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Original Article

Upper arm circumference measurement for detecting overweight and obesity in children aged 6-7 years

Dewi Rosariah Ayu[1], Aditiawati[1], Julius Anzar[1], Erial Bahar[2]

Abstract

Background Obesity is a worldwide problem and is associated with increased risk of metabolic syndrome. Nutritional status in children has traditionally been determined by body mass index (BMI) scores, but with limitations. Upper arm circumference measurement may be a better predictor of energy, protein, and fat storage, as well as a simpler method for screening overweight and obesity in children.

Objective To determine the diagnostic value of upper arm circumference compared to BMI for detecting overweight and obesity in children aged 6-7 years.

Methods This diagnostic study with a cross-sectional design was performed from September to October 2015 at 16 primary schools in Palembang, Indonesia. We measured the heights, weights, and upper arm circumferences, and calculated BMIs of 2,258 children. Receiver-operator characteristic (ROC) curve analysis was used to find an optimal upper arm circumference cut-off point to detect overweight and obesity. Diagnostic value was calculated by using a 2x2 table analysis.

Results The prevalences of overweight and obesity were 5.8% and 11.7%, respectively. The optimal upper arm circumference cut-off points for detecting overweight in children aged 6-7 years was 185 mm (sensitivity 88.1% and specificity 78.3%), and for obesity was 195 mm (sensitivity 90.15% and specificity 86.65%). Upper arm circumference had a strong correlation with BMI.

Conclusion Upper arm circumference measurement is an accurate method for–distinguishing between normoweight, overweight, and obesity in children aged 6-7 years. **[Paediatr Indones. 2017;57:23-9. doi: 10.14238/pi 57.1.2017.23-9]**.

Keywords: *childhood obesity; upper arm circumference; children aged 6-7 years*

Obesity is a worldwide problem. Pediatric obesity is associated with increased risk of metabolic syndrome in adulthood. The prevalence of obesity is increasing in both developed and developing countries. The prevalence of obesity has increased from 5% in 1963-1970 to 17% in 2003-2004.[1] The 2013 Indonesian Health Research Survey (*Riskesdas*) reported that the prevalence of overweight in children 5-12 years old were 10,8% and obesity were 8,8%.[2]

Obesity is defined as a disorder or a disease characterized by the accumulation of excessive body fat tissue. Using BMI charts (CDC 2000), a BMI ≥ 85 - <95 percentile is classified as overweight, and BMI ≥ 95th percentile is classified as obese.[3,4] Obesity occurs because of an imbalance between energy intake and energy output (expenditure).[5] Most energy homeostasis disorders are caused by idiopathic factors (primary and nutritional obesity), while fewer are caused by endogenous factors (secondary or non-nutritional obesity, caused by hormonal disorders,

From the Department of Child Health[1] and Health and Medicine Research Unit[2], Sriwijaya University Medical School/Dr. Mohammad Hoesin Hospital, Palembang, South Sumatera, Indonesia.

Reprint requests to: Dewi Rosariah Ayu, Department of Child Health, Faculty of Medicine/Dr. Mohammad Hoesin Hospital, Jl. Jenderal Sudirman Km. 3,5, Palembang, 30126, Indonesia. Fax/Tel: +62-81285480316; E-mail: dewirosariahayu@yahoo.com.

syndromes, or genetic defects).[6] The clinical manifestations of obesity are a rounded face, chubby cheeks, double chin, chest with enlarged breast tissue, and an abdominal wall with folds. Management of obesity consists of several stages which include prevention, structured weight management, and comprehensive multidisciplinary intervention.[3] Body fat content can be measured by underwater weighing examination (hydro-densitometry), magnetic resonance imaging (MRI), computerized tomography (CT), dual-energy X-ray absorptiometry (DEXA), or bioelectrical impedance analysis (BIA). Anthropometric examinations are done by measuring body weight, height, skin fold thickness, abdominal circumference, or upper arm circumference and comparing the results to standardized growth charts for children of similar age and sex.[7]

Determining children's nutritional status generally refers to BMI percentile curve measurements, according to age and sex. However, BMI has several drawbacks including not distinguishing between fat and non-fat mass, or between total body fat and body fat distribution.[8,9] The measurement of BMI requires height and weight scales, as well as the BMI reference charts.[8] An alternative method for diagnosing overweight and obesity is the upper arm circumference measurement. Upper arm circumference can be used to measure growth, protein and energy reserves, as well as to provide information about body fat mass.[10,11] It can be used as a reference because the upper arm is, in theory, cylindrical with subcutaneous fat evenly distributed around the middle upper arm muscles.[12,13] Upper arm circumference measurements also have the advantages of being easier and less expensive, as only a measuring tape and reference tables according to age and gender are required. As such, the measurements can be easily done in community and health facilities.[3, 14] Upper arm circumference based on age can be used to assess nutritional status of children who are sick or have abnormalities in the legs or spine. It is also relatively less influenced by edema and ascites.[15,16]

