Relationship between body composition and BMI in preschool children

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＜**Original Article**＞

Confirmation regarding Relational Construction of Body Composition and BMI in Preschool Children.

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Abstract

Childhood obesity is one of the most serious public health challenges of the 21st century. Obesity is a state wherein body fat accumulates to an abnormal degree, and detailed information about body composition is necessary to inspect the problems of obesity in children. In the present study, we measure body composition with machinery which can measure lean body mass in addition to a quantity of fat based on the multi-frequency BI (bioelectrical impedance analysis) method. This examines differences in body composition for young children from 3 to 5 years old, including differences according to sex, and correlates them within the measured values of BMI.

The fat percentages for girls were higher than boys, and the muscle percentages (muscle mass/weight＊100) were the opposite. These results show that there were differences according to sex. We made our evaluations based on a regression analysis of fat percentages for BMI and muscle percentages. As a result, a high correlation was found between BMI and fat percentages. The relation of BMI and muscle percentages was the opposite of the relation of BMI to fat percentages, and we found a high negative relation between boys and girls. A significant regression tendency was confirmed from the present results of the regression analysis of fat and muscle percentages for BMI for preschool children. This suggests that BMI can also be used to evaluate the fatness or thinness of a preschool child. In short, BMI can be regarded as the index that can evaluate fat and muscle percentages from early childhood.

Keywords: Preschool Children, Body composition, BMI

Introduction

Childhood obesity is one of the most serious public health challenges of the 21st century. Globally, in 2010 the number of overweight children under the age of five, was estimated to be over 42 million [1]. The increase of a tendency toward corpulence in children has existed in Japan since 1977, and such children have increased two or three times in the last 30 or more years [2]. However, since the latter half of the 1990's there has been a slowing of this tendency. Recently, a tendency toward thinness in children has increased, and differences in body growth between boys and girls have become apparent.

By the way, obesity is defined as "a state where body fat is abnormally accumulated" but there is not a method to measure body fat simply and precisely, and a judgment on the basis of a ratio of weight to height (degree of obesity, BMI, Rohrer index) is used generally. Above all, the BMI shows a high relation between fat percentage and degree of obesity [3, 4]. And for adults, the World Health Organization (WHO) sets the standard at BMI 25 or greater for pre-obesity, and BMI 30 or greater for obesity. Concerning children, the problem has been that the international obesity measurements have not shown differences according to race or age. However, if many countries use BMI as an index of obesity for children, it can be used for international comparisons as well [5]. Furthermore, Mei et al [6], in a study of 2-19 year olds, suggests that the BMI is more suitable than the Rohrer index and relative body weight measurements for evaluating degrees of obesity. Freedman et al [7] reports that BMI measurements in childhood are a strong indication of tendencies toward obesity in later adulthood, but few studies have shown BMI measurements of children in relation to their body compositions.

Obesity is a state wherein body fat accumulates to an abnormal degree, and detailed information about body composition is necessary to inspect the problems of obesity in children. Fukunaga [8] investigated the age-related changes for subcutaneous fat and the cross-sectional area of muscles, and reported that they increase dramatically from the time of puberty. Similarly, Sugiyama [9] also reported on the age-related changes in subcutaneous FM, body FM, and body fat percentage. These studies clarified an enlargement of the gender difference with age in elementary school and middle school students, but the studies did not examine preschool children. According to reports on the body compositions of preschool children, Otoki et al [10] clarified a gender difference in the subcutaneous FM and its proportion to body weight, and Eto et al [11] clarified that the change in total FM over one year was larger in young boys than in girls. Teramoto et al [12] studied the relationship between age-related changes and body composition in preschool children, and insisted on the need of longitudinal studies in order to clarify the changes of body composition in Japanese preschool children.

The best method for measuring body composition is the dual energy X-ray absorptiometry (DXA), followed by the underwater weighing method and the potassium method. However, these three methods have been limited to the laboratory only. The bioelectrical impedance analysis (BI) and the body fat caliper (skinfold thickness) methods have been used more widely, for children in schools and in general society. However, we cannot apply a body density prediction equation (Nagamine's methods [13]), using the skinfold thickness method, to preschool children. And a prediction equation to estimate body compositions of preschool children is not yet established by the BI method. Therefore, when we use a body composition analyzer for body composition evaluation of preschool children, the measurement results of body composition values are estimates that can be used as a reference for future studies. In this way there are problems of methodology, and it is thought that there are only few studies about body composition of the preschool children.

