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Community childhood obesity assessment in elementary school, anthropometric indices as screening tools: a community cross-sectional study in Indonesia

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ABSTRACT

Background Representative anthropometric epidemiological data are needed to formulate screening and intervention methods to prevent obesity in children. This study aims to conduct community childhood obesity assessment in elementary school based on anthropometric measurements and evaluate its predictive value.

Methods This cross-sectional study was carried out in Palembang, Indonesia, and involved 1180 elementary school students. The anthropometric parameters were divided into (1) basic data: stature, weight and waist circumference (WC), hip circumference (HC); (2) structural dimensions: the segmental dimensions of head-neck, trunk, upper extremity, hand, lower extremity and foot and (3) postural dimensions: the relative spacial dimensions when standing. Six anthropometric indices were considered: body mass index, waist-to-hip ratio (WHR), waist-to-height ratio (WHtR), Conicity Index (CI), Body Adiposity Index (BAI) and Tri-ponderal Mass Index (TMI).

Results The proportion of overweight and obesity was 50.17% (n=592) and normal weight was 49.83% (n=588). The mean age was 8.26±1.71 years. The averages of all measured indices in overweight/obese versus normal weight were significant difference among boys and girls in height, weight, WC, HC, neck circumference, WHR, WHtR, neck-to-height ratio, BAI, TMI and CI ($p<0.05$ for all). TMI was the best predictor of obesity based on area under the curve (AUC) values, both in boys (sensitivity=90.48; specificity=91.53; AUC=0.975) and in girls (sensitivity=90.28; specificity=90.00; AUC=0.968).

Conclusions A trustworthy anthropometric database of primary school students might be a helpful local resource when working on projects involving children. In order to improve the quality of life through better-suited and secure products and environmental designs, it is crucial to build an anthropometric database.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Obesity in children is a global problem, but the anthropometric database of Indonesian children is still limited. Research has provided representative anthropometric data to formulate screening and intervention methods to prevent obesity in children.

WHAT THIS STUDY ADDS

⇒ This research adds to understanding of the prevalence of childhood obesity in Indonesia and makes an important contribution to planning more effective obesity prevention programmes at the local level.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ An anthropometric database produced by this research has the potential to impact clinical practice and policy. Reliable anthropometric data can be used to monitor progress and evaluate the effectiveness of adopted interventions, as well as make product and environmental design adjustments that are safe for children at the local level.

INTRODUCTION

Obesity is a significant health problem, affecting both adults and children. WHO report shows that the rates of overweight and obesity in children under 5 years of age and the 5–18 year age group are 38 and 380 million, respectively.[1] Obesity is mostly caused by unhealthy lifestyles where increased intake of energy-dense foods is combined with increased sedentary lifestyle, reduced physical activity and reduced sleep quality and time.[2–4] However, a complete picture of all risk factors associated with obesity remains elusive, but many studies agree that prevention is a key strategy to control this problem.[5] The combination of diet, exercise and physiological and psychological factors is an important factor in controlling and preventing obesity and diabetes.[6 7] Children who are overweight or obese cannot

yet be treated with medication unless significant comorbidities persist despite lifestyle modifications.[8]

Failure to take appropriate action will certainly further expose the child to further weight gain, impaired glucose tolerance and other accompanying health effects.[9 10] Despite being the most accurate techniques, CT and MRI are impractical for those with a low or moderate income.[11] Analyses of anthropometry are commonly employed to assess population-level obesity.

Recent assessments from several studies including neck circumference (NC) and waist-to-hip ratio (WHR) show good predictive value for the risk of metabolic syndrome and cardiometabolic disease in adolescents and adults.[12 13] The conicity index (CI), ponderal index (PI) and body adiposity index (BAI) are all trustworthy indicators of the proportion of body fat and abdominal obesity, respectively, in children.[14 15] The significance of taking a more complete approach to tackling the complexity of paediatric obesity supports the use of measurements other than body mass index (BMI). While BMI is a commonly used statistic to evaluate body weight, its limitations render it inappropriate for reflecting the multifaceted character of obesity.[11] Muscle mass and fat distribution are two distinct body compositions that have diverse health implications. When children experience rapid physical development, this limitation is particularly apparent. In order to increase the precision of forecasting health risks related to obesity and to more effectively coordinate preventative and intervention activities, this study investigated several other measures of anthropometric indices.

