Original Article

Body mass index is associated with fat mass in normal, overweight/obese, and stunted preschool children in central Thailand

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Background and Objectives: Body mass index (BMI) is widely used as a surrogate measure of adiposity. The relationship between BMI and body fatness varies by race, sex, and age and more variations have been found among children. This study investigated the relationship between BMI and fat mass among 3-5 year old children having different nutritional status. **Methods and Study Design:** A cross-sectional study was conducted in 15 daycare centers in central Thailand. 137 healthy preschool children were recruited according to their nutritional status: thin [BMI for age Z scores, (BAZ) <-2 SD], normal BMI (-2 SD≤ BAZ ≤+2 SD), overweight/obese (BAZ >+2 SD), and stunted [height for age Z scores < -2 SD]. Fat-free mass was determined by deuterium dilution technique. Fat mass (FM) in kilograms (TFM) and in percentage (FM%), and fat mass index (FMI, FM/height^2) were calculated. **Results:** FM and FMI were the highest in the overweight/obese groups. In the thin group, girls had higher FMI compared to boys (3.2 vs 2.8 kg/m^2, p<0.05). The relationship between BMI with FMI and FM differed by nutritional status. BMI was more strongly associated with FMI, TFM, and FM% in the overweight/obese (r=0.97, 0.95, 0.80, p<0.05) and the normal (r=0.88, 0.84, 0.68, p<0.05) groups but not in the stunted group, and inconsistent in the thin group. **Conclusions:** The inconsistency in the relationship between BMI and body fatness suggests that BMI is appropriate for reflecting adiposity in normal and overweight/obese children, but not undernourished preschool children.

Key Words: preschool children, fat mass, BMI, deuterium, nutritional status

INTRODUCTION

The Fifth National Nutrition Survey in Thailand (2003) indicated that the prevalence of obesity (using weight-for-height z score >+2SD) in children aged 0-5 years increased from 5.4% in 1995 to 6.9 % in 2003.[1,2] This equaled a 20% increase in prevalence of obesity in this age group. In the same survey, prevalence of wasting and stunting was 9.0% and 15.6%, respectively, suggesting the existence of a 'double burden of malnutrition'.[1,2] A later survey in 2006 also confirmed the double burden of malnutrition (DBMN), with a slightly decreased stunting prevalence (11.9%), while overweight/obesity was 6.9%.[3] Postnatal growth associated with feeding, especially around 4 y of age onward, results in the differential accretions of fat and muscle mass, and becomes an important risk factor of obesity and non-communicable diseases (NCD) in later life. Prevention of obesity and stunting in young children remains a high priority in populations with nutrition in transition.[4] Understanding the pattern of adiposity and fat-free mass among children with a mix of nutritional status will contribute to better planning for appropriate prevention strategy. Despite the increasing trend of childhood obesity, only a few studies have been conducted on body composition among preschool children. There are several methods for measuring body composition in children; accuracy and cost are often considered.[5] The deuterium dilution technique is an accurate method for assessing body composition of children. This study used the deuterium dilution technique to assess fat mass and fat-free mass in preschool children aged 3-5 years old having different nutritional (anthropometric) status, namely, stunting, thin, normal, and overweight/obesity. We aimed to determine the relationship between nutritional status and fat mass in these children.

MATERIALS AND METHODS

Study design and participants

A cross-sectional study was conducted in preschool children aged 3-5 years old in 15 purposively selected daycares in 2 provinces (Nakhon Pathom and Samut Prakan) in central Thailand. Children in each daycare center were screened and categorized into 4 nutritional status groups based on WHO growth reference 2006: 1) thin [body mass index for age z scores, (BAZ) <-2 SD], 2) normal

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BMI (-2 SD≤ BAZ ≤+2 SD), 3) overweight/obese (BAZ >+2 SD), and 4) stunted [height for age z scores, (HAZ) <-2 SD].[6] The total of 845 children was screened and 5%, 3%, and 14% were categorized as stunted, thin, and overweight/obese, respectively. Among the normal and overweight/obese children, they were randomly selected into the respective categories. Due to a low prevalence of wasting and stunting, a non-random purposive sampling approach was employed to enroll children into the thin and stunted groups. The exclusion criteria included particular medical history, chronic diseases, ongoing medical treatments likely to affect body composition, and malformation or muscle diseases. Sample size for the study was calculated using the equation by Kirk at the power of 80%, 25 children (n=25) per group were needed.[7] An additional 20% of the sample size was recruited to compensate for incomplete data. Therefore, a total sample of 30 children in each group was recruited. Ethical clearance was approved by the Mahidol University Institutional Review Board, Thailand. The study protocol was explained to parents, children, and daycare center staff and written informed consent was obtained from a parent/guardian of each child.

