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REVIEW

Lean body mass in preschool aged urban children in India: gender difference

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Objective: To estimate lean body mass (LBM) in preschool aged boys and girls in India and explore gender difference.
Design: Crossectional.
Setting: Immunization clinic of a charitable Government General Hospital in Kolkata, India.
Subjects: Two-hundred and forty-five children (147 boys and 98 girls) aged 1 – 5 y from among the urban poor were admitted in the study between July 1999 and December 2000. Children with acute or chronic illness or congenital malformation were excluded.
Methods: Length/height to the nearest 0.1 cm, weight to the nearest 10 g and total body resistance using multifrequency bioelectrical (Xitron 4000B) impedance analyzer (BIA) at 50 kHz were measured. Their nutritional status was compared with National Center for Health Statistics (NCHS) median data and lean body mass (LBM) was calculated using anthropometry and BIA equations. The groups were compared using analysis of variance and multiple linear regression.
Results: Girls were more stunted ($P<0.001$) and underweight ($P<0.047$), while the degree of wasting was similar. Mean LBM percentage was higher in boys compared with girls by anthropometry ($P<0.001$) and BIA ($P<0.005$), which persisted after adjusting for age. With increasing age, LBM percentage declined in girls ($P<0.02$) in contrast to reference girls, in whom it increased. In boys LBM percentage increased with age as is in reference boys.
Conclusions: In addition to the girls being more stunted and underweight, LBM% decreased in girls with increasing age but steadily increased in boys, suggesting hidden deprivation of female children.
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Introduction

An important nutritional problem in preschool age children in the developing world is that of protein-energy malnutrition (PEM; Bourdel-Marchasson *et al*, 1999, 2000; Frongillo, 1999). Three measurements, ie age, weight and height, are usually combined to form three indicators of nutritional status, ie height-for-age, weight-for-age and weight-for-height (WHO, 1995b) which are compared with international reference population data such as those collected by the US National Center for Health Statistics (NCHS). Height-for-age, weight-for-age and weight-for-height less than -2 *Z*-score of NCHS reference data indicate stunting, underweight and wasting respectively (WHO, 1995; De Onis and Blossner, 1997). These indicators are widely used because of their simplicity and usefulness in diagnosing and estimating the problem of malnutrition (National Academy, 1998) and for global comparison. These measurements have also been used for guiding intervention programmes. However, rapid changes in lean body mass (LBM) and fat mass (FM) occur during growth and development and the LBM is a more precise measure of somatic growth. Because it is difficult to measure LBM in preschool age children it has not been used

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to monitor malnutrition. Data for lean body mass in normal children is sparse. Fomon *et al* (1982) compiled normative data for Western children but no data is available on LBM in undernourished preschool children in boys and girls from developing countries. Several techniques available for measuring body composition are sophisticated (Going, 1996; Henderson *et al*, 2001; Heymsfield *et al*, 1996; Janssen *et al*, 1997; VanderJagt *et al*, 2001; Wang *et al*, 1999) and limited to laboratory research. LBM in preschool-age children can, however, be estimated using suitable anthropometric equations and by bioelectric impedance analysis (NIH, 1994). In the present study we have measured the LBM in a group of urban preschool children belonging to low socio-economic group using bioelectrical impedance analysis (BIA) and anthropometric equations as validated earlier (Shaikh *et al*, 2002) for this population and investigated the pattern of percentage LBM (LBM%) in boys and girls.

Subjects and methods

The study was conducted in 245 children (147 boys and 98 girls) from among the urban poor attending an immunization clinic of a charitable government hospital in Kolkata. Parents of children attending the clinic were approached for participation of their children in this study. Informed consent was obtained from their parents. Subjects with illness or congenital malformation were excluded after a clinical evaluation. A total of 245 children were recruited from 239 families. These families come from among the urban poor and their family income ranged from US 25 to 63 per month. Mean $\pm$ s.d. family size (defined as numbers eating from the same cooking pot) was 5.7 ± 2.7. It may be noted that per-capita gross national product (GNP) in India is US 38 per month (UNICEF, 2001). Sixty percent of the families lived in one room and 78% of the living rooms were temporary structures. Twenty three percent of fathers and 35% of mothers were illiterate. In comparison, 56% of adult females and 29% of adult males in India are illiterate. The Institutional Ethical Committee approved the study.

