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ORIGINAL CONTRIBUTION

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Use of BMI as a measure of overweight and obesity in a field study on 5–7 year old children

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Summary *Objective* The present field study examines the use of BMI in comparison with estimates of percent fat mass to screen for overweight and obesity in children. *Design* Cross-sectional field study. *Setting* Four waves of children 1996–1999 at Kiel, North West Germany. *Subjects* A representative large sample of 2286 5–7 year old children representing 40 % of the total child population examined by school physicians within the same period in Kiel. *Main outcome measures* BMI was compared with anthropometric measures (TSF, BSF, SIF, SSF) and bioelectrical impedance analysis (BIA). The 90th and 97th BMI percentiles were used as cut offs for overweight and obesity, respectively. *Results* BMI reached a low sensitivity to identify overweight children when compared with the two estimates of % FM (0.60 to 0.78 for girls, 0.71 to 0.82 for boys, respectively). The specificity of BMI was 93 to 95 %. By contrast, BMI reached higher sensitivity to screen for obese children of 0.83 to 0.85 for boys and 0.62 to 0.80 for girls at a concomitant specificity of 0.95 to 0.98 for boys and 0.96 to 0.97 for girls as defined by assessment of body fat mass. Comparing nutritional status of overweight children classified as overweight or non overweight by BMI shows that BMI only identified obese but not-overweight children. *Conclusion* BMI can be used to screen for obese children. In contrast BMI has a poor sensitivity to screen for overweight children. Body composition analysis should be used to screen for children at risk of becoming obese.

Key words BMI – fat mass – overweight – obesity – children

Introduction

There is no uniform definition or assessment of overweight and obesity in children. Some authors suggest the use of BMI to assess obesity in children [1–9]. In addition there is no consensus regarding the cut off to define overweight and obesity in children, i. e., above the 85th percentile of BMI as overweight (i. e., at risk of obesity) and above the 95th percentile as obese [1, 10]. Other authors use the 90th and the 97.5th BMI percentile as cut offs for overweight and obesity [2, 3], respectively the 97th percentile [9]. In addition a low (75th or even 66th) cut off percentile has been recommended for screening "preobese" children because of the low sensitivity of BMI [10]. Up to now, BMI reference data for prepubertal children have been published for German [9, 11], North American [2, 12], French [3, 4], British [13–15], Swedish [16], and Italian [17, 18] children.

However the accuracy as well as the use of the BMI has been questioned in children [7] as well as in adults [19]. Alternative assessments of nutritional state in children should include direct estimates of body fat [9, 11]. Skinfold measurements as well as BIA have been recom-

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mended for assessment of fat mass in greater populations of children [20–27]. However the advantage of body composition analysis over BMI has not been evaluated in field studies. The Kiel Obesity Prevention Study (KOPS) is a cross-sectional and longitudinal field study [28], which has the objective to reduce the incidence and prevalence of overweight and obese children and adolescents. Within KOPS, anthropometry and BIA are used to estimate fat mass. The present study examines the use of BMI in comparison with BIA and anthropometric measurements of fat mass regarding screening for overweight and obesity in a group of 2286 5–7 year old children in Kiel (North West) Germany.

Methods

Subjects

Between 1996–1999 five different investigators assessed the nutritional status of 1146 boys and 1140 girls aged 5–7 years living in Kiel, North West Germany. Anthropometry and bioimpedance analysis were trained weekly in the first month and every 14 days during the following weeks. The children were randomly sampled and examined in 29 out of a total of 32 primary schools in Kiel. The 2286 children represented 40 % of the total children population examined by the school physicians within the same time period. Age, gender, body weight and height, as well as sociodemographic data of our study population were compared with data obtained in the total population of 5–7 year old children assessed by school physicians during the same time period. These data suggest that our sub-population is representative of the total population of 5–7 year old children in Kiel. The procedures had been explained to all parents. All parents had given their informed written consent. The study was approved by the local ethical committee of the Christian Albrechts University of Kiel.