Socio-demographic data

Socio-demographic data were collected: maternal age, education and family income were interviewed using socio-demographic questionnaire. Child birth date and birth-weight data were taken from birth certificates. Child age was calculated from birth date and the date when anthropometric assessment was done.

Anthropometric measurements

Weight and height of all children were measured using a standard technique.[8]The measurements were repeated in selected children on the day of deuterated water administration. Body weight was measured with light-weight clothing to the nearest 0.1 kg using a digital weighing scale (Seca digital scale model841, Seca Corporation, Hamburg, Germany). Standing height (without shoes and socks) was determined to the nearest 0.1 cm using a UNICEF wooden height board. Waist circumference (WC) was also measured on the same day. WC measurement was taken at the midpoint between the superior border of the iliac crest and the lowest rib cage, to the nearest 0.1 cm using a non-stretching tape. All measurements were performed in triplicate and the average was used for analysis. Body mass index (BMI) was calculated. Weight for age z scores (WAZ), weight for height z scores (WHZ), HAZ, and BAZ were determined using the 2006 World Health Organization (WHO) growth standard for children 0-5 years old.[6]

Body fat

Total body water (TBW) was assessed by the deuterium dilution technique. In brief, after the baseline urine sample was collected, 20-mL deuterated water containing 2 g of 99% D_2O was administered orally through a drinking straw. The three post-dose samples were collected at approximate 3 h, 4 h and 5 h after the dose was given. All urine samples were analyzed for the deuterium enrichment using the Isotope Ratio Mass Spectrometry (SerCon Limited, United Kingdom). The TBW content was derived using the plateau approach.[9] Fat-free mass (FFM) was calculated from TBW using Lohman's age appropriate hydration constants for preschoolers.[10,11] Fat mass (FM) was obtained by subtracting FFM from total body weight and was expressed in kilograms and percentage. Fat mass index (FMI, FM/height^2) and fat-free mass index (FFMI, FFM/height^2) were calculated.

Data analysis

All continuous variables were tested for normality using the Kolmogorov-Smirnov test. Descriptive analyses were undertaken for demographic and anthropometric data using Analysis of Variance (ANOVA) or Chi square test. Differences of FM and FFM of children with different nutritional status were examined using ANOVA; differences between sexes using unpaired T-test. Pearson's correlation was used to explore the relationship of FMI and FM with BMI and WC in each nutritional group. All statistical analyses were performed using SPSS for Windows version 18 (SPSS Inc., Chicago, IL, USA) and a *p*-value of 0.05 was considered statistically significant.

RESULTS

Overall, 137 preschool children (70 boys and 67 girls) participated in the study. Due to a time gap between screening and assessment of body composition, more children were enrolled to replace the children who shifted to normal status. The proportion of boys and girls was similar in each nutritional status group.

Background and anthropometric characteristics

General and socio-economic characteristics are summarized in Table 1. Data were compared among stunted, thin, normal BMI, and overweight/obese children. Mean age of children was not different among groups, and ranged from 46.0±5.7 to 49.0±6.5 months. Age of mothers, maternal education, and percentage of families with income below median were similar among all groups.

Anthropometric data are presented in Table 2. Children in the obese group had the highest birth weight (3.2±0.4 kg) compared to other groups. There were no differences in birth length among the groups. Means of weight, height, WC, WAZ, HAZ, WHZ, and BAZ were the highest in the overweight/obese group compared to others. Weight and WAZ of the stunted children was similar to that of the thin children (12.6±0.8 kg vs 12.3±1.4 kg and -2.0±0.5 vs -2.3±0.7) but was less than that of the normal BMI children. The means of WC were similar among children in stunted and thin groups (46.9±1.5 cm vs 44.9±1.7 cm), and significantly lower than that of the overweight/obese and normal BMI groups.

