria for inclusion in the review, the results of which were classified into 9 categories: 1) milk and nutritional status ($n = 12$); 2) milk and cognitive function ($n = 3$); 3) milk and hydration status ($n = 3$); 4) milk and dental health ($n = 3$); 5) milk and bone health ($n = 7$); 6) milk and physical stature ($n = 12$); 7) milk and body mass and/or composition ($n = 27$); 8) milk and the metabolic syndrome ($n = 8$); and 9) milk and appetite regulation ($n = 5$).

As a guide, the following terms have been used throughout this resource.

BMI: Body mass index. An approximate measure of whether someone is over- or underweight.

Cross-Sectional: Observational study involving data analysis collected from a population at a specific time point.

Prospective: Watch for outcomes, such as the development of a disease, during a determined period and relates this to other factors such as suspected risk or protection factor.

Retrospective: Longitudinal study that studies a cohort of individuals who share a common exposure factor to determine its influence on the development of a disease.

Intervention: Randomised trial where participants are assigned groups: an experimental group receiving the intervention and a comparison group (controls) which receives a conventional treatment or placebo.

MILK COMPOSITION AND RECOMMENDATIONS

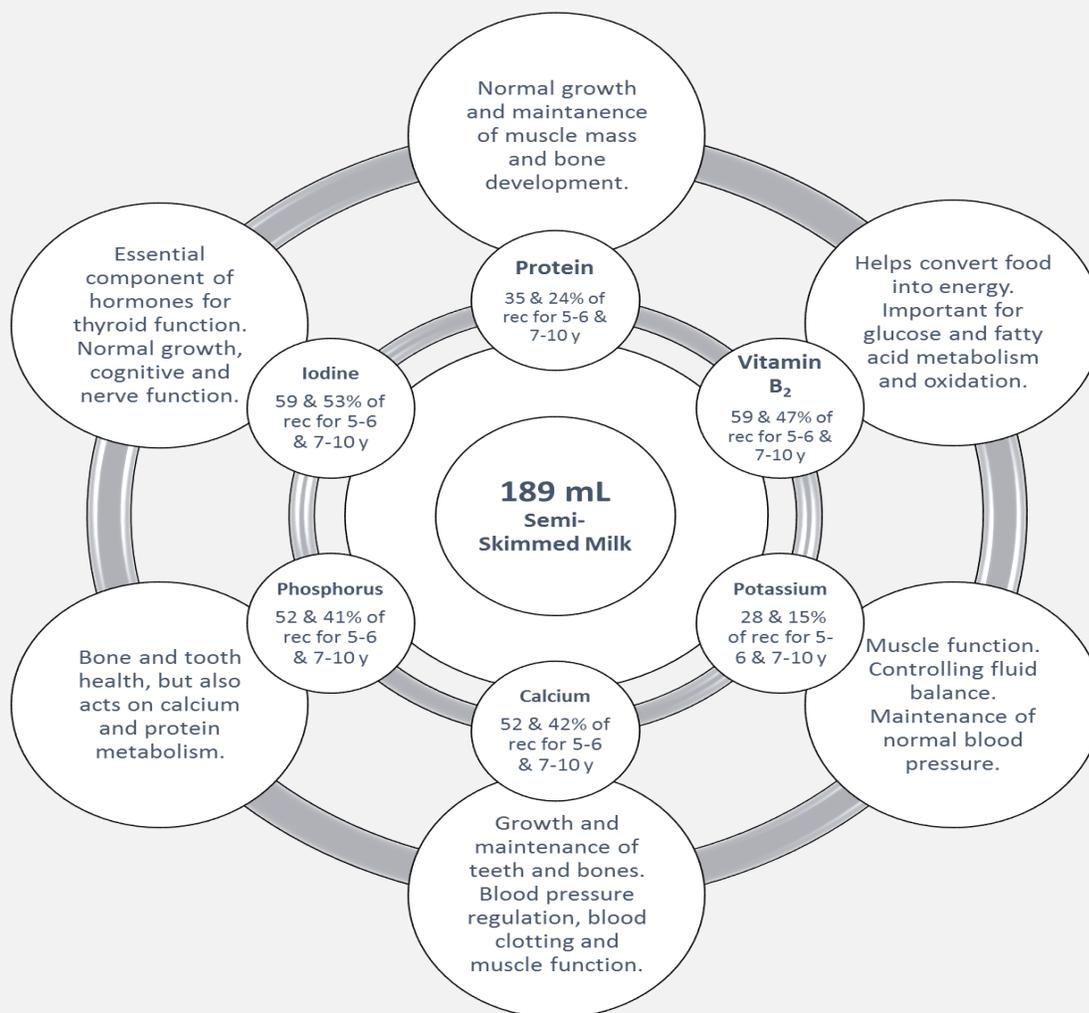
The composition of milk is approximately 87% water and 13% solids. Overall, the calorie content of milk is primarily dependent on the amount of fat, but may also be influenced by added sugars and sweeteners. For example, a **200 mL** serving of whole milk (3.5% fat) delivers 136 kcal, semi-skimmed milk (1.7% fat) delivers 95 kcal, skimmed milk (0.1% fat) delivers 70 kcal and flavoured milk (1% fat) delivers 132 kcal. As mentioned, milk is a naturally rich source of many essential nutrients. It contains a complex mixture of proteins, fats, and carbohydrates, in addition to providing high-quality vitamins and minerals with no artificial preservatives or colourings and is therefore child-friendly. Even the smallest serving of milk can make a significant contribution to daily nutrient requirements.

A 189 mL portion of semi-skimmed milk, for example, provides essential macro and micronutrients (as depicted in **Figure 1.0**) to diets of 5-11-year old children. Milk, therefore, plays a significant role in helping children meet multiple nutrient intake recommendations. For this reason, sufficient intakes of milk are encouraged particularly during childhood to help avoid any micronutrient deficiencies that may incur unfavourable nutritional and health-related implications. With the exception of vitamin C (which is broken down during pasteurisation), milk is a source of many vitamins and minerals (some that can only be obtained through the diet).