Past studies have reported upper arm circumference cut-off points,[17] but BMIs and eating habits differ among ethnic groups, necessitating reference values for nutritional status specific to a particular developing country, such as Indonesia. We chose to include subjects aged 6-7 years because adiposity rebound tends to occur at that age period, when rapid body weight increases, may affect the prevalence of obesity in adolescence and adulthood.[4, 18]

We aimed to assess upper arm circumferences of 6-7-year-olds and compare them to their BMI measurements, in order to determine upper arm circumference cut-off points for detecting overweight and obesity in children aged 6-7 years.

Methods

This diagnostic study with a cross-sectional design was done in September to October 2015. Data are presented in tabular form and ROC curve analysis. Subjects were children aged 6-7 years from 16 primary schools in Palembang, who were recruited by cluster sampling determined by the topography of Palembang which devided into area ulu and ilir. Three until four shcool in a subdistrict were chosen to included in this reasearched. Children with severe deformity of vertebrae, upper arm, or lower extremity, Down or Turner syndrome, received long-term steroid treatment, or who were uncooperative during the examination were excluded. Subjects indicated they were willing to join the study and their parents provided informed consent. The study was approved by the Committee for Medical Research Ethics of University of Sriwijaya Faculty of Medicine.

We measured subjects' heights, weights, upper arm circumferences, and waist circumferences, as well as calculated their BMIs. Data on parental education, job, and income were collected by questionnaire The researchers and five trained assistants used measuring tools that had been calibrated for accuracy, including weight scales, stature meters, and measuring tapes SECA brand. We used the 2000 CDC BMI reference standard curves.[3] Subjects were classified as normoweight for BMI $< 85^{th}$ percentile, overweight for BMI $\geq 85^{th}$ - $<95^{th}$ percentile, and as obese for BMI $\geq 95^{th}$ percentile.

Data were analyzed by *SPSS for Windows 19.00* (*SPSS Inc*) software. The ROC curve analysis was used to determine optimal upper arm circumference cut-off points to detect overweight and obesity and to distinguish between them. Diagnostic values were calculated by a 2x2 table analysis.

We used ROC curve analysis to determine the validity of upper arm circumference for detecting

overweight in children aged 6-7 years compared to BMI. The area under the curve (AUC) and the coordinates were used to determine the optimal upper arm circumference cut-off values for assessing nutritional status. The analysis was done in two stages: first, by including normoweight, overweight, and obese; and second, by normoweight and overweight only, in order to determine the diagnostic upper arm circumference value to distinguish between normoweight and overweight.

Results

From September to October 2015, anthropometric measurements were taken on 2,258 children who met the inclusion criteria. Using BMI reference standards, 131 (5.8%) were classifed as overweight, 264 (11.7%) were obese, 581 (25.9%) were underweight, and 1,282 (56.6%) were normoweight. No subjects dropped out of the study. The ratio of boys to girls was 1.05:1.

The upper arm circumference AUC value for males and females to distinguish normoweight from overweight and obese was 89.8% (95%CI 87.7 to 91.9%). The AUC value for males was 89.8% (95%CI 87 to 92%), and for females was 88.1% (95%CI 84 to 92%; P<0.001). The optimal upper arm circumference cut-off point for detecting overweight in children was 185 mm. The table analysis and diagnostic values of upper arm circumference for detecting overweight compared to BMI are shown in **Table 1**.

An upper arm circumference cut-off point of 185mm for distinguishing normoweight from overweight and obese in children as compared to BMI had a sensitivity of 88.1%, specificity of 78.3%, positive predictive value of 55.6%, negative predictive value 95.5%, positive likelihood ratio 4.05), negative likelihood ratio of 0.15, and accuracy of 80.6%. For boys alone, this cut-off point had a sensitivity of 89.2%, specificity of 78.3%, positive predictive value of 59.4%, negative predictive value of 96.8%, positive likelihood ratio of 4.1, negative likelihood ratio of 0.15, and accuracy of 81.2%. For girls alone, this cut-off point had a sensitivity of 86.6%, specificity of 78.3%, positive predictive value of 51.2%, negative predictive value of 95.7%, positive likelihood ratio of 3.99, negative likelihood ratio of 0.17, and accuracy of 66.2%.

