

# Gender Differences in Relationship between Fat-Free Mass Index and Fat Mass Index among Korean Children Using Body Composition Chart

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**Purpose:** This study aimed to investigate gender differences in the relationship between fat-free mass index (FFMI) and fat mass index (FMI) by applying body composition chart on Korean elementary students. **Materials and Methods:** Data from 965 healthy Korean children of 8 to 12 years of age (501 boys, 464 girls) were obtained. FFMI and FMI were plotted on the body composition chart, and the differences in the relationships between FFMI and FMI were separately evaluated by gender or grade. **Results:** Weight was heavier and BMI was higher in 3rd and 4th grade boys compare to girls. The value of FFM was higher in boys, but FM was not different. In subgroup analysis by grade, significant gender by FFMI interaction ( $p=0.015$ ) was found, indicating that the slope of the lines for FMI vs. FFMI was different between boys and girls (Figure was not shown). In subgroup analysis by gender, grade by FFMI interaction was significant in boys, indicating that FMI vs. FFMI relationship differed according to grade only in boys. **Conclusion:** Boys are leaner than girls, despite having similar BMI. Gender difference in the direction of the change of the FFMI and FMI relationship is evident in children.

**Key Words:** Obesity, child, Korea

## INTRODUCTION

The recent increase in the prevalence of childhood obesity has been well-established around the world, including South Korea and concerns about the excess adiposity in childhood are increasing.<sup>1-3</sup>

Body mass index (BMI) is widely used as a surrogate marker of fatness.<sup>4,5</sup> The statistical definition of BMI is that it adjusts weight (WT) for variability in height (HT)<sup>6</sup>:

$$\text{BMI} = \text{WT}/\text{HT}^2 \text{ (equation 1)}$$

However, it has limitations and should be used with caution when assessing children as the change in BMI does not reflect the change in adiposity during child-

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hood.<sup>7-9</sup> The simplest model of body composition divides WT into fat mass (FM) and lean mass (LM) components:

$$WT=LM+FM \text{ (equation 2)}$$

VanItallie, et al.<sup>10</sup> proposed that equations 1 and 2 could be combined in order to divide BMI into its fat and lean components:

$$BMI=fat\text{-free mass index (FFMI)}+fat \text{ mass index (FMI)} \text{ (equation 3)}$$

In general, lean mass index (LMI) and FFMI can be used to mean the same thing. Body composition is difficult to measure in children because accurate techniques require participant compliance and are only available in specialized research institutions. Recently, more practical methods such as bioelectrical impedance analysis (BIA) for epidemiologic studies and clinical practice are available.<sup>11</sup> Although increases in FM are generally observed in boys and girls, increases in BMI throughout childhood are driven primarily by increases in FFM, particularly in boys.<sup>12</sup> The relationships between FFMI and fat mass index (FMI) can be delineated on the body composition chart. Hattori<sup>13</sup> have devised a chart, based on FFMI and FMI on the x and y axes, respectively. It has advantage of expressing both aspects of body composition in common units.<sup>14</sup> The effects of variation in FFM and FM on BMI can be explored using body composition chart, and various combinations of FFMI and FMI can result in a similar BMI.<sup>15</sup>

The objective of this study was to determine the gender difference in the relationship between FFMI and FMI with increasing age by applying body composition chart analysis on Korean elementary school children.

## MATERIALS AND METHODS

### Subjects

Data from 965 healthy Korean children of 8 to 12 years of age (501 boys, 464 girls) were obtained from the annual school health examination at a primary school, located in Seoul, South Korea.

### Measurements

While subjects were dressed in light sports attire, body weight was measured to the nearest 0.1 kg on a calibrated

digital electric scale. Height was measured to the nearest 0.1 with barefoot, using stadiometer.

FM (kg) and FFM (kg) were measured with bioelectrical impedance analysis (BIA) using multi frequency bioelectrical impedance analyzer (InBody J10, Biospace, Seoul, Korea). Subjects emptied their bladders first to minimize measurement errors and were asked to stand barefoot, facing forward. Anthropometric measurements and BIA were conducted in the morning on the same day.

The values of body compartment of FM (kg) and FFM (kg) measured with BIA were used for FMI and FFMI. FFMI and FMI were plotted on the body composition chart, and the relationships between FFMI and FMI were explored on the body composition chart in common units (kg/m<sup>2</sup>).

### Statistical analysis

All data were analyzed using software version 11.0 for windows (SPSS Inc., Chicago, IL, USA), and *p* value of less than 0.05 was considered to be statistically significant. T-test was used to test for gender differences. Analysis of variance was conducted for grade differences separately in both genders. The relationship between FMI and FFMI was assessed by multiple regression analysis. The differences in the relationships between FFMI and FMI by gender and grade were evaluated. Regression analysis was conducted separately in each gender, also. In multiple regression analysis, grade and FFMI by grade interaction were the final independent variables.