To highlight this, **Table 1.0** displays the nutritional composition of semi-skimmed milk (specific to the UK) and the nutritional contribution 189 mL of semi-skimmed milk makes to the diets of 5-11-year-old children, in comparison to recommended nutrient intakes.

FIGURE 1.0.

KEY NUTRIENTS PROVIDED IN 189 mL GLASS OF MILK. NOTE: rec = recommended, where percentages relate to reference nutrient intakes of children 5-11 years.



	Recommended Nutrient Intake (5-11 y)			Milk [‡] Per 189 mL	Percentage Contribution [‡]			Percentage Contribution [‡]		
	Boys: girls 5-6 years	Boys: girls 7-10 years	Boys: girls 11 years		Semi Skimmed Milk	Boys 5-6 years	Boys 7-10 years	Boys 11 years	Girls 5-6 years	Girls 7-10 years
Energy (kcal)	1530: 1420	1815: 1700	2125: 2030	89.8	5.9%	4.9%	4.2%	6.3%	5.3%	4.4%
Protein (g)	19.7	28.3: 28.3	42.1: 41.2	6.8	34.5%	24%	16.2%	34.5%	24.0%	16.5%
Carbohydrate (g)	204: 189	242: 227	283: 270	9.2	4.5%	3.8%	3.2%	4.9%	4.0%	3.4%
which sugars (g)	19	24	28	9.2	48.2%	38.2%	32.7%	48.2%	38.2%	32.7%
Fat (g)	59.5: 55.2	70.6: 66.1	82.6: 78.9	3.3	5.6%	4.7%	4.0%	6.0%	5.0%	4.2%
of which saturates	17: 15.8	20.2: 18.9	23.6: 22.5	2.2	12.8%	10.8%	9.2%	13.8%	11.5%	9.7%
Calcium (mg)	450	550	1000	233.4	51.9%	42.4%	39.4%	51.9%	42.4%	43.0%
Riboflavin (mg)	0.8	1.0	1.2: 1.1	0.5	59.1%	47.3%	39.4%	59.1%	47.3%	39.4%
Vitamin B ₆ (mg)	0.9	1.0	1.2: 1.0	0.1	12.6%	11.3%	9.5%	12.6%	11.3%	11.3%
Vitamin B ₁₂ (µg)	0.8	1.0	1.2: 1.2	1.8	224.4%	179.6%	149.6%	224.4%	179.6%	149.6%
Vitamin C (mg)	30	30	35	3.8	12.6%	12.6%	10.8%	12.6%	12.6%	10.8%
Retinol (µg)	400	500	600	36.9	9.2%	7.4%	6.1%	9.2%	7.4%	6.1%
Sodium (mg)	1200	2000	2400	84.1	7.0%	4.2%	3.5%	7.0%	4.2%	3.5%
Potassium (mg)	1100	2000	3100	303.3	27.6%	15.2%	9.8%	27.6%	15.2%	9.8%
Magnesium (mg)	120	200	280	21.7	58.6%	53.3%	45.1%	58.6%	53.3%	45.1%
Phosphorus (mg)	350	450	775: 625	183.3	52.4%	40.7%	23.7%	52.4%	40.7%	29.3%
Zinc (mg)	6.5	7.0	9.0	0.8	11.6%	10.8%	8.4%	11.6%	10.8%	8.4%
Iodine (µg)	100	110	130	58.6	58.6%	53.3%	45.1%	58.6%	53.3%	45.1%

TABLE 1.0.

Reference nutrient intakes for selected nutrients, nutritional composition semi-skimmed milk (189 mL) and the nutritional contribution made to the diet of 5-11-year-old children.

*NOTE: n/a = values not available for this food; [n] = values have been estimated; Trace = nutrient is present in less than 0.1g per 100g. *non-milk extrinsic sugars (NMES). ‡ Adapted from the Dairy Council, UK. Available at: <http://www.milk.co.uk/publications>.

VITAMINS AND MINERALS

The nutrients outlined in **Table 1.0** are vital in a child's diet and assist with proper growth and maturation but also contribute to overall health and dietary quality. In the UK, recommendations and advice on milk intake for children are broad and encourage a 'moderate amount' with no specific suggestion given about serving sizes. Based on evidence from the UK's dietary surveillance data, the total amount of milk consumed daily has remained stable over the past ten years in children. In particular, milk contributed 8%, 12%, 5% and 10% to total daily energy, protein, carbohydrate and fat intake, respectively. Milk also made a substantial contribution to and was the primary dietary sources of, calcium (29%), iodine (37%), Vitamin B2 (30%), magnesium (10%) and potassium (14%).

Despite the apparent importance of milk in the everyday diet, intakes steadily decline as children age. This is not just a trend reported in the UK. It is also true in America and other European countries. Establishing and shaping healthy eating habits during this period is, therefore, vital. Dietary habits formed throughout childhood and adolescence progress through to adulthood and for that reason a healthy school food environment is crucial. Therefore, we must continue to promote the consumption of milk for its many health benefits, and school milk is a great way of doing this. This is of particular importance for primary school-age children considering 35% to 40% of their daily nutritional needs are met at school.

In school, there are a variety of beverages on offer to children including fruit juices, water, sugar-sweetened beverages and milk. However, these other drinks do not provide the various nutrients found in milk. Milk is a natural source of calcium, vitamin B12, Vitamin B2 (riboflavin), phosphorus, potassium and iodine. It also contains smaller amounts of other nutrients including vitamin A, niacin, folate, Vitamin B6, magnesium, selenium and zinc. The nutrients present in milk are involved in many important functions in the body. For a thorough depiction of the role of these nutrients in the body, among others, see **Table 2.0**.

