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Effect of milk and milk products consumption on physical growth and bone mineral density in Korean adolescents

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Abstract

This study was conducted to investigate the relationship among the current status of calcium intake from milk and milk products, physical growth and bone mineral density in 664 male and female middle school and high school students aged 15-17 years. In the study, the current status of calcium intake from milk and milk products was analyzed, and the height, body composition, and bone mineral density of the right heel bone (calcaneus) were measured. The daily calcium intake of milk and milk products was calculated as the 'dairy equivalent of calcium', which is the calcium content in 200 mL of white milk. The cutoffs of tertiles of the dairy equivalent of calcium were calculated and then the subjects were categorized into 3 groups according to the tertiles, Q1 group (lower intake group), Q2 group (middle intake group) and Q3 group (upper intake group). The daily calcium intake of milk and milk products in Q1, Q2 and Q3 groups was 16.2 mg, 99.7 mg, and 284.0 mg, respectively, and the ratio of milk and milk product consumption to the daily total calcium intake was 5.4%, 27.4%, and 49.7%, respectively. The ratio of total calcium intake to the daily recommended intake in study subjects was 30.5% in Q1, 42.3% in Q2, and 60.7% in Q3, with significant differences ($P < 0.05$). Height, body weight, BMI, and % of body fat in three tertile groups (Q1, Q2 and Q3) were not significantly different. However, the T scores for bone mineral density in female students in three tertile groups (Q1, Q2 and Q3) was significantly different ($P < 0.05$). The study showed that the intake of milk and milk products in adolescents, particularly in girls, can improve the bone mineral density without increasing body weight, and thus confirmed that milk intake is important in adolescence.

Key Words: Milk and Milk products, calcium, physical growth, bone mineral density, adolescents

Introduction

Adolescence is the period that requires the highest nutrient intake during the lifecycle due to not only the rapid physical growth and development of individuals but also the increased activity and heavy academic workload. However, Korean adolescents have some nutritional problems regarding unbalanced energy intake and improper dietary habits such as frequent intake of instant foods and fast foods and frequent breakfast skipping [1,2]. Also, an increasing obesity rate, improper body fat and lean body mass ratio, and low bone mineral density are current health problems in Korea adolescents [3,4].

According to the 2005 KNHANES data, the average daily calcium intake of adolescents was 528.4 mg, which was 55.4% of the recommended intake and lower than the national average daily intake of 76.3%, suggesting that adolescence was the most vulnerable period for calcium intake among other lifecycle periods [5]. The DRI for Koreans [1] recommends that adolescents should take 2 cups (400 mL) of milk a day for calcium supply, but the 2005 KNHANES reported that the ratio of calcium intake from milk, ice cream, and yogurt to the total calcium intake in 13-19-year-old adolescents was 13.2%, 1.4%, and 1.1%, respectively, making only a total of 15.7% [5]. Also, the ratio of students participating in the school milk program was as low as 25.4% in middle school and 20.6% in high school [6]. Thus, it is thought that the low calcium intake in Korean adolescents is because of low intake of milk and milk products, which are good food sources of calcium.

Several studies have reported the relationship among milk intake, height, weight, and body fat ratio. Wiley [7] studied 1,002 24-59-month-old preschool children using 1999-2002 NHANES data and reported that there was a significant positive correlation between milk intake and children's height, which was not observed in the intake of other dairy products. Also, the analysis of the relationship between the intake of milk and milk products and the change of body weight in 19,352 40-55-year-old Swedish

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women showed that there was a negative correlation between the intake of milk and milk products and the body weight increase in groups regularly taking milk and milk products more than once a day for 9 years [8-10]. Meanwhile Kim [11] reported that there was no relationship between the school milk program and the height and weight of adolescents.

The positive relationship between milk intake and bone mineral density has been reported in several studies. In a follow-up study on 20-49-year-old women, the bone mineral content was 5.6% lower in individuals who consumed milk less than once a week compared to those who had milk more than once a day during childhood, and was 3 % lower particularly when milk intake was low during adolescence [12]. Also, Lee *et al.* [3] reported that appropriate calcium intakes of milk and milk products during adolescence can increase the level of peak bone mass accomplished in ones 30s, minimize bone loss afterwards by aging, and also minimize the risk of fracture due to osteoporosis during old age.