## RESULTS

### Subject characteristics

The characteristics of the subjects are provided in Table 1, as well as the various body components. Weight was heavier and BMI was higher in 3rd and 4th grade boys compare to girls. The value of FFM was higher in boys, but FM was not different. FFMI was higher in boys. In terms of body fat percent and FMI were not different in boys and girls.

### Gender difference in relationship between FFMI and FMI

Gender difference was demonstrated in the relationship between FFMI and FMI using body composition chart (Fig. 1). In subgroup analysis by grade, significant gender by FFMI interaction (*p*=0.015) was found, indicating that the slope of the lines for FMI vs. FFMI differed between boys and

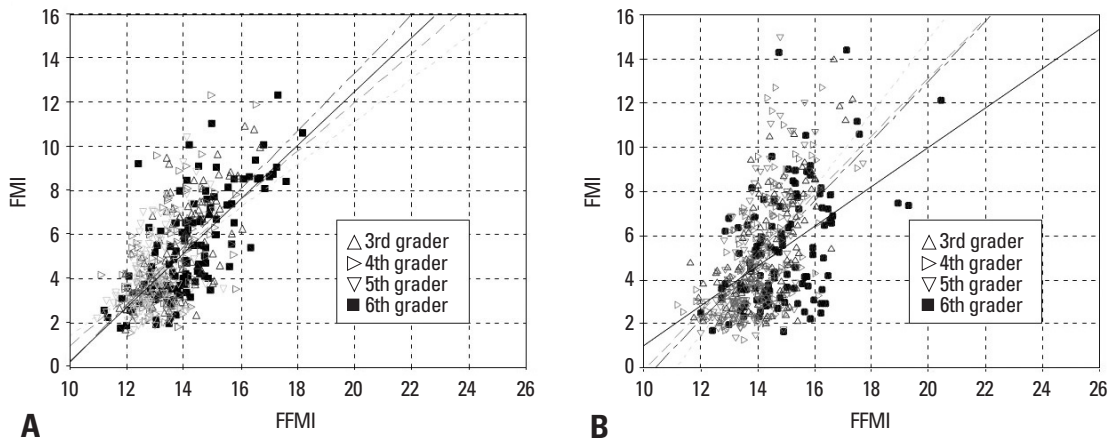
**Table 1.** Characteristics in Girls (a) and Boys (b) by Grade in School

(a)	3rd (n=114)	4th (n=129)	5th (n=103)	6th (n=118)
Age (yrs) <sup>†</sup>	8.75 (8.17-9.34)	9.59 (8.83-10.25)	10.59 (9.42-11.25)	11.67 (10.83-12.17)
Height (m)	1.30±0.06	1.37±0.06	1.44±0.06	1.50±0.06
Weight (kg)	29.5±5.1	33.9±6.9	39.7±8.4	44.2±10.2
BMI (kg/m <sup>2</sup> )	17.4±2.3	17.9±2.7	19.1±3.0	19.6±3.5
Fat free mass (kg)	22.1±2.5	25.1±3.4	28.7±4.1	31.9±5.1
Fat mass (kg)	7.4±3.4	8.8±4.2	11.1±5.1	12.3±5.8
Body fat percent (%)	24.2±7.2	24.9±6.9	26.6±7.2	26.5±7.2
FFMI (kg/m <sup>2</sup> )	13.0±0.8	13.3±1.0	13.9±1.1	14.2±1.4
FMI (kg/m <sup>2</sup> )	4.3±1.9	4.6±2.0	5.3±2.2	5.4±2.3
(b)	3rd (n=142)	4th (n=129)	5th (n=120)	6th (n=110)
Age (yrs) <sup>†</sup>	8.75 (7.34-9.92)	9.67 (9.17-10.25)	10.67 (10.17-11.25)	11.59 (11.17-12.25)
Height (m)	1.31±0.06	1.37±0.06	1.42±0.06*	1.49±0.07
Weight (kg)	31.9±7.4 <sup>†</sup>	36.5±7.6 <sup>†</sup>	39.4±8.9	45.3±10.3
BMI (kg/m <sup>2</sup> ) *	18.5±3.3 <sup>†</sup>	19.4±3.3 <sup>†</sup>	19.6±3.4	20.4±3.5
Fat free mass (kg) *	23.9±3.2 <sup>†</sup>	26.5±3.3 <sup>†</sup>	28.8±4.2	33.2±5.6
Fat mass (kg)	8.1±4.9	10.1±5.2*	10.7±5.6	12.1±6.3
Body fat percent (%)	23.5±8.9	26.1±8.4	25.7±8.0	25.6±8.2
FFMI (kg/m <sup>2</sup> ) *	13.9±0.9 <sup>†</sup>	14.1±1.1*	14.3±1.2*	14.9±1.4 <sup>†</sup>
FMI (kg/m <sup>2</sup> )	4.6±2.7	5.3±2.6 <sup>†</sup>	5.3±2.5	5.5±2.6

BMI, body mass index; FFMI, fat free mass index; FMI, fat mass index.