On the basis of studies about the body compositions of preschool children by Sakaida et al [14] and Sakai et al [15], we measure body composition with machinery which can measure lean body mass (LBM) in addition to a quantity of fat based on the multi-frequency BI method. This examines differences in body composition for young children from 3 to 5 years old, including differences according to sex, and correlates them within the measured values of BMI. Through this study, we offer basic information about preschool children's body compositions. We also aim to show how this information relates with BMI.

Methods

1. Subjects

The subjects were 533 preschool children comprised by those 3 years old (91 boys and 83 girls), 4 years old (90 boys and 83 girls), and 5 years old (79 boys and 81 girls). To properly examine their body compositions according to age, a statistical method that included large enough samples for each age group was gathered. Based on the birth dates, their exact ages until the measurement day were calculated. The purpose and design of this study were explained to children and their parents in advance and informed consent was obtained from them. The subjects were healthy children without acute or chronic diseases. The study was approved by the institutional ethics committee and was conducted according to the principles of the Declaration of Helsinki.

2. Physique and body composition

Body composition was measured using the Tanita MC-190EM body composition analyzer (Tanita Corp., Tokyo Japan) with a correction for light indoor clothing. The subjects participated in the measurement at least three hours after their last meal and were also asked to urinate just prior to the measurement. The measurement procedure required the subject to stand barefooted on the analyzer and to hold a pair of handgrips, one in each hand. The device uses multi-frequency (5, 50, 250, and 500kHz) body impedance analysis (BI) technology, and has 8 tactile electrodes: 2 are in contact with the palm and thumb of each hand, and 2 are in contact with the front and back part of the sole of each foot. This device can calculate body weight, soft lean mass (SLM), body fat percentages (%Fat), lean body mass (LBM), fat mass (FM), mineral mass and total body water. The MC-190EM uses data acquired using dual X-ray absorptiometry (DXA) from both Japanese and Western subjects as well as a regression formula derived through repeated regression analysis of height, weight, age, and impedance between the right hand and foot as variables. The height was measured using the Tanita digital height scale. BMI was calculated by dividing weight (kg) by the square of height (m). All the measurements were done by experts in using the Tanita MC-190EM body composition analyzer, in the morning with the surrounding air at about 20℃.

３． Analysis

Statistical values for physique (height, weight and BMI) and body composition (FM, %Fat and SLM) were calculated according to gender and age (3, 4 and 5 years old). The analysis procedure was as follows.

1) In each age group of boys and girls (3, 4 and 5 years old), a regression analysis of %Fat for BMI was performed, based on the report of Tanaka et al' [16], after drawing regression polynomials from the first to the third order, a regression polynomial of a proper order was determined.

2) With a similar method to that of measuring fat percentage, a regression polynomial of a proper order for muscle percentage was determined for each age group of boys and girls (3, 4 and 5 years old).

4. Validity of regression polynomial order

A regression line from a regression analysis with two variables is generally applied to a regression polynomial equation. However, even in regression analyses with two variables, there are cases in which the second and higher order relationship is judged to be more valid than the first order relationship. In such cases, the second, third, fourth, or higher order approximation polynomials are applied. Matsuura and Kim [17](1991) applied the least square approximation polynomials to height and weight growth and investigated their growth patterns. Largo et al. [18] applied spline smoothing in a study of height growth patterns.

All of these methods used least square approximation polynomials, and produced useful findings. Based on these reports, valid orders were made up by examining the residual sum of squares adopted by Matsuura and Kim [17] (1991) in determining regression polynomials for %Fat against BMI in this study. In addition, by applying the Akaike information criterion (AIC) simultaneously, the validity of the orders was confirmed. The AIC is calculated as follows.

$$AIC = n \times log \frac{\sigma}{n} + 2 \times (k + 2) + (log 2\pi + 1)$$

Here, **σ** is the sum of the squared deviation, **n** is the data number, and **k** is the number of explanatory variables.

Results

1. Correlation analysis for physique and body composition

Tables 1 shows the statistical values for physique and body composition and the results of the variance analysis in 3, 4, and 5 year old boys and girls. The height and weight of the Japanese subjects in this study were within a standard deviation range of ± 1, and this also applied to their ages.