Therefore, the intake of milk and milk products during adolescence can influence physical development and bone mineral density; few studies regarding adolescents and milk consumption in Korea have been conducted. Thus, the purpose of this study was to find the relationship among the calcium intake from milk · milk products, physical growth, and bone mineral density in Korean adolescents.

Subjects and Methods

Subjects

The subjects of this study were male and female students aged 15-17 years, mostly 9th grade (middle school) students and 10th and 11th grade (high school) students. The area of the subjects included Daejeon metropolitan district (big urban area), Chungnam Gongju (small and middle urban area), and Gyeonggi-do Pyeongtaek Anjung-eup (eup · myeon area), and the survey was conducted from June to July of 2009.

At first, 1,035 students were surveyed in regard to their milk consumption and final data from 664 students who sincerely responded to the dietary survey, anthropometric measurement, and bone mineral density measurement was used in the statistical analysis. Approval for the study was obtained from the Institutional Review Board of the Hannam University (2013-03k).

Methods

Milk · milk products intake and milk calcium equivalent calculation

The intake of milk and milk products in the subjects was obtained by a dietary record, which was conducted for 3 days including 2 weekdays and 1 weekend day. The subjects were instructed to fill out the dietary record with their intake of various kinds of milk and milk products such as white milk, flavored milk, liquid-type yogurt, curd-type yogurt, and cheese for 3 days. The calcium intake through milk and milk products was calculated using CAN pro (computer aided nutritional analysis program) 3.0 developed by the Korean Nutrition Society. While considering the calcium content (200 mg) in 200mL of whole, white milk in the market [13] as '1', the concept of 'calcium intake equivalent through milk·milk products' (dairy equivalent of calcium), which calculates the relative value of the daily average total calcium from milk and milk products consumed by subjects in the results of the dietary survey, was applied [14]. As the KDRI for calcium [1] for 15-18 year olds is 900 mg/day for males and 800 mg/day for females, the above 'dairy equivalent of calcium' was applied as it is in case of female subjects and the 'corrected dairy equivalent of calcium', which was obtained by dividing the above calculated 'dairy equivalent of calcium' with 1.1 (900 mg/800 mg), was applied in case of male subjects. The daily average 'dairy equivalent of calcium' of the subjects calculated in such a way was divided into tertiles, Q1 (less than 0.30; low group), Q2 (0.30-0.79; medium group), and Q3 (0.79-5.1; high group).

Total calcium intake

Daily total calcium intake from three meals and snacks including milk·milk products was assessed from all subjects by food record methods for 3 days including 2 weekdays and 1 weekend day. Subjects were trained on how to record foods, including details and recipes commonly used by them. If the food intakes during the surveyed period were markedly different from regular intakes, the surveying periods were extended until they were similar to regular days. The typical size of bowls generally used by Koreans, three dimensional food models, and real snack foods that were chosen frequently by teenagers were used to assist the subjects in estimating the portions consumed before the dietary survey was undertaken. Daily total calcium intake from three meals and snacks was calculated using CAN pro (computer aided nutritional analysis program) 3.0 developed by the Korean Nutrition Society. Total calcium intake was compared with the KDRI [1] for 15-18 year old males and females.

Physical growth

The status of physical growth of the subjects was measured by trained assistants. The height was measured using a manual height scale and the weight and body fat were measured using Inbody 430 (Biospace Co., Ltd, Cheonan). The body mass index (BMI, kg/m^2) was calculated using weight and height, and the body weight status by BMI (under, normal, over), and % of body fat status (under, normal, overweight) were obtained from the Inbody 430 measurement.

