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RELATIONSHIP BETWEEN BODY MASS INDEX (BMI) AND DUAL-ENERGY X-RAY ABSORPTIOMETRY (DXA) DETERMINED ADIPOSITY INDICES IN KOREAN CHILDREN AND ADOLESCENTS; THE INFLUENCE OF GENDER, AGE GROUPS, AND PHYSIQUE

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ABSTRACT

Aim: Dual-energy X-ray absorptiometry (DXA) is considered a reference method for adiposity measurements in epidemiologic studies. The purpose of this study was to evaluate the influence of gender, age, and physique in the relationship between body mass index (BMI) and DXA derived adiposity indices for Korean children and adolescents. **Methods**: Using a nationally representative sample taken from the Korean National Health and Nutrition Examination Survey (KNHANES), 2009 to 2011, BMI of Korean children and adolescents was compared with DXA determined adiposity indices (fat mass index, FMI and percentage body fat, PBF). The correlation was subsequently evacuated according to the genders, age groups (children aged 10-12.9 yrs, early adolescents aged 13-15.9 yrs, and late adolescents aged 16-18.9 yrs.) and BMI level (< or ≥85th percentile for age and sex). **Results**: In 1919 (1024 boys) Korean children and adolescents, BMI was more strongly correlated with FMI than PBF (r = 0797 and r = 0.519, respectively all study subjects, *P* < 0.05), across all age groups, gender, and physiques. **Conclusions**: BMI is more highly correlated with FMI than PBF in Korean children and adolescents.

INTRODUCTION

Obesity is a medical condition of increased body weight caused by the excessive accumulation of body fat, and childhood obesity and obesity related cardiometabolic risk factors are important predictors of adult disease[1]. In particular, metabolic syndrome (MS) is a cluster of cardiometabolic risk factors associated with morbidities and mortalities resulting from cardiovascular diseases and type 2 diabetes[1], and the development of MS is closely related to body composition, because adiposity is intimately linked to insulin resistance[2]. Although body mass index (BMI) is used as a simple surrogate measure of obesity because they are commonly measured during health examinations, BMI is limited in terms of representing fat tissue quantification. A wide range of techniques, such as, magnetic resonance imaging (MRI), computed tomography (CT), dual-energy X-ray absorptiometry (DXA), bioelectrical impedance analysis (BIA) can be used to assess body fat, and CT and MRI are regarded as reference standards for the analysis of body composition in research field because the precision of these imaging modalities can be used to differentiate fat from other soft tissues. DXA provides a more practical means of quantifying body fat amount because of its availability and low cost[3], and validation studies have demonstrated strong correlations between DXA and CT with respect to the quantification of body fat[4-5], which suggests DXA could serve as a reference method for measuring adiposity in epidemiologic studies. Accumulated data indicated a strong correlation between percentage body fat (PBF) and FMI as determined by DXA and BMI[6-8]. However, this relationship is influenced by age, gender, and ethnic differences[6-9]. Accordingly, the purpose of the present study was to evaluate the correlation between DXA determine adiposity indices and BMI.

MATERIAL AND METHODS

The retrospective study protocol was reviewed and approved by the Korean Center for Disease Control and Prevention (KCDC). The study was approved by the institutional review board and written consent was obtained from all study subjects. The inclusion criteria were as follows; Korean children and adolescents aged 10 – 18.9 yrs who were enrolled in the Korean National Health and Nutrition Examination Survey (KNHANES) between January 2009 and May 2011. Among them, Korean children and adolescents who didn't underwent a DXA examination during the study period were excluded. KNHANES is an annually conducted nationwide cross-sectional survey that uses stratified multi-stage clustered probability sampling to select a representative sample of the non-institutionalized civilian Korean population and has been performed in Korea since 1998 by the KCDC[10]. Anthropometric and Laboratory Measurements: Anthropometric measurements (height, weight) obtained during health examinations were used. Body mass index (BMI) was defined as weight divided by height squared (kg/m^2). Trained research assistants measured