VITAMIN	ROLE IN BODY	MINERAL	ROLE IN BODY
FAT SOLUBLE VITAMINS			
Vitamin A	Vitamin A is an antioxidant that supports formation and maintenance of healthy skin and teeth. It is also important for the promotion of good vision.	Sodium	Sodium is needed by the body to maintain normal blood pressure, and muscle and nerve function.
Vitamin D	Vitamin D is needed to help absorb calcium and phosphorus. It also helps build strong bones.	Iron	Iron is essential for transferring oxygen through the body. It is also important for blood production.
Vitamin E	Vitamin E is another antioxidant and helps maintain normal immune function.	Potassium	Potassium is important for normal heart function, fluid balance, nerve transmission, and muscle contraction.
Vitamin K	Vitamin K plays a role in bone health and most importantly contributes to normal blood clotting. It also aids fat digestion.	Calcium	Calcium is needed for bone and teeth formation, blood clotting, and nerve transmission. It also creates and maintains skeletal structure, and muscle contraction.
Vitamin B1 – Thiamine	Vitamin B1 is needed to produce adenosine triphosphate (ATP), the main energy source for all cells. It also plays a role in many metabolic reactions.	Phosphorous	Phosphorus works alongside calcium to help build strong teeth and bones. It also helps with normal energy formation.
Vitamin B2 – Riboflavin	Vitamin B2 helps the body convert food into energy. It is also important for glucose and fatty acid metabolism and oxidation.	Chlorine	Chlorine is an important part of our extracellular fluids.
Vitamin B3 – Niacin	Vitamin B3 helps the body convert food into energy. It is also important for glucose and fatty acid metabolism and oxidation.	Selenium	Selenium helps produce antioxidant enzymes that help prevent cell damage.
Vitamin B6 – Pyridoxine	Vitamin B6 helps the body convert food into energy. It is also important for normal brain development, hormone production and normal nerve function.	Iodine	Iodine is an essential component of hormones for thyroid function. It also contributes to the normal growth, cognitive and nerve function of children.
WATER SOLUBLE VITAMINS		Copper	In the body copper helps absorb iron and both works alongside one another to aid red blood cell production.
Vitamin B5 – Pantothenic acid	Vitamin B5 helps the body convert food into energy. It is also important for making red blood cells and hormone production.	Zinc	Zinc is needed for cell growth, wound healing and carbohydrate metabolism.
Vitamin B9 – Folic acid	In the body folic acid is needed for normal brain and mental health. It also help the synthesis of DNA and RNA.	Chromium	Chromium helps with insulin action and blood sugar regulation. It also helps with cellular glucose uptake, fat and protein metabolism.
Vitamin B12 – Cobalamin	Vitamin B12 helps the body convert food into energy. It is also important for normal brain function and making red blood cells.	Magnesium	Magnesium aids blood sugar regulation, energy and protein production. It also helps maintain normal muscle and nerve function, a healthy immune system and keeps our bones strong.
Vitamin B7 – Biotin	Vitamin B7 helps the body convert food into energy. Vitamin B7 is also needed for building amino acids and fatty acids.		
Vitamin C	Vitamin C is needed for growth and repair of tissues. It is also helps produce collagen, which helps the body make skin, blood vessels, cartilage and ligaments.		

TABLE 2.0.

Table displaying vitamins and minerals, and the role they play in the human body.

MILK and

NUTRITIONAL STATUS

Cross-sectional data suggests regular milk intake improves the overall dietary quality of children's diet.

People generally associate milk consumption with calcium and bone building properties, however, as evidenced throughout **Table 2.0** milk is a food of rich nutritional value. Nutritionally, milk is considered a powerhouse and studies in children demonstrate that regular intake of milk improves overall dietary quality.

Many observational and intervention studies in children have reported that a dietary pattern characterised by high milk consumption (both plain and flavoured milk) leads to significantly greater intakes of energy, protein, phosphorus, magnesium, calcium, potassium, vitamin A, zinc, riboflavin (vitamin B₂), and niacin. In fact, some researchers have concluded that milk intake may act as a primary indicator of diet quality. Indeed, the importance of regular milk consumption concerning nutritional status and nutrient intake has been recognised for over 40 years (in an early study assessing the contribution of school milk to the nutrition of primary school children). It has also been observed that high milk intakes while providing an abundance of nutrients, may also limit the intake of foods and beverages high in fat and sugar. In studies of Dutch and American children, for example, milk intake was inversely related (as one variable increases, the other decreases) with the intake of sugar-sweetened beverages.

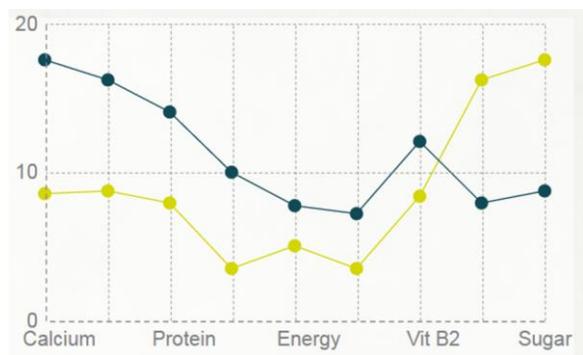
In these studies, children who displayed low milk intakes had lower protein, fibre, calcium, magnesium, potassium and phosphorus intakes.

A study of 151 girls who were followed from age 5 through to 11 years showed that although total dairy intake remained stable, milk consumption (as a beverage) declined. Consequently, decreased milk consumption resulted in nutritional inadequacies where suboptimal intakes of calcium and phosphorus were observed between the ages of 9 and 11 years. Similarly, studies have shown that milk consumption decreases biennially throughout childhood, and appear to be replaced with alternative foods and beverages such as sugar-sweetened drinks. As mentioned earlier in this resource, low milk intake has significant implications for intakes of several key nutrients that are of great importance during childhood. Based on the nutritional contribution to dietary intakes, it is important to note that children who drink milk regularly are more likely to meet dietary recommendations for many nutrients, and thus have a better nutritional status. So much so it is very difficult for individuals to meet nutrient requirements of the many nutrients outlined in **Table 1.0** if milk is absent from the diet.

