Universal Journal of Public Health 13(2): 336-344, 2025 http://www.hrpub.org
DOI: 10.13189/ujph.2025.130206

Can MUAC Be Used to Determine the Nutritional Status of Adolescent Girls?

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Received November 22, 2024; Revised January 26, 2025; Accepted February 19, 2025

Cite This Paper in the Following Citation Styles

(a): *[1] Firda Fibrila, M. Ridwan, Herlina Herlina, I. Putu Suiraoka, Andiyan Andiyan , "Can MUAC Be Used to Determine the Nutritional Status of Adolescent Girls?," Universal Journal of Public Health, Vol. 13, No. 2, pp. 336 - 344, 2025. DOI: 10.13189/ujph.2025.130206.*

(b): *Firda Fibrila, M. Ridwan, Herlina Herlina, I. Putu Suiraoka, Andiyan Andiyan (2025). Can MUAC Be Used to Determine the Nutritional Status of Adolescent Girls?. Universal Journal of Public Health, 13(2), 336 - 344. DOI: 10.13189/ujph.2025.130206.*

Abstract Body mass index is a measure used to assess whether a person is underweight or overweight. However, BMI does not take into account muscle mass and fat mass, making it less accurate for determining nutritional status values in this condition. The purpose of this study was to determine whether upper arm circumference has a correlation with BMI and to determine the threshold value for detecting undernutrition in adolescent girls aged 15 to 19 years. This study used a cross-sectional design involving 380 healthy adolescent girls. Anthropometric measurement procedures are implemented under strict supervision after obtaining consent from respondents. There is a strong correlation ($r = 0.841$) where the effect of MUAC variables on BMI variables was 70.7% (R square $=0.707$, $p = 0.000$), AUC of 0.899 (95% CI: 0.86 - 0.92) for MUAC on BMI, sensitivity = 0.896, specificity = 0.711, PPV = 0.869, and NPV = 0.761. The cutoff value was 23.7 cm and the Youden Index was 0.647, with a good accuracy value of 83.68%. MUAC has good accuracy and is supported by a strong correlation to detect nutritional status in adolescent girls aged 15 to 19 years, where the resulting sensitivity and specificity are high. This study also produced a cutoff value that was not much different, namely 23.7. Based on these results, MUAC can be recommended for early assessment in the detection of malnutrition in adolescent girls. The drawback of this study is the relatively small sample size.

Keywords Adolescents, BMI, MUAC, Underweight

1. Introduction

The problem of under- and overnutrition and micronutrient deficiencies is still a nutritional burden for adolescents aged 10 to 19 years in Indonesia. Adolescents aged 13 to 18 years are stunted, accounting for 25% of the adolescent population, 9% of which have a low BMI, and 16% are obese. In addition, about 25% of adolescent girls have anemia [1].

Growth is second only to infancy and is particularly rapid in adolescence [2]. Adolescents not only grow physically, but they also develop mentally, cognitively, and psychologically. In this period, there is an increase in energy and nutritional needs, so adolescents are vulnerable to malnutrition if there is food insecurity in the household [3]–[5].

Malnutrition in adolescents aged 15-19 years contributes to decreased academic performance, decreased work productivity, increased risk of developing infectious diseases, and increased incidence of diseases [6], [7]. Undernourished adolescent girls may experience menstrual delays and the risk of giving birth to low birth weight babies [8]. Malnutrition in adolescents not only causes health problems but also reduces the quality of future generations. For this reason, an effective, cheap, and easy early detection method is needed for screening nutritional status, especially for adolescent girls. The results suggest that more nutritional interventions are needed to increase awareness of healthy dietary practices among Malaysians [9].

In anthropometry, body mass index (BMI) has been shown to be a useful tool for measuring human body metabolism, including nutritional status [10]–[12]. BMI is a reliable measure that considers a person's height and weight [13]. BMI is used to identify whether they are underweight or overweight in school children and adolescents. However, one of the disadvantages of BMI is that it does not take into account muscle mass versus fat mass [14], [15].

Despite the popularity of BMI, there are limitations to measuring it at the community level. Complex and continuously calibrated equipment is required, as well as reliability in calculations. It is for these reasons that less-trained health workers dislike the method [11], [16]. The application of the BMI method in identifying nutritional status takes a long time, because it must interpret the values of weight and height measurements using a reference chart [3], therefore it is necessary to choose an alternative method of measuring nutritional status that is less expensive, easy to apply and reliable to detect adolescents who are overweight or underweight [13].