Bone mineral density

The bone mineral density (BMD) of the subjects was measured by trained assistants. The bone mineral density of the right heel

bone (calcaneus) was measured using an ultrasound bone mineral densitometer SONOST-3000 (OsteoSys Co., Ltd., Seoul) based on DEXA (dual-energy X-ray absorption). The bone mineral density was evaluated on the basis of the T-score calculated from the ultrasound bone mineral densitometer, according to the WHO guidelines [15]: osteoporosis when $T \leq -2.5$, osteopenia when $-2.5 < T < -1.0$, and normal when $T \geq -1.0$.

Statistical analysis

The statistical analysis was performed using the SPSS program (Statistical Package for Social Science, SPSS Inc., Chicago, USA). For age, total calcium intake, calcium intake from milk and milk products, body composition, and bone mineral density, the mean and the standard of error (SE) were obtained according to the dairy equivalent of calcium, and the one-way ANOVA was performed to find the significance among groups and then the LSD-test was performed as a post-hoc test in case of the presence of significance. The χ^2-test was performed to test the difference of distribution for physical growth and bone mineral density by the dairy equivalent of calcium.

Results

General characteristics

The general characteristics of the subjects are shown in Table 1. The age of the subjects ranged from 15-17 years, with 79.3% of 15 years, 18.7% of 16 years, and 2.0% of 17 years. Half of the subjects (339, 51.1%) were middle school students and sixty percent of subjects (398, 60.0%) were girls. Most of the subjects resided in a small urban area (46.8%) or large urban area, such as a big city (43.8%). Most subjects (83.7%) were living with their parents at home with 14.8% of subjects living in a dormitory.

Calcium intake from milk and milk products

The daily calcium intakes of milk and milk products were 16.2 mg/day in the Q1 group, 99.7 mg/day in the Q2 group, and 284.0 mg/day in the Q3 group (Table 2). The ratio of calcium intake of milk and milk products to total calcium intake was 5.4%, 27.4%, and 49.7%, respectively, with significant differences among groups ($P < 0.05$). The ratio of the daily total calcium intake to the recommended intake [1] in study subjects was

Table 1. General characteristics N (%)

	Middle school students			High school students			Total
	Boy	Girl	Total	Boy	Girl	Total	
Age (yrs)							
15	119 (100.0)	216 (98.2)	335 (98.8)	91 (61.9)	101 (56.7)	192 (59.1)	527 (79.3)
16	0 (0.0)	4 (1.8)	4 (1.2)	51 (34.7)	69 (38.8)	120 (36.9)	124 (18.7)
17	0 (0.0)	0 (0.0)	0 (0.0)	5 (3.4)	8 (4.5)	13 (4.0)	13 (2.0)
Residence area							
Rural area	0 (0.0)	12 (5.5)	12 (3.5)	19 (12.9)	31 (17.4)	50 (15.4)	62 (9.4)
Urban area	0 (0.0)	123 (55.9)	123 (36.3)	102 (69.4)	86 (48.3)	188 (57.8)	311 (46.8)
Big city	119 (100.0)	85 (38.6)	204 (60.2)	26 (17.7)	61 (34.3)	87 (26.8)	291 (43.8)
Living Status							
Home with family	119 (100.0)	219 (99.5)	338 (99.7)	82 (55.8)	136 (76.4)	218 (67.1)	556 (83.7)
Dormitory	0 (0.0)	0 (0.0)	0 (0.0)	62 (42.2)	6 (20.2)	98 (30.2)	98 (14.8)
Relative's house	0 (0.0)	0 (0.0)	0 (0.0)	2 (1.4)	1 (0.6)	3 (0.9)	3 (0.4)
Self-Living	0 (0.0)	1 (0.5)	1 (0.3)	1 (0.6)	5 (2.8)	6 (1.8)	7 (1.1)
Total	119 (17.9)	220 (33.2)	339 (51.1)	147 (22.1)	178 (26.8)	325 (48.9)	664 (100.0)