1) Differences between each age groups

Table 1 shows the statistical values for physique and body composition and the results of the variance analysis in 3, 4, and 5 year old boys and girls. Significant differences were found among each of the age groups, in both boys and girls, and gradually increasing trends were found in height, weight, LBM, SLM, bone mass and total body water. The % of Fat for 4 and 5 year old boys' and girls' age groups were significantly lower than 3 year old age groups significantly. There were no significant differences among each of the age groups in FM and muscle percentages for the boys. However, significant differences were found in FM and muscle percentages for the girls. 5-year-old girls were significantly higher in FM and muscle percentages than 3 and 4 year old girls, and 4-year-old girls were significantly higher in muscle percentages than 3-year-old girls. As for the BMI, 4 and 5 year old boys were significantly lower than 3-year-old boys, and 4-year-old girls were significantly lower than 3-year-old girls.

2) Gender difference

There were no significant gender differences among each of the age groups in weight, however, significant differences were found in height within the 4-year-old age group (boys > girls). Significant differences were found among each of the age groups in %Fat (boys < girls), and between 3 and 5 year old age groups in FM (boys < girls). On the other hand, regarding muscle percentages, boys were significantly higher than girls in all age groups. As for bone mass, girls were significantly heavier than boys at 5 years of age. Significant differences were found in total body water for 3 and 4 year old age groups (boys > girls). There were no significant gender differences among each of the age groups in BMI.

3) Correlations of each element in 3 year-old children

Table 2 shows the results of a correlation analysis for physique and body composition in each age group according to the children's sexes. For boys there were significant correlations between height and weight and for the variables: FM, LBM, SLM, bone mass and total body water ($p<.001$), however, no significant correlations between height and %Fat, muscle percentages, and BMI.

In girls there were significant correlations between height and weight and for the variables: FM, LBM, SLM, bone mass and total body water ($p<.001$～.01), however, no significant correlations between height and %Fat, FM, muscle percentages, and BMI, and also between %Fat and LBM, SLM, muscle percentage, and bone mass.

In both boys and girls there were positive and high correlations（r =0.787～0. 908）between BMI and %Fat, and negative and high correlations（r =-0.804～-0. 911）between BMI and muscle percentages.

4) Correlations of each element in 4 year-old children

In boys there were significant correlations between height and weight and for the variables: FM, LBM, SLM, bone mass and total body water ($p<.001$), however, no significant correlations between height and %Fat, muscle percentages, and BMI. In girls there were significant correlations between height and weight and for variables: FM, LBM, SLM, bone mass and total body water ($p<.001$), however, no significant correlations between height and %Fat, FM, muscle percentages, and BMI. In both boys and girls there were positive and high correlations（r =0.812～0. 937）between BMI and %Fat, and negative and high correlations（r =-0.829～-0. 939）between BMI and muscle percentages.

5) Correlations of each element in 5 year-old children

In boys there were significant correlations between height and weight and for variables: FM, LBM, SLM, bone mass and total body water ($p<.001$), however, no significant correlations between height and %Fat, muscle percentages, and BMI. In girls there were significant correlations between height and weight and for variables: FM, LBM, SLM, bone mass and total body water ($p<.001$～0.01), however, no significant correlations between height and BMI. In both boys and girls there were positive and high correlations (r=0.896～0. 947) between BMI and %Fat, and negative and high correlations (r =-0.903～-0. 950) between BMI and muscle percentages.

２． The Structure of a regression polynomial of fat and muscle percentages for BMI

The results of the regression analysis of fat and muscle percentages for BMI showed different regression tendencies by age. Table 3 shows a determination coefficient in regression polynomials from the first to the third order, the residual sum of squares and the AIC of fat and muscle percentages for BMI in boys and girls. Figs 1 and 2 show the least square approximation polynomials for %Fat, Figs 3 and 4 show the least square approximation polynomials for muscle percentages in boys and girls. The regression of fat and muscle percentages for BMI was significant.

In boys all of the coefficients of determination (R^2) of fat percentages for BMI were more than 0.8 from the first to the third order regression. A residual sum of squares slightly decreased in the second regression polynomial for the boys, and the AIC was the minimum. In girls all of the coefficients of determination (R^2) of fat percentages for BMI were more than 0.7 from the first to the third order regression. The AIC was the first regression line in the case of the minimum for the girls.

In boys all of the coefficients of determination (R^2) of muscle percentages for BMI were more than 0.8 from the first to the third order regression. The AIC was the first regression line in the case of the minimum for the boys. In girls all of the coefficients of determination (R^2) of muscle percentages for BMI were more than 0.7 from the first to the third order regression. The AIC was the third regression polynomial in the case of the minimum for the girls.

