Relationship between body mass index and body composition in Japanese children and adolescents

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ABSTRACT

The present study examined how body mass index (BMI) is associated with body composition in children who are in around puberty. Fat mass relative to body mass (%FM) was estimated using a bioelectrical impedance analyzer in 416 Japanese children aged 9 to 14 years. Fat mass relative to body height squared (FM/ht^2) and fat-free mass relative to body height squared (FFM/ht^2) were calculated from body height, body mass and %FM. On the basis of the heights at the ages of peak height velocity (PHV) of Japanese boys (153.4 cm) and girls (141.3 cm) reported in earlier literatures, the participants were allocated to prepubertal or pubertal group. Regardless of sex, BMI was significantly higher in pubertal group than in prepubertal group. %FM and FM/ht^2 for girls were significantly higher in pubertal group than in prepubertal group, whereas those for boys were similar between both groups. In both sexes, BMI percentile was significantly correlated to %FM and FM/ht^2, regardless of group. In the corresponding relationships, the slope of the regression line was similar between both groups, regardless of sex. BMI percentile was significantly correlated to FFM/ht^2, regardless of group and sex. In the girls, there were no significant differences between both groups in the slope of regression line for the corresponding relationship, whereas, in the boys, the slope differed between both groups. In Japanese boys and girls, while BMI percentile can be a convenient measure for assessing %FM, FM/ht^2 and FFM/ht^2, adolescents have higher fat and fat-free mass than children across BMI percentile.

Keywords: bioelectrical impedance analysis, peak height velocity, prepuberty, puberty, maturity-related difference.

1. INTRODUCTION

To date, various techniques such as dual-energy X-ray absorptiometry (DXA) [1-4], hydrodensitometry[5-8], and bioelectrical impedance analysis (BIA) [9-11] have been used to determine body composition in children. However, these need special apparatus and skills, so their usage in field surveys examining large samples of subjects is limited. The most frequently used tools in field settings in public health research are anthropometric-based measurements such as BMI, expressed as body mass (kg) per height squared (m^2) [4]. Cole et al. [12] provided age- and gender-specific BMI cut-off points for child overweight and obesity worldwide, although there is a need to take into consideration ethnic differences in the association between BMI and body composition [4, 10]. However, not only age and gender but also maturity influence BMI and body composition in children [1, 13]. The rapid growth in body size during puberty is accompanied by marked changes in body composition [14]. It is unknown how the association between BMI and body composition differs between prepubertal and pubertal children.

In both boys and girls, body composition during puberty is characterized by a greater increase in fat-free mass (FFM) [7, 8, 15]. Maynard et al. [7] have indicated that, in each sex, annual increases in BMI are driven primarily by the increase in the FFM component until late adolescence. For boys, however, pubertal changes in body composition are accompanied by a relatively small annual decrease or increase in fat mass (FM) [7, 8, 15], which results in a decrease in the annual change of the FM component of BMI [7, 8]. In girls, annual FM gain during puberty has been shown to be significant [15], and it increases the contribution of the FM component to BMI gains compared with that of boys [7]. Taken together, it can be assumed that the association between BMI and body composition differs between prepubertal and pubertal children. In the

present study, we examined this in Japanese boys and girls.

2. METHODS

2.1. Participants

Two hundred and twenty boys and 196 girls aged 9 to 14 years voluntarily participated in this study. Data was sampled in pilot schools for research of Kagoshima prefecture (Japan) from 2011 to 2012. All subjects were free of long-term use of oral steroids or other medications that can influence weight gain, multiple food allergies, moderate or substantial physical or developmental disability, or any infection. In addition, they were not involved in any specific physical training program beyond their normal school curriculum activities. BMI values for the participants were within the range between the 5th percentile and the 95th percentile in the corresponding age group of Japanese [16]. In a prior study [17], the intermediate value between the body heights of the Japanese boys who were in Tanner stages II and III, which corresponds to prepuberty and puberty, respectively [18, 19], was about 154 cm. This value was almost the same as that reported as the height at the age of peak height velocity (PHV) of Japanese boys (153.4 cm) [20]. On the basis of the heights at the ages of peak height velocity (PHV) of Japanese boys and girls, 153.4 cm and 141.3 cm, respectively [20], therefore, the participants were allocated to the prepubertal or pubertal group. The boys and girls whose heights were less than 153.4 cm and 141.3 cm, respectively, were classified as the prepubertal group (119 boys and 62 girls), and those whose heights were more than 153.4 cm and 141.3 cm, respectively, were categorized as the pubertal group (101 boys and 134 girls) (Table 1). Mino et al. [13] demonstrated that normal ages at PHV in both sexes are 12.28 to 13.70 years for boys and 10.36 to 11.71 years for girls. In the present study, the mean values of chronological ages in prepubertal and pubertal groups were 11.3 ± 1.3 years and 10.3 ± 0.7 years for prepubertal boys and