Table 2. Calcium intake according to dairy equivalent of calcium

	Q1 (n = 219)	Q2 (n = 224)	Q3 (n = 221)	Total (n = 664)
Calcium intake from milk and milk products (mg/day)	16.2 ± 1.9[1)c2)]	99.7 ± 2.0[b]	284.0 ± 11.1[a]	133.5 ± 5.8
Total calcium intake (mg/day)	285.2 ± 7.4[c]	397.4 ± 9.9[b]	572.6 ± 14.3[a]	418.7 ± 7.8
% of calcium intake from milk and milk products for total calcium intake	5.4 ± 0.5[c]	27.4 ± 0.7[b]	49.7 ± 1.0[a]	27.6 ± 0.8
% of calcium intake from milk and milk products for recommended calcium intake[3)]	1.6 ± 0.1[c]	10.7 ± 0.2[b]	30.1 ± 1.1[a]	14.2 ± 0.6
% of total calcium intake for recommended calcium intake	30.5 ± 0.8[c]	42.3 ± 1.0[b]	60.7 ± 1.4[a]	44.5 ± 0.8

[1)] Mean ± SE
[2)] Means with different superscripts in the same row are significantly different by LSD-test.
[3)] The percentage of daily calcium intake which was compared with the Korean recommended daily amount of calcium intake of 15-18 yr old of female for 800 mg/day and male for 900 mg/day [1] respectively.

Table 3. Height, weight, body composition, and bone density according to dairy equivalent of calcium

Variables	Boy (n = 266)				Girl (n = 398)			
	Q1 (n = 87)	Q2 (n = 85)	Q3 (n = 94)	Total (n = 266)	Q1 (n = 132)	Q2 (n = 139)	Q3 (n = 127)	Total (n = 398)
Age (yrs)	15.1 ± 0.0[1)b2)]	15.3 ± 0.1[a]	15.3 ± 0.1[a]	15.2 ± 0.0	15.2 ± 0.0	15.2 ± 0.0	15.3 ± 0.0	15.2 ± 0.0
Height (cm)	169.8 ± 0.6	170.5 ± 0.6	171.2 ± 0.6	170.5 ± 0.3	159.9 ± 0.4	159.4 ± 0.5	160.0 ± 0.5	159.8 ± 0.3
Weight (kg)	62.6 ± 1.4	61.3 ± 1.2	64.1 ± 1.2	62.7 ± 0.3	54.9 ± 0.8	54.6 ± 0.8	55.2 ± 0.7	54.9 ± 0.5
BMI (kg/m^2)	21.6 ± 0.4	21.0 ± 0.4	21.9 ± 0.4	21.5 ± 0.3	21.4 ± 0.3	21.5 ± 0.3	21.5 ± 0.2	21.5 ± 0.2
Body fat (kg)	11.8 ± 0.9	10.2 ± 0.6	12.3 ± 0.7	11.5 ± 0.3	17.1 ± 0.6	17.1 ± 0.5	17.1 ± 0.5	17.1 ± 0.3
% of body fat	17.6 ± 0.8	15.9 ± 0.7	18.2 ± 0.7	17.3 ± 0.3	30.3 ± 0.5	30.5 ± 0.5	30.5 ± 0.5	30.4 ± 0.3
T-score[3)]	-1.25 ± 0.09	-1.07 ± 0.09	-0.97 ± 0.08	-1.09 ± 0.05	-1.63 ± 0.06[ab]	-1.74 ± 0.05 [a]	-1.48 ± 0.07 [b]	-1.62 ± 0.03

[1)] Mean ± SE
[2)] Means with different superscripts in the same row are significantly different by LSD-test
[3)] Referring to bone mineral density

Table 4. Distribution of weight and body fat according to dairy equivalent of calcium N (%)