Athropometry

All measurements were taken in the morning (Ulijaszek & Kerr, 1999). Anthropometric measurements were carried out as described previously (Gibson, 1990). For infants and children less than 2 y of age recumbent length was measured with a wooden measuring board to the nearest 0.1 cm. Children over 2 y of age were measured in the standing position using a stadiometer to the nearest 0.1 cm. Weight was measured with one layer of light underclothing on an electronic weighing balance (Avery India Limited) to the nearest 5 g for children less than 2 y of age and to the nearest 10 g for those older than 2 y of age. The weighing instrument was checked regularly using standard weights. Anthropometric equations for body composition as developed by Mellits and Cheek (1970) were used for deriving total body water. These equations are:

$$\text{for boys—TBW (kg)} = -1.927 + 0.465 \times W + 0.045 \times H \quad (1)$$

$$\text{for girls—TBW (kg)} = 0.076 + 0.507 \times W + 0.013 \times H \quad (2)$$

where TBW is total body water, H is height in cm and W is weight in kg. Lean body mass was calculated from total body water using eqn (4), as stated later.

Bioelectrical impedance analysis

Resistance was measured with a multifrequency bioelectrical impedance analyzer (Xitron model 4000B; Xitrons technologies Inc., San Diego, CA, USA) using 50 kHz at an oscillating current of 100 μA (NIH, 1994; Ward *et al*, 1998). Measurement was taken in the morning after overnight fast with restriction of food and fluid intake and the bladder emptied. Children with dry light clothes were put supine with arms apart from the body and legs separated so that the thighs did not touch. After cleaning the skin contact area with alcohol, one pair of electrodes (disposable ECG electrode foils) was placed on the dorsal surface of the right hand between the distal metacarpal and radio-ulnar joints. Another pair of electrodes was placed between the lateral malleoli and ankle joints of the right foot (Kushner, 1992; Tyrrell *et al*, 2001; Simons *et al*, 1995). A minimum distance of 3 cm has been maintained between the electrode pair on the foot and hand respectively. Resistance (R) value was recorded and used to calculate the total body water (TBW) using the following equation (Fjeld *et al*, 1990):

$$\text{TBW (kg)} = 0.76 + 0.18 \times H^2 \div R_{50} + 0.39 \times W \quad (3)$$

where H is height in cm, W is weight in kg and R is resistance at 50 kHz.

Lean body mass was calculated from TBW derived from eqns (1), (2) and (3) using the following equation:

$$\text{Lean body mass (kg)} = \text{TBW} \times 100 \div P \quad (4)$$

where P is the proportion of LBM as water for reference children in the age group 1–5 y (Fomon *et al*, 1982).

Statistical analysis

Analysis was done using Epi Info Version 6.0 (Epi, Version 6, 1994, CDC, Atlanta, GA, USA, and WHO, Geneva) and Stata Version 5.0 (Stata Corporation, TX, USA, 1985–1997). For anthropometric data, a software package based on National Center for Health statistics (NCHS) database as provided with Epi Info software was used. Mean values were compared for body composition between boys and girls using analysis of variance. Multiple linear regression was used for adjusted analysis. A difference was considered significant if $P < 0.05$.

Table 1 Age, height, weight and calculated LBM% by anthropometry and BIA methods in boys and girls and age-averaged reference values for LBM%

Variables	*Boys* (n = *147*) *mean* ± *s.d.*	*Girls* (n = *98*) *mean* ± *s.d.*	P-*values*
Age (months)	26.8 ± 14.84	30.1 ± 15.82	$P = 0.104$
Height (cm)	83.9 ± 9.23	83.1 ± 9.59	$P = 0.649$
Weight (kg)	10.4 ± 2.26	9.9 ± 2.20	$P = 0.805$
LBM%[a]			
Anthropometry	83.6 ± 2.90	80.3 ± 2.06	$P < 0.001$
BIA method	81.9 ± 2.95	79.7 ± 2.16	$P < 0.005$
LBM%S[b] (age averaged reference values)	82.0	80.7	

[a]Lean body mass percentage in study children.
[b]Lean body mass percentage in reference children (Fomon *et al*, 1982).