adolescents' heights and weights using standard procedures. Height was measured using a stadiometer (SECA, Hamburg, Germany) and weight using a balance beam scale (G-TECH, Uijeongbu, Korea) with participants wearing a standardized gown. Blood pressure (BP) was measured with subjects in a sitting position after a 5-minutes rest period. **Dual-energy X-ray Absorptiometry Measurements:** In the KNHANES, whole body DXA examinations were conducted using a QDR Discovery fan beam densitometer (Hologic, Inc., Bedford, MA, USA). The DXA scanner was calibrated daily using a spine phantom and weekly using a step phantom. Examinations were performed with subjects wearing light clothing; all items that could possibly interfere with results were removed. Head, arms, legs, and trunk were delineated in whole body scans to determine regional fat levels. FMI was calculated as FM/height^2, and PBF was defined as FM/body weight x 100. **Statistical Analysis**: Boys and girls were analyzed separately. Descriptive statistics were calculated for anthropometric measures and results are expressed as means ± standard errors (SEs). Sample-weighted Pearson's correlation coefficients were calculated for relations between BMI and DXA indices. To determine differences between correlation coefficients, correlations were transformed using Fisher's z transformation and this was followed by the t-test. The 1919 study subjects were divided into three age groups; 10-12.9 year olds (children), 13-15.9 year olds (early adolescents), and 16-18.9 year olds (late adolescents), and subjects were classified as non-obese (< 50th and 50th to 84th percentile for age and sex) or obese (≥ 85th percentile for age and sex) based on the Standard Growth Charts of Korean children and adolescents in 2007 as determined by the KCDC and the Korean Pediatric Society[11-12]. Statistical analyses were performed using R software version 3.0.1. and PASW version 17.0 (SPSS, Chicago, IL, USA). All statistical analyses used sample weights and accounted for the complex survey design. Statistical significance was accepted for p values < 0.05.

RESULTS

Characteristics by Gender and Age

A total of 1919 (1024 boys) Korean children and adolescents were included in this study. Table 1 summarizes mean heights, weights, BMIs, waist circumferences, and DXA derived adiposity indices (FM, FMI, and PBF) by gender and age. Generally, adolescent boys were taller and heavier than adolescent girls but their DXA adiposity indices were lower.

Correlations between BMI and DXA-determined FMI and PBF

Sample-weighted Pearson correlations between BMI and DXA derived adiposity indices are shown in Table 2 by gender and age. Both of FMI and PBF were significantly correlated with BMI; and correlation coefficients ranged from 0.883 to 0.929 between FMI and BMI and from 0.686 to 0.792 between PBF and BMI. BMI was significantly more strongly correlated with FMI than PBF in all study subjects (r = 0.797 for FMI and BMI, and r = 0.519 for PBF and BMI, $P < 0.05$), and the superiority of this correlation between FMI and BMI was consistently noted across age groups and genders. Approximately 19.2% of subjects were obese based on BMI. Correlations between PBF and BMI were weaker than those between FMI and BMI in both of obese and non-obese children and adolescents, and no correlation was found between PBF and BMI in female children of BMI level of ≥ 85th percentile for the age and sex (r = 0.193, $P = 0.09$).

Table1: Demographic and anthropometric characteristics of Korean children and adolescent aged 10 to 18.9 years who underwent DXA, KNHANES 2009-2011.

Characteristics	All	Child (10-12.9 yr)		Early Adolescence (13-15.9 yr)		Late Adolescence(16-18.9 yr)	
		Boys	Girls	Boys	Girls	Boys	Girls
Un weighted sample size	1919	378	314	358	318	288	263
Height (cm)	161.02± 0.35	149.72± 0.57	149.49 ± 0.54	168.42 ± 0.48	159.29± 0.37	173.60± 0.43	160.81± 0.42
Weight (kg)	54.03 ± 0.40	44.83 ± 0.72	42.03 ± 0.61	59.81 ± 0.79	52.25 ± 0.67	65.52 ± 0.80	55.25 ± 0.84
BMI (kg/m$^{2)}$	20.57 ± 0.10	19.78 ± 0.24	18.60 ± 0.19	20.94 ± 0.22	20.54 ± 0.23	21.71 ± 0.25	21.33 ± 0.28
DXA based adiposity indices							
FM, kg	14.71 ± 0.20	12.95 ± 0.46	12.78 ± 0.29	13.36 ± 0.47	16.91 ± 0.44	13.77 ± 0.45	18.51 ± 0.50
FMI, kg/m^2	5.68 ± 0.07	5.71 ± 0.19	5.65 ± 0.11	4.67 ± 0.16	6.64 ± 0.16	4.56 ± 0.15	7.14 ± 0.18
PBF, %	27.07 ± 0.27	27.82 ± 0.60	29.87 ± 0.35	21.48 ± 0.51	31.98 ± 0.45	20.41 ± 0.47	33.06 ± 0.40
PTF, %	11.29 ± 0.14	11.30 ± 0.32	11.90 ± 0.20	8.86 ± 0.27	13.30 ± 0.28	9.03 ± 0.27	14.13 ± 0.29

Note- Data are mean ± standard error.