In clinical and epidemiological studies, one of the indicators for assessing the nutritional status of individuals is using the measure of upper arm circumference (MUAC) [17], [18]. MUAC measure is easier to apply without special training or complicated calculations. In addition, this method is cheaper as it does not require a lot of equipment. It can help primary health care workers with limited resources to collect data quickly [19].

MUAC is one of the simple and inexpensive screening tools used in developing countries to identify undernutrition in children under five, aged between 6 and 59 months [20]. In famine situations and refugee crises, MUAC is an option for identifying undernutrition in adults and children less than five years of age, where measuring height and weight is difficult [21]. In addition, MUAC is used to assess the nutritional status of pregnant women in resource-limited countries. The independent variable was community-based total sanitation, which includes the behaviors of open defecation, drinking water and food management, household waste management, and household wastewater management [22].

Currently, MUAC is not used in screening for nutritional status in adolescents. This is more due to the fact that there is no universally acceptable cut-off standard among adolescents. Several studies have shown that MUAC is a reliable tool for predicting whether or not adolescents are malnourished. From the results of these studies, the ROC values in the lower area of the curve ranged between 88% and 97%, the cut-off value for BMI of 18.5 (normal) was 23.2 cm, and the cut-off value for MUAC was also not too different from the value set by WHO of 23.5 cm [17].

A study in Ethiopia reported a prevalence of adolescent emaciation of 9.5% (95% CI: 7.7-11.7%). The optimal limit of MUAC to identify emaciation was at 22.6 cm (AUC 0.91, 95% CI: 0.88-0.93), with a sensitivity value of 100% and specificity of 88.2% [13]. In another study in Sudan, adolescents who were underweight had a MUAC cutoff of ≤21.2 cm (YI = 0.66, sensitivity = 86.0%, specificity = 80.0%, AUROCC = 0.87) [23]. Limited research on the ability of MUAC to detect malnutrition in adolescents aged 15 to 19 years and mixed results that cannot be applied universally are the reasons for this study. The aim was to assess the ability of MUAC to detect malnutrition in adolescent girls aged 15 to 19 years in Metro City.

2. Methodology

2.1. Study Setting, Design and Participants

Sampling technique uses multistage sampling. In the first stage, the area of Metro City, consisting of five sub-districts, was determined. At this stage, through the lottery method, the districts of Central Metro, East Metro, and South Metro were selected. To cover the entire age group from 15 years to 19 years, the lottery was then conducted in turn at each level of education. From 16 junior high schools, 11 senior high schools, and 3 universities, SMPN 5 Metro City, SMAN 4 Metro City, and Poltekkes Kemenkes Tanjungkarang were selected. Three hundred and eighty (380) healthy adolescent girls were randomly selected based on class groups according to the predetermined age range. Adolescent girls who actively participated were those in the second and third grades of junior high school and over 15 years old, the first and second grades of senior high school, and university students who were a maximum of 19 years old. Adolescent girls who had physical abnormalities that could affect their weight and height were excluded.

2.2. Sampling Procedure

Before participating, all prospective respondent adolescent girls were given an explanation of the procedures that would be carried out, namely anthropometric examination, including height, weight, and upper arm circumference for study purposes. Those who were willing were young women who had filled out informed consent as a sign of agreement. A total of 204 students from SMAN 4 were selected based on study groups in grades 1 and 2. In addition, 45 students from SMPN 5 Metro City were randomly selected from study groups in grades 2 and 3, all of whom were 15 years old. As the time of data collection coincided with the final exams at the junior high school level, the shortfall was met by selecting 131 students from the Poltekkes.

2.3. Study Procedures and Anthropometric Measurements

Recording was done on all anthropometric measurements of height, weight and MUAC. The tools used have been calibrated regularly. To prevent technical errors, when anthropometric measurements are taken, participants are in a relaxed position. In addition, measurements are carried out by trained personnel. BMI was calculated using the formula weight (in kilograms) divided by height (in square meters). Participants who had a BMI of less than 18.5 kg/m^2 and a MUAC of less than 23.5 cm were categorized as low nutritional status [14].

MUAC measurement using a standard measuring tape with an accuracy of 0.1 cm in the hand is not dominant in performing daily activities. The measurement location is midway between the olecranon of the scapula and the acromion (elbow), not too loose and not too tight on the surface of the skin without clothing. MUAC should be measured before weight and height measurements to minimize measurement bias [24].