With the same cut-off point of 185mm, the AUC value of upper arm circumference to distinguish between normoweight and overweight children was 82.8% (95%CI 78.6 to 87%; P < 0.001). The AUC value of upper arm circumference for males was 80.5% (95%CI 74.3 to 86.7%; P<0.001), while that for females was 84.8% (95%CI 79.2 to 90.4%; P<0.001). The 2x2 table analysis results and diagnostic value of upper arm circumference for detecting overweight in children as compared to BMI is shown in **Table 2**.

An upper arm circumference cut-off point of

Table 1. Diagnostic value of upper arm circumference for detecting overweight and obesity compared to BMI (cut-off point ≥185 mm)

Criteria	Upper arm circumference	BMI		Total
		>P_{85}	P_{5-85}	
Male & female,* n	≥185 mm (overweight + obese)	348	278	626
	<185 mm (normoweight)	47	1,004	1,051
	Total	395	1,282	1,677
Male,** n	≥185 mm (overweight + obese)	199	136	335
	<185 mm (normoweight)	24	491	515
	Total	223	627	850
Female,*** n	≥185 mm (overweight + obese)	149	142	291
	<185 mm (normoweight)	23	513	536
	Total	172	655	827

*(Sen 88.1%; Spec 78.3%; PPV 55.6%; NPV 95.5%; LR^+ 4.05; LR^- 0.15 accuracy 80.6%)

**(Sen 89.2%; Spec 78.3%; PPV 59.4%; NPV 96.8%; LR^+4.1; LR^- 0.15 accuracy 81.2%)

***(Sen 86.6%; Spec 78.3%; PPV 51.2% NPV 95.7%; LR^+3.99; LR^- 0.17, accuracy 66.2%)

Sen=sensitivity; Spec=specivicity; PPV=positive predictive value; NPV=negative predictive value; CR+=positive likelihood ratio; LR-=negative likelihood ratiO

Table 2. Diagnostic value of upper arm circumference for detecting overweight in children aged 6-7 years (cut-off point ≥185 mm)

Criteria	Upper arm circumference	BMI		Total
		P_{85-P95}	P_{5-85}	
Male and female,* n	≥ 185 mm (overweight)	103	278	381
	< 185 mm (normoweight)	28	1,004	1,032
	Total	131	1,282	1,413
Male,** n	≥ 185 mm (overweight)	44	136	180
	< 185 mm (normoweight)	16	491	507
	Total	60	627	687
Female,*** n	≥ 185 mm (overweight)	59	142	201
	< 185 mm (normoweight)	12	513	525
	Total	71	655	726

*(Sen 78.6%; Spec 78.3%; PPV 27%; NPV 97.2%; LR^+ 3.46; LR^- 0.28 accuracy 78.3%)
**(Sen 73.3%; Spec 78.3%; PPV 24.4%; NPV 96.8%; LR^+ 3.22; LR^- 0.35 accuracy 77.8%)
***(Sen 83%; Spec 78.3%; PPV 41.5%; NPV 97.7%; LR^+ 3.8; LR^- 0.21 accuracy 78.8%)

185 mm for distinguishing between normoweight and overweight in children aged 6-7 years compared to BMI had sensitivity of 78.3%, specificity of 78.3%, positive predictive value of 27%, negative predictive value of 97.2%, positive likelihood ratio of 3.46, negative likelihood ratio of 0.28, and accuracy of 78.3%. For boys alone, this cut-off point had sensitivity of 73.3%, specificity of 78.3%, positive predictive value of 24.4%, negative predictive value of 96.8%, positive likelihood ratio of 3.22, negative likelihood ratio of 0.36, and accuracy of 77.8%. For girls alone, this cut-off point had sensitivity of 83%, specificity of 78.3%, positive predictive value of 41.5%, negative predictive value of 97.7%, positive likelihood ratio of 3.8, negative likelihood ratio of 0.21, and accuracy of 78.8%.

ROC analysis revealed that the optimal upper arm circumference cut-off point to distinguish obesity from overweight and normoweight was 195 mm. The AUC value of upper arm circumference for detecting obesity in children aged 6-7 years was 92.9% (95%CI 90.9 to 94.9%; P < 0.001) (**Figure 1**). The AUC value of upper arm circumference for boys was 94.8% (95%CI 92.7 to 96.8%; P < 0.001), while that for detecting obesity in girls was 90% (95%CI 86.1 to 94%; P < 0.001). The table analysis results and diagnostic value of upper arm circumference for detecting obesity in children compared to BMI is shown in **Table 3**.

