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<https://doi.org/10.15017/20702>

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出版情報：健康科学. 33, pp.63-68, 2011-03-25. 九州大学健康科学センター  
バージョン：  
権利関係：



—ORIGINAL—

## Estimate of the Body Fat in Nepalese Children by Their Body Mass Index

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### Abstract

The body mass index (BMI, kg/m<sup>2</sup>) is widely used to assess the prevalence of childhood obesity in populations, and to infer the risk of subsequent obesity-related disease. However, there are limitations regarding the use of the BMI based on stature and body mass. The purpose of this study was to determine a prediction equation for the fat mass (FM, kg) in Nepalese children using the relationship between the fat mass index (FMI, kg/m<sup>2</sup>) and the BMI. A cross-sectional design was used for the study. Data from 51 healthy children ranging from 3.0 to 5.0 years of age, including 24 boys and 27 girls selected from the ongoing Q-dai Nepal Health Survey (QNS), were used for these analyses. BMI was significantly and positively correlated with the FM (boys;  $r=0.564$ , girls;  $r=0.555$ ) and %FM (boys;  $r=0.686$ , girls;  $r=0.693$ ) in each gender group ( $p<0.05$ ). There was a significant linear correlation between the FMI and BMI in both boys ( $r=0.740$ ,  $p<0.05$ ) and girls ( $r=0.789$ ,  $p<0.05$ ). The Bland-Altman limits of agreement (-2 to +2 SD of the difference) were  $\pm 0.59$  for boys and  $\pm 0.39$  for girls. Of the 24 boys subjects, 22 (91.7%) were within  $\pm 2$  SD, and of the 27 girls subjects, 27 (100%) were within  $\pm 2$  SD. It can therefore be concluded that the BMI formula is a good indicator for measuring the nutritional status in Nepalese children. This equation is very easy to apply to children with any degree of obesity or thinness, and it also provides an estimate of the FM that is not much less accurate than that obtained by specialized laboratory methods.

**Key words:** children, body mass index, fat mass, fat mass index, body composition.

(Journal of Health Science, Kyushu University, 33: 63-68, 2011)

### Introduction

The body mass index (BMI) is widely used to assess the prevalence of childhood obesity in populations, and to predict the risk of subsequent obesity-related diseases<sup>1-4)</sup>. However, there are limitations regarding the use of the BMI. For example, the BMI is generally defined in

adults as an index of obesity that is largely independent of height. However, this characteristic of the BMI in adults does not necessarily hold true in children. On the other hand, the major shortcoming of the BMI is that the actual composition of the body mass (BM) is not taken into account. Excess body mass may be made up either

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of adipose tissue or muscle hypertrophy, both of which will be judged as 'excess mass'<sup>5)</sup>. Therefore, to resolve these issues, the BMI can be separated into two indices: the fat-free mass (FFM) and fat mass (FM). Traditionally, the FM has been normalized by expressing data as a percentage of the body mass (%FM), whereas FFM tends to be expressed in absolute units (in kg) unadjusted for body size<sup>6)</sup>. One such approach is to adjust body mass for stature, and then separate this adjusted body mass into its FFM and FM components. The BMI is the established index of body mass relative to stature.  $BMI = \text{body mass (kg)} / \text{stature (m}^2)$ . Hence,  $BMI = \text{FFM (kg)} / \text{stature (m}^2) + \text{FM (kg)} / \text{stature (m}^2)$ . These two component indices, known as the FFM index (FFMI) and FM index (FMI) are both discrete and adjusted for stature<sup>7)</sup>. The amount of body fat is a good indicator of the health and nutritional status<sup>8)</sup>. In addition, the BMI levels were more strongly associated with FMI ( $r=0.93-0.97$ ) in both children and adults<sup>9-10)</sup>.

Obesity is increasing worldwide and there is evidence that this increase has been faster among the developing countries<sup>11-12)</sup>. In Nepal, a developing country, the body fat of children has not been measured in recent times, and there have been no representative studies that have assessed the nutritional status on the basis of body composition in Nepalese children. In addition, childhood obesity often continues into adulthood<sup>13)</sup>. Therefore, it is thought that it might be possible to suppress the prevalence of obesity by better investigating the body composition of children allowing time for intervention. Recently, Komiya<sup>14)</sup> reported a prediction equation for FM determination in Japanese children aged 2.4-5.1 years old using the regression of the FMI on BMI. The purpose of this study was therefore to determine an accurate prediction equation for FM (kg) in Nepalese children using the relationship between the FMI and BMI.

