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Cutoff points of mid-upper arm circumference (MUAC) for diagnosis of adolescent obesity: A systematic review with metanalysis and MOSTA tape proposal

MUAC cutoff for diagnosis of adolescent obesity

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ABSTRACT

Adolescents are particularly vulnerable to obesity. The initial step to implement preventive and therapeutic measures is the detection of patients affected. In some circumstances, it may be important that the diagnosis is made more quickly, and the mid-upper arm circumference (MUAC) has been used for this. The present study is a systematic review with meta-analysis seeking aiming to suggest cutoff points and propose a simple tool for screening or rapid diagnosis of adolescent obesity. Studies published between January 1990 and December 2022 on MUAC and obesity in adolescents from 10 to 18 years were researched. PRISMA statement and checklist were followed. Optimal cutoff values and the corresponding sensitivity and specificity were estimated using a meta-analysis of diagnostic accuracy studies, by maximizing the Youden index using the new "diagmeta" package of the R software. PROSPERO Submission number: 387,301. From 92 initially screened, a total of six papers fully met the inclusion criteria and were included in the meta-analysis, involving 39,149 adolescents from five countries. Using the proposed methodology, simplified cutoff points of MUAC (cm) were obtained for screening adolescents at risk for obesity: 23 for girls and 23.5 for boys (10–14 years); 28.14 for girls and 27.14 for boys (15–20 years). In conclusion, the present study proposes, through a systematic review with meta-analysis, simplified cutoff points of MUAC aiming for obesity screening for adolescents and the creation of a tool called MUAC Obesity Screening Tool for Adolescents (MOSTA tape) aimed at simple use and rapid diagnosis.

Introduction

Obesity in adolescence has shown high and increasing prevalences in virtually all the world.[1] Adolescents are particularly vulnerable to obesity due to the presence of risk factors such as sedentary lifestyle,[2] unhealthy eating habits,[3] excessive use of screens associated with the habit of snacking,[4] consumption of alcoholic beverages,[5] and mental health issues specific to this stage of life.[6] A Brazilian study of national sampling showed adolescent prevalence of overweight and obesity, respectively, of 17.1 and 8.4 %.[7] Comorbidities, such as dyslipidemia,[8] arterial hypertension[7] and metabolic syndrome[9] also become prevalent, along with excessive adiposity.

The initial step to implement preventive and therapeutic measures is the diagnosis of patients affected by this condition. Since obesity is defined as excess body adiposity, the most accurate approaches refer to those capable of defining body composition and body fat percentage (BFP), such as dual-energy X-ray absorptiometry (DXA), bio-impedanciometry, among others, however, these are complex and costly procedures.[10] Therefore, body mass index (BMI) has been used frequently, considering the premise that most individuals with high

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weight for their height will be obese.[11] Despite limitations from the individual point of view, BMI is suitable for population use, especially for screening, however, it requires two measurements (weight and height) and a mathematical calculation.[12]

In some circumstances, it may be important that the diagnosis is made more quickly, selecting the patients at higher risk to be reassessed more thoroughly.[13] This may occur in population studies, public health strategies, and even outpatient care, where the focus is directed to other conditions, but the recognition of obesity can help in the taking of conducts.[14] In emergency services, where children with respiratory, and gastrointestinal infections, among others, the associated diagnosis of obesity can direct therapy, knowing its influence, for example, on asthmatic conditions, immunity, and the presence of dysbiosis and subclinical inflammation.[15].

The mid-upper arm circumference (MUAC) has been used for many years to diagnose malnutrition, especially since Jelliffe[16] and Shakir's studies,[17] evolving to the use of MUAC reference curves developed by Word Health Organization for children under five years of age.[18] At the end of the last century and the beginning of the present, the first studies emerged seeking to evaluate the feasibility of using MUAC for the diagnosis of obesity.[19–21] Later, other researchers also evaluated this possibility using different methodologies.[22–46] At this moment, it is important to know whether the set of publications allows this measure to be effectively proposed as a diagnostic strategy. The present study is a systematic review of the scientific literature with a subsequent meta-analysis seeking to answer this question, suggesting cutoff points, and proposing a simple tool for screening or rapid diagnosis of adolescent obesity.