Abbreviations: DXA, dual-energy X-ray absorptiometry; KNHANES III, Third National Health and Nutrition Examination Survey; BMI, body mass index; FM, fat mass; FMI, fat mass index; PBF, percentage body fat; PTF, percentage trunk fat

Table 2. Correlations of BMI to fat mass index (FMI) and percentage body fat (PBF) by sex and age, and BMI level.

	Boys			Girls		
	Overall correlation	BMI-for-age		Overall correlation	BMI-for-age	
Age (y)		< 85th P	≥85th P		< 85th P	≥85th P
10-12.9 yr	n =378	n = 296	n =82	n =314	n = 256	
FMI (kg/m^2)	0.923	0.809	0.865	0.901	0.803	0.744
PBF (%)	0.793	0.648	0.551	0.686	0.575	0.193*
13-15.9 yr	n =358	n =293	n =65	n =318	n =250	n =68
FMI (kg/m^2)	0.897	0.760	0.805	0.929	0.854	0.866
PBF (%)	0.771	0.596	0.557	0.746	0.656	0.551
16-18.9 yr	n =288	n =236	n =52	n =263	n =220	n =43
FMI (kg/m^2)	0.883	0.758	0.829	0.929	0.822	0.839
PBF (%)	0.740	0.573	0.632	0.747	0.549	0.518

Note- Pearson correlation coefficients between BMI and the specific characteristics (considering the weight of the cases). All *P*s are less than 0.01 except * (*P* = 0.09)

DISCUSSION

In general, BMI values calculated by dividing weight (in kg) by height (in meters) squared are considered to provide a simple indicator of obesity in epidemiologic studies. In children, BMI is calculated as in adults, but BMI values are compared against percentiles of the same gender and age to diagnose obesity rather than using fixed thresholds, because healthy weight ranges depend on age and gender; a BMI above the 95th percentile for age and gender or a BMI of ≥ 25 kg/m^2 if lower is considered to indicate an obesity, and a BMI between the 85th and 95th percentiles an overweight in Korean children and adolescents[12]. However, BMI values do not accurately measure adiposity because they do not directly quantify fat mass, rather PBF values, obtained by DXA, are considered better for diagnosing obesity in epidemiologic studies[13-14]. Several studies have investigated the relationship between BMI and DXA-derived PBF or FM. Although BMI is highly correlated with PBF (R values of 0.7-0.9) in adults, this association has been reported to be more variable and relatively weak in children and adolescents[15-17]. Furthermore, correlations between DXA derived fat indices and BMI have been reported to highly dependent on race, gender, age, and BMI[15-17]. In the present study, the overall correlation between BMI and PBF was 0.519 for all study subjects and varied between 0.686 and 0.793 in the different age and gender subgroups, which is substantially lower than that observed in a previous study (r = 0.910 between BMI and BIA determined PBF) in Korean children (438 boys and 454 girls, aged 8-12 yrs)[14]. This discrepancy may have been caused by different study populations (a relatively large, nationally representative sample of Korean children and adolescents in the present study versus primary school students located in a specific region in the previous study) and different evaluation methods (DXA in the present study and BIA in the previous study). Although BIA is being used increasingly in clinical practice, it does not directly measure body fatness, and DXA is considered the more reliable method for body composition analysis[14, 18]. In the present study, we also evaluated the correlation between BMI and FMI, and found the correlation (overall correlation coefficient = 0.797 for all study subjects; range = 0.883-0.929 for age and gender subgroups) was significantly higher than that between BMI and PBF. In a recent study that evaluated Korean adults using the KNHANES dataset[19], BMI was also more highly correlated with FMI than PBF, like our results. Interestingly, BMI had no correlation with PBF in female children of BMI level of ≥ 85th percentile for the age and sex; this indicates BMI for this group should be interpreted cautiously to determine body fatness.

CONCLUSION

Our findings suggest BMI better reflects absolute body fat amount than PBF in Korean children and adolescents; the higher correlation between BMI and FMI is observed all age group, gender, and BMI level.

Conflict of Interest: Nil

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