## Methods

A cross-sectional design was used for the study. This study was conducted in a private school (Saraswoti Kunj HSS) in the Katmandu valley in September of 2009 and 2010. Data from 51 healthy

children ranging from 3.0 to 5.0 years of age, including 24 boys and 27 girls selected from the ongoing Q-dai Nepal Health Survey (QNS), were used for these analyses. The procedures were explained to the teacher. The principal gave his informed consent. Anthropometric data were assessed for the stature and body mass of the children. Stature was measured to the nearest 0.1 cm (Standing scale, TTM, Japan) and body mass to the nearest 0.02 kg on a balance beam scale (UC-322, A&D, Japan) with subjects wearing light clothing.

The equation used for children was based on the total body water (TBW) as determined by the deuterium oxide (D<sub>2</sub>O) dilution technique<sup>15)</sup> and BIA measurement as previously described<sup>16)</sup>. FFM was then given by the TBW / hydration of FFM<sup>17)</sup>. The FM was calculated as the difference between the BM and FFM.

The body mass index (BMI) was calculated as the body mass / Stature (kg/m<sup>2</sup>). Similar to the standardized body mass for stature<sup>2</sup> in the BMI, and we standardized the two components of body mass, FM and FFM, for stature<sup>2</sup>. These are FM / Stature<sup>2</sup> (kg/m<sup>2</sup>) and FFM / Stature<sup>2</sup> (kg/m<sup>2</sup>); that is,  $BMI = BM / \text{Stature}^2 = (FM + FFM) / \text{Stature}^2 = FM / \text{Stature}^2 + FFM / \text{Stature}^2$ .

## Statistical analysis

The results are expressed as the means  $\pm$  SD. Gender differences for anthropometric data were examined by the unpaired *t*-test. Differences with *p* values less than 0.05 were considered to be significant. In addition to the standard procedure for the assessment of agreement between a new method and the traditional method, a Bland and Altman plot<sup>18)</sup> was used to compare any differences between the two methods with the mean values.

## Results

The boys had greater stature and body mass than the girls ( $p<0.05$ ). The girls in the study had a

greater BMI ( $p < 0.05$ ) than the boys. The FM tended to be greater in girls, whereas %FM of girls was significantly ( $p < 0.05$ ) higher than that of boys (Table 1).

The correlation of the BMI with stature, body mass, FM and %FM by gender is presented in Table 2. There were no statistically significant difference between the BMI and stature (boys;  $r = -0.081$ , girls;  $r = -0.415$ ), between the BMI and body mass (boys;  $r = 0.222$ , girls;  $r = -0.006$ ) in either gender. The BMI was significantly and positively correlated with the FM (boys;  $r = 0.564$ , girls;  $r = 0.555$ ) and the %FM (boys;  $r = 0.686$ , girls;  $r = 0.693$ ) in each gender group ( $p < 0.05$ ).

There was a significant linear correlation between the FMI and BMI in both boys ( $r = 0.740$ ,  $p < 0.05$ ) and girls ( $r = 0.789$ ,  $p < 0.05$ ) (Figure 1). Regression of FMI on BMI yielded lines with relatively similar slopes of 0.668 for boys and 0.622 for girls.

The mean values of the estimates of body fat (FM, kg) based on the BMI and the values derived from the BIA method appear in Table 3. The mean values of the FM estimates based on the BMI were very similar to the values of the estimates of the BIA method (1.65 vs. 1.72 for boys and 2.11 vs. 2.13 for girls). The differences between the FM based on BMI and FM obtained as the value of the BIA method were 0.070 kg for boys and 0.021 kg for girls.

Table 1. Characteristics of the Nepalese children

	Mean $\pm$ SD (range)	
	Boys (n=24)	Girls (n=27)
Age, years	4.3 $\pm$ 0.8 (3.0-5.0)	4.1 $\pm$ 0.9 (3.0-5.0)
Stature, cm	101.8 $\pm$ 9.2 (87.0-116.6)	94.6 $\pm$ 6.1 (82.4-105.5)*
Body mass, kg	15.59 $\pm$ 2.9 (10.9-21.3)	13.81 $\pm$ 1.6 (10.3-16.6)*
Body Mass Index, kg/m <sup>2</sup>	14.9 $\pm$ 0.9 (13.0-16.7)	15.4 $\pm$ 0.8 (13.8-17.6)*
Fat mass, kg	1.7 $\pm$ 1.0 (0.1-4.4)	2.1 $\pm$ 0.6 (1.0-3.1)
%FM, %	10.5 $\pm$ 5.0 (0.9-20.5)	15.3 $\pm$ 3.6 (9.2-22.2)*

%FM = percentage of fat mass. Gender difference were analysed by t-test; \* $p < 0.05$

Table 2. Correlation coefficients between the body mass index (BMI) and stature, body mass, fat mass (FM), and percentage of body fat (%FM).

