

RELATIONSHIP OF PHYSICAL ACTIVITY TYPE, NUTRITION, AND BONE MINERAL DENSITY IN KOREAN ADOLESCENTS

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Abstract

Background and Objective

Bone density reaches its peak in the mid-20s and manifests as osteoporosis and osteopenia with aging. Bone density is affected by body mass index, muscle mass, nutritional calcium and vitamin D, as well as lifestyle, type and duration of physical activity, and level of physical strength. The purpose of this study was to investigate the difference in diet and bone density according to physical activity level in growing male and female adolescents.

Material and Methods

This study involved 646 male and 581 female adolescents using data from the Korea National Health and Nutrition Examination in 2009-2011. The measurement of bone density consisted of dual-energy X-ray absorptiometry, and was classified into low-, middle-, and high-density groups at different ages based on total bone mineral density. The Korean version of the International Physical Activity Questionnaire by the World Health Organization was used to measure physical activity level, and a survey regarding strength, exercise, and stretching was conducted. In the nutritional survey, data from a 24-hour recall were analyzed. One-way analysis of variance and chi-square tests were conducted to examine the presence and significance of any differences.

Results

Even though there was no difference among groups in both males and females, there was a significant difference in weight ($p < 0.05$). There was no significant difference ($p > 0.05$) among groups by nutritional intake in female adolescents. In males, the high-density group showed significantly higher intake of calories ($p = 0.032$), protein ($p = 0.015$), calcium ($p = 0.043$), and phosphorus ($p = 0.013$) compared with the low group.

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There was a significant difference in bone density related to physical activity level. In the low and high bone density groups, the proportion of strength exercises increased to more than 3 times a week was 18.1% and 27.2%, respectively in males ($p=0.046$), and was 1.0% and 6.1% respectively in females ($p=0.014$). The proportion of high-intensity exercise 6–7 times a week also showed a significant difference as the low, middle, and high bone density groups showed 5.1%, 5.5%, and 14.1%, respectively ($p<0.001$).

Conclusion

Among adolescents, bone density in females was affected by strength exercise, and bone density in males was affected by physical activity level and nutrition, showing a clearer tendency in the males. Particularly, regarding physical activity level, high intensity and strength exercise had more positive effects.

Key words: *bone mineral density, nutrition, physical activity*

Bone density is an important factor to consider in the diagnosis of osteoporosis and osteopenia and is defined as the amount of bone mineral in a given volume of bone tissue.¹ In humans, bone density reaches its peak in the early 20s and then starts decreasing with increasing age.² A decrease in bone density leads to an increased risk of fractures which is more common in the elderly, especially females. As such, bone density is not treated with much importance at an early age. However, as mentioned above, with life expectancy in the mid-80s, having a peak bone density in your mid-20s is comparatively early. Thus, the period of adolescence is a very important and meaningful one in the development of bone density.³

It is known that genetic factors largely influence bone density. Together with acquired factors such as high body-mass index (BMI) and muscle mass, nutritional factors like calcium and vitamin D, and lifestyle factors such as high level of exercise and physical activity, as well as physical strength also have an impact.¹ However, as an increase in weight is *not* the solution to bone health, a healthy diet and regular exercise are recommended.⁴

Also, advanced studies related to nutrition have focused on calcium which is the main component of bone,⁵ but some studies have reported that irregular diets such as fast food, even with adequate intake of nutrition can result in low bone density.⁶

Another significant effect on bone density during adulthood is the intake of milk during adolescence as reported in a 3-year follow-up study.^{7,8} Studies in Korea also showed similar results of a significant relationship between calcium intake in adolescence and bone density.⁹

In terms of physical activity, it is challenging to realistically participate in exercise during adolescence, since the amount of time spent studying is very high. However, many studies have reported that exercise is a very important determinant of bone density; it is affected by exercise, as well as the nature of the exercise. A study on weight-bearing exercises by Duncan et al. revealed significantly higher levels of bone density in runners compared to cyclists and swimmers.¹⁰ Another study compared soccer players, swimmers, and weight lifters to assess the effects of resistance exercises as well as weight-bearing exercises. In that study, soccer players were found to have the highest level of bone density.¹¹ Also, another study reported that long-term resistance exercise was associated with significantly higher bone density.¹²

The American College of Sports Medicine (ACSM) also recommends strength or impact exercises such.¹³ However, most advanced studies conducted previously have focused on females, and the number of participants has been in the tens. Thus, the aim of this study was to investigate the level of bone density according to participation in physical activity and nutrition factors, including calcium intake, in a large number of male and female adolescents.