Published studies in Indonesia that examine representative anthropometric epidemiological data to formulate screening methods and interventions to prevent obesity in children are still limited. In fact, in 2021, Indonesia is the 5th ranked country with the highest number of adults (20–79 years) suffering from diabetes and the 3rd ranked country with the highest number of undiagnosed diabetes sufferers after China and India.[16] Between 1996 and 2016, the prevalence of children and adolescents in Indonesia who were overweight or obese (5–19 years) increased from 3.9% to 15.4%, a fourfold increase.[17] In contrast, based on data from the 2018 Indonesian Basic Health Survey (RISKESDAS), the prevalence of overweight and obesity among children aged 5–12 years was 20% and 9.2%, respectively.[18] If the current trend continues, efforts must certainly be made to stem the tide of new cases that are most likely to experience an onset in the future. This study aims to conduct community childhood obesity assessment in elementary school based on anthropometric measurements and evaluate its predictive value. Knowing and predicting who is most vulnerable and where they live will guide efficient allocation of prevention resources.

METHOD

Population

This cross-sectional study was conducted during May–August 2023 in 1180 elementary school children. The multistage cluster random sampling method was used to select a representative sample of the population. Palembang is geographically divided into two areas, namely Seberang Ulu and Ilir (separated by the Musi River) which consist of 17 subdistricts. 2 of 12 Seberang Ilir subdistricts and 2 of 5 Seberang Ulu subdistricts were randomly selected, and for the third stage, 25% of the elementary schools from each subdistrict were randomly selected. We included elementary school children aged 5–12 years. Children who were twins, or suffered from growth hormone disorders, metabolic disorders (hypothyroidism, hyperthyroidism and diabetes), heart disease, kidney dysfunction or bone disease were excluded from the study.

Anthropometry measurement

The anthropometric parameters in the present study were divided into three categories: (1) basic data: stature, weight and waist circumference (WC), hip circumference (HC); (2) structural dimensions: the segmental dimensions of head-neck, trunk, upper extremity, hand, lower extremity and foot and (3) postural dimensions: the relative spacial dimensions when standing. A general practitioner assistant measured the weight and height of children under standard conditions. Height was recorded using a commercial non-elastic tape measure. Children stand barefoot, with shoulders straight, feet hanging freely and heads looking straight. A point is marked on a large piece of white cardboard attached to the wall that corresponds to the highest point of the head. The tape is used to measure the distance from the floor to that point. Height rounded to the nearest 0.1 cm. Electronic weight scales are used to measure body weight in light clothing and without heavy shoes, jackets or accessories. Readings are rounded to the nearest 100 g. Several circumferences, for example, WC at the umbilical level, HC at the widest part of the buttocks and the NC in between mid-cervical spine and mid-anterior level, were measured using an anthropometric tape (to the nearest 0.1 cm) in a relaxed position. The measurements were repeated 2–3 times and the mean of the results was calculated.

Calculation of indices

The BMI and tri-ponderal mass index (TMI) were estimated by dividing the weight (kg) to the squared-height (m^2) and the weight (kg) to cubed-height (cm^3), respectively. The definition of childhood obesity was based on the BMI-for-age (z-score) by WHO which was divided into two groups: overweight/obese and normal-weight. We calculated the WHR as WC (cm) divided by height (cm), the waist-to-height ratio (WHtR) as WC (cm) divided by HC (cm) and the neck-to-height ratio (NHR) as NC (cm) divided by height (cm). The CI was calculated based on WC, weight and height using the Valdez's formula.[19] The

BAI was computed from the HC and the height based on the formula reported by Aarbaoui *et al*, taking into account the overestimation/underestimation of body fat in paediatrics.[20] The employed formulas are depicted below:

BAI: HC (cm)/height$^{0.8}$ (m).
TMI: weight (kg)/height^{3} (cm^{3}).
CI: waist (m)/0.109 √ (weight (kg)/height (m)).
BMI: weight (kg)/height^{2} (m^{2}).