Results

Baseline features and mean LBM% in boys and girls are shown in Table 1. Mean age tended to be higher in girls. Mean height and weight in the two age groups were similar. Calculated LBM% using either anthropometric equations or BIA method was higher in boys ($P < 0.005$). Derived nutritional indicators such as height-for-age, weight-for-age and weight-for-height *Z*-score compared with the US National Center for Health Statistics (NCHS) data are shown in Table 2 and values less than -2 *Z*-score were taken to indicate stunting, underweight and wasting, respectively. Compared with boys, mean height-for-age ($P = 0.001$) and weight-for-age ($P = 0.047$) *Z*-scores were lower in girls. However, mean weight-for-height *Z*-score was similar in the two groups ($P = 0.50$), suggesting a similar degree of wasting, which remained similar after adjusting for age ($P = 0.49$, multiple linear regression).

In Figure 1 we compared changes in the mean *Z*-scores for stunting and underweight with increasing age. While the mean values tended to decrease with increasing age the girls were consistently more stunted ($P = 0.005$, age adjusted) and underweight ($P = 0.13$, age-adjusted) compared with study boys. The changes in the mean LBM% in study boys and girls with increasing age are shown in Figure 2 along with reference values according to age group. LBM% in study boys was higher ($P = 0.02$) than the reference values in the youngest age group, which steadily increased with age both in the study and reference boys. However, the rate of increase was slower than the reference values, so that in the highest age group the mean LBM% in reference boys was higher than the study boys ($P = 0.02$). In study girls also the mean LBM% in the youngest age group was higher than the reference values ($P = 0.001$). However the LBM% steadily decreased in study girls while it increased in reference girls. In the highest age group the LBM% in study girls was substantially lower than the reference values ($P = 0.001$). Furthermore, the mean LBM% in girls in the highest age group was significantly less ($P = 0.005$) than in the lowest age group. In addition, the LBM% in boys compared with girls in the highest age group was considerably higher ($P = 0.001$).

Discussion

This was a purposive sample and recruitment took place in a clinic of a public hospital. The study children belong to low socio-economic group as indicated by their economic and education indicators. The boys and girls came from a closely similar background. High prevalence of children with stunting, underweight and wasting indicates malnutrition (WHO, 1995; De Onis & Blossner, 1997). Stunting indicates long-term, cumulative inadequacies of health or nutrition or both. It refers to shortness that is a deficit in linear growth that failed to reach potential as a result of sub-optimal health or nutritional conditions. It may be noted that underweight is a function of short stature, low tissue mass or both. Although it is more difficult to interpret, weight-for-age is often used to screen for undernutrition because it does not require measurement of height. On the other hand, wasting refers to thinness that is often due to a recent and severe event leading to significant weight loss, which may result from acute starvation, severe disease, chronic dietary deficits and/or disease alone.

The global prevalence of stunting and underweight in developing countries in children under 5 y averages about 33 and 27%, and in South Asia, 44 and 29%, respectively. The prevalence of wasting in developing countries is considerably lower than that of stunting and underweight. The expected prevalence of wasting in developing countries is 2–3% and in South Asia it is 15% (ACC/SCN, 2000). Our study was conducted in preschool-aged children aged 1–5 y and in this age group prevalence of stunting, underweight and wasting were very high (Table 2). Furthermore, the prevalence of stunting was higher in girls than boys (Figure 1) after

Table 2 Derived nutritional indices in boys and girls

	Boys (n = *147*)		*Girls* (n = *98*)	
z-scores[a]	*Mean* ± *s.d.*	*z-scores* < -2	*Mean* ± *s.d.*	*z-scores* < -2
Height-for-age	−1.05 ± 1.28*	25.2%	−1.58 ± 1.13*	31.6%
Weight-for-age	−1.90 ± 0.93†	47.6%	−2.13 ± 0.81†	54.1%
Weight-for-height	−1.56 ± 0.80‡	28.0%	−1.49 ± 0.78‡	25.5%

[a]The height-for-age and weight-for-age *Z*-scores are significantly higher in boys than girls. The weight-for-height *Z*-scores are not significantly different (*$P = 0.001$; †$P = 0.047$; ‡$P = 0.50$).