Variables	Boy (n = 266)					Girl (n = 398)				
	Q1 (n = 87)	Q2 (n = 85)	Q3 (n = 94)	Total (n = 266)	χ^2-test	Q1 (n = 132)	Q2 (n = 139)	Q3 (n = 127)	Total (n = 398)	χ^2-test
Weight[1)]										
Under	17 (19.5)	21 (24.7)	20 (21.2)	58 (21.8)		17 (12.9)	15 (10.8)	7 (5.5)	39 (9.8)	
Normal	59 (67.8)	53 (62.4)	59 (62.8)	171 (64.3)	NS[2)]	87 (65.9)	94 (67.6)	102 (80.3)	283 (71.1)	NS
Over	11 (12.7)	11 (12.9)	15 (16.0)	37 (13.9)		28 (21.2)	30 (21.6)	18 (14.2)	76 (19.1)	
% of body fat[1)]										
Under	10 (11.5)	13 (15.3)	7 (7.4)	30 (11.3)		4 (3.1)	0 (0.0)	0 (0.0)	4 (1.0)	
Normal	54 (62.1)	56 (65.9)	57 (60.7)	167 (62.8)	NS	39 (29.5)	48 (34.6)	41 (32.3)	128 (32.1)	NS
Over weight	10 (11.5)	6 (7.1)	13 (13.8)	29 (10.9)		42 (31.8)	43 (30.9)	39 (30.7)	124 (31.2)	
Obese	13 (14.9)	10 (11.7)	17 (18.1)	40 (15.0)		47 (35.6)	48 (34.5)	47 (37.0)	142 (35.7)	
Total	87 (32.7)	85 (32.0)	94 (35.3)	266 (100.0)		132 (33.2)	139 (34.9)	127 (31.9)	398 (100.0)	

[1)] The body weight status by BMI (kg/m^2, under, normal, over) and % of body fat status (under, normal, overweight, obese) were obtained from the results of Inbody 430 measurements.
[2)] NS, not significant

Table 5. Distribution of bone mineral density according to dairy equivalent of calcium N (%)

T- score	Boy (n = 266)					Girl (n = 398)				
	Q1 (n = 87)	Q2 (n = 85)	Q3 (n = 94)	Total (n = 266)	χ^2-test	Q1 (n = 132)	Q2 (n = 139)	Q3 (n = 127)	Total (n = 398)	χ^2-test
T ≤ -2.5	4 (4.6)	1 (1.2)	1 (1.1)	6 (2.3)		5 (3.8)	14 (10.1)	10 (7.9)	29 (7.3)	
-2.5 < T < -1.0	50 (57.5)	46 (54.1)	46 (48.9)	142 (53.4)	NS[1)]	103 (78.0)	108 (77.7)	87 (68.5)	298 (74.9)	*[2)]
T ≥ -1.0	33 (37.9)	38 (44.7)	47 (50.0)	118 (44.3)		24 (18.2)	17 (12.2)	30 (23.6)	71 (17.8)	
Total	87 (32.7)	85 (32.0)	94 (35.3)	266 (100.0)		132 (33.2)	139 (34.9)	127 (31.9)	398 (100.0)	

[1)] NS, not significant
[2)] Significant at $\alpha = 0.05$ by χ^2-test
T ≤ -2.5: osteoporosis, -2.5 < T < -1.0 osteopenia, T ≥ -1.0: normal

30.5% in the Q1 group, 42.3% in the Q2 group, and 60.7% in the Q3 group ($P < 0.05$).

Physical growth and bone mineral density by milk · milk products

The average height was 170.5 cm in males and 159.8 cm in females, and the average body weight was 62.7 kg in males and 54.9 kg in females (Table 3). The average BMI was 21.5 in both males and females, and the fat content and % of body fat were higher in females. However, there was no difference of BMI or % of body fat among the three groups, regardless of sex. For bone mineral density, it was significantly higher in the Q3 group, in which the dairy equivalent of calcium was high, in case of female students ($P < 0.05$).

Milk and milk products intake and the distribution of physical growth and bone mineral density

The distributions of body weight and body composition by gender according to the dairy equivalent of calcium are shown in Table 4. For body weight, the ratio of 'normal' was 64.3% in males and 71.1% in females. According to the % of body

fat 10.9% in males and 31.2% in females were overweight.

The distribution of bone mineral density by gender according to the dairy equivalent of calcium is shown in Table 5. In males, the percentage of bone density score between -2.5 ~ -1.0, characterized by osteopenia, was 53.4% with no differences by group tertiles. However, in females, osteopenia was 74.9%, normal 17.8%, and osteoporosis 7.3%, showing a higher ratio of poor bone mineral density compared to males and also significant differences by the level of dairy equivalent of calcium, that is, the ratio of 'normal' bone mineral density was high when the dairy equivalent of calcium was high ($P < 0.05$).