METHODS

Participants

This cross-sectional study used data derived from the Korea National Health and Nutrition Examination Survey, carried out by the Korea Centers for Disease Control and Prevention, under the Ministry of Health and Welfare in the years 2009, 2010, and 2011. Only participants who had available survey

data regarding physical activity, nutrition, and bone density were included in the analysis. The study participants comprised middle and high school students with ages ranging from 13 to 18 years. A total of 646 male and 581 female students were selected for the study. Informed consent from was obtained from all the participants, and the survey was conducted with the approval of the research ethics committee of the Korean Centers for Disease Control and Prevention (approval numbers 2009-01CON-03-2C, 2010-02CON-21-C, and 2011-02CON-06-C in 2009, 2010, and 2011, respectively).

Dual-Energy X-Ray Absorptiometry (DXA) Measurement

Bone density was measured by DXA (QDR-4500A; Hologic Inc., Bedford, MA, USA) for partial area, bone mass and density, muscle mass, and body fat mass. The data to be obtained were for total area and total bone mass; so, the total bone density except for the skull, lumbar vertebrae 1 to 4, and the neck of femur were calculated. In the analysis, males and females were separated to assess the differences according to gender. Since adolescents show large differences in bone density from the ages of 13 to 18, it is appropriate to adjust the disease standard for adults, as their bone densities are reduced. Thus, the low-, middle- and high-bone density groups were classified according to terciles of gender and age based total bone mineral density (BMD), and the mean value of variables in each group was calculated. Characteristics and DXA of the survey participants is outlined in Table 1.

Physical Activity Questionnaire

Physical activity was assessed with the Korean version of the International Physical Activity Questionnaire from the World Health Organization,¹⁴ and the performance of strength exercises and gymnastic stretching exercises were additionally surveyed.^{15,16} This was done by recalling the recent week, and recording the date of performance of vigorous and moderate physical activity as well as walking for more than 10 minutes. In addition to the question regarding strength exercise, the number of days, except for the duration of exercise, for exercises such as push-ups, dumbbells, and sit-ups were recorded. The number of days of exercise for this study was classified into

3 groups, with 0 to 2 days being considered as a low frequency, 3 to 5 days as mid frequency, and 6 to 7 days being considered as high frequency. Strength and flexibility exercises were classified into more than 3 days and 0–2 days.

Diet Questionnaire

The survey of dietary habits involved a 24-hour recall questionnaire with questions about the type and amount of food eaten, calorie intake, and component ingredients. These data were analyzed by the Computer Aided Nutritional Analysis Program (CAN-PRO 3.0, Seoul, Korea) which was developed by the Korean Nutrition Society.¹⁷ Having breakfast was classified into “yes” when the participant had eaten breakfast in the preceding 2 days and “no” when had no breakfast for at least a day.

STATISTICAL ANALYSES

The collected data were analyzed using SPSS version 21.0 (IBM Inc., Armonk, NY, USA). Continuous variables with normal distribution were recorded as the mean and standard deviation, and categorical variables were recorded as percentages. One-way analysis of variance to examine the significance within the groups, with Bonferroni correction as the post-hoc test and chi-square analysis was conducted for categorical variable. All significance was set at $p < 0.05$.

RESULTS

General Characteristics

In the results of the analysis of the data collected, there was no significant difference in age between males and females in the low-, middle-, and high-bone density groups groups, i.e., 15.33±1.68 vs. 15.32±1.67 vs. 15.32±1.69 ($p=0.999$) and 15.24±1.7 vs. 15.2±1.7 vs. 15.3±1.7 ($p=0.998$), respectively. From the anthropometric point of view, there was a significant difference in heights among the groups for both males and females (men: $p=0.001$, women: $p=0.001$), and height, weight, and waist circumference were significantly higher as the bone density increased ($p < 0.001$). Particularly, in the case of males, there was no difference in the variables except for weight, but females showed significant differences between the middle and high groups ($p < 0.05$). In the results of the DXA, there were significant differences in the

