Short Communication

Regional percent fat and bone mineral density in Korean adolescents: The Fourth Korea National Health and Nutrition Examination Survey (KNHANES IV-3), 2009

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The effects of total and regional (trunk, arm, and leg) percent fat on total and regional (arm, leg, rib, thoracic spine, lumbar spine, proximal femur, and pelvis) bone mineral density (BMD) in Korean adolescents were examined using the Fourth Korea National Health and Nutrition Examination Survey, 2009. Percent fat and BMD were measured by dual energy X-ray absorptiometry in a population-based sample of 710 Korean adolescents (365 boys and 345 girls), aged 10-19 years. After adjusting for age, height, weight, serum vitamin D, dietary calcium intake, and menarche for girls in complex sampling linear regression analysis, higher total and regional percent fat were associated with low total BMD and BMD in all regions in boys aged 13-16 years, while the associations were inconsistent for early and late adolescent boys. In girls, the inverse associations were more consistent for those aged 17-19 years than for younger girls. While most of total and regional percent fat were negatively associated with BMD of thoracic and lumbar spine and femur in boys, most of these relationships were not significant in girls. The negative association with total BMD was consistent for trunk percent fat but variable for arm and leg percent fat according to age subgroup and gender. In conclusion, the unfavorable effect of regional percent fat on all regional BMD is more consistent in boys aged 13-16 years and in girls aged 17-19 years, while the relationship appears to be gender and age subgroup-specific.

Key Words: percent body fat, bone mineral density, gender, development stage, adolescent

INTRODUCTION

Achievement of high bone mineral density (BMD) in adolescence is associated with delay of the development of osteoporosis[1] and soft tissue composition is accepted as a modifiable determinant of BMD during adolescence. A positive association between lean mass and BMD has been consistently demonstrated, while data are conflicting regarding the association of fat mass (FM) and bone.[2-4] The positive relationship between FM and BMD has been explained by the effect of soft tissue mass on skeletal loading and the secretion of bone active hormone from pancreatic beta cells and adipocytes,[5] while the negative effect of FM on BMD has been explained by increase in marrow adipogenesis and osteoclastogenesis and reduced adiponectin production.[6] In spite of these proposed mechanisms, evidence of the association between regional body fat and BMD is still limited. Although recent reports indicated an inverse association between abdominal adipose tissue and bone-related outcome in non-Asian adolescents,[7,8] research on the association between regional fat and BMD in Asian adolescents is sparse. The present study examined the relationship of percent body fat at different regions with BMD in Korean adolescents using a nationally representative dataset.

METHODS

The Fourth Korea National Health and Nutrition Examination Survey, which was conducted in 2009 by the Korea Centers for Disease Control and Prevention, involved population-based random sampling of 12,722 individuals in households across 200 national districts and 3,975 households. The sampling frame was based on the 2005 population and housing census in Korea. The household units were selected using a stratified, multistage probability sampling design. A total of 10,533 people participated in the Health Behavior Survey and the Health Examination Survey, or the Nutrition Survey. The present study included 710 Korean adolescents (365 boys and 345 girls) aged 10-19 years with complete data for body composition and BMD. BMD (total, arm, leg, rib, thoracic and lumbar spine, left proximal femur, and pelvis) and FM (total, trunk, arm, and leg) were measured by dual energy X-ray absorptiometry (DXA, DISCOVERY-W fan-beam densitometer, Hologic, Inc., Bedford, MA, USA).

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Table 1. Body composition components according to age groups of Korean boys and girls

	10-12y		13-16y		17-19y	
	Boys (n=102)	Girls (n=97)	Boys (n=158)	Girls (n=143)	Boys (n=105)	Girls (n=105)
Body mass index (kg/m^2)	19.62 (0.38)	18.66 (0.33)	21.28 (0.28)	20.79 (0.28)	22.59 (0.40)	21.43 (0.32)
%body fat						
Total	26.12 (0.99)	28.90 (0.69)	21.41 (0.56)	32.27 (0.61)	20.81 (0.75)	33.35 (0.67)
Trunk	24.22 (1.16)	25.60 (0.85)	19.92 (0.62)	29.46 (0.74)	20.67 (0.92)	31.10 (0.80)
Arm	6.19 (0.31)	6.79 (0.19)	4.54 (0.15)	7.93 (0.15)	4.25 (0.18)	8.17 (0.19)
Leg	5.75 (0.18)	6.75 (0.14)	4.66 (0.12)	7.40 (0.13)	4.24 (0.14)	7.55 (0.14)
Bone mineral density (mg/cm^2)						
Total	89.67 (1.22)	89.73 (1.38)	105.81 (1.36)	103.37 (1.52)	113.98 (1.20)	106.50 (1.32)
Arm	56.73 (1.12)	55.19 (1.02)	69.13 (0.89)	62.84 (0.92)	74.73 (0.90)	63.95 (0.89)
Leg	93.93 (1.37)	91.16 (1.43)	116.21 (1.42)	103.62 (1.74)	125.74 (1.48)	104.86 (1.44)
Rib	54.52 (0.58)	54.07 (0.76)	64.24 (0.68)	62.09 (0.78)	67.94 (0.72)	63.95 (0.93)
T-spine	62.01 (1.14)	64.95 (0.88)	79.80 (1.24)	77.62 (0.85)	84.95 (1.00)	82.19 (1.37)
L-spine	64.24 (1.01)	71.63 (1.01)	85.42 (1.09)	88.87 (0.91)	94.23 (0.72)	95.74 (1.34)
Femur	80.23 (1.04)	77.27 (0.96)	95.94 (1.15)	89.80 (1.00)	101.59 (0.96)	93.11 (1.41)
Pelvis	82.64 (1.06)	85.60 (1.37)	103.23 (1.34)	100.02 (1.40)	109.67 (1.47)	102.05 (1.56)