Discussion

This study was conducted to find the relationships among calcium intakes from milk and milk products, body composition and bone mineral density in Korean adolescents. The mean of daily total calcium intake of the subjects was 418.7 mg/day, which was low as 44.5% of the recommended intake in Korea [1]. In 2005 KNHANES [5] data, the daily average total calcium intake of Korean adolescents was 528.4 mg/day, which was 55.4% of the recommended intake and similar to the result of this study. The ratio of calcium intake from milk and milk products to total calcium intake in the subjects of this study was 27.6%, which was higher than 15.7% in the 2005 KNHANES but lower than 46.8% in Americans [5]. Yoon reported that in Korean female adolescents 84.0% consumed one or less than one cup of milk per day and only 13.1% consumed 2 cups of milk per day which is the recommended amount for Korean adolescents [16].

In this study, there were no differences in body weight and % of body fat among tertile groups, which was categorized by the dairy equivalent of calcium, suggesting that milk consumption does not affect the increase of body weight or body fat in adolescents. In addition to this study, other studies showed the increased calcium intake through the consumption of milk and milk products without the increase of body weight and body fat. Yu *et al.* [17] reported that a negative correlation among BMI, body fat, % of body fat and milk consumption was observed in college women. It was reported that the intake of calcium and dairy products help to maintain the fat contents in adipocyte and body weight in mice via regulating energy metabolism [18]. Kim [19] reported that the average body weight of students in schools with the school milk program were 58.7 kg in boys and 50.5 kg in girls, and those in schools without the school milk program were 59.1 kg in boys and 50.4 kg in girls, showing no difference in the body weight of male and female students depending on the school milk program. Also, Heaney *et al.* [20] and Barr *et al.* [21] reported that milk consumption increased calcium intake without increase in body weight. Therefore, it might help increase calcium intake in adolescents who worry about body weight increase through the perception that the consumption of milk and milk products can increase calcium intake without an increase in body weight.

The ratio of 'normal' bone mineral density in female students in this study was the highest in the Q3 group. Heaney [22] analyzed studies on the relationship between calcium intake and bone health published since 1975 and reported that calcium intake had a good influence on bone health and the positive effect on bone formation was observed during the growth period as calcium intake was increased. Lanou *et al.* [23] comprehensively reviewed studies about the effect of calcium and dairy product intake on bone health and concluded that sufficient intake of calcium and dairy products can promote bone formation in children. According to the Saskatchewan Bone Mineral Accrual Study (BMAS) [24], which investigated the factors influencing bone mineral density during the growth spurt of adolescents, dietary patterns have great influence on the maximization of bone mass during adolescence. Also, when milk was replaced by soft drinks, bone formation was significantly and negatively influenced by the replacement in female students but not in male students. In addition, according to another study on women aged 20-49 years, the bone mineral content was 5.6% lower in subjects who consumed milk less than once a week during childhood compared to those who had milk more than once a day, and was 3% lower particularly when milk intake was low during adolescence [12]. In addition, similar results have been reported that higher bone mineral density was observed with higher calcium intake [17,25]. Therefore, it has been reported that the intake of appropriate amounts of calcium through milk and milk products during adolescence helps increase the level of peak bone mass accomplished in the 30s and minimize bone loss afterward by aging, and also minimize the risk of fracture due to osteoporosis during old age [26]. In this study, 55.7% of male and 82.2% of female subjects had low bone density, less than the normal range, which may lead to serious bone- health problems when they become adults. This low bone density of this study's subjects is maybe due to the low daily intake of milk and dairy products in subjects, which is 44.5% less than the amount of daily recommended calcium intake for adolescents.

From the above results, it is shown that the consumption of milk and milk products during adolescence improves bone mineral density without the increase of body weight or accumulation of body fat. Thus, it is necessary that the perception on the relationships among intake of milk and milk products and physical growth and bone mineral density should be provided to adolescents through nutrition education to improve calcium intake during adolescence and bone health afterwards.

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