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# **Milk and Human Development: An Essay on the "Milk Hypothesis"**

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## **Abstract**

The "milk hypothesis" predicts that a greater consumption of milk during infancy and childhood will result greater stature in adult life. Evidence is reviewed to evaluate this hypothesis. Data from post-World War II Japan, several pastoralist cultures around the world, nutrition supplementation programs, and experimental studies are, generally, consistent in support of the hypothesis. The nutrients contained in milk, especially calcium, vitamin D<sub>3</sub>, protein, and fats, are known to be necessary for adequate bone development and growth, both in length and in bone density. The risk for health problems in later life, particularly for osteoporosis, may be reduced by greater consumption of milk during infancy and childhood. Milk supplementation programs in schools improve both school attendance and school performance. The Portuguese milk supplementation program is highlighted as an example of the benefits of milk on both physical and cognitive development.

## **Keywords**

Milk hypothesis, growth, milk supplementation, infancy

## **Resumo**

A "hipótese do leite" prediz que um maior consumo de leite durante a infância resultará numa estatura mais elevada na vida adulta. As evidências são revistas para avaliar esta hipótese. Os dados da população Japonesa após a Segunda Guerra Mundial, de várias populações de pastoralistas em todo o mundo, os programas de suplementos nutricionais, e os estudos experimentais são, geralmente, consistentes em suportar esta hipótese. Os nutrientes que o leite contém, especialmente o cálcio, a vitamina D<sub>3</sub>, proteínas, e gorduras, sabe-se serem necessários para um desenvolvimento e crescimento ósseo adequado, quer em comprimento quer em densidade óssea. O risco posterior para os problemas de saúde, particularmente para a osteoporose, podem ser reduzidos por um maior consumo de leite durante a infância. Os programas de suplemento de leite nas escolas melhoram a participação e o rendimento escolar. O programa português de suplemento de leite nas escolas é um exemplo elucidativo dos benefícios do leite no desenvolvimento físico e cognitivo.

## **Palavras Chave**

Hipótese do leite, crescimento, suplemento alimentar, infância.

## **Introduction**

**I**N THE GROWING HUMAN BEING, the multiplication of cells or their enlargement in size depends upon an adequate supply of nutrients. Nutritional biochemists have determined that there are about 50 essential nutrients required for growth, maintenance, and repair of the body. Essential nutrients are those substances which the body needs, but cannot manufacture. These substances are divided into six classes: protein, carbohydrate, fat, vitamins, minerals, and water. One way that nutrients are shown to be essential is via experiments with non-human animals. A young rat, pig, or monkey is fed a diet that includes all the known nutrients except the one being tested. If the animal gets sick, stops growing, loses weight, or dies it usually means that the missing nutrient is essential for that animal. Such experiments do not prove that the same nutrient is needed for people. Some controlled experiments were done in the 20th century with humans, such as with prisoners and with residents of villages in underdeveloped nations. Since about 1980 these experiments have been considered unethical to conduct. Certain medical conditions deprive people of nutrients, and social, economic, and political conditions of life also deprive people of food and nutrients. By using these "experiments of nature," and past research, it is possible to prove the necessity of the essential nutrients.

By definition, the lack of specific essential nutrients can delay growth and may be the cause of some population differences in size. Iron deficiency is a serious problem in many parts of the world, affecting about two billion people (Ryan, 1997). Iron deficiency causes anemia, and about 51 percent of all children and infants under age five years old are anemic. Iron-deficiency anemia may lead to delays in both physical growth and psychomotor development, reduced resistance to infectious disease, and increases in gastrointestinal disorders (Ryan, 1997). Iodine deficiency is another widespread nutrient problem, afflicting about 1.5 billion people world-wide. Iodine deficiency disease causes both physical and mental growth retardation in infants and children.

People do not usually eat the essential nutrients directly as pure chemicals, such as iron or iodine, rather we eat food. This was certainly true for all of our animal ancestors throughout evolutionary history. Human foods come from five of the six Kingdoms of living organisms: plants,

animals, fungi (e.g., mushrooms), protists (e.g., species of algae referred to as "seaweed") and eubacteria (e.g., bacteria used in fermented foods). The sixth Kingdom, archaeobacteria, are not eaten directly, but are essential in the diet of other species that people do eat. Herbivores, for example, have archaeobacteria in their guts to digest the plant cellulose.