\* $p < 0.05$ ; <sup>†</sup> $p < 0.01$  for boys compare to girls.

<sup>†</sup>Data are presented as median (range), others data are presented as mean±standard deviation.



**Fig. 1.** Fat mass index (FMI) versus fat free mass index (FFMI) in girls (A) and boys (B). Solid and dashed lines represent 6th graders and 3rd to 5th graders respectively.

girls (Figure was not shown). In subgroup analysis by gender, grade by FFMI interaction was significant in boys indicating that FMI vs. FFMI relationship differed according to grade only in boys (Table 2).

## DISCUSSION

The gender difference in the relationship between FFMI and FMI was demonstrated in this study. Girls are generally known to have relatively more fat. In contrary to such ex-

pectation, however, this study proved to be not always true, especially in children. Girls did not have higher levels of fat mass or percentage body fat than boys did.

Although boys showed higher BMI, FM was not different between boys and girls. The higher values of FFM in boys could explain the difference of BMI in this age group. Even though body fat percent, FFMI and FMI were not different between boys and girls, the relationships between FFMI and FMI were different by gender using body composition chart (Fig. 1).

In subgroup analysis by grade, there was a significant

**Table 2.** Relationship between FMI and FFMI in Girls (a) and Boys (b) by Grade in School

Independent variables		Dependent variable (fat mass index)			
		Regression coefficient (SE)	<i>p</i> value	R <sup>2</sup>	SE
(a)	Intercept	-9.115 (2.221)	<0.001	0.400	1.672
	FFMI	1.044 (0.168)	<0.001		
	Grade	-0.442 (0.424)	0.299		
	FFMI X grade*	0.029 (0.031)	0.356		
(b)	Intercept	-22.812 (3.106)	<0.001	0.323	2.152
	FFMI	1.992 (0.221)	<0.001		
	Grade	1.872 (0.529)	<0.001		
	FFMI X grade*	-0.137 (0.037)	<0.001		

FFMI, fat free mass index.

\*Interaction variable between FFMI and grade.

gender by FFMI interaction, indicating that the boys gain FFM more rapidly compared to girls during 6th grade period. In subgroup analysis by gender, grade by FFMI interaction was significant in boys, indicating that FMI vs. FFMI relationship differed according to the grade of the boys. FFM gain was more accelerated in 6th grade boys, indicating that the magnitude of this gender difference in elementary school children increased with grade.

This study result also showed the limitation of BMI in children, that has already been known,<sup>7-9</sup> and the needs for FMI and FFMI chart plotting.

Over the last two decades, the importance of body composition measurement according to nutritional status has increasingly been recognized, especially in pediatric age group.<sup>15</sup> Tracing body composition in children is not only to detect excessive fatness but also concerns in the acquisition of FFM. FFMI and FMI are used to express both aspects of body composition in common units. It should be kept in mind that the same BMI value can result from various combinations of FMI and FFMI, and the range of variability in the levels of both FM and FFM is wide in growing children.<sup>12,16</sup> The accuracy of BMI among children varies, depending on according to the degree of fatness: BMI fits for relatively heavy weight children (e.g., BMI-for-age $\geq$ 85th P) but it does not for light weight children.<sup>17</sup>

Previous studies indicated the importance of FMI and FFMI, however, there was no result on the difference between boys and girls.<sup>18,19</sup> FFMI in boys and girls, gender difference and year in year out these were very diverse between childhood and adolescent.<sup>20-22</sup>

In the present study, we found definite differences in FFMI and FMI relationship between boys and girls as they grew. We also found the time of change in body composition through slope variation, a marked change occurring in 6th

grade boys (Table 2).

Our results have several limitations. In the result of this research, difference by the grade was marked and as the Table 1 suggests average grade age rarely goes out the actual school year age. Moreover, in order to find the overall general differences between children, pubertal stage should be included, however, the present study was limited within a single elementary school.