Statistical analysis

The statistical analyses were performed using the STATA, V.15. The variables were tested for normality using the Kolmogorov-Smirnov test. Continuous data are presented as mean±SD and compared using the independent sample test. The receiver-operating characteristic (ROC) curves were constructed to evaluate the ability of anthropometric measurements as obesity predictors (based on BMI-for-age). The most accurate cut-off points were identified through sensitivity, specificity and area under the curve (AUC). The hypotheses were tested at a 5% significance level.

Patient and community involvement

Patient and community involvement first begins at the research planning stage. Before the measurements were taken, a notification was made to the school to be forwarded to parents. Then informed consent was given to students, teachers and school administration to assist with approval and authorisation for carrying out the measurements. All feedback and suggestions were provided regarding the research objectives, participant information sheets and interview question design were considered and implemented. Apart from that, the results of the findings were also conveyed to the school.

RESULT

In this study, boys represented 521 (44.15%) and 659 (55.85%) girls. Of the 1180 children, the proportion of overweight/obesity was 50.17% (n=592) and normal weight was 49.83% (n=588). There were two participants who had a BMI-for-age >+2SD (3.11) in the obese category whose data was combined with overweight. The mean age of the participants was 8.26±1.71 (5–12 years). The anthropometric indices of the elementary school children stratified by sex are represented in table 1. As compared with boys, girls showed a significant difference in NC, NHR, head circumference, head breadth, face breadth, chest circumference, hand circumference, fist circumference and ankle height (p<0.05 for all).

There are some significant differences in the head-and-trunk between boys and girls. The head circumference is significantly different between boys and girls (p=0.016). The head breadth is also significantly different between boys and girls (p=0.001). Finally, the face breadth (p=0.024) and chest circumference (p=0.029) are significantly different between boys and girls. In the upper extremity, hand circumference (p=0.007) and fist circumference (p=0.002) are also significant differences between boys and girls. Based on postural dimensions, only ankle height was significantly different between boys and girls (p=0.005). Meanwhile, for the lower extremity, both foot breadth, foot length and ankle breadth were not significant differences between boys and girls (p>0.005).

The averages of all measured indices in overweight/obese versus normal weight were significant difference among boys and girls in height, weight, WC, HC, NC, WHR, WHtR, NHR, BAI, TMI and CI (table 2). The same and interesting finding is the mean WHtR in the normal weight between boys (0.45±0.03) and girls (0.45±0.03) is not different. But, in boys WHtR was not significantly (p=0.059) different between normal weight (0.45±0.03) versus overweight/obese (0.46±0.06), but in girls the difference in WHtR was significant between normal weight (0.45±0.03) versus overweight/obese (0.47±0.06). Apart from that, the mean CI in the normal weight group between boys (1.24±0.06) and girls (1.24±0.06) was also found to be no different. However, there was a significant difference in mean CI between normal weight versus overweight/obese for both boys and girls (p<0.001).

The sex-based ROC curves for all the anthropometric indices employed as predicting tools for the detection of paediatric obesity are represented in table 3. Overall, we discovered that, of all the obesity indices, TMI was the best predictor of obesity based on AUC values, both in boys (sensitivity=90.48; specificity=91.53; AUC=0.975) and in girls (sensitivity=90.28; specificity=90.00; AUC=0.968).