Adequacy of the total quantity of food consumed is a major determinant of growth. This is so because, in part, nutrients may be widely distributed across many different types of food. An adequate diet in terms of food quantity is important because of the energy (kilocalories) that food provides, and different kinds of food can substitute for each other to produce energy. During the years from birth to adulthood, the human body requires energy for several process which may be summarized by the following formula:

Energy required = Growth + Maintenance + Repair + Work

where maintenance means the energy used in basal metabolism, repair means the energy used to restore cells, tissues, or systems following disease or damage, and work means the energy used in voluntary activity. After these requirements are met any energy that remains may be used for growth. Growth and nutrition are, therefore, closely correlated. Indeed. It is well known that in populations where food shortages are present growth delays occur, and children are shorter and lighter than in populations with adequate or overabundant supplies of food.

### ***The Milk Hypothesis***

To what extent can a specific food make an impact on human growth and development? There has been considerable interest in this question and of all the foods studied so far, milk has generated the most important results. Takahashi (1984) made a strong case in favor of what may be called the milk hypothesis, which posits that increased consumption of milk by infants and children is directly related to greater average height of a population. Takahashi found an association between changes in dietary practices, especially milk consumption, and growth in Japan. Rice has been, and still is, the dietary staple of Japan. Until 1950, fish and shellfish were the major sources of animal protein, although most dietary protein was of plant origin, from soybean products.

Post-war changes in Japan, including greater contact with Western cultures and economic development, altered the traditional diet. These diet changes began in the late 1950's, but became pronounced in the mid-1960's. From 1966 to 1976, rice consumption decreased from about 350 to 225 grams per person per day. During the same time, meat consumption rose from about 35 to 60 grams per person per day and milk consumption rose from about 55 to 100 grams per person per day. The height of school boys, aged six to 17 years, rose by an average of 4.1 cm between 1930 and 1960, a period of relatively great social and economic change, but rose by an average of 5.3 cm between 1960 and 1975. Takahashi attributes almost all of the increase in the 1960 to 1975 period to changes in diet, especially the increased consumption of milk. Other factors, such as lower rates of childhood disease and reduced family size, may also have contributed to the height increase, but the result is that between 1960 and 1975 the average height of 17 year old Japanese boys increased from about 163 cm to 168 cm. That increase in height is remarkably close to the 5.5 cm difference in height that exists between chronically undernourished Maya children living in rural Guatemala and adequately nourished Maya refugee children living in the United States (Bogin and Loucky, 1997 — more will be said about these Maya refugees later in this essay). Viewed in this perspective, the secular trend in stature of post-war Japan seems to be due, in large part, to improved nutrition. But, was milk the food primarily responsible for this?

To further support the "milk hypothesis," Takahashi (1984) reviewed data on the growth of pastoralists, living in traditional, non-Western cultures, whose diet is based on animal milk, and agriculturalists, whose diet is usually devoid of milk and milk products. The pastoralists of Central Asia (peoples of the Gobi, Takola Makan, and Kavil Deserts) and the pastoralists of East Africa (the Masai, Samburu, and Datoga) were found to be taller than their rice or grain growing counterparts. In a related study, the growth of the Turkana, a pastoral people of Kenya, East Africa, was evaluated by Little et al. (1983). Their findings support Takahashi's "milk hypothesis." The basic staple of the Turkana diet is milk, supplemented with blood and meat from their animals, and grains and sugar which were acquired through trade. Little *et al.* found that the Turkana are significantly taller than their agricultural neighbors with whom they trade. At age 23 years, the Turkana are relatively tall — the

mean height of men is 177 cm and the mean for women is 163 cm, which is about the same average height as men and women in the United States. In contrast, the mean weight of the Turkana is significantly below that of the American blacks and whites at the same ages – American men and women average 72 kg and 57 kg respectively, and Turkana men and women average 50 kg and 47 kg. Little *et al.* suggested that the Turkana have high protein, but low calorie intakes that, "...contribute to an adequate lean tissue disposition but limits the storage of adipose tissue" (p. 826). These findings indicate that the energy supplied by the milk, and other foods of animal origin, is not the factor that results in the increased growth in height. Rather, the "height factor" is likely to be some other nutrient, or combination of nutrients, found in milk.