Anthropometry

Anthropometric measurements were performed by trained observers, according to standard procedures [29]. Weight was measured to the nearest 0.1 kg on a calibrated balance-beam scale with subjects wearing light underwear and height was estimated to the nearest 0.5 cm. From weight and height, body mass index (BMI) was calculated as follows: BMI [kg/m^2] = weight [kg]/(height [m])^2. Skinfold thickness was determined to the nearest 0.2 mm at the right triceps (TSF), biceps (BSF), subscapular (SSF) and suprailiacal (SIF) sites, with a Lafayette skinfold caliper (Model 01127, Lafayette Instrument Company, Indiana 47903) calibrated to exert a constant pressure of 10 g/mm^2. Between observers the coefficients of variations for measurements of TSF, BSF, SSF and SIF were 5.7 %, 8 %, 13.2 % and 8.4 % (n=15). The coefficients of variation within observers for repeated (n=3) measurements of TSF, BSF, SSF and SIF in 150 children aged 5–7 y were 4.2 %, 6.8 %, 5.1 % and 5.3 %, respectively. Fat mass (FM) was determined by age- and gender-specific formulas, according to Lohmann [20], involving weight and the log-transformed sum of TSF; BSF, SIF and SSF skinfolds for subjects aged < 12.0 y. Fat free mass (FFM) was calculated as the difference between body weight and fat mass.

Bioelectrical impedance analysis (BIA)

Measurements of whole body impedance in children have been described previously [30]. Measurements were performed at a single frequency (50 kHz) with one pair of electrodes appropriately placed on the dorsal surfaces of the right hand and a second pair of electrodes placed on the right foot using a Multi-Frequency-Monitor 2000-M (Data Input GmbH, Frankfurt/M, Germany) [31]. Three different analyzers were crosscalibrated in 10 children aged 5–7 y including disconnected electrodes and differences in the results of measurements using different analyzers were found to be < 1 %. With the subjects lying in a supine position, measurements were performed while the hands and feet were extended by about 30° from the side of the trunk. The coefficients of variation (cv) for repeated (n=3) estimations of R (resistance, Ω) and Xc (reactance, Ω) in 10 children aged 5–7 y were 1.0 and 2.1 %, respectively, resulting in a cv of 1.5 % in %FM. Fat free mass (FFM) was derived from an algorithm published by Schaefer et al. for a German population of children [25]. These authors used total body potassium as the reference method [25]. FM was then calculated from the difference between body weight and FFM.

Definition of nutritional status

Underweight is defined as BMI ≤ 10th percentile of the German sex- and age-specific reference values (10th BMI percentile for 5 year old boys/girls: 13.83 kg/m^2/13.61 kg/m^2; for 6 year old boys/girls: 13.79 kg/m^2/13.59 kg/m^2; for 7 year old boys/girls: 13.88 kg/m^2/13.69 kg/m^2 [9]). The German reference data were based on a data set of 34 422 children and percentile curves for BMI were constructed by sex using the LMS method [8]. Normal weight is defined by a BMI between 10th and 90th percentile of the German sex- and age-specific reference values [9]. In addition sex- and age-specific 10th and 90th percentiles of estimates of fat mass obtained within our own population were used. Overweight is defined by BMI (≥ 90th percentile of the German sex- and age-specific reference values, i. e., for 5 year old boys/girls: 17.61/17.69 kg/m^2; for 6 year old boys/girls: 17.86/17.99 kg/m^2; for 7 year old boys/girls: 18.34/18.51 kg/m^2 [9] or the respective values of sex- and age-specific estimates of fat mass obtained within our own population. Obesity is defined by a BMI ≥ 97th percentile of the German sex- and age-specific reference values (97th BMI percentile for 5 year old boys/girls: 19.02/19.16 kg/m^2; for 6 year old boys/girls: 19.44/19.67 kg/m^2; for 7 year old boys/girls: 20.15/20.44 kg/m^2 [9]).

Statistical analyses

All statistical analyses were performed using Excel 5.0 or SPSS for windows. The data were presented as median and interquartile range (Table 1) or as means and ranges (Table 3). Basic statistics included Mann-Whitney-U-Test for comparison between gender groups, chi^2-test for differences between overweight and obese children and correlation analyses for the relation of BMI versus assessments of fat mass. Sensitivity and specificity were calculated for BMI using the 90th or 97th percentile of estimates to FM as cut offs. Sensitivity records all overweight or obese children; specificity records all non-overweight or non-obese children.