TABLE 1. Characteristics and DXA of Participants

	Boys (n=646)			Girls (n=581)			p
	Low (n=215)	Middle (n=217)	High (n=214)	Low(n=192)	Middle (n=192)	High (n=197)	
Age, years	15.33±1.68	15.32±1.67	15.32±1.69	15.24±1.70	15.24±1.70	15.25±1.69	0.998
Height, cm	168.76±8.68	170.93±6.61 ^a	172.42±6.53 ^b	158.53±5.60	160.38±5.30 ^a	161.55±5.31 ^b	<0.001***
Weight, kg	57.38±12.37	63.44±11.98 ^a	67.01±12.94 ^{b,c}	49.75±7.91	54.09±9.31 ^a	57.27±10.1 ^{b,c}	<0.001***
BMI, kg/m ²	20.02±3.43	21.66±3.62 ^a	22.46±3.69 ^b	19.76±2.67	21.00±3.30 ^a	21.91±3.51 ^{b,c}	<0.001***
Waist circumference, cm	69.34±9.20	73.76±9.99 ^a	75.71±9.58 ^b	65.14±6.60	69.18±8.27 ^a	71.39±8.43 ^{b,c}	<0.001***
DXA							
Total BMC, g	1917.73±385.84	2235.40±321.18 ^a	2564.50±375.86 ^{b,c}	1680.38±253.63	1883.53±195.82 ^a	2153.68±224.35 ^{b,c}	<0.001***
Total BMD, g/cm ²	0.95±0.08	1.06±0.07 ^a	1.19±0.09 ^{b,c}	0.93±0.06	1.03±0.03 ^a	1.14±0.06 ^{b,c}	<0.001***
L1-4 BMC, g	48.17±12.96	55.95±12.21 ^a	61.94±12.47 ^{b,c}	48.74±10.19	53.15±10.24 ^a	58.85±10.98 ^{b,c}	<0.001***
L1-4 BMD, g/cm ²	0.88±0.12	0.96±0.11 ^a	1.05±0.12 ^{b,c}	0.93±0.09	1.00±0.09 ^a	1.09±0.11 ^{b,c}	<0.001***
Femur neck BMC, g	4.01±0.66	4.60±0.61 ^a	5.13±0.71 ^{b,c}	3.22±0.50	3.64±0.48 ^a	4.03±0.52 ^{b,c}	<0.001***
Femur neck BMD, g/cm ²	0.76±0.11	0.86±0.10 ^a	0.95±0.12 ^{b,c}	0.69±0.10	0.76±0.09 ^a	0.84±0.09 ^{b,c}	<0.001***
Fat, %	21.2±7.1	21.4±7.4	21.2±6.9	33.6±6.03	33.49±5.9	33.91±5.99	0.775

DXA = Dual-energy X-ray absorptiometry, BMI = body mass index, BMC = bone mineral content, BMD = bone mineral density.

p<0.001***, tested by one-way analysis of variance with post-hoc (Bonferroni)

p<0.05, A: Low vs. Middle, B: Low vs. High, and C: Middle vs. High

TABLE 2. Nutrition and BMD

Nutrition(day)	Boys (n=646)			Girls (n=581)			p
	Low (n=215)	Middle (n=217)	High (n=214)	Low (n=192)	Middle (n=192)	High (n=197)	
Calorie, kcal	2315.95±980.79	2503.04±909.93	2562.02±924.34 ^b	1827.70±724.88	1900.02±905.12	1755.17±788.09	0.265
Carbohydrate, g	361.68±138.68	378.29±133.76	389.46±135.40	289.34±118.98	292.52±129.38	273.47±116.26	0.308
Fat, g	59.91±43.20	68.39±41.76	68.26±40.37 ^b	47.10±27.67	52.84±37.34	46.19±34.16	0.144
Protein, g	81.21±38.59	91.82±40.86 ^a	92.16±44.39 ^b	62.04±26.95	65.30±38.94	62.98±32.29	0.649
Calcium, mg	514.80±337.11	552.05±374.19	608.82±369.43 ^b	420.08±254.74	452.49±360.24	419.30±235.10	0.488
Iron, mg	13.39±10.23	14.44±7.70	14.82±8.48	10.44±6.82	10.85±7.96	10.27±6.79	0.756
Phosphorus, mg	1275.27±534.32	1416.08±572.37	1435.64±602.41 ^b	1000.26±429.83	1028.78±551.48	989.76±426.89	0.739
Breakfast, Yes %	63.4%	67.2%	70.1%	54.6%	61.7%	64.5%	0.154

BMD = bone mineral density.

p<0.05*, tested by one-way analysis of variance with post-hoc (Bonferroni)

p<0.05, A: Low vs. Middle, B: Low vs. High, and C: Middle vs. High

lumbar vertebrae and the neck of the femur when they were divided based on BMD. However, there was no significant difference in the percentages of body fat as males and females showed $p=0.964$ and $p=0.793$, respectively.