In recent years, there has been increasing concerns about the added sugars found in certain foods and beverages. As a result, some schools have taken action and have begun to limit access to foods and beverages that are high in added sugars. Consequently, this has included flavoured milks, which may have been counterproductive. Studies assessing the removal of flavoured milk from the school environment have observed reduced overall calorie and sugar intake, but also reported that children suffered a loss of essential nutrients. In one study, the removal of flavoured milk also reduced the overall intake of plain milk significantly.

In particular, the total consumption (both plain and flavoured) of milk decreased by 12.3%. The nutritional implications of this must be taken into account. A recent review published in a reputable scientific journal concluded that children who drink more flavoured milk generally have higher milk intakes. Interestingly, in children, the consumption of flavoured milk showed nutritional intakes similar to children who only drank plain milk. In all of these studies, greater milk consumption (plain and flavoured) was associated with higher daily energy intake, yet intakes did not negatively impact on body weight or fatness. Consequently, if daily calorie intake is of concern (for example in children predisposed to overweight and obesity), results of a recent study indicate that replacement of whole-milk or semi-skimmed milk with skimmed milk may help reduce total daily energy intake, without impacting on the provision of beneficial nutrients.

Overall, findings from all twelve available studies confirm that the consumption of milk (plain and flavoured) significantly improves nutritional status and might be a marker for healthier eating habits. This, therefore, demonstrates the need for the continual promotion of milk intake in primary school-aged children to help prevent nutritional inadequacies, but also promote healthy eating behaviours. Consequently, increasing milk intake among all children (5-11-years old) should continue to be a major focus of nutritional interventions, especially within the school environment. Based on the methodological approach exercised by the studies included in this section, there appears to be a need to assess to the influence of milk consumption on nutritional status in controlled studies.



MILK and

COGNITIVE FUNCTION

Early findings from intervention studies suggest milk may have a beneficial effect on cognitive function in children.

Anecdotal evidence suggests links between the food we eat and cognitive function, however, very few studies have assessed this relationship in children. Compared to children with better dietary quality, those with nutrient poor diets demonstrate decreased attention and academic performance. Aside from improving nutritional quality and eating behaviours, there is some emerging evidence that milk may positively influence cognitive function in children.

In a recent study involving 40 children (mean age 11 years), the effects of a carbohydrate drink, a milk drink or a combination of both on subsequent cognitive function (processing speed, memory, attention and perceptual speed) in children was assessed over a 3-hour period. Results showed that short-term memory was improved when milk was consumed. In this sense, children were able to recall 0.7–0.8 more words compared with 0.5 fewer words after the carbohydrate drink. However, it is interesting to note that this effect was only seen in girls and not in boys. Similarly, in a larger study involving 469 boys and girls, conducted to evaluate the effects of daily mid-morning milk consumption on physical, mental and school performance children consumed 250 mL of semi-skimmed milk at break time daily for 12-weeks. At the end of the 12-week period, the researchers found that a school feeding scheme focusing on daily milk intake had beneficial effects on the school performance of children. Interestingly, as stated above, this effect was strongest among girls.

Although conducted using an adolescent cohort, results of a Korean study illustrated that high intakes of milk were positively associated with academic performance. In addition, adolescents with high milk intakes expressed increased motivation for learning.

The mechanisms for the beneficial effects of milk on improved cognitive function are unclear. Reasons facilitating these observations may relate to the blood glucose response following consumption. However, it may also include the micronutrient content of milk. In this sense, low intakes of vitamin B₁, folate and vitamin B₁₂ affect short-term memory and impair learning, causing low cognitive scores and development in primary school age children. In addition, low iron and riboflavin intake may adversely affect motor skill development and psychomotor performance. All of these nutrients are heavily present in milk.

Based on the three available intervention studies, milk appears to be an attractive drink to offer children throughout the school day. Although the above studies did not measure overall academic achievement, these findings have relevant educational implications. One could assume that if daily milk intakes were maintained for an extended period of time it may subsequently result in better classroom behaviour and consequently impact on learning and academic achievement. These, however, are yet to be fully assessed especially in children. Due to the lack of studies, however, there remains a large scope for further research and conclusions to date should be taken cautiously.



MILK and HYDRATION STATUS

Early findings suggest milk helps improve the hydration status of children, however, more school-based intervention studies are required

The human body is made up of approximately 60% water. Water plays a vital role in many body functions. The body is unable to store water, so it is important we have a constant supply to replenish fluid losses and prevent dehydration. Not only does milk provide us with an abundance of essential nutrients, but it is also composed of 87% water. Milk is, therefore, a great beverage for hydration purposes. For children, staying hydrated is paramount for the maintenance of good health, but may also boost concentration and mental performance (cognitive function) while helping to reduce instances of headaches, constipation and other physiologic disorders. There is very little scientific research, however, in the area of milk and hydration, especially in children.

Children are at increased risk of dehydration compared to adults as they have relatively high fluid losses, high activity levels and are sometimes unable to recognise thirst. Children spend a vast majority of their time at school. Improved access to fluids in schools may help improve children's ability to learn by improving attention, concentration and short-term memory. Despite access to fluids during school hours (although this may be restricted) many children do not consume enough fluids. It is, therefore, essential that the fluids children choose to drink offer the best tool for hydration purposes. Evidence (primarily from exercise studies) shows that milk may hydrate better than water or alternative beverages.