Results

The nutritional state of our children is presented in Table 1. There are no gender differences in BMI. In contrast, there are significant sex differences in height, weight, skinfold thickness, impedance as well as estimates of FM. Using anthropometry, skinfold thicknesses are greater in girls than in boys but FM (as calculated from Lohmann's formula) is greater in boys aged 6 and 7 years than in girls (Table 1). This is contrary to the BIA-data where FM in girls always exceeds the respective data in boys (Table 1). Within KOPS, the 10th, 50th and 90th percentiles of height are 1.13, 1.20 and 1.26 m for 6 year old boys. For 6 year old girls, the respective values

Table 1 Median and interquartile range of anthropometric measurements in 2286 5–7 year old boys and girls in Kiel

	children aged 5 years				children aged 6 years				children aged 7 years			
	boys		girls		boys		girls		boys		girls	
n	23		15		765		819		357		306	
age (y)	5.02	(0.2)	5.5	(0.2)	6.1	(0.4)	6.1	(0.4)	6.7	(0.2)	6.6	(0.2)
Anthropometry												
height [m]	1.20	(0.1)	1.17	(0.1)***	1.20	(0.1)	1.19	(0.1)***	1.23	(0.1)	1.22	(0.1)***
weight [kg]	21.6	(3.2)	19.5	(8.2)**	22.3	(4.5)	22.0	(4.5)**	23.5	(4.9)	23.0	(4.6)**
BMI [kg/m^2]	14.8	(1.4)	14.5	(2.9)	15.5	(2.0)	15.6	(2.1)	15.6	(2.0)	15.5	(1.9)
w/h ratio	0.92	(0.1)	0.90	(0.1)***	0.91	(0.1)	0.89	(0.1)***	0.90	(0.1)	0.88	(0.1)***
TSF [mm]	9.0	(3.2)	12.0	(5.4)***	10.3	(3.7)	11.3	(4.6)***	9.8	(4.3)	11.6	(4.4)***
BSF [mm]	5.0	(1.8)	7.3	(5.5)***	5.6	(3.4)	6.3	(3.3)***	5.3	(3.3)	6.0	(3.6)***
SIF [mm]	5.3	(2.8)	7.6	(4.4)***	6.3	(4.3)	8.0	(5.4)***	6.0	(4.4)	7.6	(4.7)***
SSF [mm]	5.0	(2.0)	6.6	(3.2)***	5.6	(2.4)	6.3	(3.2)***	5.0	(2.3)	6.0	(3.0)***
sum of four skinfolds [mm]	24.0	(8.8)	33.3	(20.7)***	28.2	(12.1)	31.7	(14.1)***	26.8	(10.8)	30.5	(14.1)***
$FM_{Lohmann}$ [%]	12.0	(5.9)	14.9	(11.9)*	14.6	(6.9)	13.8	(8.9)*	13.8	(6.5)	13.1	(8.9)*
$FM_{Lohmann}$ [kg]	2.6	(1.8)	2.5	(3.0)*	3.2	(2.0)	3.0	(2.5)*	3.1	(2.0)	20.1	(3.1)*
$FFM_{Lohmann}$ [%]	88.0	(5.9)	85.2	(11.9)	85.4	(6.9)	86.2	(8.9)	86.2	(6.5)	87.0	(8.9)
$FFM_{Lohmann}$ [kg]	19.0	(3.5)	17.3	(6.5)	19.1	(3.3)	18.9	(3.0)	20.3	(3.6)	20.1	(3.1)
Bioelectrical Impedance Analysis												
R [Ω]	768	(80.5)	805	(87.3)***	749	(101.9)	788.4	(95.3)***	739	(94.1)	791	(118.3)
Xc [Ω]	68	(6.0)	73	(9.1)***	68.0	(10.0)	72.0	(12.9)***	67.1	(11.2)	72	(12.0)
phase angle α	5.0	(0.6)	5.2	(0.6)	5.1	(0.6)	5.2	(0.7)	5.2	(0.7)	5.2	(0.7)
RI [cm^2/Ω]	18.8	(2.9)	17.1	(3.7)***	19.2	(3.8)	18.0	(2.2)***	20.4	(3.7)	19.0	(4.1)***
$FM_{Schaefer}$ [%]	27.1	(6.4)	29.2	(15.4)***	25.4	(8.2)	27.6	(9.8)***	23.7	(8.8)	27.0	(8.5)***
$FM_{Schaefer}$ [kg]	5.9	(1.4)	5.0	(4.5)**	5.5	(2.8)	6.0	(3.3)**	5.4	(2.9)	6.1	(3.2)**
$FFM_{Schaefer}$ [%]	72.9	(6.4)	70.8	(15.4)***	74.6	(8.2)	72.4	(9.8)	76.3	(8.8)	73.0	(8.5)***
$FFM_{Schaefer}$ [kg]	15.7	(1.7)	14.9	(2.4)**	16.7	(2.6)	16.0	(2.1)	18.0	(2.5)	17.0	(2.6)**