### **Experimental studies of milk and growth**

Takahashi was not the first to find an association between milk consumption and increased growth in height. Orr (1928) and Leighton and Clark (1929) gave school children, in several cities in Scotland, an extra pint of milk per day for seven months. Some children received whole milk and some skimmed milk. Both groups increased faster in height and weight than two control groups of children of the same ages, one group given no supplement and the other given a supplement of biscuits, equaling the milk in total calories. Since the biscuit supplement had no effect on growth, it was concluded that some factor in milk, either whole or skimmed, accelerated growth. Several other milk supplementation studies show similar results, including studies in the United States (Spies *et al.*, 1959) and New Guinea (Lampl *et al.*, 1978).

In a reanalysis of the Scottish studies of the 1920s, Celia Petty (1989) found that the milk supplemented groups included, "...a disproportionate number of children who were stunted (i.e., whose height for age was below the third centile)..." (p. 106) compared with either the group receiving the biscuit supplement or the unsupplemented group. Petty believes that the reason why the milk groups grew significantly faster than the non-milk groups may have been due to their catch-up growth following a more severe period of undernutrition. By this Petty means that the milk supplement provided needed energy, protein, and other nutri-

ents, but that any other foods supplying these same nutrients would have had the same positive effect on growth.

### ***Economic history, milk, and growth***

There are some historical data that support the milk hypothesis. The data were discovered by economic historians, who analyze records of height to reconstruct the standard of living at times, and in places, where modern economic data do not exist (Komlos, 1994; Steckel, 1995). One example comes from a study of the heights of conscripts into the Bavarian army in the 19<sup>th</sup> century (Baten, 1998). The Kingdom of Bavaria was an independent state in the early 19<sup>th</sup> century; today it is a region of Germany. All young men of the Kingdom were measured for height as part of mandatory military conscription. Baten analyzed conscription lists for about 15,000 men born between 1815 to 1849, who were 21 years old at the time of measurement. He analyzed variation in height in relation to real wages, food production, urban-rural location, and estimates of disease impact. Average heights were greatest in the dairy herding regions, and milk consumption was the single most important variable associated with stature variation. Milk consumption was very high in the dairy regions because it was not possible to transport fresh milk to markets in other regions. Cheese was not an important trade good either at that time. Instead, dairy farmers produced clarified butter (which is essentially milk fat, devoid of protein and calcium) for trade to other regions. Conscripts from grain or potato producing regions, and from weaving districts where workers had money to purchase food, were significantly shorter than conscripts from the milk regions. So again, it seems that some factor in milk is the cause of increased height.

### ***Evidence from recent clinical research***

It is known today, of course, that milk contains many essential nutrients, including protein (amino acids), calcium, and vitamin D<sub>3</sub>, and fats. A list of the major nutrients in human and bovine (cow) milk is given in Table 1. Human infants cannot tolerate bovine milk, in part due

to the high levels of protein and minerals, and the low level of carbohydrates. Other differences in composition, including immune factors, also exist. Human infants must be fed human milk or formulas designed to imitate the composition of human milk. Human children can consume and tolerate bovine milk, and derive many of the benefits of the higher levels of protein and minerals.

**Table 1.** Macronutrient Composition of Human Milk vs. Bovine Milk. This is a partial list, compiled from Hurley (1997) and Jelliffe and Jelliffe (1979).

Component	Human Milk	Bovine Milk
<b>Carbohydrates</b>		
Lactose	7.3 g/dl	
Oligosaccharides	1.2 g/dl	0.1 g/dl
<b>Proteins</b>		
Caseins	0.2 g/dl	2.7 g/dl
$\alpha$ -Lactalbumin	0.2 g/dl	0.1 g/dl
Lactoferrin	0.2 g/dl	Trace
Secretory IgA	0.2 g/dl	0.003 g/dl
$\beta$ -Lactoglobulin	None	0.36 g/dl
<b>Milk Lipids</b>		
Triglycerides	4.0 %	4.0 %
Phospholipids	0.04 %	0.04 %
<b>Minerals</b>		
Sodium	5.0 mM	15 mM
Potassium	15.0 mM	45 mM
Chloride	15.0 mM	35 mM
Calcium	8.0 mM	30 mM
Magnesium	1.4 mM	4.0 mM
<b>Vitamins</b>		
Vitamin D <sub>3</sub>	2.2 IU/dl	1.4 IU/dl
Vitamin C	0.4 g/dl	0.1 g/dl
Vitamin A	189 IU/dl	103 IU/dl
Thiamin	16 mg/dl	44 mg/dl
Riboflavin	36 mg/dl	175 mg/dl
Niacin	147 mg/dl	94 mg/dl
Folacin	5.2 mg/dl	5.5 mg/dl