Nutrition and Bone Density

From the findings in the data analysis regarding nutrition and bone density, there was no significant differences in females, but there were significant differences in males. Particularly, there was a significant difference between the lowest bone density and the highest bone density groups, but not between the middle and highest bone density groups. There was, in males, a significant difference ($p=0.032$) between calorie intake in the lowest and highest bone density groups, as they showed 2315.95 ± 980.79 kcal and 2562.04 ± 924.34 kcal, respectively. Even though the difference in the intake of carbohydrates (which is the main energy source) did not show significance ($p=0.143$), protein showed significance ($p=0.015$) with the results being 81.21 ± 38.59 vs. 92.16 ± 44.39 . The group with the highest bone density consumed more calcium, with the calculated figure 514.80 ± 337.11 vs. 608.82 ± 369.43 ($p=0.043$). Regarding dietary habits, both males and females showed a higher proportion of having breakfast, but there was no significant difference ($p<0.05$). These results are outlined in Table 2.

Physical Activity and Bone Density

Aerobic exercise was classified into high, moderate, and walking intensity, and strength exercise and stretching were included. Chi-square analysis was conducted, and there was significance noted at high intensity ($p<0.001$) for strength exercise ($p=0.046$) in males and strength exercise ($p=0.014$) in females. At high intensity for males, the highest bone density group performed high-intensity exercise at 14.1% for 6–7 days and performed strength exercise at 27.2%, but the lowest group performed 5.1% and 18.1% of high intensity and strength exercise, respectively. Particularly in females, the highest bone density group recorded high proportions of 6.8% and 6.1% for high intensity and strength exercises, respectively, compared to the group with the lowest bone density with only 1.0%. Results are outlined in Table 3.

DISCUSSION

Bone mineral deposition occurs mostly in the period of adolescence, but it reaches its peak in the mid-20s.¹⁸ The factors affecting the bone density in this period of growth are gender, genetics, race, as well as acquired factors such as exercise, nutrition, sedentary lifestyle, lack of sleep, low weight and muscle mass, and lack of vitamin D.¹ This study aimed to investigate the difference in bone density according to these factors, including physical activity, muscle mass, and exercise-related physical activity as well as difference in nutritional intake.

First of all, from the analysis of difference in bone density by physical activity type, the group that performed more than 3 days of strength exercise showed significantly higher bone density compared to those that performed for less than 2 days (see Table 3), and this pattern was similar in both males and females. Particularly, in males, the group with high bone density showed a very high percentage of strength exercise (27.2%), and female adolescents showed 1.0–6.8% which far lower than the 18.1–27.2% for males. This result was similar to that of previous studies. Bone density is known to be sensitive to compressive force by weight bearing or strength exercise, and the ACSM recommends impact exercise such as strength and jumping exercise for patients with osteoporosis.¹³ Previous studies based on this phenomenon reported that soccer players showed significantly higher BMD than swimmers who had no weight bearing, but there was no difference between swimmers and weightlifters after the analysis of BMD in soccer players, swimmers, and weight lifters.¹¹ These results are not consistent as one study showed higher bone density in weight lifters than runners,¹⁹ while another study reported that weight lifters showed significantly higher bone density than non-athletes.²⁰ In summary, athletes show higher bone density than non-athletes, and it is assumed that the reason for the different results in each study may be the small number of participants and the absence of surveying exercise experience.