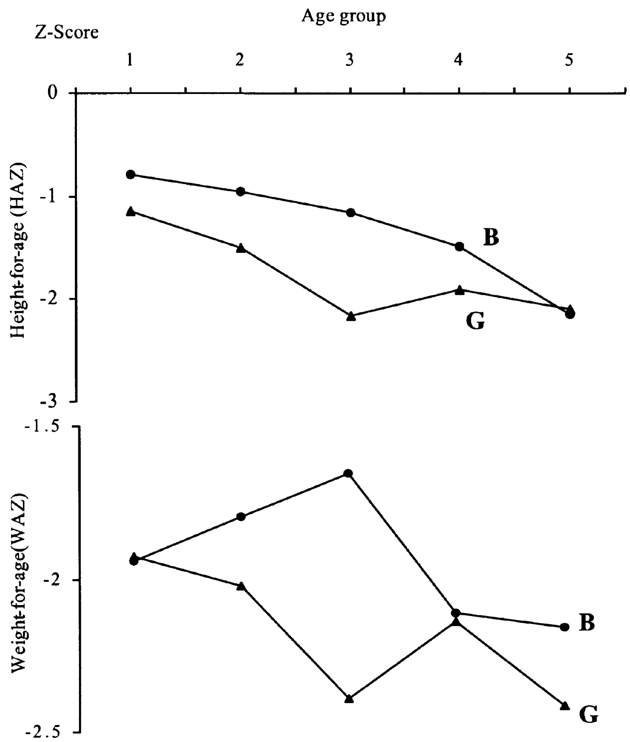

Figure 1 The mean height-for-age *Z*-score ($P < 0.005$, age adjusted) and weight-for-age *Z*-score ($P < 0.04$, age adjusted) in boys (B) and girls (G) according to age group. Age groups: 1, 12–20 months (B = 40, G = 28; $P_{HAZ} = 0.439$ and $P_{WAZ} = 0.339$), 2, 21–30 months (B = 34, G = 20; $P_{HAZ} = 0.077$ and $P_{WAZ} = 0.383$); 3, 31–40 months (B = 26, G = 16; $P_{HAZ} < 0.001$ and $P_{WAZ} < 0.001$), 4, 41–50 months (B = 22, G = 16; $P_{HAZ} = 0.098$ and $P_{WAZ} = 0.452$); and 5, 51–60 months (B = 25, G = 18; $P_{HAZ} = 0.833$ and $P_{WAZ} = 0.295$).

adjusting for age. A similar trend was found for the age-adjusted prevalence of underweight (Figure 1).

Due to substantial technical difficulties in measuring the LBM in preschool-aged children, data on normal children is sparse. However, based on normative data compiled by Fomon *et al* (1982), growth curves for LBM in normal Western children were constructed (Forbes GB, 1987) which showed that LBM in absolute quantity increases in a nearly linear fashion in this age group of 1–5 y. However, a small difference is maintained between boys and girls in that the absolute LBM is consistently higher in boys. It may be noted that the degree of wasting in the study children was similar in boys and girls (Table 2), ie no significant effect of gender was seen on weight-for-height *Z*-score after adjusting for age. We can only speculate on the reason why the LBM% in the youngest age group was consistently higher than in the reference children. The practice of prolonged breast-feeding combined with late and inadequate introduction of semisolid and solid foods, common in this population, may be a contributing factor. An important new finding of this study was that LBM% declined sharply with age in study girls while it rose in reference girls. In contrast, LBM% in study boys increased with age and the direction of change is similar to that reference boys (Figure 2). This is so despite the fact that the degree of wasting was similar in boys and girls across this age group. Not only were the girls more stunted and underweight, the LBM% also declined with increasing age (unlike reference girls). Comparing this trend with the reference data for LBM% in boys and girls in the same age range may have revealed a hidden deprivation in girls.