A group of researchers in Canada, for example, tested the effect of milk on rehydration in children (7-11 years) compared to water or a carbohydrate-electrolyte drink (such as those commercially available in the supermarkets) after exercise in a hot condition. Immediately after exercise, children consumed one of the three drinks before resting for 2-hours. During this time the rehydration potential of the beverages was calculated. The results showed that milk consumption was more effective than both water or the carbohydrate-electrolyte drink at replacing fluid loss during exercise, thus improving hydration status. The same research group conducted a similar study and identified that the protein found in milk might be a factor responsible for the rehydrating potential of milk.

In another study, the primary aim of which was to establish the contribution of fruit and vegetable intake to hydration status, researchers had children record all foods eaten using a 3-day food diary alongside 24-hour urine samples. The research team found that regular consumption of fruit and vegetables made a substantial contribution to hydration status. Interestingly, the researchers also identified that milk consumption was a significant dietary predictor of hydration status. Nevertheless, it should be considered that while these findings suggest that milk helps improve the hydration status of children, there remains considerable room for further studies to clarify the role of milk in hydration, especially in a free-living school setting.



MILK and DENTAL HEALTH

Cross-sectional data suggests milk may offer protection against the development of dental caries (tooth decay) and supports dental health in children.

Our nutritional habits play a significant role in oral and dental health. Synonymous with bone health, milk contains multiple nutritional properties that offer anticariogenic properties to protect against dental caries development (tooth decay) and thus support dental health in children. Milk components thought to influence dental health include calcium, phosphorus and protein, which are found in high quantities in milk. Calcium is needed for bone and teeth formation, whereas phosphorus works alongside calcium to help keep teeth strong. Milk proteins (namely casein) act to prevent tooth enamel erosion and demineralisation of the tooth surface.



In the three studies suitable to the age criteria of this resource (5-11 years), they all report an inverse association between milk (and dairy) intake and the incidence of tooth decay. In a recent study, the association between milk and the development of dental caries was stronger for children with diets high in sugar, and may begin to suggest that milk offers a protective effect against the harmful effects of sugar. In another study, milk intake in 7-11-year-old children was also associated with a reduced incidence of dental caries at 11-15 years and supports the idea that dietary habits established and maintained during the school years (childhood years) may have longer-term effects on health outcomes.

The exact mechanism by which milk reduces the incidence of dental caries remains to be established. It is suggested, however, that calcium, phosphate and casein in milk may all play a role. When by-products of milk proteins react with calcium and phosphate at the tooth surface, they form complexes which promote remineralisation of the enamel. Nonetheless, all of the abovementioned studies have been of a cross-sectional nature. Therefore, a causal relationship between milk and dental health cannot be concluded. More research is certainly needed. Nonetheless, the available literature suggests that milk (and dairy foods), can help the incidence of dental caries and contribute to dental health in children. In an effort to reduce the occurrence of tooth decay, it is recommended children limit their consumption of sugary beverages (especially when not consumed with a meal), and increase consumption of milk.



MILK and

BONE HEALTH

Milk contains multiple nutritional properties that support childhood growth, and thus bone health, however study methods are diverse and therefore further research is required.

Childhood is a critical time for bone growth, and lasting bone health. Milk contains multiple nutritional properties that support childhood growth and has therefore long been encouraged as an important nutritional strategy for building strong bones and thus lasting bone health. Indeed, a 'bone healthy' diet is difficult to achieve without milk (and dairy) present. The benefits of milk consumption during childhood include increased bone mineral content (BMC) and bone mineral density (BMD), characteristics necessary for the prevention of bone-related diseases later in life (osteoporosis). In numerous trials, but not all, the beneficial effects of milk (and dairy) supplementation on BMC and BMD have been confirmed in children.

Many retrospective studies have found that milk consumption in childhood is related to better bone health. In two recent studies, school milk interventions increased total body and regional (forearm) BMC and BMD compared to children who drank milk seldom. In these studies, the beneficial effects of milk on bone health were observed in 435-757 children (aged 10-12 years) following daily school milk intake for 1-2 years.

Milk represents the best source of dietary calcium during childhood. In addition, milk delivers more protein, phosphorus and calcium per calorie than any other food, alongside magnesium, potassium and zinc. During childhood, the beneficial effects of milk on bone health in children are commonly attributed to calcium. However, many other nutrients including phosphorus and protein are needed for normal growth, and lasting bone health. In 5-11-year-old children (n = 99), for example, calcium supplementation for 10 months did not influence total body or regional BMC. In contrast, in an earlier study when milk (and dairy) was supplemented daily for 1 year (distributed to deliver 1200 mg calcium daily) lumbar (lower back) BMD increased compared to children who maintained their usual eating habits. Indeed, this may illustrate that calcium is not the sole driving force behind bone health and may indicate that other nutrients work together for bone growth, and thus lasting bone health. It is important to note, however, that children in the calcium supplementation study were already consuming near daily recommended amounts, which may illustrate intakes exceeding calcium recommendations (from either supplemental calcium or milk) offers no further benefit to bone health in children.

In several studies, it has been observed that children who avoid consuming milk characteristically exhibit low calcium intakes, short stature, increased fatness and lower BMC (and thus exhibit reduced bone health) compared to their milk drinking counterparts. Interestingly, in children (mean age = 8 years) who previously avoided milk, the introduction of milk to the diet increased not only habitual milk consumption but also increased total body BMC. Thus, it is never too late for children to start introducing milk into their daily diet.

It can, therefore, be concluded that maintaining adequate calcium intake during childhood is advantageous for the attainment of peak bone mass, which may be crucial in reducing the risk of bone-related diseases later in life. From the available evidence, it appears that milk (and dairy) is beneficial to bone health in children and whole foods may offer greater benefits than the equivalent amount of calcium in the form of supplements. It is important to consider, however, that the methods of the studies have been diverse and therefore further research is required.



MILK and PHYSICAL STATURE

Intervention, prospective and cross-sectional data suggest increased milk consumption increases physical stature in children.