Calcium and vitamin D<sub>3</sub> are essential for normal bone formation and growth in height. Some recent research indicates that calcium is the leading nutrient responsible for the milk effect. In one United States study a group of lactose-intolerant children and juveniles (ages six to 12 years), all identified as "white" and including six boys and 13 girls with a mean age of 9.6 years, were measured for height, weight, and bone mineral content (Stallings *et al.*, 1994). These lactose-intolerant children and juveniles could not drink milk. Their dietary intakes were assessed by using both 24-hour recalls of foods eaten and a six-day food record. Their mean intake of calcium was 583 mg/day, which is only 61 percent of the appropriate age- and sex-specific recommended daily allowance (RDA). All other nutrients analyzed were consumed at rates above 100 percent of the RDA, except for total energy (calories) which were consumed at 89 percent of the RDA. The average height of these subjects is 134.2 cm, which is the 39<sup>th</sup> percentile of the reference charts for the United States (the 50<sup>th</sup> percentile is considered "average"). Their mean weight of 32.1 kg places them at the 53<sup>rd</sup> percentile of the reference, and indicates that their growth in height is more effected than their growth in weight.

Similar results are reported in a study of 18 infants (1.0 to 3.5 years old) in Finland with clinically proven cow's milk allergy (Tiainen *et al.* 1995). These infants were compared with healthy infants and it was found that both groups had similar intakes of total energy, but the allergic infants consumed less protein. The allergic infants were supplemented with calcium, but despite this they were 0.8 standard deviation units shorter than the healthy group. This is a relatively large difference in body length and suggest that the lack of milk in the diet has negative consequences on skeletal growth. In another study, 84 seven-year-olds living in Hong Kong were given either a calcium supplement of 300 mg/day or a placebo tablet over an 18 month "double-blind" trial (Lee *et al.*, 1995). The Chinese typically consume little or no milk after infancy, and the pre-trial calcium intakes of the subjects were low, about 570 mg/day. The addition of the supplement, therefor, increased daily calcium intake to about 870 mg/day. After the 18 months the supplemented group had significantly greater increases in bone mineral density, which is a sign of positive bone growth. But there were no differences in the amount of growth in height during the trial.

In another "double-blind" study, 149 healthy Swiss girls, mean age 7.9 years, were provided a supplement of 850 mg/day or a placebo for 12 months (BonJour *et al.*, 1997). The supplemented group achieved both greater increases in bone mineral density and in height compared with the placebo group. The greatest differences in bone growth were found between the supplemented group and those girls in the placebo group with a natural calcium consumption below 880 mg/day. This finding may explain the lack of a significant effect on height growth in the Hong Kong study. In that study, even the supplemented group consumed, on average, less than 880 mg/day of calcium. That amount may be enough to influence bone density but not enough to promote additional growth in bone length.

### ***Evidence from anthropological research***

The research reviewed here provides considerable support for the "milk hypothesis," that is, greater consumption of milk by infants and children results in taller average stature in a sample or population. My own recent research focuses on the growth and development of Maya children, juveniles, and adolescents in different social, economic, and political environments (Bogin, 1995; Bogin and Loucky, 1997). From this research there is some additional anthropological and correlational support for the milk hypothesis. Two samples of Mayan are compared in my studies; one a group living in their homeland of Guatemala, and the other a group of refugees living in the United States. Both groups include individuals between the ages of 5 and 14 years old. The Guatemala sample live in a village with no safe supply for drinking water, an irregular supply of water, and unsanitary means for waste disposal. The parents of the Mayan children are employed, predominately, as tailors or seamstresses by local clothing manufacturers and are paid minimal wages. There is one public health clinic in the village, which administers treatment of infants and preschool children with clinical undernutrition — an omnipresent problem. The incidence of infant and childhood mortality, and morbidity from infectious disease is relatively high. The United States sample reside in two places, a rural agricultural community in Florida and Los Angeles, California. Adults in the Florida community work as day laborers in agriculture, landscaping, construc-

tion, child care and other informal sector jobs. Many of the Los Angeles Maya work in the "sweatshops" of the garment industry, although a few have jobs in health or technical professions.