	Stature	Body mass	FM	%FM
BMI-Boys	-0.081	0.222	0.564*	0.686*
BMI-Girls	-0.415	-0.006	0.555*	0.693*

Significant level: \* $p < 0.05$

Table 3. Estimates of the body fat in children by equation based on the body mass index (FM-BMI). The difference is expressed as a deviation from the value derived from the FM.

	Boys (n=24)	Girls (n=27)
FM-BMI (kg)	1.65 $\pm$ 0.63	2.11 $\pm$ 0.42
FM (kg)	1.72 $\pm$ 1.02	2.13 $\pm$ 0.60
Deviation from FM (kg)	0.070 $\pm$ 0.384	0.021 $\pm$ 0.185

Figure 2 shows the differences between the FM based on BMI and the FM obtained using the values of the BIA method plotted against the means of these differences. The Bland-Altman limits of agreement ( $-2$  to  $+2$  SD of the difference) were  $\pm 0.59$  for boys and  $\pm 0.39$  for girls. Of the 24 subjects in boys, 22 (91.7%) were within  $\pm 2$  SD, and of the 27 subjects in girls, 27 (100%) were within  $\pm 2$  SD.

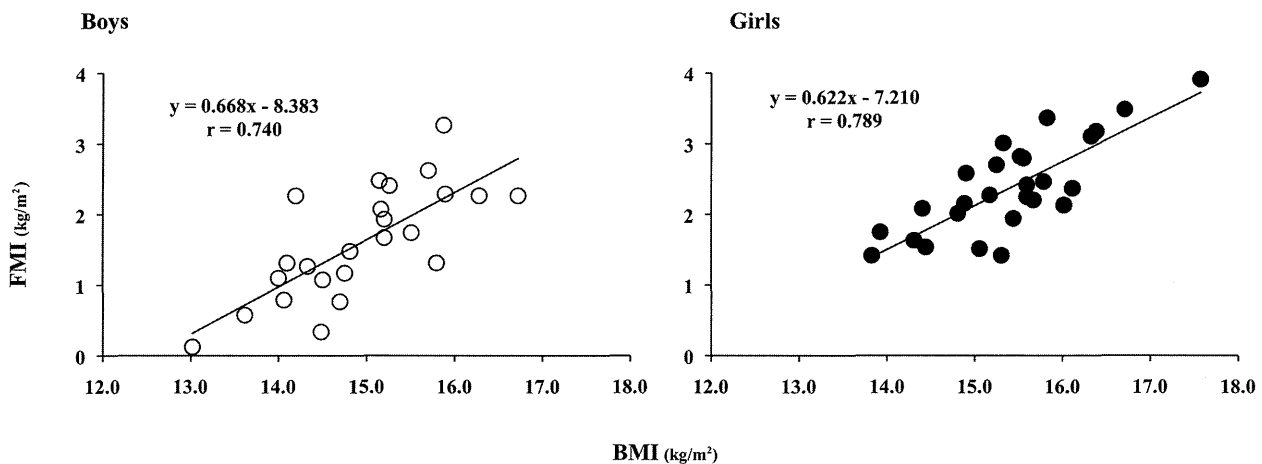


Fig 1. Correlation between BMI and fat mass index (FMI) in children aged 3.0-5.0 years.

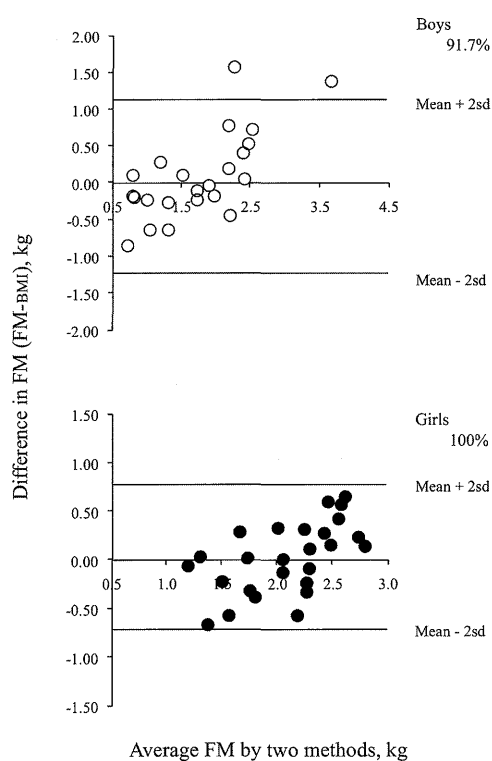


Fig 2. Difference against mean for fat mass (FM) data.