Height and weight were measured to obtain BMI values. Height measurement uses a stadiometer with an accuracy of 0.5 cm without shoes. The height measurement indicators set is as follows: the stadiometer is placed near the wall, and when measuring, the head, back, buttocks, and heels should touch the wall. The position of the knees is stretched and the heels remain tight. Hair conditions do not use accessories that can interfere with measurement results to avoid measurement bias. Body weight is measured using digital scales where the results are displayed on a scale of 0-1 kg. When taking measurements, it is ensured that the scales are in the zero position, and the clothes used do not affect the results and are barefoot [25]. To avoid bias and errors in assessment, each reading of measurement results was carried out by 2 enumerators who had previously equalized perceptions and standardization in measurement.

2.4. Data Analysis

After the data was collected, it was validated before being entered into the SPSS program version 26. Data normality test was conducted using Kolmogorov-Smirnov test. The test results showed that the BMI and MUAC variables were normally distributed with p-values of 0.079 and 0.111, respectively. The next step was to analyze the correlation of BMI and MUAC using a Simple Linear Regression Test with 95% CI. To assess the ability of MUAC to detect nutritional status, an assessment was made through the calculation of sensitivity and specificity [26].

3. Results and Discussion

3.1. Results

Table 1 shows the results of the analysis of participant characteristics based on age and anthropometric measures.

Table 1 shows the characteristics of the participants. The results of the minimum value analysis showed that some adolescents had parameter values below the current gold standard. A 15-year-old adolescent girl should weigh at least 40.6 kg and be at least 147.9 cm tall [27], [28], BMI value of at least 17.8 kg/m^2 [29], and MUAC value of at least 23.5 cm [30].

3.1.1. Undernutrition Screening Based on BMI

Figure 1 shows that the frequency of normal BMI is more dominant, namely 215 adolescent girls (56.6%). It was also found that 121 adolescent girls (31.8%) had an underweight nutritional status. This value exceeds the number of underweight cases in adolescents in Indonesia, which is 7.2% in adolescents aged 13 to 15 years and 8.3% in adolescents aged 16 to 18 years [31].

The results showed that there was a strong positive influence ($r = 0.841$), with a value of R square = 0.707 which means that there is an influence of MUAC variables on BMI by 70.7% with a significance value of $p = 0.000$ [32], [33]. The plot spreads according to the diagonal line, as shown in Figure 2. It is also known that the constant value (a) is -3.396 and the coefficient value is 0.958, so the prediction that can be made is $y = -3.396 + 0.958$. This equation means that MUAC increases by 95.8% if the BMI value changes by one unit.

Table 1. Characteristics of adolescents involved in the study

Characteristics	Mean	SD	SE	Minimum	Maximum
Age (year)	16,90	1,521	0,078	15	19
Body Weight (kg)	50,59	9,626	0,494	32	92
Height (cm)	156,13	5,649	0,290	135	179
BMI (kg/m^2)	20,71	3,610	0,185	13,7	37,9
MUAC (cm)	25,16	3,170	0,162	17	34