Methods

This meta-analysis was undertaken according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[47] The protocol of this systematic review and meta-analysis was submitted to PROSPERO (number: CRD42023387301).

Search strategy and study selection

Studies on MUAC and obesity were researched in adolescents from 10 to 18 years, published between January 1990 and December 2022, in the databases PubMed, Scopus, SciELO, Lilacs, Google Scholar, Web of Science and Cochrane Library. The keywords used for search were as follows: [MUAC OR mid-upper arm circumference OR arm circumference OR *perímetro do braço* OR *perímetro do meio do braço* OR *circunferência do braço* OR *perímetro del brazo* OR *perímetro de la mitad del brazo* OR *circunferencia del brazo*] AND [obesity OR overwheight OR fat excess OR adiposity excess OR *obesidade* OR *sobrepeso* OR *excesso de gordura* OR *adiposidade excessiva* OR *obesidad* OR *exceso de peso* OR *exceso de grasa* OR *adiposidad excesiva*] AND [adolescents OR *adolescentes*]. Studies that met the following inclusion criteria were selected:

1. Year of publication: 1990 to 2022.
2. Population: adolescents aged 10–18 years.
3. Index test: MUAC diagnostic performance to identify adolescents with obesity.
4. Comparator: compared with weight-for-height index, BMI-for-age, BMI z-score, skinfold thickness, waist circumference, bio-impedance, dual-energy X-ray absorptiometry, plethysmography, and hydrodensitometry.
5. Outcome: obesity.
6. Study design: observational studies (cohort, case-control, and cross-sectional).
7. Language: studies published in any language were included.

Data extraction and risk of bias/quality assessment

First, titles and abstracts were screened by two independent reviewers (CANA and FVU). Reviewers extracted the following information from included studies: first author's name, country, year of publication, study design, total sample size, number of males and females, age of study participants, diagnostic criteria of obesity (reference standard), MUAC cutoff values, sensitivity, and specificity. These data were extracted and compared by two independent reviewers, and any discrepancies were resolved by consensus. The risk of bias was assessed using the Quality Assessment of Diagnostic Accuracy Studies (QUADAS-2) tool.[48].

Statistical analysis

Optimal cutoff values and the corresponding sensitivity and specificity were estimated using the method introduced by Steinhauser et al.[49] for meta-analysis of diagnostic accuracy studies with several cutoff points. This method uses a SROC (summary receiver operating characteristic curve), calculated using a multilevel random-effects model, considering sensitivity and specificity as functions of the thresholds, accounting for heterogeneity across studies and the correlation of sensitivity with specificity. The optimal cutoffs were estimated by maximizing the Youden index. This approach is implemented in the "diagmeta" package of the R software version 4.1.1, published in December 2022 and available in CRAN (The Comprehensive R Archive Network).[50].

Ethical approval and informed consent

No ethical approval is required as this is a systematic review study.

Results

Selection of studies

The search of articles in the databases identified 92 records from January 1990 to September 2022. Of these, 46 records remained after the removal of duplicates. Based on the title and screening of the abstract, 18 records were removed due to not meeting the inclusion criteria. In total, 28 full-text articles were reviewed. In this full-text screening, 22 articles were excluded due to the sample including children, overweight individuals, or lack of sensitivity and specificity. A total of six papers met the inclusion criteria and were included in the meta-analysis (Fig. 1)

Characteristics of studies

The studies included in the systematic review are shown in Table 1. All the studies were cross-sectional and were published from 1999 to 2022. They were conducted in five countries including India, Nigeria, Thailand, Portugal, and Turkey. The number of participants varied between studies (ranging from 328 to 16,158), with a pooled population of 39,149 adolescents. The studies used different reference methods for the diagnosis of obesity: five studies used BMI and one study used DXA. Most studies used the 95th percentile (Z score $> +2$SD) of the BMI curve for obesity. The study that used DXA classified obesity as a BFP $\geq$25 % in males and $\geq$30 % in females. Table 1 shows the details of the studies included in the meta-analysis (Fig. 2).[21,30,35,44–46]