Total fat mass (TFM) among the stunted (3.3±0.5 kg) and thin children (2.9±0.5 kg) was lower than those of the normal BMI (4.3±1.1 kg) and overweight/obese (10.1±2.9 kg) children (p<0.05) (Table 2). However, there were no significant differences in fat mass percentage (FM%) among stunted children when compared to normal, and thin children. Similar patterns were found for FFM and fat-free mass percentage (FFM%) among these anthropometric groups. FMI and FFMI were similar between the normal BMI and stunted groups; lowest in

Table 1. Socio-economic characteristics and anthropometry by nutritional status of 3-5 y old children

Characteristics	Normal BMI (n=47)	Stunted (n=30)	Thin (n=30)	Overweight/obese (n=30)	p value[†]
Sex, men (%)	53	50	50	50	0.989
Age (mo)	46.0±5.7	48.9±5.3	49.0±6.5	47.8±4.7	0.067
Age of mothers (y)	31±7	30±6	31±6	33±7	0.307
Maternal education (%)					0.080[‡]
No education	2.2	3.4	0	3.3	
Grade 1-4	10.9	17.2	16.7	36.7	
Grade 7-12	41.3	51.7	63.3	36.7	
>grade 12	45.7	27.6	20.0	23.3	
Family income below median (<15,000 THB/mo) (%)	31.9	40.0	36.7	33.3	0.897[‡]
Birth weight (kg)	2.9±0.5[a]	2.8±0.5[a]	2.8±0.6[a]	3.2±0.4[b]	0.001
Birth length (cm)	49.1±3.1	48.5±3.1	48.7±2.7	50.5±2.8	0.065
Weight (kg)	15.2±2.0[a]	12.6±0.8[b]	12.3±1.4[b]	24.5±4.8[c]	<0.001
Height (cm)	99.1±4.3[a]	93.3±2.7[b]	98.8±5.6[a]	106.0±4.4[c]	<0.001
BMI (kg/m^2)	15.5±1.4[a]	14.4±0.9[a]	12.5±0.4[b]	21.9±3.0[c]	<0.001
Waist circumference (cm)	49.8±3.3[a]	46.9±1.5[b]	44.9±1.7[b]	63.8±6.5[c]	<0.001
Weight for age z scores	-0.4±1.0[a]	-2.0±0.5[b]	-2.3±0.7[b]	3.0±1.6[c]	<0.001
Height for age z scores	-0.6±0.8[a]	-2.4±0.3[b]	-1.1±0.9[c]	0.6±0.8[d]	<0.001
Weight for height z scores	0.0±1.0[a]	-0.9±0.7[b]	-2.5±0.4[c]	3.9±1.6[d]	<0.001
BMI for age z scores	0.0±1.0[a]	-0.7±0.6[b]	-2.4±0.3[c]	3.9±1.8[d]	<0.001

[†]ANOVA (Tukey's post hoc test), values in a row without a common superscript letter differ, p<0.05.
[‡]Chi square test.
Normal BMI: -2 SD≤ BAZ ≤2 SD; Stunting: HAZ <-2 SD; Thinness: BAZ <-2 SD; Overweight/obesity: BAZ >2 SD.

Table 2. Body composition of preschool children by nutritional status of 3-5 y old children

Nutritional status	Normal BMI (n=47)	Stunted (n=30)	Thin (n=30)	Overweight/ obese (n=30)	p value[†]
Total body water (kg)	8.6±1.0[a]	7.2±0.6[b]	7.3±0.9[b]	11.3±1.6[c]	<0.001
Total body water (%)	56.4±3.2[a]	57.6±2.5[a,b]	59.4±2.6[b]	46.5±3.0[c]	<0.001
Fat mass (kg)	4.3±1.1[a]	3.3±0.5[b]	2.9±0.5[b]	10.1±2.9[c]	<0.001
Fat mass (%)	27.8±4.1[a]	26.2±3.2[a,b]	23.9±3.4[b]	40.5±3.9[c]	<0.001
Fat mass index (kg/m^2)	4.3±0.9[a]	3.8±0.6[a]	3.0±0.4[b]	8.9±2.0[c]	<0.001
Fat-free mass (kg)	10.9±1.2[a]	9.3±0.7[b]	9.3±1.1[b]	14.5±2.0[c]	<0.001
Fat-free mass (%)	72.2±4.1[a]	73.8±3.2[a,b]	76.1±3.4[b]	59.5±3.9[c]	<0.001
Fat-free mass index (kg/m^2)	11.1±0.8[a]	10.7±0.7[a]	9.5±0.5[b]	12.9±1.1[c]	<0.001

[†]ANOVA (Tukey's post hoc test), values in a row without a common superscript letter differ, p<0.05.

the thin group and highest in the overweight/obese group.

In each nutritional group, girls tended to have higher FM% compared to boys (Table 3). There was a significant difference in FM% between boys and girls in all nutritional groups, except for the overweight/obese group. However, statistical significant differences in FMI and TFM by sex was found only in the thin group (3.2 kg/m^2 in girls vs 2.8 kg/m^2 in boys and 3.2 kg in girls vs 2.7 kg in boys, p<0.05).