The nutritional composition of milk is designed to stimulate and support growth. The scientific opinion that regular milk consumption is associated with greater physical stature has a long history, dating back to the 1920s, and the available data to date appear to suggest that milk consumption almost certainly has a positive effect on growth in children.

In the existing studies, milk intake is positively associated with physical stature in children. Beneficial effects on growth in physical stature were observed with both whole and reduced fat milk, distributed at a range of 190 mL – 568 mL. In several of these studies, it was reported that childhood milk intake also influenced physical stature in adolescence and adulthood, supporting the notion that dietary habits established and maintained during the primary and secondary school years may not only induce short-term effects but offer lasting benefits. Indeed, in children with prolonged milk avoidance stunted growth and physical stature is observed compared to children who habitually consume milk, and this is maintained into adulthood.

Interestingly, in a study that explored both milk and supplemental calcium, it was noted that those children in the milk (and dairy) group were significantly taller compared to the supplemental calcium (and placebo) group. Indeed, this may indicate that milk has more of a beneficial effect on physical stature and growth than single milk constituents (i.e. calcium). The precise mechanisms or nutrients in milk responsible for stimulating growth are not yet fully clear. In the scientific literature there is some suggestion that the growth-stimulating effect of milk is likely attributed to hormonal effects which can be influenced in response to ingested milk proteins, micronutrients and also energy. Together, these nutrients stimulate the secretion of insulin-like growth factor-1 and insulin, both anabolic hormones that play an essential role in the regulation of growth.

Overall, the twelve studies to date provide strong evidence that milk makes positive contributions to physical stature in children. This shows the importance of milk consumption during childhood to ensure full growth potential is achieved. While there is some suggestion about the mechanisms responsible for the growth-stimulating properties of milk, more intervention studies are needed to elucidate the components responsible for this effect.

MILK, BODY MASS and BODY COMPOSITION

Cross-sectional and intervention data suggest that milk may have a beneficial role in body mass control and body composition in children.



The prevalence of childhood overweight and obesity has risen dramatically over the past two decades. In England, it is estimated that 29.2% of children (2-10 years) are classified as being either overweight or obese, an increase of 26.74% compared to levels in 1995. This is of increasing concern to public health professionals. Children who are overweight or obese are more likely to be ill, be absent from school and experience more health-related implications than normal weight children. In this sense, unfavourable body mass and body fatness during childhood is a significant precursor to the development of cardiovascular disease, hypertension, dyslipidaemia, and insulin resistance. Furthermore, overweight and obese children are also more prone to become obese adults.

Physiological, behavioural and environmental factors all contribute to the development of overweight and obesity. From a simplistic nutritional standpoint, however, it is acknowledged that overweight and obesity develops following a long-term caloric imbalance (whereby our calorie intake is greater than needed). Many consumers also often perceive milk (and dairy foods) to be fattening, and thus a factor in the development of overweight and obesity, due to its calorie, fat and saturated fat content. Because of these concerns, many individuals eliminate milk (and dairy) from the diet. Contrary to popular perception, however, the scientific evidence does not support this. In fact, a growing body of research suggests that milk may have a potentially beneficial role in body mass control and body composition in children, a finding that is also reflected in the adult literature.

Although the evidence to date is mixed, the majority of data suggests milk does not adversely affect body mass or indices of body composition in children. In some cases, milk appears to offer a protective effect against unfavourable changes in body mass and body composition.

Observational studies (both cross-sectional and prospective studies) have investigated the relationship milk (and dairy) in relation to body mass index (BMI), body mass, or indices of body composition (waist circumference, body fat percentage and fat mass) in children. From the available studies (n = 27) relevant to the age criteria of this resource (5-11 years), 11 support an inverse relationship between milk (and dairy) consumption. Thus, children who consume greater volumes of milk (both flavoured and plain, regular- and reduced-fat) have significantly lower body mass, BMI, percentage body fat and waist circumferences than children who consume milk seldom. Fifteen studies supported a neutral effect between milk (and dairy) consumption, BMI, body mass, and indices of body composition, while one reported increased body mass and BMI. In these latter studies, greater milk consumption was associated with higher daily energy intake. The authors of these studies concluded that the added calories, as a consequence of increased milk intake, appeared responsible for the increases in body mass and BMI. This may suggest a potential benefit from shifting from whole milk to semi-skimmed milk to reduce calorie intake. This is an important consideration for children predisposed to overweight and obesity.

In several of the longitudinal prospective studies (tracking participants throughout childhood into adolescence), milk consumption between the ages of 5-11 years was significantly associated with body mass, or indices of body composition in adolescence. For example, habitual childhood milk consumption was associated with lower waist circumference, percentage body fat and fat mass in adolescence. Indeed, conclusions arising from a recent review accumulating all the available data from prospective studies suggest that milk (and dairy) is inversely and longitudinally associated with the risk of overweight and obesity in children. Evidence concerning the relationship between milk, body mass and body composition are not constrained to observational investigations. Few clinical trials and intervention studies have been conducted in the age range specified to this resource. From the five available studies, two illustrated increased lean body mass, reduced BMI and waist circumference with increased milk (and dairy) consumption, whereas the remaining studies all showed a neutral effect of increased milk (and dairy) consumption on BMI, body mass, or indices of body composition. Taken together, the current research continues to show that milk does not elicit a harmful effect on body mass and body composition in children.