The optimal cutoff points obtained are shown in Table 2. In total, six studies were included, which were unfolded in 52 points of analysis because they presented different cutoffs according to gender and age: 18 (boys) and 14 (girls) cutoff points for the age group between 10 and 14 years and 8 (boys) and 8 (girls) cutoff points between 15 and 20 years. The application of the proposed statistical model allowed the definition of optimal cutoff points for boys and girls in these two age groups. The

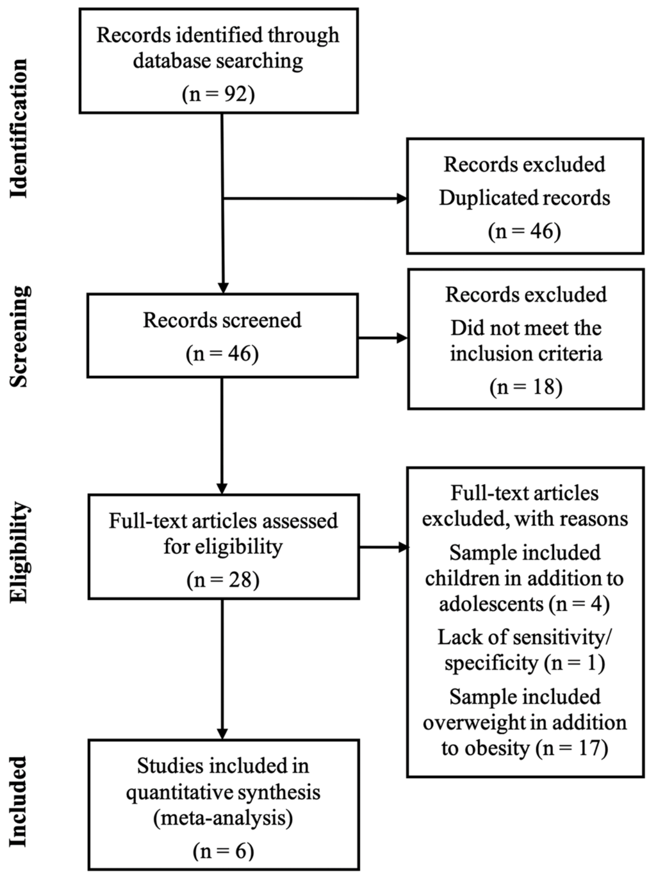

Fig. 1. PRISMA flow diagram.

sensitivity and specificity were consolidated by the statistical model and values are shown in Table 2.

Risk of bias

The QUADAS-2 tool was used to assess the risk of bias and applicability, and the results are presented in the supplemental material (Supplemental Table 1). The design and procedure of the studies were homogeneous and met the QUADAS-2 domains. Five included studies had a "high risk" of bias in the "reference standard" item because they used BMI as a reference standard, which is not a gold standard for measuring excess adiposity. Only one study used the BFP assessed by DXA as a reference standard, and for this reason, it was classified as "low risk" of bias. No study reported the time interval between performing the index test and the reference standard. However, this time interval between performing the index test and the reference standard is unlikely to introduce bias. The studies adequately described the index tests and reference standards.

Discussion

The arm has the potential to be a representation of the body since it includes major tissues such as bone, muscle mass, blood vessels, nerves, fat, and skin. Thus, changes in body composition, such as gains or losses of adiposity or lean mass, edema, or vasodilation are reflected in the arm and its measurements. Especially due to the presence of subcutaneous adiposity, variations in arm measurement, and discarded changes in other tissues, which are less frequent in the pediatric age group, almost always indicate fat gain or loss. Studies conducted since the 1950s by Jelliffe have already suggested MUAC as a criterion for nutritional assessment.[16] In the 1970s, Shakir[17] proposed, for example, that eutrophic children aged between 1 and 5 years had MUAC greater than 13.5 cm. Due to the higher prevalence of malnutrition in the 20th century, most authors studied MUAC as a screening method for children at risk for this condition. Only more recently has this method also been sought for obesity diagnosis.