Data are given as median (interquartile range), statistical test for gender differences: Mann-Whitney U-Test:
*: significant differences between boys and girls with $p \leq 0.05$
**: significant differences between boys and girls with $p \leq 0.01$
***: significant differences between boys and girls with $p \leq 0.001$
TSF triceps skinfold, *BSF* biceps skinfold, *SSF* suprailiacal skinfold, *SSF* subscapular skinfold, *sum of four skinfolds* sum of triceps-, biceps-, subscapular- and suprailiacal-skinfold, *FM* fat mass, *FFM* fat free mass, *R* resistance [Ω] from bioimpedance-analysis (BIA); *Xc* reactance [Ω] from bioimpedance analysis (BIA); *RI* (Resistance Index) height [cm]*height [cm]/R [Ω]

are 1.13, 1.19 and 1.26 m. Regarding body weight the 10th, 50th and 90th percentiles in 6 year old boys and girls are 19.0, 22.3, 28.7 kg and 18.5, 22.0 and 27.7 kg, respectively. The 10th, 50th and 90th percentiles of BMI are 14.1, 15.5, 18.5 kg/m^2 and 13.8, 15.6 and 18.4 kg/m^2 in 6 year old boys and girls, respectively. Our BMI data are higher than the German reference data. Using the German reference data as the cut offs [9] gave a mean prevalence of overweight of 12.8 % (13.4 % for boys, 12.3 % for girls) and 6.3 % (7.2 % for boys, 5.4 % for girls) for obesity.

Comparing BMI with estimates of FM obtained for boys and girls results in correlation coefficients ranging from 0.63 to 0.70 for boys and 0.60 to 0.70 for girls, respectively (Fig. 1). Separate analyses showed increasing correlation coefficients between BMI and % FM_{BIA} in underweight (0.42 for boys, 0.61 for girls), normal (0.38 for boys, 0.50 for girls), overweight (0.54 for boys, 0.63 for girls) and obese children (0.47 for boys, 0.43 for girls), respectively. When compared with these data the association between BMI and % $FM_{Lohmann}$ is low (0.11 for underweight girls to 0.51 for normal weight girls). The highest correlation coefficient is observed in overweight children (0.54 for overweight boys, 0.63 for overweight girls), whereas the correlation coefficient is 0.25 and 0.30 for obese boys and girls, respectively.

Regarding sensitivity and specificity to identify overweight children, BMI reaches a sensitivity of 0.60 to 0.78 for girls and 0.71 to 0.82 for boys. The specificity of BMI was 93 to 94 % for boys and 93 to 95 % for girls (Table 2a). By contrast sensitivity reached 0.83 to 0.85 for obese boys and 0.62 to 0.80 for obese girls. The specificity was 0.95 to 0.98 for obese boys and 0.96 to 0.97 for obese girls (Table 2b; no significant sex differences).

Table 3 shows the characteristics of overweight boys and girls classified as non-overweight and overweight by BMI. Boys and girls classified as non-overweight by

Fig. 1a–f Comparison of BMI and estimates of fat mass in 2286 5–7-year-old boys and girls (*BMI* body mass index; *TSF* triceps skinfold-thickness; *FM* fat mass; *Anthrop.* Anthropometry; *BIA* Bioelectrical Impedance Analysis; *p* percentile).
For BMI cut off, the 90th percentile of the German reference values [9] is used; for TSF, % FM, Anthrop.$_{Lohmann}$ and % FM, $BIA_{Schaefer}$ the age, sex and methods specific 90th percentiles of our own study population were used