girls, respectively, and 13.7 ± 0.8 years and 12.6 ± 1.3 years for pubertal boys and girls, respectively. Furthermore, the heights for the boys (141.4 ± 7.0 cm) and girls (134.8 ± 4.9 cm) who were classified as prepubertal group were lower, and those for the pubertal group (163.6 ± 5.5 cm for boys and 152.0 ± 6.2 cm for girls) were higher than the heights at the age of PHV (153.4 ± 5.5 cm for boys and 141.3 ± 5.5 cm for girls) reported by Suwa et al [20]. This study was approved by the ethical committee of the National Institute of Fitness and Sports in KANOYA, and was consistent with their requirements for human experimentation in accordance with the Declaration of Helsinki. Prior to the experiment, all participants and their parents were informed of the purpose and procedures of this study and possible risks of the measurements. Written informed consent was obtained from each participant and their parents.

2.2. Measurements of anthropometry and body composition

Height and body mass were measured using standard techniques to the nearest 0.1 cm and 0.1 kg, respectively. BMI was converted to BMI percentile based on the criteria reported by The Japanese Association for Human Auxology and The Japanese Society for Pediatric Endocrinology (http://jspe.umin.jp/medical/taikaku.html). A bioelectrical impedance analyzer with a leg-to-leg system (DC-320, Tanita, Japan) was used to estimate %FM in accordance with the procedure used in a prior study [21]. The Tanita device has been shown to have excellent test-retest reliability and moderately strong absolute agreement with DXA for children [22]. The leg-to-leg system has a reliability for estimating body composition [23]. This method has been successfully adopted for determining body composition for children [10]. Furthermore, in our preliminary study, the intra-class correlation coefficient for the %FM

measurement was 0.98 in this device, when seven healthy adults were determined two times with an interval of 6 hours within a day. FM and FFM were calculated using body mass and %FM, and were expressed as the values relative to height squared (FM/ht^2 and FFM/ht^2, respectively).

2.3. Statistics

Descriptive data are presented as means ± standard deviations (SDs). Pearson's product-moment correlation coefficient (r) was used to examine the significant relationship between each of %FM, FM/ht^2, and FFM/ht^2 and BMI percentile in each group. The present study intended to examine the difference between prepubertal and pubertal groups in terms of the associations between BMI percentile and measured variables in each sex. Therefore, a Student's unpaired t-test was used to test the difference between the two stages within the same sex. Furthermore, an analysis of covariance (ANCOVA) was used to test the differences between the two stages within the same sex in the regression equation for the relationship between each of %FM, FM/ht^2, and FFM/ht^2 and BMI percentile. Statistical significance was set at $p<0.05$. All statistical procedure were conducted by using statistical software (SPSS ver.22, IBM SPSS Statistics, Japan).

3. RESULTS AND DISCUSSION

The mean values of %FM for all boys and girls, 17.2% and 22.6% (Table 1), respectively, were within the ranges of those (boys: 13.8-23.5%, girls: 19.2-28.2%) reported by previous studies in which DXA [2, 24, 25], hydrodensitometry [5], or BIA [9, 10] was applied to measure body composition in individuals aged 7 to 17 years. The mean values of BMI in both sexes (Table 1) are comparable to those reported in previous studies that examined Japanese children (17.4-18.4 kg/m^2 for 11 years old boys, 16.8-17.5 kg/m^2 for 10 years old girls) and adolescents (18.2-19.4 kg/m^2 for 13 years old boys, 19.2-19.3 kg/m^2 for 12 years old girls) [6, 9, 16]. In both

sexes, BMI was significantly higher in the pubertal than in the prepubertal group. %FM and FM/ht^2 for boys had no significant effect of group, but those for girls were significantly higher in the pubertal group than in the prepubertal group. In both sexes, FFM/ht^2 was significantly higher in the pubertal group than in the prepubertal group. Thus, the difference in BMI for boys could be attributable to that in FFM/ht^2 and the corresponding difference in girls to those in FM/ht^2 and FFM/ht^2, as observed in previous studies [7, 8].

In each group, %FM and FM/ht^2 was significantly correlated to BMI percentile, with correlation coefficients of 0.721 to 0.891 for %FM (p<0.0001, Fig. 1) and 0.783 to 0.889 for FM/ht^2 (p<0.0001, Fig. 2). In both sexes, ANCOVA showed that there were no significant differences between prepubertal and pubertal groups in the slopes of the regression line for the relationship between BMI percentile and each of %FM and FM/ht^2, but most of the corresponding values for adolescents were located above the regression line for children. This suggests that, while BMI percentile in each group can be a convenient measure for assessing %FM and FM/ht^2 in Japanese boys and girls aged 9 to 14 years, the corresponding relationships differ between the prepubertal and pubertal groups.