The rapid diagnosis of obesity, either for screening purposes or to make up the initial evaluation of pediatric patients, is essential today, given the high prevalence of this condition. A recent metanalysis published by Sisay et al.[51] showed that, in comparison with BMI, MUAC has an excellent performance in identifying overweight and obesity in children and adolescents, but insufficient evidence on the performance compared with gold standard measures of adiposity. Considering the composition of the arm, it seems quite possible that the MUAC measurement can estimate nutritional status including overweight. On the other hand, the cutoff points suggested by different authors are similar, but not identical, which makes it difficult to propose unique values for the whole world. It is possible that, if there was the availability of representative studies of populations from different countries, the construction of a curve presented in percentiles or z scores would be the best solution, however, these data are not available for the entire adolescent age group. Taking as an example the age of 10 years, the male sex, and the objective of detecting obesity, the proposed cutoff points would be, according to different authors and methodologies, 22.4 cm or 24.9 cm in India,[44,45] 25.4 cm in Nigeria,[35] 19.9 cm or 26.5 cm in Turkey,[46,52] 22.4 cm in Thailand[30] and 22.8 cm in Portugal.[21] The differences often reflect each researcher's options about their objectives, reflecting on the choice of different gold standards for validation (BMI, DXA, waist circumference) and different sensitivities and specificities. When aiming to seek MUAC as a diagnosis, the values defined for cutoff, in general, seek to reflect more specificity; on the other hand, higher sensitivity is sought when the objective is to screen cases at higher risk for further evaluation or the necessity of rapid diagnostic.

Sisay et al.[53] recently published a protocol created to develop the first meta-analysis study that sought to evaluate the performance of the MUAC for the diagnosis of overweight and obesity and subsequently published their results in a new article.[51] Following this same line, the present study also made a systematic review of the literature with meta-analysis, however, the main objective was to take a step forward, seeking not only to check the potential of MUAC for the diagnosis of obesity but also to establish cutoff points based on the findings of different authors, using mixed methodologies. The initial review showed that studies defined cutoff points using different sensitivities and specificities, as also verified by Sisay et al.[51] and using different outcomes (BMI z-score, BMI percentiles, and BFP), which would make conventional meta-analysis impossible to meet the proposed objectives. However, the methodology proposed by Steinhauser[49] for meta-analysis of diagnostic accuracy studies with several cutoff points based on a summary SROC curve, made it possible to reconcile studies with different approaches. Considering the approach implemented in the "diagmeta" package of the R software, the analysis was based on a parametric model with random effects that fit the data for both groups (with and without obesity) and all available cutoffs over all selected studies. The model provides estimates of the two cumulative distribution functions for the two groups across all studies, accounting for the between-study heterogeneity and correlation between groups.

The cutoff points suggested in the present study are close to those suggested by other authors and have some advantages that allow proposing their use. The first concerns statistical methodology, which allows the consolidation of studies with different sensitivities and specificities. Additionally, it was possible to obtain a simplification of the way of using the measure, having established only two values for each gender, being two broad age groups, which makes the practical application quite simple.

The sensitivity and specificity obtained through meta-analysis that generated the cutoff points present values close to those obtained by other studies that use anthropometric variables for the diagnosis of

Table 1
Characteristics of included studies.