Values were estimated mean (standard error) from complex sampling analysis.

Percent body fat (%BF) was calculated as FM (kg) divided by body weight (kg). The stability of DXA measurements was determined by a daily calibration with phantom supplied from the manufacturer.[9] BMI was calculated as measured weight (kg) divided by square of measured height (m). 25-hydroxy vitamin D concentrations were assayed with a radioimmunoassay kit (DiaSorin, Still Water, MN, USA). Dietary intake of calcium was assessed using a single 24-hour dietary recall method. The menarche status for girls was assessed using a question "Do you menstruate at present?"

The IBM SPSS statistics version 19.0.0 (IBM, New York, USA) was used to calculate weighted means, standard errors, and regression coefficients given the complex sampling design of this survey. Stratification, clustering, and unequal weighting pertaining to the complex sampling design were combined to estimate the parameters. All analyses were separately conducted by sex and three age subgroups: 10-12 years of age, 13-16 years of age, and 17-19 years of age. Associations between %BF and BMD were quantified using linear regression coefficients of the complex sampling design. The associations were adjusted for age, weight, height, serum 25-hydroxy vitamin D level, daily calcium intake, and menarche status for girls which were conventional covariates in earlier studies. A p-value <0.05 was considered significant.

RESULTS AND DISCUSSION

Percent BF in whole body and all regions were lower in older boys but higher in older girls, while BMD in whole body and all regions were higher in both of older boys and girls (Table 1). After adjustment for age, weight, height, serum 25-hydroxy vitamin D level, calcium intake, and menarche status (for girls), total BMD was negatively associated with trunk %BF in all adolescent, while the relationships with arm and leg %BF were variable according to age groups and gender. The inverse associations between %BF and BMD were more likely to be consistent for boys aged 13-16 years but for girls aged 17-19 years. Also, %BF was negatively associated with BMD in spine and femur in most of boys, whereas the relationships were not significant in most girls.

In this nationally representative sample of data from Korean adolescents, higher total or regional %BF was detrimental for total BMD in boys and girls. This finding confirms previous reports that total body fat had a negative or no relationship with BMD in adolescents or young adults.[3,4] In addition, the present study found that trunk %BF was negatively associated with total and most of regional BMD in boys, particularly for those aged 13-16 years than for younger and older boys and girls, which is partially consistent with studies on the inverse associations between visceral abdominal fat and bone mass.[7,8] This finding implies that the pattern of fat distribution may be an important determinant of BMD for boys in the middle period of adolescence. This gender and age group-specific relationships between %BF and BMD may be explained by differential distribution of visceral fat and subcutaneous fat, which have a differential impact on the secretion of inflammatory cytokines and adipokines[7] and may be mediated by differences in synthesis of estrogen in adipose tissue, which promotes accrual of bone mass on the cortical and trabecular bone during puberty and then alleviates the adverse effect of adipokines on bone density.[10] Although the current results were derived from a nationally representative sample of Korean adolescents, the causality of the relationship cannot be determined. In addition, the classification of adolescence was not based on sex-specific pubertal status because information for sexual maturation was not available. Therefore, discordant sexual maturation stages may mingle within the age groups. The accuracy of BMD measurements by DXA can be affected by height status and body fat level[11] and then, measurement errors may influence the observed relationships.

In conclusion, the current findings reinforce evidence from previous studies that the effect of percent fat on BMD is unfavorable in adolescence and suggest possible differential relationships by gender and age group.