An upper arm circumference cut-off point of 195 mm for detecting obesity in children aged 6-7 years compared to BMI had a sensitivity of 90.2%, specificity of 86.5%, positive predictive value of 47.1%, negative predictive value of 98.5%, positive likelihood ratio of 6.28, negative likelihood ratio of 0.13, and accuracy of 87%. For boys alone, this cut-off point had sensitivity of 93.25%, specificity of 86.9%, positive predictive value of 53.9%, negative predictive value of 98.7%, positive likelihood ratio of 6.64, negative likelihood ratio of 0.77, and accuracy of 87.8%. For girls alone, this cut-off point had sensitivity of 85.1%, specificity

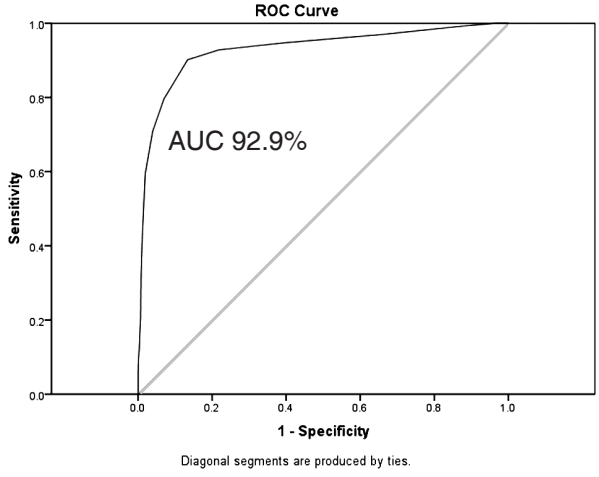

Figure 1. ROC curve of upper arm circumference compared to BMI for distinguishing obesity in children aged 6-7 years

of 86.2%, positive predictive value of 38.6%, negative predictive value of 98.28%, positive likelihood ratio of 6.15, negative likelihood ratio of 0.17, and accuracy of 86.1%.

Pearson's correlation test revealed that the upper arm circumference had a strong correlation with weight (r=0.78; P=0.000), height (r=0.44; P=0.000), and BMI (r=0.73; P=0.000).

Table 3. Diagnostic value of upper arm circumference for detecting obesity in children aged 6-7 years (cut-off point ≥195 mm)

Criteria	Upper arm circumference	BMI		Total
		≥ P_{95}	< P_{95}	
Male & female,* n	≥ 195mm (obese)	238	267	505
	< 195mm (non-obese)	26	1,727	1,753
	Total	264	1,994	2,258
Male,** n	≥ 195mm (obese)	152	130	282
	< 195mm (non-obese)	11	866	877
	Total	163	996	1,159
Female,*** n	≥ 195mm (obese)	86	137	223
	< 195mm (non-obese)	15	861	876
	Total	101	998	1,099

*(Sen 90.15%; Spec 86.65%; PPV 47.1%; NPV 98.5%; LR^+ 6.28; LR^- 0.13 accuracy 87%)
**(Sen 93.25%; Spec 86.9%; PPV 53.9%; NPV 98.7%; LR^+ 6.64; LR^- 0.77 accuracy 87.8%)
*** (Sen 85.1%; Spec 86.2%; PPV 38.6%; NPV 98.28%; LR^+ 6.15; LR^- 0.17; accuracy 86.1%)

Discussion

This diagnostic study was done to determine the accuracy of diagnostic upper arm circumference values compared to body mass index for detecting overweight and obesity in a pediatric population. The male to female ratio of children aged 6-7 years was 1.05:1.

In Indonesia, children's nutritional status is generally determined by BMI curves (CDC 2000), according to age and sex. Children with BMI in the 85th to < 95th percentile are considered to be overweight, and those with BMI ≥ 95th percentile are considered to be obese.[3] In our study, the prevalence of overweight and obesity were 5.8% and 11.7%, respectively. This finding is consistent with the 2013 *Riskesdas* prevalence of obesity in school-aged children of (11.9%).[2] The obesity prevalence of boys in our study (14%) was higher than that of school-aged boys in Indonesia (10.7%) (2010 *Riskesdas*), but lower than that of boys in South Sumatra (16.0%) (2007 *Riskesdas*).[19,20] The obesity prevalence of girls in our study (9.2%) was higher than that of school-aged girls in Indonesia (7.7%) (2010 Riskesdas), but lower than that of school-aged girls in South Sumatra (11.0%) (2007 Riskesdas).[19,20] Furthermore, we found that the prevalence of obesity in boys was higher than in girls, consistent with the 2007 and 2010 *Riskesdas* results.[19,20]