Even with a cross-sectional design, many studies have reported a positive relationship between strength and bone density.^{21,22} Also, experimental studies have reported the importance of strength exercise. Females

with 8 months of training showed a 1.2% improvement in bone density, and 20 weeks of training for young people resulted in a significant increase as well.^{23,24} After the analysis of strength exercise in controls, low, and high intensities for 1 year, the high-intensity exercise group showed improvement in BMD.²⁵ It was reported that endurance running exercise was also helpful to BMD.²⁴ However, some studies reported no significant improvement. In a study of adolescents, 26 weeks of training resulted in an improvement in strength, but there was no significant change in total BMD or in the lumbar spine.²⁶ In the background of this result, it was reported that bone density did not show a rapid change within a short period of time compared with several months and 1–2 years, and the degree of persistence of exercise and sedentary lifestyle affected the bone density.

This study also investigated the difference in BMD according to walking participation, but there was nothing of significance. From the result of the analysis of exercise type and present BMD from females in their 20–30s by recalling their teenage period, persons engaged in high-impact exercise showed significantly higher BMD than those who engaged in low-impact exercise.⁴ Also, from the result of a large-scale study related to recreation activity, including sports, and bone density, the group exercising for more than 4 hours a week showed significantly higher bone density, and it was reported that this is the minimum time needed to increase bone density.²⁷ In the Korean culture which emphasizes the importance of study, there is a lack of opportunity to perform weight-bearing physical activity except during the physical education class in school. However, it is very important to vary the

TABLE 3. Physical Activity and BMD

Exercise type (days/week)	Boys (n=646)			p	Girls (n=581)			p
	Low (n=215)	Middle (n=217)	High (n=214)		Low (n=192)	Middle (n=192)	High (n=197)	
High intensity								
0-2 days	71.2%	63.1%	51.2%	<0.001***	90.1%	85.3%	80.7%	0.115
3-5 days	23.7%	31.3%	34.7%		7.8%	12.6%	15.2%	
6-7 days	5.1%	5.5%	14.1%		2.1%	2.1%	4.1%	
Moderate intensity								
0-2 days	74.9%	74.7%	70.9%	0.298	85.4%	85.3%	83.8%	0.855
3-5 days	21.9%	20.3%	21.1%		11.5%	11.6%	11.2%	
6-7 days	3.3%	5.1%	8.0%		3.1%	3.2%	5.1%	
Walking exercise								
0-2 days	13.5%	12.0%	14.1%	0.653	14.1%	11.6%	17.8%	0.343
3-5 days	27.0%	25.3%	21.1%		28.6%	27.4%	22.3%	
6-7 days	59.5%	62.7%	64.8%		57.3%	61.1%	59.9%	
Stretching exercise								
0-2 days	82.8%	80.2%	75.1%	0.137	77.1%	77.4%	72.6%	0.467
3-7 days	17.2%	19.8%	24.9%		22.9%	22.6%	27.4%	
Strengthening exercise								
0-2 days	81.9%	80.6%	72.8%	0.046*	99.0%	93.2%	93.9%	0.014*
3-7 days	18.1%	19.4%	27.2%		1.0%	6.8%	6.1%	

BMD = bone mineral density.

p<0.001***, p<0.05*, tested by Chi-square

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type of exercise as much as possible as weight bearing activities are very closely related to bone density.³ Even in a study comparing weight-bearing activity and calcium intake, it was reported that weight-bearing activity was a more important factor than calcium intake.²⁸ However, this result does not lower the importance of nutrition, and many studies have already reported the high relationship between calcium and bone density.^{5,29} This study also showed a significant difference in calcium intake in males, but not in females. Boot et al. also reported this significance in males, but not in females.³⁰ It is assumed that the overall lower intake would affect the results. It is certain that nutrition and some types of physical activity have positive cross-sectional and longitudinal effect, but do not show large changes within several months or years. Thus, it should be managed with a long-term perspective. The limitation of this study is that there was no follow up. Because this was a cross-sectional study and exercise does not affect the bone density within a short period of time; it seems necessary to investigate how the present bone density affected the maximum bone density in adulthood. Another limitation of this study is that there was no analysis of the genetic factor of parents' bone density as well as other related lifestyle variables such as sleep.

CONCLUSION

In adolescents, strength exercise in females, and physical activity and nutrition in males can affect bone density, and this tendency is more apparent in males. Particularly, high intensity and strength exercise in physical activity have more positive effects on bone density. It is recommended that balanced nutrition, as well as exercise, should be emphasized for the health of adolescents, and higher intensity or strength exercise should be included in the physical education program throughout their stay in school.

DISCLOSURE

The authors have no conflicts of interest to declare.

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