In summary, this study demonstrates that body composition chart containing FFMI and FMI is appropriate for expressing both aspects of body composition in children. Gender difference in the direction of change of FFMI and FMI relationship is evident in children. Thus, the use of this chart should highly be encouraged, and extensive studies to establish gender and age specific cut-off values that are valid for the health risk-based definitions of pediatric obesity should follow. This task is important not only for the research/public health, but also imperative in clinical settings.

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## REFERENCES

1. Obesity: preventing and managing the global epidemic. Report of a WHO consultation. World Health Organ Tech Rep Ser 2000;894:i-xii, 1-253.
2. Park YS, Lee DH, Choi JM, Kang YJ, Kim CH. Trend of obesity in school age children in Seoul over the past 23 years. Korean J Pediatr 2004;47:247-57.
3. Kim HM, Park J, Kim HS, Kim DH, Park SH. Obesity and cardiovascular risk factors in Korean children and adolescents aged 10-18 years from the Korean National Health and Nutrition Examina-

- tion Survey, 1998 and 2001. *Am J Epidemiol* 2006;164:787-93.
4. Poskitt EM. Defining childhood obesity: the relative body mass index (BMI). European Childhood Obesity group. *Acta Paediatr* 1995;84:961-3.
  5. Dietz WH, Robinson TN. Use of the body mass index (BMI) as a measure of overweight in children and adolescents. *J Pediatr* 1998;132:191-3.
  6. Quetelet LAJ. A treatise on man and the development of his faculties. In: *Comparative statistics in the 19th century*. Edinburgh: William and Robert Chambers; 1842.
  7. Gallagher D, Visser M, Sepúlveda D, Pierson RN, Harris T, Heymsfield SB. How useful is body mass index for comparison of body fatness across age, sex, and ethnic groups? *Am J Epidemiol* 1996;143:228-39.
  8. Horlick M. Body mass index in childhood--measuring a moving target. *J Clin Endocrinol Metab* 2001;86:4059-60.
  9. Franklin MF. Comparison of weight and height relations in boys from 4 countries. *Am J Clin Nutr* 1999;70:157S-62S.
  10. VanItallie TB, Yang MU, Heymsfield SB, Funk RC, Boileau RA. Height-normalized indices of the body's fat-free mass and fat mass: potentially useful indicators of nutritional status. *Am J Clin Nutr* 1990;52:953-9.
  11. Van Itallie TB, Segal KR. Nutritional assessment of hospital patients: new methods and new opportunities. *Am J Hum Biol* 1989;1:205-8.
  12. Bell W. Fat-free mass and fat mass in active boys during adolescence. *Am J Hum Biol* 1997;9:617-27.
  13. Hattori K. Body composition and lean body mass index for Japanese college students. *J Anthropol Soc Nippon* 1991;99:141-8.
  14. Hattori K, Tatsumi N, Tanaka S. Assessment of body composition by using a new chart method. *Am J Hum Biol* 1997;9:573-8.
  15. Demerath EW, Schubert CM, Maynard LM, Sun SS, Chumlea WC, Pickoff A, et al. Do changes in body mass index percentile reflect changes in body composition in children? Data from the Fels Longitudinal Study. *Pediatrics* 2006;117:e487-95.
  16. Maynard LM, Wisemandle W, Roche AF, Chumlea WC, Guo SS, Siervogel RM. Childhood body composition in relation to body mass index. *Pediatrics* 2001;107:344-50.
  17. Freedman DS, Wang J, Maynard LM, Thornton JC, Mei Z, Pierson RN, et al. Relation of BMI to fat and fat-free mass among children and adolescents. *Int J Obes (Lond)* 2005;29:1-8.
  18. Nakao T, Komiya S. Reference norms for a fat-free mass index and fat mass index in the Japanese child population. *J Physiol Anthropol Appl Human Sci* 2003;22:293-8.
  19. Wells JC. A Hattori chart analysis of body mass index in infants and children. *Int J Obes Relat Metab Disord* 2000;24:325-9.
  20. Buyken AE, Bolzenius K, Karaolis-Danckert N, Günther AL, Kroke A. Body composition trajectories into adolescence according to age at pubertal growth spurt. *Am J Hum Biol* 2011;23:216-24.
  21. Eissa MA, Dai S, Mihalopoulos NL, Day RS, Harrist RB, Labarthe DR. Trajectories of fat mass index, fat free-mass index, and waist circumference in children: Project HeartBeat! *Am J Prev Med* 2009;37:S34-9.
  22. Castilho SD, Cocetti M, de Azevedo Barros Filho A. Body mass index and body composition in relation to sexual maturation. *J Pediatr Endocrinol Metab* 2008;21:127-33.