Author, year, sample size	Location	Study design	Reference	Sex	Age (years)	Cutoff MUAC (cm)	Sensitivity (%)	Specificity (%)
Nitika, 2021, 31,471	India	Cross-sectional	BMI z score > +2SD	Boys	10	22.4	78.3	92.6
					11	23.4	80.3	91.8
					12	24.5	80	93.4
					13	26.4	75.7	96.2
					14	27.2	91.4	95
					15	27.4	94.1	93.7
					16	29.7	84	95.8
					17	29.6	90	94.6
					18	31.1	94.4	97.5
				Girls	10	23.9	68.8	97.1
					11	24.2	95	94.8
					12	25.7	82.1	95.6
					13	26.6	81.8	95.8
					14	27.6	84.4	97.3
					15	28	80.9	96.4
					16	27.3	83.3	94.2
					17	29.1	89.3	97.6
					18	29.9	77.8	97.9
Okosun, 2019, 715	Nigeria	Cross-sectional	BMI z score > +2SD	Boys	10–14	25.4	82.0	88.0
					15–18	27.8	11.0	81.0
				Girls	10–14	24.8	92.0	84.0
					15–18	27.8	86.0	75.0
Rerksuppaphol, 2017, 1714	Thailand	Cross-sectional	BMI z score > +2SD	Boys	10	22.4	95.7	92.2
					11	23.3	92.8	93.2
					12	25.5	94.7	97.2
				Girls	10	22.7	83.3	94.3
					11	24.4	81.8	93.9
					12	25.4	85.3	93.7
Sardinha, 1999, 165	Portugal	Cross-sectional	BFP ≥ 25 %	Boys	10–11	22.8	96	14
					12–13	25.8	71	18
					14–15	28.2	50	24
Mercan, 2022, 307	Turkey	Cross-sectional	BMI ≥ 95th percentile	Boys	10–14	26.5	76.1	98.4
Khadilkar, 2021, 4777	India	Cross-sectional	BMI ≥ 95th percentile	Boys	10	24.9	62.9	97.10
					11	26.3	62.10	97.11
					12	27.6	62.11	97.12
					13	28.6	62.12	97.13
					14	29.5	62.13	97.14
					15	30.2	62.14	97.15
					16	30.8	62.15	97.16
					17	31.4	62.16	97.17
				Girls	10	24.0	57.8	97.12
					11	25.2	57.9	97.13
					12	26.4	57.10	97.14
					13	27.3	57.11	97.15
					14	27.8	57.12	97.16
					15	28.1	57.13	97.17
					16	28.5	57.14	97.18
					17	28.9	57.15	97.19

obesity. Javed et al.[54] conducted a systematic review with meta-analysis and evaluated BMI performance, compared with BFP to identify obesity among adolescents and had a sensitivity of 73 % and specificity of 93 %. In a systematic review study with meta-analysis, Sommer et al.[55] showed the following sensitivities and specificities for 18-year-old men for anthropometric variables compared with BFP (dexacytometry, ultrasound, computed tomography or magnetic resonance imaging): 49.6 e 97.3 % for BMI and 62.4 e 88.1 % for waist circumference. Karchynskaya et al.[56] compared BMI with BFP (bioimpedance) and obtained a sensitivity of 82 % and specificity of 92 % for the diagnosis of obesity in adolescents. Antunes et al.[57] compared anthropometric variables in adolescents with BFP (skinfolds) and verified the following sensitivities and specificities for girls: 75.0 e 86.6 % for BMI; 72.4 e 79.4 % for weight for height; 87.0 e 67.1 % for waist circumference and 36.8 e 75.1 % for conicity index. The cutoff points suggested in our study present high sensitivities and specificities, between 74.8 and 94.5 %, and, like most similar studies, the specificities are always higher than sensitivities. Additionally, aiming primarily at screening adolescents at higher risk of obesity, what is expected is a high sensitivity and the values obtained in our study are always between 74.82 and 86.38 %, which can be considered quite satisfactory when compared to the recent studies presented above 73;%[54] 49.6 e 62.4;%[55] 82;%[56] 75, 72.4, 87 e 36.8 %.[57].

It is the first-ever study that was able to propose cutoff points for MUAC for obesity diagnosis among adolescents based on a compilation of published data from different parts of the world. On the other hand, the study has some limitations. The number of articles included was low, mainly due to the strict inclusion criteria used, and it is not possible to guarantee that the set can represent the profile of adolescents around the world. It should also be considered that some patients do not present a uniform distribution of body adiposity. For this reason, the estimation of the presence of excess fat and obesity, based only on the measurement of the arm, can always lead to errors. The criteria used by the different studies that compose our meta-analysis for obesity diagnosis are different. Finally, there may be ethnic variations in MUAC in populations originating from different regions of the world, which can lead to errors when seeking to establish universal cutoff points.