The growth in height, weight and body composition of the children and youth living in Guatemala is significantly retarded compared with reference data for healthy, well-nourished children, including better nourished Ladinos living in Guatemala (Ladinos are the other predominant ethnic group in Guatemala and they control the political economy of the country). The United States-living Maya are significantly taller, heavier, and carry more fat and muscle mass than Mayan children living in Guatemala. The average increase in height is 5.5 cm for Maya in the United States – perhaps the largest one-generation increase recorded.

In both Guatemala and the United States, Maya parents say that children raised in the United States are more likely to survive, grow better, and be healthier than children raised in Guatemala. In the Florida sample, women state that their infants and children are nearly twice the size as they would be if raised in Guatemala. The mothers of Indiantown often ascribe the effect to the infant formulas they use (Stebor, 1992). One mother explains: "My daughter, Rosita, is four years old and is very small, I think she will be small all her life because she was so sick in Guatemala when she was a baby. She still doesn't eat well. Now look at my son who is almost a year old [born in the U.S.]. Already he is walking, which means his legs are very strong. He is twice the size of Rosita when she was a baby. I tell you the difference is milk" [formula] (*ibid*, p.106).

Maya women living in Florida, both those pregnant and those with infants, receive free or low cost health care and nutritional supplements from the WIC (Women, Infants and Children) Program. A major component of the nutritional supplementation is infant formula and milk. Andrea Stebor reports that Maya women acknowledge the value of the WIC program, and justify the investment of time and money (lost wages) required to enroll in the program by pointing to their bigger, healthier babies and children. Infants in Florida are fed more total food, including some breast feeding along with formula feeding. Maya mothers generally follow hygienic practices when preparing and storing formula, and safe drinking water is used to mix the formula. In contrast, prenatal and postnatal infant medical care and safe drinking water are usually not available in rural Guatemala. Due to chronic undernutrition for the rural poor in Guate-

mala, Maya women may not produce a sufficient quantity of breast milk, and infant formulas are too expensive for most Maya to purchase.

Clearly, more than the use of formula alone explains improved growth of the Maya refugee children in the United States. Nevertheless, milk is a part of reason for the growth differences between Maya in Guatemala and the United States.

A milk supplementation program in Portugal is known to play a role in improved cognitive development and school success of Portuguese primary school children. A summary of the Portuguese program is provided by Henriques and Henriques (1990). As of 1968, Portugal was the only western European country without a national program of milk supplementation in schools. In that year a planning committee was established to institute such a program and by 1973 milk was being provided to 22,000 primary school students. By 1987, approximately 800,000 Portuguese primary school students participated in the milk program. The authors report that the milk program had three main effects: 1) an increase in the overall rate of school attendance, 2) improved attention to school work in class rooms, and 3) improved school performance in student test scores and promotion to higher grades.

This program may also be partly responsible for a trend toward increased average stature for the Portuguese population. As of 1980, the mean stature of young adult men in Portugal (military conscripts 18 years old) was 169.4 cm (Sobral, 1990). These men were primary school children from about 1969 to 1975. Some of them received the milk supplement in the schools. But the supplementation program was relatively restricted in those early years, never exceeding 73,000 children. In 1975 milk supplementation was provided to 507,000 children and increased to 795,327 children by 1987. The mean stature of military conscripts also increased in these same years. In 1985 the mean stature was 169.2 cm, in 1990 it was about 170.5, and in 1996 it was 172.5 (Padez, 1998). Equally important is that as the milk supplementation program spread to include all regions of Portugal, the variation in mean stature decreased. The difference in mean stature between the shortest and tallest regions was 4.5 cm in 1985, but only 2.0 cm in 1996.

Cristina Padez has analyzed the trends in stature of these Portuguese conscripts and she points out that the increases in stature are associated with many improvements in the public health system, the nu-

tritional status, the economic system and the political environment of Portugal since the mid-1970s. These gains in the quality of life spread across Portugal along with the milk supplementation program. Milk, then, is only one part of the reason for the increase in mean stature, but in light of the known effects of milk on human growth it seems milk may have been an important part of the story.

## **The Future**

Given all of the evidence available, it seems that the combination of nutrients contained in milk are able to promote not only increased bone growth in length, but also bone density. The later plays an especially important role in the risk for development of osteoporosis in later life. As the human population in many nations ages, that is, as the percentage of the population living to older ages increases, the risk for osteoporosis also has increased. The most cost effective strategy to combat that risk for future cohorts of elderly women and men may be to provide the current generation of infants and children with more milk.

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