Discussion

There have been few studies on the relationship between the physiques and body compositions of preschool children. The limited number of reports on preschool children's body compositions may be due to problems in limitations in the methodology of BI. However, this does not mean that the BI method cannot be used to evaluate the body compositions of preschool children. Fujii and Sakai [19] applied the BI method to preschool children and examined a canalization effect between parents and children. Furthermore, examining the data distributions based on the following two methods: regression polynomial results derived from standard height and weight curves and results derived from statistical values for %Fat by the BI method, it was reported that there was little difference [15]. These findings suggest that even for preschool children, when using a lot of data, it is possible to examine their body compositions, and this will offer useful, fundamental data.

This study measured the body compositions of preschool children with the BI method from the perspectives noted above. As a result, for all age groups of boys, no correlation was found between height and BMI, height and %Fat, as well as height and muscle percentages. In addition, the fat percentages for girls were higher than boys, and the muscle percentages were the opposite. These results show that there were differences according to sex. Furthermore, we made our evaluations based on a regression analysis of fat percentages for BMI and muscle percentages. As a result, the coefficient of determination in regression formula of fat percentages for BMI was 0.866-0.705, and a high correlation was found between BMI and fat percentages. This agrees with the reports of Sakaida et al. [14] and Sakai et al. [15]. Keys et al. [3] and Garrow and Webster [4] also accept that BMI has a complementary relationship with %Fat in preschool children. The regression analysis results of %Fat for BMI in this study may suggest that an increase in BMI affects an increase of %Fat in preschool children's infancy.

On the other hand, regarding the relation of BMI and muscle percentages for all age groups, the coefficients of determination in a regression polynomial of muscle percentages for BMI in boys showed more than 0.8 from the first to the third order, and more than 0.7 in girls. The relation of BMI and muscle percentages was the opposite of the relation of BMI to fat percentages fat percentages, and we found a high negative relation between boys and girls (coefficients of correlation: r =-0.903 - -0.950). A significant regression tendency was confirmed from the present results of the regression analysis of fat and muscle percentages for BMI for preschool children. This suggests that BMI can also be used to evaluate the fatness or thinness of a preschool child. Additionally, the possibility that the increase and decrease of muscle percentages can be evaluated with BMI suggests a new finding. In short, BMI can be regarded as the index that can evaluate fat and muscle percentages from early childhood.

These findings were made in a situation in which a completely accurate calculation using the impedance method for preschool children under the age of six has not been established. With the progress of preschool children science and technology, the establishment of such a method to measure the body compositions of preschool children is hoped for in the near future.

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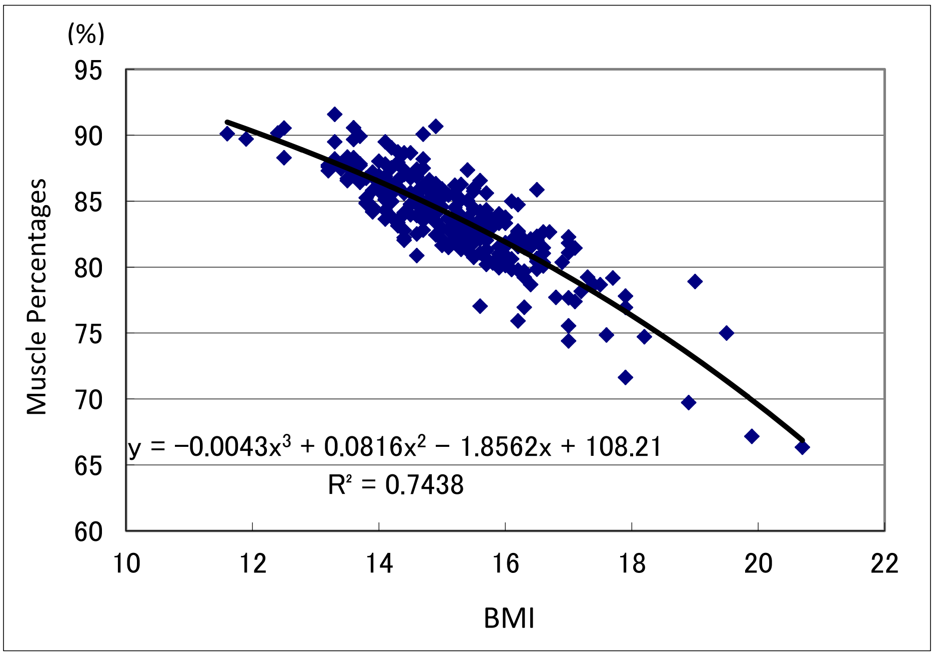

Fig. 4 A least square approximation polynomials for Muscle percentages in girls.