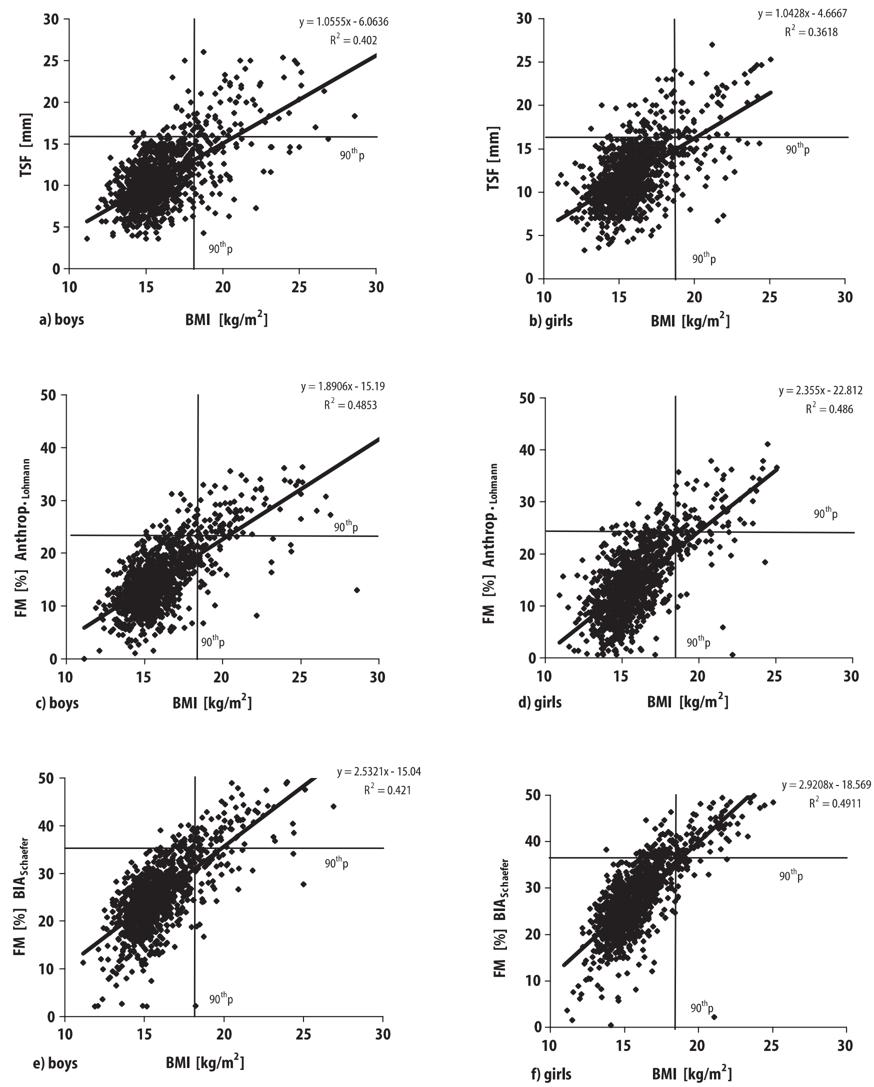

Table 2a Sensitivity and specificity for identifying overweight children by 90th percentile of BMI[1] in 2286 5–7-year-old boys and girls based on estimates of fat mass[2]

	sensitivity		specificity	
	boys	girls	boys	girls
Anthropometry				
TSF [mm]	0.71	0.60	0.93	0.93
FM, Anthrop.$_{Lohmann}$ [%]	0.80	0.66	0.94	0.94
Bioelectrical Impedance Analysis				
FM, BIA$_{Schaefer}$ [%]	0.82	0.78	0.94	0.95

Sensitivity records all overweight children, specificity records all non-overweight children *TSF* triceps-skinfold-thickness, *FM, Anthrop.* fat mass from anthropometric measurements, *FM, BIA* fat mass from Bioelectrical Impedance Analysis
[1] 90th percentile from German BMI reference values (Kromeyer-Hauschild et al. 2001) were used as the cut off
[2] 90th age, sex and methods specific percentile of own study population were used as the cut off

Table 2b Sensitivity and specificity for identifying obesity by 97th percentile of BMI[1] in 2286 5–7-year-old boys and girls based on estimates of fat mass[2]

	sensitivity		specificity	
	boys	girls	boys	girls
Anthropometry				
TSF [mm]	0.83*	0.62***	0.95*	0.96***
FM, Anthrop.$_{Lohmann}$ [%]	0.80	0.73**	0.95	0.96**
Bioelectrical Impedance Analysis				
FM, BIA$_{Schaefer}$ [%]	0.85***	0.80*	0.98***	0.97*

Sensitivity records all obese children, specificity records all non-obese children, *TSF* triceps-skinfold-thickness, *FM, Anthrop.* fat mass from anthropometric measurements, *FM, BIA* fat mass from Bioelectrical Impedance Analysis
[1] 97th percentile from German BMI reference values (Kromeyer-Hauschild et al. 2001) were used as cut off
[2] 97th age, sex and methods specific percentile of own study population were used as cut off, statistical test for differences between overweight and obese children: chi^2-test
* significant differences between overweight and obese children with $p < 0.05$
** significant differences between overweight and obese children with $p < 0.01$
*** significant differences between overweight and obese children with $p < 0.001$