Conclusions

In conclusion, the present study proposes, through a systematic

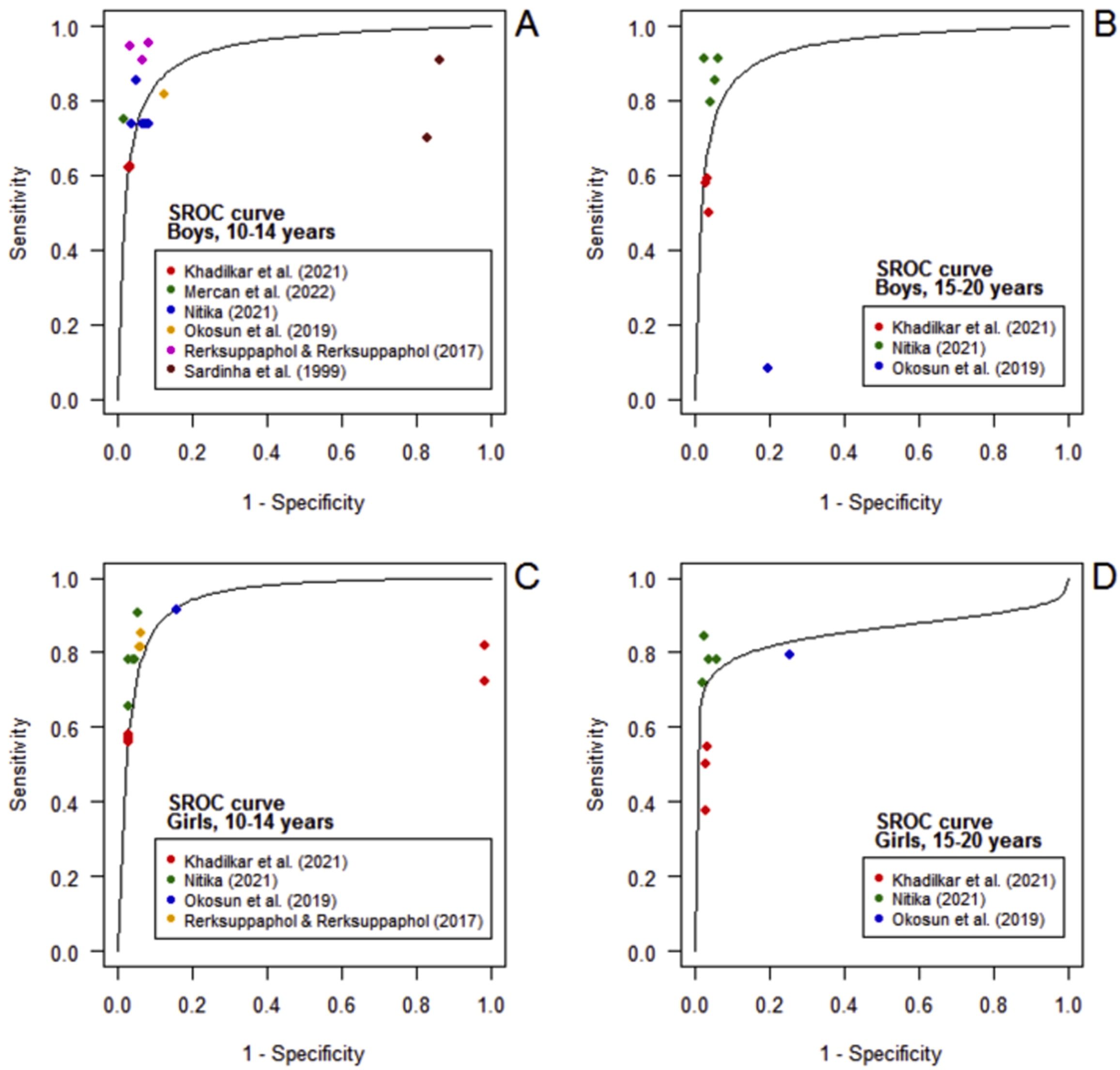

Fig. 2. SROC curves regarding the performance of MUAC for obesity classification.

Table 2
Optimal MUAC cutoff points to identify obesity in adolescents according to gender and age group.