Based on the above information, the opposite appears true for low milk (and dairy) and high sugar-sweetened beverage consumption, whereby children who drink high levels of sugar-sweetened beverages and milk seldom display greater BMI, body mass, and indices of body composition. Where evidence suggests sugar-sweetened beverages may have displaced milk consumption, consuming beverage items of

a high nutritive value or reducing sugar-sweetened beverage consumption may help prevent the onset of weight gain and obesity, particularly in children. Relative to sugar-sweetened beverages, milk is recognised as holding a high nutritive value. Interestingly, several studies in children have analysed the impact of replacing sugar-sweetened beverages with milk or fruit juice on BMI, body mass, and indices of body composition. In all studies, substituting sugar-sweetened beverages with milk (but not fruit juice) was inversely associated with BMI, body mass, body fatness (alongside increased lean body mass) throughout the transition from childhood to adolescence. Collectively, these findings illustrate milk is an attractive alternative to fruit juice and sugar-sweetened beverages for body mass control and body composition in children. Moreover, replacing sugar-sweetened beverages with milk rather than non-caloric beverages may be more effective for enhancing nutritional status in children consuming nutritionally lacking diets.

The possible mechanisms underlying the beneficial role of milk consumption on body mass and composition have not been clearly revealed, especially in children. In adults, calcium may play a specific role in the breakdown of fat that subsequently affects the way the body utilises energy, which was initially suggested over 30 years ago. Calcium also seems to decrease fatty acid absorption. Though there is some suggestion regarding the role of calcium, accumulating evidence suggests additional nutrients contained in milk (e.g. milk proteins) may confer an anti-obesity effect through favourable actions on appetite and feeding behaviour, however more intervention studies are needed to fully elucidate the components responsible for this effect in children.

While additional research is needed to better understand the relationship between milk consumption and body mass maintenance in children, the current research continues to show that milk provides important nutrients to the diets of children without adversely affecting body mass or body composition. Moreover, the majority of cross-sectional and prospective studies indicate a beneficial inverse relationship between the consumption of milk on body mass and body composition in children. The inverse association between milk and body mass and body composition brings into question the potential for a protective effect of milk against the development of conditions associated with the metabolic syndrome that are indeed a direct cause of unfavourable changes in body mass and body composition.



MILK and the

METABOLIC SYNDROME

Cross-sectional and intervention data suggest milk may provide protection against the development of cardiometabolic conditions associated with the metabolic syndrome, however findings are equivocal for some parameters.



The term metabolic syndrome encompasses a cluster of inter-related cardiometabolic conditions that include obesity, hypertension (high blood pressure), dyslipidaemia (elevated blood cholesterol and triglycerides) and type 2 diabetes (impaired glucose and insulin responses). Individually these conditions may increase damage to our blood vessels, but having all three together is particularly dangerous and favours the development of cardiovascular disease. In adults, results from epidemiological studies generally demonstrate an inverse relationship between milk consumption on cardiometabolic risk factors. For children, there are only seven studies regarding milk consumption and the various contributors to metabolic syndrome. To date, the scientific literature appears to suggest that milk consumption may provide protection against the development of the metabolic syndrome.

Milk contains a number of nutrients which may offer protection against the development of cardiometabolic conditions associated with the metabolic syndrome. This includes bioactive peptides, calcium and other minerals such as potassium. Milk, however, also makes a somewhat large contribution to fat and saturated fat intake. In the UK, milk consumption contributes 10% toward total fat and 16% to saturated fat intakes in children aged 4-10 years. Public perception typically portrays dairy fat as a negative component of milk, largely because it is energy-dense and a rich source of cholesterol and saturated fatty acids.

Elevated concentrations of plasma cholesterol (low-density lipoprotein (LDL) cholesterol, reduced high-density lipoprotein (HDL) cholesterol) and triglycerides have been associated with an increased risk of developing cardiovascular disease. However, the observational evidence does not fully support the hypothesis that milk fat or indeed high-fat dairy foods contribute to the development of cardiometabolic conditions associated with the metabolic syndrome.

In an Iranian study, researchers found that increased milk (and dairy) consumption decreased the risk of children developing certain cardiometabolic conditions and the metabolic syndrome. This protective effect, however, was also observed with greater fruit and vegetable consumption, and may illustrate the wider importance of consuming a healthy balanced diet. In two other recent studies, comprising American and Ecuadorian cohorts, the protective effect of milk on blood lipids is questionable. In a cross-sectional study of African-American and white children (n = 95; mean age = 10 years), daily habitual milk (and dairy) intake did not influence total cholesterol, triacylglycerol, insulin sensitivity or acute insulin response.

In contrast, the Ecuadorian data (children (n = 328; age = 6-10 years)) illustrated increased total blood cholesterol (both LDL and HLD) and triglycerides following 23 weeks of daily whole milk and fortified milk consumption. Nonetheless, concentrations of cholesterol (both LDL and HLD) and triglycerides remained within a healthy classification. Together, the findings of these studies are equivocal and demonstrate a neutral effect of milk on blood lipid levels in children. Consequently, recommendations to reduce milk consumption due to its saturated fat content are not supported by evidence and complying may compromise the intake of other essential nutrients.

The effect of protein (milk protein vs. animal protein) on insulin and glucose responses (and insulin resistance) was recently assessed in boys (8 years). A total of 24 boys consumed 53 g of milk protein or animal protein (meat) daily for seven days. On day seven, no changes in insulin or glucose were observed following animal protein. However, milk protein increased insulin concentrations which equally caused insulin resistance to increase. In the milk protein group fasting glucose was attenuated but this was not significant. The potential long-term consequences of elevated insulin are unknown and need to be further elucidated. For 5-11-year-old children, however, stimulation of insulin secretion may be complementary to growth (see page 9).

Beyond blood lipid outcomes, milk contains several nutritional properties (calcium, magnesium and potassium) that are associated with blood pressure control. Childhood blood pressure is known to track into adulthood, and therefore maintaining an optimal blood pressure throughout childhood may be important to help prevent blood-pressure related morbidities in later life. Although there is very little evidence concerning children, results from prospective cohort studies suggest that milk could have a beneficial effect on blood pressure regulation and thus contribute to the prevention of hypertension.