Table 3 Characteristics of overweight children[a] classified as such by triceps skinfold, anthropometry and bioelectrical impedance analysis

	Overweight children according to TSF		Overweight children according to anthropometry$_{Lohmann}$		overweight children according to BIA$_{Schaefer}$	
	Classified as not overweight by BMI	Classified as overweight by BMI	Classified as not overweight by BMI	Classified as overweight by BMI	Classified as not overweight by BMI	Classified as overweight by BMI
Boys						
n	32	80	21	86	19	86
age (y)	6.2 (5.6–6.9)	6.3 (5.0–7.5)	6.2 (5.8–7.3)	6.3 (5.0–7.5)	6.2 (5.8–7.0)	6.3 (5.0–7.5)
height [m]	1.23 (1.13–1.34)	1.25 (1.11–1.36)	1.24 (1.14–1.41)	1.25 (1.09–1.38)	1.22 (1.10–1.34)	1.24 (1.09–1.36)
weight [kg]	25.3 (20.0–30.5)***	32.6 (24.7–45)	26.0 (20.0–34.5)***	32.5 (24.7–45.0)	25.1 (18.8–31.0)***	22.2 (24.7–45.0)
BMI [kg/m^2]	16.6 (14.1–17.9)***	21.0 (17.9–32.1)	16.9 (15.1–17.8)***	21.0 (17.9–32.1)	16.7 (14.8–17.9)***	21.1 (17.9–32.1)
w/h ratio	0.89 (0.78–0.98)**	0.92 (0.72–1.04)	0.88 (0.78–0.98)***	0.93 (0.72–1.04)	0.88 (0.77–0.98)***	0.93 (0.72–1.06)
Girls						
n	45	67	40	79	24	4
age (y)	6.3 (5.4–6.9)	6.3 (5.5–7.5)	6.3 (5.4–6.9)	6.3 (5.5–7.5)	6.2 (5.5–7.0)	6.2 (5.5–7.5)
height [m]	1.22 (1.10–1.32)	1.24 (1.12–1.38)	1.21 (1.13–1.31)	1.24 (1.11–1.38)	1.24 (1.13–1.35)	1.23 (1.09–1.38)
weight [kg]	24.6 (18.0–30.5)***	31.4 (23.0–45.0)	24.5 (17.5–30.0)***	31.4 (24.0–45.0)	25.9 (16.8–30.3)***	31.2 (22.1–45.0)
BMI [kg/m^2]	16.5 (13.2–18.0)***	20.4 (18.0–25.1)	16.7 (13.7–18.0)***	20.6 (18.1–25.1)	16.8 (13.2–18.0)***	20.7 (18.1–25.1)
w/h ratio	0.89 (0.78–0.96)*	0.91 (0.78–1.05)	0.88 (0.74–0.96)**	0.91 (0.78–1.24)	0.88 (0.72–1.0)**	0.91 (0.79–1.24)

Data are given as mean and range. *BMI* body mass index, *w/h ratio* waist to hip-ratio
* significant differences between overweight children classified as not overweight by BMI and overweight children classified as overweight by BMI with $p < 0.05$
** significant differences between overweight children classified as not overweight by BMI and overweight children classified as overweight by BMI with $p < 0.01$
*** significant differences between overweight children classified as not overweight by BMI and overweight children classified as overweight by BMI with $p < 0.001$
[a] Overweight defined ≥ sex and age specific 90th percentile of methods and equations to estimate fat mass

BMI but as overweight by % FM have lower body weights, BMIs and w/h ratios when compared to children classified as overweight by BMI.

Discussion

BMI can be easily obtained. It is generally accepted as an index of overweight and obesity in adults. However, in children and adolescents, the interpretation of BMI data is only possible if the age-dependent distribution is known, because BMI shows developmental variation [11]. Up to now, a number of population-specific BMI reference data have been published for prepubertal children. Although some authors suggest the use of BMI to assess overweight and obesity in prepubertal children [1–6, 9], the accuracy of the BMI has been questioned [7]. In addition other authors recommend the use of more accurate estimations of body fat instead of BMI [10].