Human activity that involves repetitive muscle movement in an upper extremity can increase muscle mass in an asymmetric fashion. Brown and Wolpert reported that upper extremities of individuals may be asymmetric and significantly different in circumference.[21] However, we found no difference between right and left upper arm circumference measurements in children because the stress markers of handedness which are influenced by repetitive movement of the dominant hand in the children aged 6-7 years has not yet happened.[21]

The mean BMI of boys aged 6-7 years in our study was 15.66 kg/m^2, which was lower than boys in the UK (15.8 kg/m^2), Germany (15.8 kg/m^2), China (16.5 kg/m^2), and Qatar (17.7 kg/m^2). The mean BMI of girls aged 6-7 years was 15.14 kg/m^2, which was similar to girls in Qatar (15.1 kg/m^2), but lower than girls in the UK (15.4 kg/m^2), Germany (15.6 kg/m^2), and China (15.9 kg/m^2).[22-25]

In our study, the mean body weights were 21.29 kg in boys and 20.16 kg in girls. Mean heights were 116 cm in boys and 114.85 cm in girls. The mean abdominal circumferences were 55.86 cm in boys and 54.87 cm in girls.

Upper arm circumference can be used to measure growth, as an indicator of protein and energy reserves, as well as provide information on body fat levels.[3] The upper arm circumference cut-off point was the same between our male and female subjects. In contrast, a South African study found different cut-off points for obesity in boys and girls aged 5-9 years (192 mm *vs.* 184 mm, respectively). A Nigerian study showed significantly higher fat mass and upper arm circumference in girls than in boys, in children aged 5-15 years. This observation may be due to total body fat increases to prepare for a future growth spurt during adolescence. This increased total body fat and puberty occurs in girls earlier than in boys (19% female and 14% male). In the early teen years, boys have more muscle mass than girls.[26] Since our sample population was 6-7-year-olds, we found no difference in cut-off point between males and females.

The mean upper arm circumferences were 182 mm in boys and 179 mm in girls. These values were higher than the mean upper arm circumference of 171 mm (males and females) reported in a Turkish study.[7] Our 185 mm cut-off point to distinguish normoweight from overweight was also higher than their cut-off points of 181 mm for boys and 179 mm for girls. However, all the values were lower than the US 90th percentile of health and nutrition of 209 mm for boys and 204 mm for girls. Our upper arm circumference cut-off point to distinguish obese from non-obese was 195 mm, which was lower than those of US children (226 mm for boys and 211 mm for the girls), but higher than the Turkish study (182 mm in boys and 180 mm in girls). This difference may be due to the small sample size in the Turkish study of 124 boys and 126 girls. [17]We found that the sensitivity of upper arm circumference in distinguishing normoweight from overweight was higher (88.1%) when the obese subjects were included in the diagnostics measurement, likely due to fewer overweight subjects in the study population. The positive predictive values in this study were lower than the negative predictive values, and were as follows: for distinguishing normoweight from overweight and obese: PPV 55.6% and NPV 95.5%; for distinguishing normoweight from overweight: PPV 27% and NPV 97.2%; and for distinguishing obese from non-obese: PPV 47.13% and NPV 98.5%. These findings may have been due to the smaller size of the overweight and obese sample of the population. Therefore, further research is recommended using a sample population of overweight and obese children with its own sample calculation.

The upper arm circumference diagnostic value compared to BMI of each cut-off point in this study was quite high, in addition to the significant correlations between upper arm circumference and BMI. As such, upper arm circumference can be used to predict the presence of overweight and obesity in children aged 6-7 years.

The gold or reference standards for assessing nutritional status are the 2000 CDC BMI curves.[3] Although the Committee for Nutrition and Metabolism of the Indonesian Pediatrics Association recommends using the 2000 CDC BMI standard for children over 5 years of age, it is a limitation of our study in that the reference standard is based on data from children in the United States, which do not necessarily correspond to those of children in Indonesia, as BMI is strongly influenced by age, gender, and race.[27,28] Further study conducted in all age groups of children and adolescents is required in order to compare upper arm circumference data to BMI for each age group.

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Conflict of interest

None declared.

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