Age group	Boys Studies/ Cutoffs	Optimal cutoff value (cm)	Sensitivity at optimal cutoff	Specificity at optimal cutoff	Girls Studies/ Cutoffs	Optimal cutoff value (cm)	Sensitivity at optimal cutoff	Specificity at optimal cutoff
10 – 14	6 (a)/18	23.50	86.38 (61.27 – 96.22)	88.05 (68.07 – 96.22)	4 (b)/14	23.00	80.38 (59.32 – 92.01)	92.87 (85.36 – 96.68)
15 – 20	3 (c)/8	27.14	86.29 (32.70 – 98.79)	88.42 (71.57 – 95.86)	3 (c)/8	28.14	74.82 (42.14 – 92.37)	94.50 (84.73 – 98.16)

(a) Khadilkar et al. (2021), Mercan et al. (2022), Nitika (2021), Okosun et al. (2019), Rerksuppaphol & Rerksuppaphol (2017), and Sardinha et al. (1999).
(b) Khadilkar et al. (2021), Nitika (2021), Okosun et al. (2019) and Rerksuppaphol & Rerksuppaphol (2017).
(c) Khadilkar et al. (2021), Nitika (2021), and Okosun et al. (2019).

review with meta-analysis, simplified cutoff points of MUAC for screening adolescents at risk for obesity. Fig. 3 summarizes the suggested values and proposes the creation of a tape called MUAC Obesity Screening Tool for Adolescents (MOSTA tape) aimed at rapid diagnosis.

CRediT authorship contribution statement

Carlos Alberto Nogueira-de-Almeida: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Patrícia Ruffo:** Conceptualization, Funding acquisition, Methodology, Writing – review & editing. **Edson Zangiacomi Martinez:** Formal analysis, Methodology, Supervision, Writing – original draft, Writing – review & editing. **Fábio da Veiga Ued:** Formal analysis, Methodology, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors Edson Z. Martinez and Fábio da Veiga Ued declare that

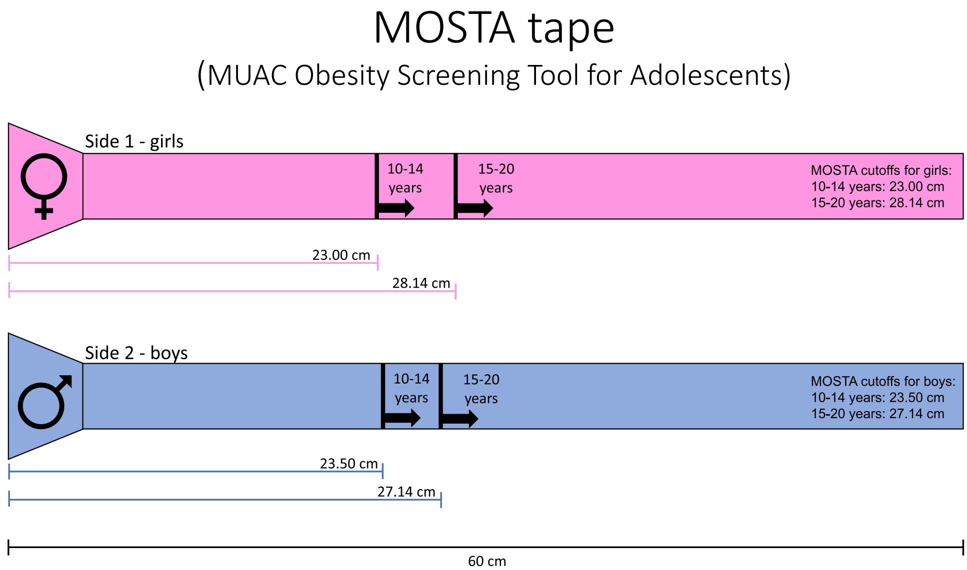

Fig. 3. MUAC Obesity Screening Tool for Adolescents (MOSTA tape).

they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Carlos Alberto Nogueira-de-Almeida reports administrative support, statistical analysis, and writing assistance were provided by Abbott. Carlos Alberto Nogueira-de-Almeida reports a relationship with Abbott that includes: non-financial support and speaking and lecture fees. Patricia Ruffo reports financial support was provided by Abbott. Patricia Ruffo reports a relationship with Abbott that includes: employment.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.gpeds.2024.100135.

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