The essential findings of the present study are that BMI has a poor sensitivity to screen for overweight 5–7 year old children. Only 65.6 % to 79.8 % of overweight children were indentified by BMI as defined by assessment of body fat mass. Our results are similar to some authors but also lower than those observed by other authors. Schaefer et al. [11] investigated nutritional state in 2554 healthy children aged 6–19 y and found a correlation between BMI and skinfold-derived fat mass of r=0.84 and r=0.54 for girls and boys, respectively. In boys, the association between BMI and % FM was restricted to the more obese subjects, whereas no association existed in the leaner two thirds of the population. In girls, BMI predicted % FM equally well in individuals below and above the 66th % FM percentile [11]. The same group of authors also found a poor sensitivity (0.64) but a high specificity (0.96) of BMI when compared with skinfold-derived % FM [11]. Reilly et al. assessed nutritional status in 240 children with a mean age of 8.5 years [32]. These authors also found a poor sensitivity of BMI for overweight children (0.60 for girls and 0.36 for boys) but again a high specificity (0.98) [32]. Daniels et al. investigated 192 children aged 7 to 17 y and found a significant association between BMI and % FM (DEXA) of r=0.5 for boys and r=0.8 for girls [33]. Using receiver operator characteristic analysis in a further study on 4175 7 y-old children Reilly et al. only found optimum combination of sensitivity (92 %) and specificity (92 %) if an appropriate BMI cut off is chosen (i. e., the 92nd percentile). In addition they found that using the new International Obesity Task Force cut off for obesity sensitivity of BMI was lower, and differed significantly between boys and girls [7].

All these findings show that by using a high cut off, BMI can be used to screen for obesity in children. By contrast BMI is of limited value in screening for overweight children and in those children who are at risk for being overweight and obese (i. e., children with increased fat mass but "normal" body weight). The latter group of children cannot be identified by BMI. Table 3 shows that overweight children, who were not classified as overweight by BMI, have lower body weights and w/h ratios. Nevertheless, they have increased % fat mass and are thus considered "preobese". We feel that these children have to be identified for prevention of obesity [see 28]. Our data provide some evidence for the idea that estimates of % FM are suitable to screen children at risk of becoming obese. Thus body composition analysis may have an advantage for studies in the area of obesity prevention.

Conclusion

The essential finding of the present study is that BMI is a suitable index to screen for obese children. However BMI has a lower sensitivity and only identifies 59.8 % to 81.9 % of overweight children as defined by assessment of body fat mass. Within obesity prevention studies there is a need to screen for children at risk of becoming obese. Thus, we feel that, in addition to BMI, body composition analysis may have an advantage in the area of obesity prevention.

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References

1. Must A, Dallal GE, Dietz H (1991) Refence data for obesity. 85th and 95th centiles of body mass index (wt/ht^2) and triceps skinfold thickness. Am J Clin Nutr 53: 839–846
2. Himes JH, Dietz WH (1994) Guidelines for overweight in adolescent preventive services: recommendations from an expert committee. Am J Clin Nutr 59: 307–316
3. Rolland-Cachera M-F, Sempé M, Guillod-Bataille M, Patois E, Péquignot-Guggenbuhl F, Fautrad V (1982) Adiposity indices in children. Am J Clin Nutr 36: 178–184
4. Rolland-Cachera MF, Cole TJ, Sempé M, Tichet J, Rossignol C, Charraud A (1991) Body mass index variations: centiles from birth to 87 years. Europ J Clin Nutr 45: 13–21
5. Zarfl B, Elmadfa I (1995) Body Mass Index (BMI) als Indikator für das Übergewicht bei Kindern und Jugendlichen – Ergebnisse der ASNS. Akt Ernähr-Med 20: 201–206
6. Zwiauer K, Wabitsch M (1997) Relativer Body-Mass-Index (BMI) zur Beurteilung von Übergewicht und Adipositas im Kindes- und Jugendalter. Monatszeitschrift Kinderheilkunde 145: 1312–1318
7. Reilly JJ, Dorosty AR, Emmett PM, The ALSPAC Study Team (2000) Identification of the obese child: adequacy of the body mass index for clinical practice and epidemiology. Int J Obesity 24: 1623–1627
8. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH (2000) Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ 320: 1–6
9. Kromeyer-Hauschild K, Wabitsch M, Geller F, Ziegler A, Geiß HC, Hesse V, v. Hippel A, Jaeger U, Johnsen D, Kiess W, Korte W, Kunze D, Menner K, Müller MJ, Niemann-Pilatus A, Remer T, Schaefer F, Wittchen HU, Zabransky S, Zellner K, Hebebrand J (2001) Perzentile für den Body Mass Index für das Kindes- und Jugendalter unter Heranziehung verschiedener deutscher Stichproben. Monatszeitschrift Kinderheilkunde 149: 807–818
10. Robinson T (1993) Defining obesity in children and adolescents: clinical approaches. Food Science and Nutrition 33 (4/5): 313–320
11. Schaefer F, Georgi M, Wühl E, Schärer K (1998) Body mass index and percentage fat mass in healthy German school children and adolescents. Int J Obesity 22: 461–469