In this study, regression of  $FM/Stature^2$  (FMI) on  $BM/Stature^2$  (BMI) among boys yielded the formula:  $FM / Stature^2 = 0.668 * BM / Stature^2 - 8.383$ , with a correlation coefficient of 0.74. A similar analysis of the data for girls gives:  $FM / Stature^2 = 0.622 * BM / Stature^2 - 7.210$ , with a correlation coefficient of 0.789. Multiplying both sides of these equations by  $Stature^2$  gives:  
 Boys:  $FM = (0.668 * BM / Stature^2 - 8.383) * Stature^2$   
 Girls:  $FM = (0.622 * BM / Stature^2 - 7.210) * Stature^2$   
 (BM; kg, Stature; cm)

## Discussion

Nepal is one of the poorest nations in the world. The reported average per capita income was only \$400/yr as of 2008<sup>19)</sup>. Brink et al<sup>20)</sup> found caste to be essentially unrelated to nutritional status in a Nepal national nutrition survey. Relative to height, arm muscle area, the FM in the Nepalese sample was smaller than in the National Center for Health Statistics (NCHS) sample<sup>21-23)</sup>. Martorell et al<sup>24)</sup> have reported that the severity of protein-energy malnutrition is greater in Nepal than in Guatemala and Brazil, and Latin American children may

be able to cope with the stress of malnutrition by growing less in body size without altering their weight / height ratios. On the other hand, obesity is increasing worldwide and there is evidence that this increase has been faster among developing countries<sup>11, 12)</sup>. It will therefore be necessary to evaluate the FM early in order to provide an opportunity to intercede in situations where there are obese children or children with stunted growth.

The BMI subsequently declines and reaches a nadir at around 6 years of age, and then increases again throughout childhood. This second BMI gain is called the adiposity rebound (AR). Recent reports indicated that an early AR is related to the development of later obesity. Also, after AR, it is found that the subcutaneous fat tissues suddenly increase<sup>25-28)</sup>. Therefore, in the physical evaluation of infants before the AR expression and the epidemiological investigation in the developing countries that are thought to be slow of the AR expression, as for the estimate expression of the body fat of this study, it may be with an effective expression.

The purpose of the present study was to establish a reasonable prediction equation with which to estimate the FM from the BMI based on stature and body mass in Nepalese children. The main criticism made of the BMI as a measure of adiposity is that this index should be totally independent of stature<sup>29)</sup>. The present study found no statistically significant correlation between the BMI and stature in either gender. In addition, the correlations between BMI and stature were generally not as high as the correlations between BMI and both the FM and %FM. The BMI of this study was significantly and positively correlated with the FM and %FM in each gender group. The sex-specific correlations of the BMI with the FM and %FM were moderate ( $r=0.555$  to  $r=0.693$ ,  $p<0.05$ ). Several studies have reported a good correlation between the BMI and obesity in childhood<sup>30-33)</sup>. In addition, the correlation between the BMI and FM of this study was the almost the same as that reported in the results of the preliminary research in Japanese children<sup>14)</sup>.

The estimated expression of body fat using the body mass and stature obtained in this study have the following advantages: 1) Neither any special measurement techniques nor special devices are required

to estimate the fat composition. 2) This method makes the performance of large-scale investigations of the growth and development of Nepalese children possible. Furthermore, 3) Both obese children and those with stunted growth or in a malnourished state can be easily identified via a simple screening program.

It can therefore be concluded that the BMI formulas were good indicator for measuring nutritional status in Nepalese children. This equation is very easy to apply to children with any degree of obesity or thinness, and it also provides an estimate of the FM that is not substantially less accurate than that obtained by specialized laboratory methods.

### Acknowledgment

We wish to thank Mr. and Mrs. K. B. Tamang for their excellent cooperation and Saraswoti Kunj HSS. This work was supported by Grants-in-Aid for Scientific Research (C21610026) from Japan Society for the Promotion of Scientific Research.

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