Relationship of body mass index and waist circumference with body fat

Associations between BMI with FMI and FM varied by nutritional status (Table 4). BMI was more strongly associated with FMI, TFM, and FM% in the overweight/obese (FMI: r=0.97, p<0.05; TFM: r=0.95, p<0.05; FM%: r=0.80, p<0.05) and the normal BMI (FMI: r=0.88, p<0.05; TFM: r=0.84, p<0.05; FM%: r=0.68, p<0.05) groups than in the stunted group (FMI: r=0.63, p<0.05; TFM: r=0.60, p<0.05; FM%: NS). There was no significant association between BMI with FMI and FM% in the thin group, while BMI was moderately significant associated with TFM (r=0.40, p<0.05).

The relationships of WC with FMI, TFM, and FM% were significant in the normal BMI and overweight/obese groups, where the greater strength of the relationship was shown in the overweight/obese group (FMI: r=0.94, p<0.05; TFM: r=0.95, p<0.05; FM%: r=0.78, p<0.05) (Table 4). WC was not associated with FMI, TFM, and FM% in the stunted group. In the thin group, WC was not significantly related with FMI and FM%, but was moderately significant correlated with TFM (r=0.45, p<0.05).

DISCUSSION

The present study aimed to examine the relationship between nutritional status defined by BMI-for-age Z-score (BAZ) and body fat measured by the deuterium dilution technique. We found that obese children had the highest fat mass and significantly different from other nutritional status group, while there were no significant differences in FM% among stunted, normal, and thin children. FM% tended to be higher in girls compared to boys; however, the gender difference was statistically significant only among the normal BMI and thin children and only among thin children when body fat is expressed as total fat mass (TFM, kg) and fat mass index (FMI, kg/m^2). Significant

Table 3. Fat mass and fat mass index by sex and nutritional status†‡ of 3-5 y old children

Nutritional status	FMI (kg/m^2)			TFM (kg)			FM (%)		
	Boys	Girls	*p* value	Boys	Girls	*p* value	Boys	Girls	*p* value
Normal BMI (n=24:22)§	4.1 (3.7, 4.5)	4.0 (4.2, 5.0)	0.118	4.1 (3.6, 4.5)	4.5 (4.0, 5.0)	0.218	26.3 (24.7, 27.9)	29.7 (28.0, 31.4)	0.006
Stunted (n=14:15)	3.6 (3.3, 3.9)	4.0 (3.7, 4.3)	0.117	3.2 (29, 3.4)	3.4 (3.2, 3.7)	0.151	24.9 (23.2, 26.5)	27.7 (26.2, 29.3)	0.018
Thin (n=15:15)	2.8 (2.6, 3.0)	3.2 (3.1, 3.4)	0.002	2.7 (2.4, 3.0)	3.2 (2.9, 3.4)	0.020	21.9 (20.4, 23.3)	25.9 (24.6, 27.3)	<0.001
Overweight/obese (n=15:15)	9.1 (7.8, 10.3)	8.8 (7.6, 10.1)	0.819	10.4 (8.7, 12.1)	9.7 (8.0, 11.4)	0.553	39.8 (37.5, 42.1)	41.2 (39.0, 43.5)	0.398

†Mean (95% CI); ANCOVA, adjusted for birth weight, age, maternal education, and household income.
‡Unpaired T-test.
§n=boys:girls
FMI: fat mass index; TFM: total fat mass in kg; FM: fat mass in %.

Table 4. Correlation coefficient (r) between body mass index (BMI, kg/m^2) and waist circumference (WC) with body fat by nutritional status of 3-5 y old children

Nutritional status	BMI and FMI (kg/m^2)		BMI and TFM (kg)		BMI and FM (%)	
	r†	*p* value	r†	*p* value	r†	*p* value
Normal BMI	0.88	<0.001	0.84	<0.001	0.68	<0.001
Stunted	0.63	<0.001	0.60	0.001	0.24	0.219
Thin	0.33	0.083	0.40	0.036	0.13	0.514
Overweight/obese	0.97	<0.001	0.95	<0.001	0.80	<0.001
Nutritional status	**WC and FMI (kg/m^2)**		**WC and TFM (kg)**		**WC and FM (%)**	
	r†	*p* value	r†	*p* value	r†	*p* value
Normal BMI	0.78	<0.001	0.84	<0.001	0.61	<0.001
Stunted	0.08	0.684	0.07	0.727	-0.03	0.902
Thin	0.32	0.096	0.45	0.018	0.21	0.283
Overweight/obese	0.94	<0.001	0.95	<0.001	0.78	<0.001

†Pearson correlation coefficients, adjusted for age and sex. Using Fisher's z transformation: significant differences in the correlation coefficients (r) between overweight/obese vs. normal BMI; $p<0.01$ for BMI vs. FMI and WC vs. FMI, $p<0.05$ for BMI vs. TFM and WC vs. TFM, no significance for FM%.
FMI, fat mass index; TFM, total fat mass in kg; FM, fat mass in %

relationships were found between BMI or WC and all body fat measures (FMI, TFM, FM%) among normal BMI and overweight/obese children. For stunted children, only the relationships between BMI vs FMI and BMI vs TFM were significant. Lastly, for thin children, the relationships between BMI vs TFM and WC vs TFM were significant.