Table 2. Associations between bone mineral density (mg/cm^2) and percent body fat among Korean boys (n=365) and girls (n=345)

	Age	Total BMD		Arm BMD		Leg BMD		Rib BMD		T-spine BMD		L-Spine BMD		Femur BMD		Pelvic BMD	
	(y)	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
%total fat	10-12	-0.26	-0.56*	-0.25	-0.51**	-0.37*	-0.62*	-0.18*	0.17	-0.52**	0.03	-0.51**	0.22	-0.49**	0.02	-0.32*	-0.37
	13-16	-1.62**	-1.26**	-0.91**	-0.72**	-1.78**	-1.18**	-0.51**	-0.26	-1.32**	-0.28	-1.26**	-0.17	-1.18**	0.05	-1.44**	-0.79**
	17-19	-0.53	-1.40**	-0.59**	-0.85**	-0.56	-1.47**	-0.31*	-0.54**	-0.70**	-0.49	-0.52*	-0.66*	-0.11	-0.63*	-0.27	-0.87**
%trunk fat	10-12	-0.30*	-0.54*	-0.28*	-0.50**	-0.33*	-0.57*	-0.16*	0.12	-0.51**	-0.01	-0.48**	0.19	-0.38*	-0.03	-0.23	-0.34
	13-16	-1.47**	-0.97**	-0.82**	-0.53**	-1.57**	-0.77*	-0.42**	-0.25*	-1.08**	-0.16	-1.08**	-0.06	-0.85**	0.10	-1.22**	-0.44
	17-19	-0.52*	-0.91**	-0.53**	-0.55**	-0.56	-0.88**	-0.27*	-0.45**	-0.56*	-0.28	-0.41	-0.50*	-0.05	-0.48	-0.16	-0.38
%arm fat	10-12	-0.12*	-0.08	-0.12*	-0.10*	-0.14*	-0.09	-0.07**	0.10**	-0.18**	-0.01	-0.20**	0.07	-0.12*	0.01	-0.14**	-0.14**
	13-16	-0.32**	-0.30**	-0.50**	-0.21**	-0.51**	-0.26*	-0.18**	-0.04	-0.42**	-0.09	-0.41**	-0.10	-0.37**	0.02	-0.45**	-0.45**
	17-19	-0.24**	-0.30**	-0.12	-0.25**	-0.17	-0.37**	-0.08	-0.15**	-0.21*	-0.08	-0.21*	-0.14	-0.01	-0.15	-0.08	-0.08
%leg fat	10-12	-0.04	-0.18*	-0.02	-0.15**	-0.12	-0.22*	-0.05	0.06	-0.17*	0.03	-0.16*	0.08	-0.24**	0.02	-0.13	-0.12
	13-16	-0.55**	-0.52**	-0.29**	-0.29**	-0.65**	-0.59**	-0.18**	-0.07	-0.50**	-0.17	-0.46**	-0.08	-0.50**	-0.03	-0.50**	-0.39**
	17-19	-0.20	-0.64**	-0.22**	-0.38**	-0.19	-0.70**	-0.13*	-0.18**	-0.34**	-0.24*	-0.24*	-0.26	-0.07	-0.25*	-0.16	-0.49**

Values were weighted linear regression coefficients for each variable after adjusting for age, weight, height, serum 25(OH) vitamin D level, calcium intake, and menarche status for girls.
BMD, bone mineral density; T-spine, thoracic spine; L-spine, lumbar spine.
*p<0.05; **p<0.01

AUTHOR DISCLOSURES
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韓國青少年之局部體脂肪百分比及骨質密度: 2009 年第四次韓國國民健康及營養狀況調查

本研究藉由第四次韓國國民營養調查資料，評估青少年總脂肪及局部脂肪(軀幹、手臂和大腿)百分比，與總骨質密度及局部骨骼(手臂、大腿、肋骨、胸椎、腰椎、股骨近端及骨盆)骨密度的相關性。利用雙能量 X 光吸收儀，測量年齡介於 10-19 歲，以人口分佈為基礎抽樣的 710 位韓國青少年(365 位男孩及 345 位女孩)的脂肪百分比及骨質密度。在校正年齡、身高、體重、血清維生素 D、膳食鈣攝取量，以及青少女經期等變項後，以複雜樣本線性迴歸分析。結果顯示 13 至 16 歲的少年，總脂肪及局部脂肪百分比，與整體及局部骨質密度呈現負相關。然而，在其他年齡層的男孩，則不具有一致的相關。女孩方面，比起較低的年齡層，17-19 歲的青少女之脂肪百分比與骨質密度的負相關性較為一致。雖然男孩之總脂肪及局部脂肪百分比，大多與胸椎、腰椎及股骨之骨質密度呈現負相關，但在女孩則多無顯著相關。將性別及年齡分層，軀幹脂肪與總骨密度呈現一致負相關，然而手臂及大腿的脂肪百分比與骨質密度關係則無一致性。結論，13 至 16 歲的男孩及 17 至 19 歲的女孩，其局部脂肪對於所有部位的骨質密度具有不佳的影響，然而此相關只呈現在特定的性別及年齡層。

關鍵字： 體脂百分比、骨質密度、性別、發育階段、青少年