DISCUSSION

The structural measurements of the head, trunk and upper and lower extremities, including their length, width and circumference, are shown in table 1. Results generally reveal consistent growth from ages 6 to 12 across all physical measurements. The findings also revealed that, although these differences were not statistically significant, boys had somewhat higher anthropometric values than girls in the majority of physical dimensions. The anthropometric measurements found in this study can serve as a trustworthy resource for Indonesian kids, allowing for the creation of environments and products that are more suited to their size. Regarding the application of anthropometric data, it is recommended that the dimensions of products be chosen in accordance with the anthropometric data and the functional characteristics of the items. As a result, it is envisioned that ergonomics would help improve the safety and adaptability of products and surroundings designed for children in Indonesia.

In this population-based study, we demonstrated that the TMI was a better predictor in identifying obesity in paediatric subjects. Similar findings have also been documented by Mardali *et al* and Lorenzo *et al*. Our study is the first attempt to compare anthropometric indices in the detection of paediatric obesity in Indonesian elementary school children.[1 21] It is vital to determine which

Table 1 The basic anthropometric data of elementary school children (n=1180)

Anthropometric indices	Boy	Girl	P value
Height	119.97±13.11	119.44±13.46	0.493
Weight	22.33±9.43	21.95±9.14	0.494
WC	54.83±8.90	54.89±7.78	0.898
HC	57.40±8.51	57.75±7.63	0.461
NC	26.85±2.70	27.19±3.06	**0.047**
WHR	0.95±0.04	0.95±0.037	0.048
WHtR	0.45±0.05	0.46±0.05	0.314
NHR	0.23±0.02	0.23±0.02	**0.007**
BMI	14.84±3.16	14.76±3.17	0.648
BAI	47.41±5.63	47.67±4.76	0.406
CI	1.20±0.11	1.21±0.08	0.247
TMI	18.09±5.61	17.88±4.46	0.520
Head-and-trunk: the structural dimensions			
Sagittal arc	30.15±3.40	30.34±5.31	0.475
Head circumference	51.74±2.04	52.02±2.06	**0.016**
Head length	28.39±28.16	28.24±3.48	0.637
Head breadth	15.86±2.62	15.36±1.37	**0.001**
Interpupillary breadth	7.90±1.49	7.78±4.58	0.558
Face breadth	9.57±1.27	9.40±1.41	**0.024**
Neck breadth	12.84±2.71	12.97±2.70	0.417
Chest circumference	54.15±11.03	52.68±11.71	**0.029**
Bust depth	17.05±6.05	16.58±5.67	0.173
Bioacromial breadth	25.79±3.55	25.64±3.90	0.456
Upper extremity: the structural dimensions			
Bideltoid breadth	32.48±7.42	32.23±5.09	0.498
Hand circumference	19.72±2.44	19.19±2.79	**0.007**
Fist circumference	21.75±2.59	21.31±2.22	**0.002**
Hand breadth	7.87±0.97	7.79±0.97	0.165
Hand length	13.51±2.82	13.38±2.83	0.446
Lower extremity: the structural dimensions			
Foot breadth	7.85±1.16	7.76±1.04	0.146
Foot length	18.35±2.17	18.20±2.17	0.351
Ankle breadth	6.79±1.35	6.81±3.20	0.924
The postural dimensions: standing			
Vertical grip reach	135.40±16.89	134±17.87	0.531
Wirst height	54.68±7.53	54.58±8.40	0.823
Palm centre height	51.53±6.31	51.63±7.56	0.809
Middle finger tip height	40.80±5.85	40.96±5.68	0.626
Knee height	32.54±4.28	32.75±4.43	0.393
Ankle height	6.01±2.54	5.80±1.03	**0.005**
Lobule height	104±11.87	103.19±14.69	0.313

Bold values are statistically significant (p<0.05).
BAI, body adiposity index; BMI, body mass index; CI, conicity index; HC, hip circumference; NC, neck circumference; NHR, neck-to-height ratio; TMI, tri-ponderal mass index; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio.

screening techniques are the most readily available, affordable and usable by medical professionals across the globe in various health settings.