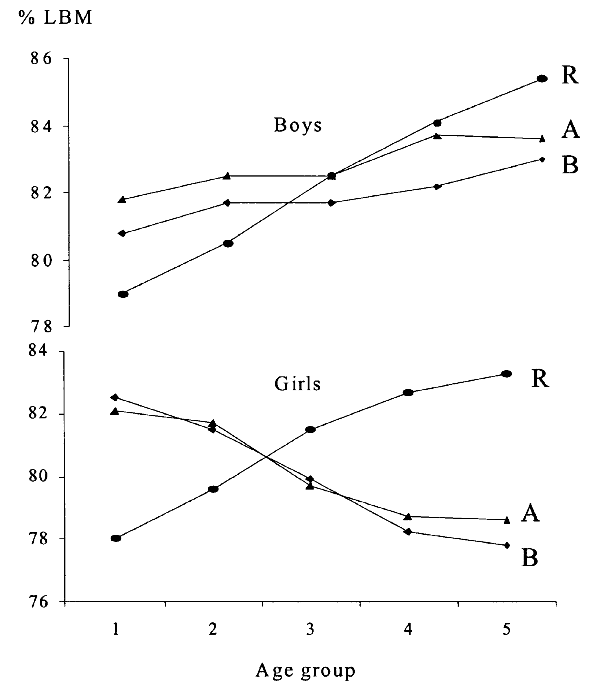

Figure 2 The mean lean body mass percentage of study boys and girls as measured by anthropometric equations (A) and BIA method (B) compared with reference (R) values according to age group. Age groups: 1, 12–20 months ($P = 0.02$, reference boys *vs* study boys; $P = 0.001$, reference girls *vs* study girls); 2, 21–30 months; 3, 31–40 months; 4, 41–50 months; and 5, 51–60 months (study boys *vs* reference boys, $P = 0.02$; study girls *vs* reference girls, $P = 0.001$).

The causes of poor growth in preschool-aged children in developing countries are poor maternal nutrition status at conception and undernutrition *in utero*, inadequate breast-feeding, delayed complementary feeding (WHO, 1999; Gillespie, 1997), inadequate quality or quantity of complementary feeding, impaired absorption of nutrients due to intestinal infections or parasites, or a combination of these problems. In an African pastoral community-based study the prevalence of all indicators of undernutrition showed a significant increase with age but the study did not show a statistically significant sex difference in any age group (Sellen, 2000). However, demographic surveillance data in rural Bangladesh demonstrated that female children had a 1.8-times higher risk of dying than male children. The cause of death, which contributed the most to this excess female mortality, was severe malnutrition and diarrhoeal diseases

(Fauveau *et al*, 1991). Gender inequalities in health in Bangladesh varied significantly according to occupational status, such that the effect of sex was dependent upon parental occupation (Rousham, 1996). This suggests both temporal and socio-economic variations in gender inequalities in health in South Asia.

Girls in South Asia seem to be generally less well cared for by their families, their parents and their society (Birch & Fisher, 2000; Fisher & Birch, 2000). It is common in South Asia for men to eat the most and the best, leaving the women and children to eat the last and the least (Schoenbanu *et al*, 1995) the mother will then feed her son the best of what is left at the expense for her own and her daughter's nutritional well-being.

Our results suggest that the degree of stunting and underweight does not fully reveal the full magnitude of nutritional deprivation of the girls, which may be brought out by measuring LBM%. This finding in girls may have an important and adverse consequence subsequently during childbearing age. Furthermore, the technical difficulty of measuring lean body mass may be overcome using appropriate anthropometric equations and/or bioelectric impedance analysis method. This finding needs confirmation in future studies designed to address this question.

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