A study of 3-6-year-old children (n = 95) found that children who consumed >2 servings of milk (and dairy) daily had smaller annual (children were followed annually until 12 years old) gains in blood pressure, yet this was only observed for systolic blood pressure. In a similar manner, Australian children (n = 335) aged 8-9 years consuming >2 servings of milk (and dairy) had significantly lower diastolic blood pressure and lower systolic blood pressure (although this was not significantly lower), compared to children with intakes lower than recommendations for their country. The mechanism by which dairy products reduce blood pressure remains to be established. As there is a close correlation between dairy consumption and intakes of calcium, magnesium and potassium, it is difficult to identify which food component, nutrient or combination of these, is responsible for the anti-hypertensive properties of milk. Nonetheless, to date, the weight of the evidence suggests that milk (and dairy foods) can help lower blood pressure and contribute to the prevention of hypertension. These findings corroborate a much larger body of evidence which suggests an inverse association between dairy product intake and blood pressure in adults.

Collectively, the findings from the eight available studies suggest that higher milk (and dairy) consumption does not contribute and may, in fact, provide protection against the development of cardiometabolic conditions associated with the metabolic syndrome. However, findings are equivocal for some parameters and consequently further research is certainly warranted.



MILK and the

APPETITE REGULATION

Intervention data suggest that milk may represent a beneficial snack option to attenuate feeding behaviour in overweight/obese and normal weight children, however more research is required.

An increasing collection of evidence suggests that one way in which milk may offer protection against weight gain and fatness is through actions on feeding behaviour and appetite. Milk contains a host of ingredients that may exert a favourable effect on our appetite and feeding behaviour, yet in children there is limited evidence concerning the short-term effect of milk consumption on measures of appetite and feeding behaviour. There is also no data available which has assessed the moderate- and longer-term effects of daily milk consumption on these outcomes.

In a robust and valid manner, the effect of milk (160 mL) or apple (153 g) consumption on appetite and calorie intake in 25 British primary school children (7-10-year-old) was studied. Scientists offered the foods as mid-morning snacks (at morning break) and assessed feeding behaviour 90 minutes after snack consumption. Although apple consumption reduced the children's self-perceived appetite more so than milk, lunch and evening calorie intakes were not different between snacks. The major finding of this study, therefore, was that both apples and milk should be equally promoted as mid-morning snacks in the school environment. Although apples provide some nutritional value, milk contains other nutrients (primarily high-quality proteins, phosphorus, magnesium and zinc) that are not offered in great quantities in apples and may, in fact, help improve vitamin and mineral absorption.

In two studies of 34 overweight and obese boys, it has been shown that 240 mL of low-fat milk when consumed alongside breakfast significantly reduced overall calorie intake at a lunch 300 minutes later, when compared with a volume matched serving of water or fruit juice. Similarly, in another study it has been demonstrated that flavoured milk consumption 60 min before lunch (250 mL) reduced calorie intake in normal weight and overweight and obese children. Reductions in feeding behaviour were reflected in self-perceived appetite. In a separate study, the same researchers looked at a set of hormones that theoretically reduce hunger. They found that compared with a fruit juice drink, milk consumption significantly increased levels of an appetite-reducing hormone (glucagon-like peptide-1), but this was only observed in overweight and obese children. This did not, however, influence calorie intake at lunch nor levels of other appetite-related hormones (insulin, glucose, or peptide tyrosine tyrosine).

The effects of milk consumption on appetite are therefore inconclusive, yet may be dependent on BMI category. The evidence from the five abovementioned studies appears to suggest that mid-morning milk consumption influences feeding behaviour at the next available opportunity in overweight and obese children, and begins to suggest that milk may be good for body mass maintenance purposes. While the effect in normal weight children is less clear, the evidence appears to suggest there is no effect of milk consumption on appetite and feeding behaviour but may boost the nutritional quality of the diet. Nonetheless, there remains considerable room for further studies to clarify the role of milk on appetite and feeding behaviour, especially in a free-living school environment. In addition, it will be important to fully distinguish the effects of milk on appetite in normal weight, overweight and obese children.



CONCLUDING REMARKS

Milk is a readily available, accessible and affordable means of providing valuable essential nutrients to the diets of children. Revisiting the key themes addressed throughout this resource, findings from the cross sectional literature consistently show that milk consumption (plain and flavoured) greatly improves the nutritional status of children, and may indeed act as a marker for healthier eating habits. Early observations to date also suggest that milk may have a beneficial role in cognitive function and hydration status in children, however these conclusions are based on a very limited number of studies and more school-based intervention studies are required. Likewise, cross sectional evidence consistently shows milk is beneficial for immediate and lasting dental and bone health and has a positive effect on stature in children. Reasons facilitating the abovementioned benefits are almost certainly attributed to the unique package of essential nutrients housed within milk. Contrary to popular perception, milk consumption does not adversely affect

body mass control or indices of body composition in children. Although the evidence to date is mixed, 11 of the available studies (27) support an inverse relationship between milk consumption, body mass control and body composition. Fifteen studies support a neutral effect between milk consumption, BMI, body mass, and indices of body composition, while only one study has reported an increased body mass and BMI. In accord with the potential anti-obesity properties of milk, the majority of the available literature surrounding milk consumption and the development of cardiometabolic conditions associated with the metabolic syndrome is largely inconclusive. Evidence shows milk reduces blood pressure in children, yet shows a neutral and equivocal effect on blood lipids, blood glucose and insulin. To date, although inconclusive, the available data also begins to suggest that milk consumption influences short-term appetite and feeding behaviour. This is particularly true for overweight and obese children, while the evidence in normal

weight children is less clear.

Given the evidence presented throughout this resource, milk appears to offer an impressive catalogue of health benefits for children (5-11 years). As a result, it seems advantageous that milk and milk products are continually promoted for children, and the school environment and school milk schemes are a great place to start. Nonetheless, due to the methodological approach of many of the studies included throughout this report, the conclusions must be taken cautiously and highlight a serious need for more robust intervention studies.



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APPETITE REGULATION

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