We also demonstrated that the CI is a suitable indicator of fat distribution in children, much like Filgueiras *et al*, as a result, other complementary indices are required to evaluate its capacity to forecast the emergence of childhood overweight and obesity.[22] As compared with boys, girls showed a significant difference in NC, NHR, head circumference, head breadth, face breadth, chest circumference, hand circumference, fist circumference and ankle height (p<0.05 for all). The averages of all

Table 2 The anthropometric characteristics on the presence of overweight/obese and normal-weight

Anthropometric indices	Boy			Girl		
	Normal	Overweight/obese	P value	Normal	Overweight/obese	P value
Height	11.64±9.25	127.54±11.41	<0.001	111.86±10.06	127.52±11.84	<0.001
Weight	15.67±3.50	28.38±9.05	<0.001	15.84±3.79	28.47±8.68	<0.001
WC	50.36±2.86	58.89±10.45	<0.001	50.48±3.02	59.60±8.51	<0.001
HC	53.29±2.82	61.14±10.09	<0.001	53.45±3.06	62.33±8.34	<0.001
NC	25.69±2.52	27.89±2.32	<0.001	25.80±1.91	28.67±3.35	<0.001
WHR	0.94±0.03	0.96±0.05	<0.001	0.94±0.02	0.96±0.04	0.001
WHtR	0.45±0.03	0.46±0.06	0.059	0.45±0.03	0.47±0.06	<0.001
NHR	23.152.90	21.95±1.61	<0.001	23.19±2.03	22.58±2.74	0.001
BAI	56.26±2.91	48.47±7.11	<0.001	46.31±2.92	49.11±5.80	<0.001
TMI	13.90±1.89	21.89±5.14	<0.001	14.01±2.03	22.00±4.92	<0.001
CI	1.24±0.06	1.16±10.13	<0.001	1.24±0.06	1.17±0.09	<0.001

BAI, body adiposity index; CI, conicity index; HC, hip circumference; NC, neck circumference; NHR, neck-to-height ratio; TMI, tri-ponderal mass index; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio.

measured indices in overweight/obese versus normal weight were significant difference among boys and girls in height, weight, WC, HC, NC, WHR, WHtR, NHR, BAI, TMI and CI. Anthropometric gender variations are probably determined by a mix of genetic, hormonal and developmental variables. Such distinctions are frequently investigated by researchers to learn more about how they relate to general health, growth patterns and potential variations in health risks between boys and girls. These results may be crucial for modifying therapies and healthcare for particular populations. Some potential genetically encoded sex differences include different genetic liability thresholds or distributions, gene-sex interactions at autosomal loci, a prominent function for the X chromosome or gene-environment interactions reflected in genes responsive to androgens or estrogens.[23 24]

This study also underscores the importance of using anthropometric indices to assess fat distribution and predict the risk of overweight and obesity in the paediatric population. The CI is emerging as a valuable tool for evaluating fat distribution in children.[25 26] However, in this study, it was found that the predictive value was inadequate. CI interpretation may be influenced by factors such as race, ethnicity and age group variations, highlighting the need to explore additional indices to improve the predictive accuracy of childhood overweight and obesity.[27 28] The WHR behaved differently in boys and girls, with the AUC for WHR above baseline only in females, according to the study. The differences in skeletal structure and HC between the sexes may be the cause of sex-related differences in WHR performance, suggesting that girls may have a higher fat proportion.

Table 3 Sex-based comparison of the receiver-operator characteristic curves for various anthropometric indices evaluated as predictors for overweight/obese among elementary school children

	Anthropometric index	AUC	Cut-off value	Sensitivity	Specificity	LR+	LR–
Boy	WHtR	0.552	0.46	44.32	66.13	1.30	0.84
	NHR	0.302	25.00	85.89	42.80	0.26	1.12
	BAI	0.662	48.00	74.60	61.42	1.95	0.68
	CI	0.185	1.30	8.79	91.94	1.09	0.99
	TMI	0.975	16.92	90.48	91.53	10.68	0.10
Girl	WHtR	0.583	0.45	67.40	49.41	1.33	0.65
	NHR	0.358	25.00	14.42	83.82	0.89	1.02
	BAI	0.703	47.02	71.47	57.65	1.69	0.49
	CI	0.177	1.25	10.97	40.29	0.18	2.21
	TMI	0.968	16.92	90.28	90.00	9.02	0.11

AUC, area under the curve; BAI, body adiposity index; CI, conicity index; LR, likelihood ratios; NHR, neck-to-height ratio; TMI, tri-ponderal mass index; WHtR, waist-to-height ratio.