12. Cronk CE, Roche AF (1992) Race- and sex-specific reference data for triceps and subscapular skinfolds and weight/stature^2. Am J Clin Nutr 35: 347–354
13. Cole TJ, Freeman JV, Preece MA (1990/1995) Body mass index reference curves for the UK. Arch Dis Childhood 73: 25–29
14. Power C, Lake JK, Cole TJ (1997) Measurement and long-term health risks of child and adolescent fatness. Int J Obesity 21: 507–526
15. Lake JK, Power C, Cole TJ (1997) Women's reproductive health: the role of body mass index in early and adult life. Int J Obesity 21: 432–438
16. Lindgren G, Strandell A, Cole T, Healy M, Tanner J (1995) Swedish population reference standards for height, weight and body mass index attained at 6 to 16 years (girls) or 19 years (boys). Acta Paediatr 84: 1019–1028
17. Luciano A, Bressan F, Zoppi G (1997) Body mass index reference curves for children aged 3–19 years from Verona, Italy. Europ J Clin Nutr 51: 6–10
18. Falorni A, Galmacci G, Bini V, Papi F, Molinari D, De Giorgi G, Faraoni F, Celi F, DiStefano G, Berioli MG, Contessa G, Bacosi ML (1998) Fasting serum leptin levels in the analysis of body mass index cut-off: are they useful for overweight screening in children and adolescents? A school population-based survey in three provinces of central Italy. Int J Obesity 22: 1197–1208
19. Prentice A, Jebb S (2001) Beyond body mass index. Obesity Reviews 2: 141–147
20. Lohmann TG (1986) Applicability of body composition techniques and constants for children and youth. In: Pandolph KB (Ed) Exercise and Sports Science Reviews, Macmillan, New York, pp 325–357
21. Cordain L, Whicker RE, Johnson JE (1988) Body composition determination in children using BIA. Growth, Development and Aging 52 (1): 37–40
22. Houtkooper LB, Lohmann TG, Going SB, Hall MC (1989) Validity of bioelectrical impedance for body composition assessment in children. J Appl Physiol 66: 814–821
23. Kushner RF, Schoeller DA, Fjeld CR, Danford L (1992) Is the impedance index (ht^2/R) significant in predicting total body water? Am J clin Nutr 56: 835–839
24. Kushner RF, Kunigh A, Alspaugh M, Andronis PT, Leitch CA, Schoeller DA (1990) Validation of bioelectrical-impedance analysis as a measurement of change in body composition in obesity. Am J Clin Nutr 52: 219–223
25. Schaefer F, Georgi M, Zieger A, Schärer K (1994) Usefulness of Bioelectric impedance and skinfold measurements in predicting fat-free mass derived from total body potassium in children. Pediatric Research 35 (5): 617–624
26. Wabitsch M, Braun U, Heinze E, Muche R, Mayer H, Teller W, Fusch Ch (1996) Body composition in 5–18-y-old obese children and adolescents before and after weight reduction as assessed by deuterium dilution and bioelectrical impedance analysis. Am J Clin Nutr 64: 1–6
27. Goran MJ, Driscol P, Johnsen R, Nagy TR, Hunter G (1996) Cross-calibration of body composition techniques against dual-energy X-ray absorptiometry in young children. Am J Clin Nutr 63: 299–305
28. Müller MJ, Mast M, Asbeck I, Langnäse K, Grund A (2001) Prevention of obesity – is it possible? Obesity Reviews 2: 15–28
29. Lohmann TG, Roche AF, Martorell R (1988) Anthropometric Standardization Reference Manual, Human Kinetics Books, Champaign, Illinois
30. Mast M, Körtzinger I, König E, Müller MJ (1998) Gender differences in fat mass of 5–7-year old children. Int J Obesity 22: 878–884
31. Müller MJ (1998) Ernährungsmedizinische Praxis. Heidelberg, Berlin
32. Reilly JJ, Savage SAH, Ruxton CHS, Kirk TR (1999) Assessment of obesity in a community sample of prepubertal children. Int J Obesity 23: 217–219
33. Daniels SR, Khoury PR, Morrison JA (1997) The utility of body mass index as a measure of body fatness in children and adolescents: differences by race and gender. Pediatrics 99: 804–807