BMI percentile was significantly associated with FFM/ht^2 (r = 0.431-0.747, p<0.0001, Fig. 3), regardless of group and sex. In the girls, ANCOVA revealed that there were no significant differences between the two groups in the slope of regression lines for the relationships between FFM/ht^2 and BMI percentile. In addition, the correlation coefficients for the corresponding relationships in the girls were similar between prepubertal (r = 0.747) and pubertal groups (r = 0.692), suggesting that the relative contributions of each of FFM/ht^2 to BMI percentile are almost the same between the two groups. For the boys, however, the slope of the

regression line for relationship between FFM/ht^2 and BMI percentile differed between the prepubertal and pubertal groups, indicating that the rate of increase in FFM/ht^2 across BMI percentile was higher in pubertal boys than in prepubertal boys.

On the whole, the findings obtained here indicate that BMI percentile is significantly correlated to the measured variables of body composition in Japanese children and adolescents, although the corresponding relationships differ with sex and the magnitude of maturation. As shown in Fig. 1 and Fig. 2, however, it should be noted that %FM and FM/ht^2 values for boys and girls with BMI of more than 90 percentile considerably deviated from the regression lines in their relationships with BMI percentile. This implies that children and adolescents with BMI of >90 percentile show different relationships between BMI percentile and body composition variables from those with BMI of <90 percentile. For the use of BMI percentile to assess body composition in children and adolescents, further study is needed to elucidate this difference.

4. CONCLUSION

The current results indicate that, at least in Japanese children and adolescents aged 9 to 14 years, BMI percentile can be a convenient measure for assessing percent body fat and fat free mass relative to body height squared, regardless of sex and the magnitude of maturation, although adolescents have higher percent body fat and fat free mass relative to body height squared than children across BMI percentile.