WHtR has also been found to be a predictor of obesity in males, possibly reflecting differences in the distribution of body fat in boys and girls.[29 30]

In both sexes, we find that BAI is higher in overweight/obese children than in normal-weight youngsters. Additionally, the ROC curve demonstrated that BAI had a moderate predictive value for predicting the likelihood of childhood obesity (boy: 0.662; girl: 0.703). These results are consistent with the work by Aarbaoui *et al*[20] and Filgueiras *et al*[22] that was published. Based on the findings, Filgueiras *et al* stated that the AUC for BAI was better at predicting obesity in Brazilian children and adolescents than the predicted AUC for both sexes. Using modern techniques like the dual X-ray absorptiometry technology, which yields precise findings, one can estimate the body fat percentage.[31] However, this method has a number of limitations, and many researchers prefer to use simpler and more well accepted approaches to calculate fat mass, such as BAI.

The fundamental advantage of our study is that we analysed and contrasted a number of useful anthropometric indices that are cheap, simple to compute and have very little error. In addition, we evaluated the TMI, NC-to-height ratio and BAI of preschool Indonesian children for the first time. One of the study's limitations is that anthropometric indices were not evaluated using MRI, to compare fat percentages. These limitations underscore the need for cautious interpretation and highlight the necessity for further research with more rigorous methodologies and diverse populations to draw more robust conclusions. The external validity, or generalisability, of the study results, may be somewhat limited due to several factors. First, the study's sample composition, which includes children aged 5–12 years, might restrict the applicability of its findings to this specific age range. Anthropometric measurements and obesity determinants can vary significantly with age. Moreover, the geographical location of the study could affect its generalisability as regional variations in lifestyle, diet and genetics can influence the relationship between anthropometric indices and obesity. In summary, while the study provides valuable insights into its specific sample, caution should be exercised when attempting to generalise these findings to broader populations, and further research in diverse settings is warranted to enhance the external validity of the results.

CONCLUSIONS

The results also showed that, in the majority of physical measures, boys had slightly higher anthropometric values than girls. The anthropometric measures discovered in this study can be a reliable resource for Indonesian children, enabling the development of settings and goods that are more adapted to their stature. It is necessary to build particular anthropometric databases for particular populations, particularly for various genders, ages and ethnicities.

Contributors IAL, ISS and MQR contributed to conceptualisation and overall content as the guarantor. IAL and MQR contributed to data curation. IAL and ISS contributed to formal analysis. IAL, MM, PP and RA contributed to investigation. ISS and RA contributed to project administration. HH contributed to supervision. IAL and MQR contributed to visualisation. IAL, ISS, MQR, MM, PP and RA contributed to writing–original draft. IAL, RA and HH contributed to writing–review and editing.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Consent obtained from parent(s)/guardian(s).

Ethics approval This study involves human participants and was approved. All procedures carried out in this study involved human participants, in accordance with the ethical standards of institutional research committees. All source documents, including questionnaires, were anonymised to ensure anonymity. This research has been approved by Chief Ethics Committee of Medical Faculty of Universitas Sriwijaya on 15 July 2022 with Protocol Number 073-2022. This certificate confirms that the ethical clearance application made by IL. Here by declared that the protocol has been granted Exempt status. This research has also been permitted by the National Unity and Politics Service, Department of Education Service, and Public Health Office of Palembang. Participants gave informed consent to participate in the study before taking part.

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