Body mass index is generally considered a practical and simple indicator to measure, especially in the population-based study for assessing nutritional status. The inconsistent relationships between BMI and body fatness found in the present study warrants a concern in using BMI for assessing adiposity in children population when malnourished children are included, which is the case in developing countries. Comparison across studies has several methodological challenges due to the use of different methods for assessing adiposity and its validation may be based on a different population from the one under study (e.g., equations based on skinfold thickness and bioimpedance analysis (BIA) were developed in Caucasian populations). Moreover, reported studies included apparently healthy children and age range which was inclusive of children from young age through adolescents, i.e., complexity due to differential pubertal growth spurt in different populations. Only a few studies were conducted in preschool children (3-5 or 6 years old) in developing countries and malnourished children using isotope dilution or dual x-ray absorptiometry (DXA).

The percent body fat in the present study is more similar to that reported in the western populations, while BMI was somewhat lower. Forsum et al (2013) found percent body fat (25-27%) for Swedish children at 4 years old (using Air displacement plethysmography), and Mei, et al (2002) in 3-5 years old American children, using DXA.[12,13] Our result on percent body fat was also similar to older children (8-10 y) reported for Thai, Malay, and Filipino children using deuterium dilution method.[14] In contrast, Yamborisut et al (2012) studied the central body fat distribution indices in 5-6 years old Thai preschool children having similar background characteristics as children in the present study and found percent body fat to be about 14% using BIA.[15] A study in Japan using multi-frequency BIA in 3-5 years old children reported similar level of FM% (10-14%).[16] Overall, however, our study confirms the previous findings that among children aged 7-12 years old, Asians of different ethnic groups tend to have higher fatness at the same BMI than Caucasians.[14,17]

Freedman, et al found a significant difference between boys and girls aged 5-17 years old in the US.[18] Girls had higher percent fat mass compared with boys, which is consistent with several studies in both preschool and school-aged children.[13,14,16] The gender difference in our study was not consistent, depending on how the body fat is expressed (Table 3). When expressed as FM%, significant gender differences were found among normal, stunted, and thin children, whereas TFM and FMI were also significant among thin children. Both stunted and thin children had lower TFM compared with normal BMI children, and thin children also had significantly lower FM%. Hoffman et al (2007) showed that at 10years old, stunted children had lower BMI and fat mass compared to non-stunted children. When followed-up four years later, stunted children had significantly higher increase in trunk fat.[19] Therefore, undernourishment during early stage of life do not necessarily have an advantage in terms of adiposity as they grow older.

The relationship between BMI and various measures of adiposity was not consistent in adults and children, and ethnic differences have been reported.[14] Moreover, the correlation may also differ whether the adiposity measure is total body fat or regional distribution. Yamborisut et al (2012) reported very high correlations both between BMI vs trunk fat (derived from equation using sub-scapular and supra-iliac skin folds) as well as WC and total fat mass (measured by tetra-polar BIA).[15] Since the deuterium dilution method cannot assess regional fat distribution, these relationships will need to be confirmed using method such as DXA.

The correlations between BMI and body fat expressed as FM% also tended to be lower than when using TFM.[13,14,16] In addition, we found that the correlation coefficients between BMI or WC with FMI and TFM were significantly higher among overweight/obese children than that in normal BMI children (data not shown). Other studies showed that the accuracy of childhood BMI as an indicator of adiposity appears to increase with the degree of body fatness.[18,20,21] Therefore, BMI or WC may still be valid indicators for assessing body fat among normal BMI to overweight/obese children, but not to be used for undernourished children. Due to relatively small sample size in the present study, this finding should be verified.

In conclusion, we did not find the continuum of associations of body mass index and body fatness from undernourished to over-nourished conditions. While BMI and fatness association was found among normal to overweight/obese children, it is less certain among undernourished (i.e., stunted and thin) children. Our study showed that BMI may not be an appropriate indicator for adiposity when malnourished (stunted and thin) young children are included.

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AUTHOR DISCLOSURES

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