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Figure 1

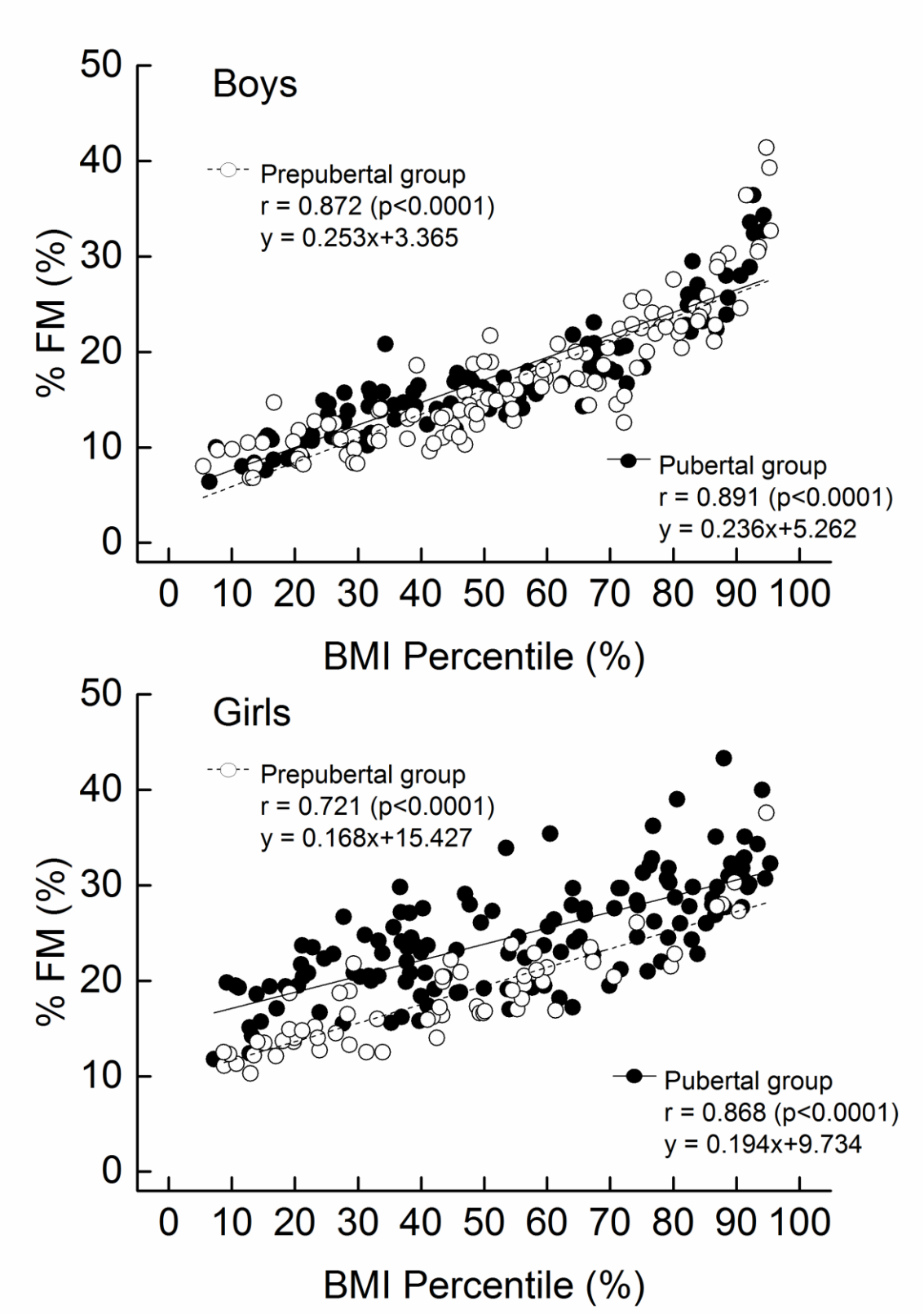

Figure 2

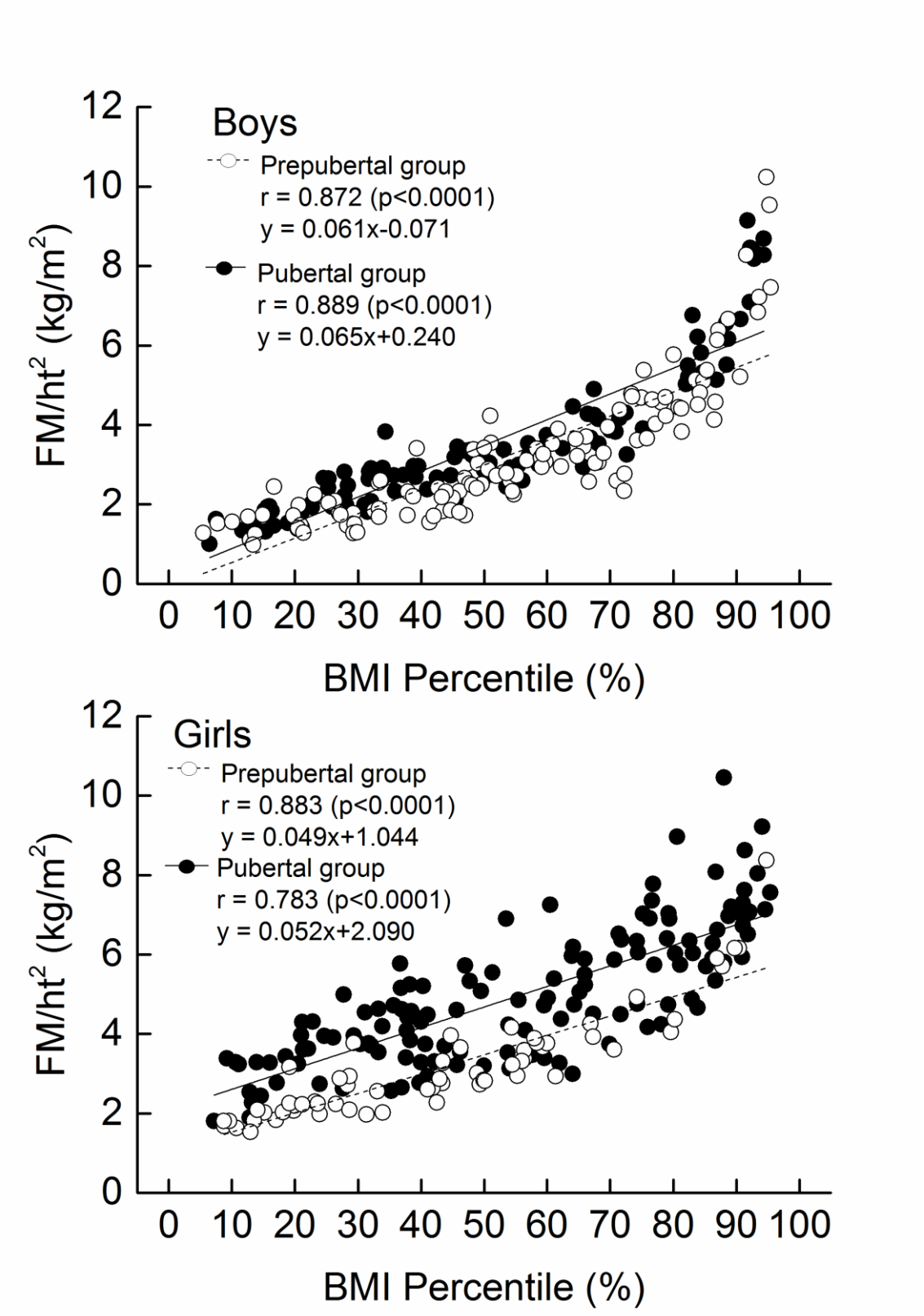

Figure 3