n=380

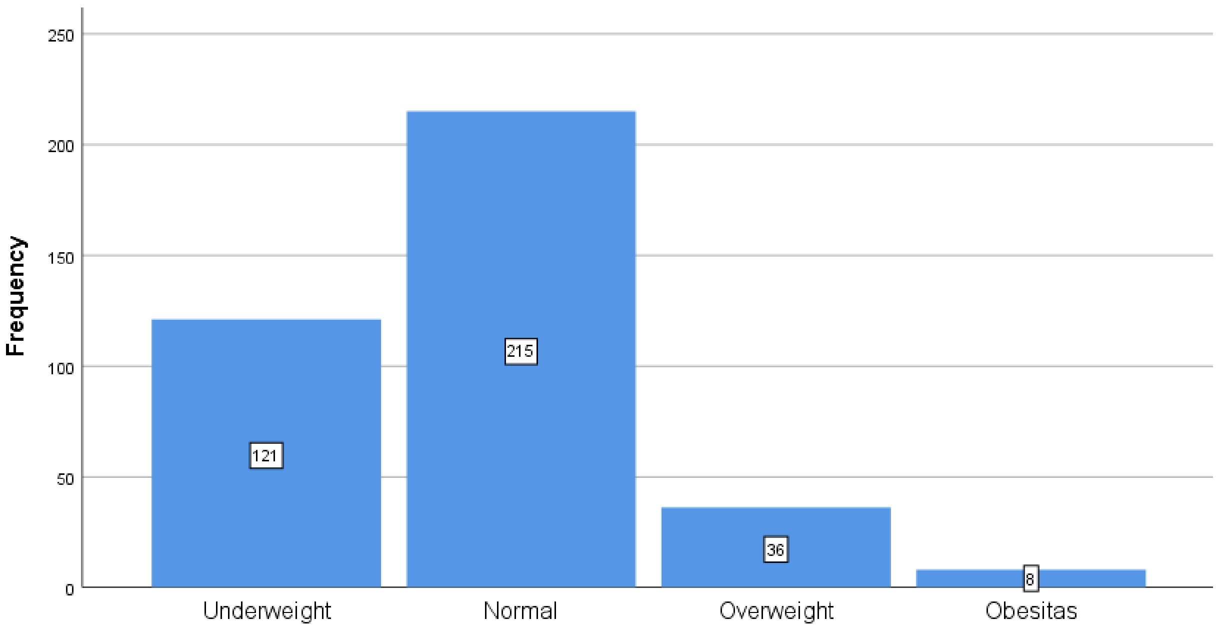

Figure 1. Distribution of participants' nutritional status classification based on BMI

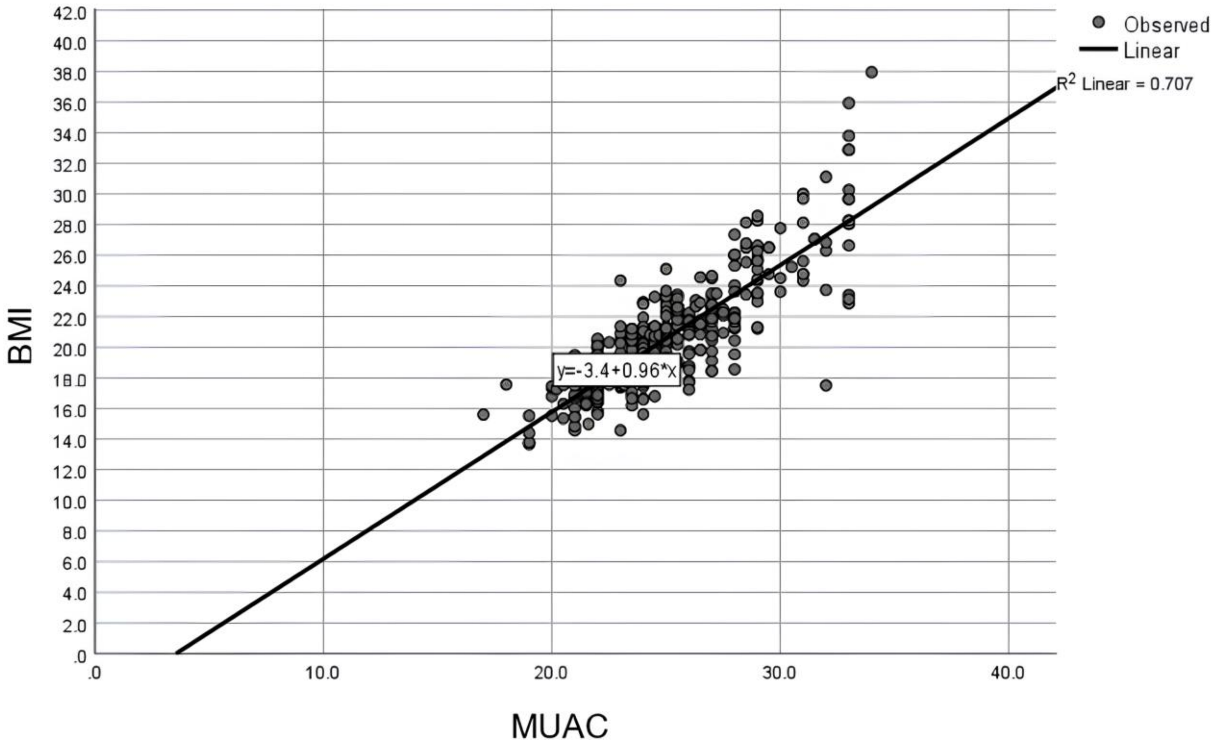

Figure 2. Overview of the distribution of BMI and MUAC values in a linear relationship

3.1.2. MUAC Capability for Diagnosis of Nutritional Deficiencies

The area formed from the *Receiver Operating Characteristic Area Under the Curve* (ROC-AUC) results between MUAC and BMI was 0.899 (95% CI: 0.86 - 0.92). This value means that the area is 89.9% (0.899 > 0.7 close to 1) which means that the prediction of MUAC on BMI is strong, in other words, MUAC is able to predict well the undernutrition status in adolescent girls (See Figure 3).

Based on the results of the ROC-AUC calculation, the sensitivity value (0.853), specificity value (0.785) and the Youden index is 0.64 based on coordinates of Curve. See Figure 4 and Table 2.

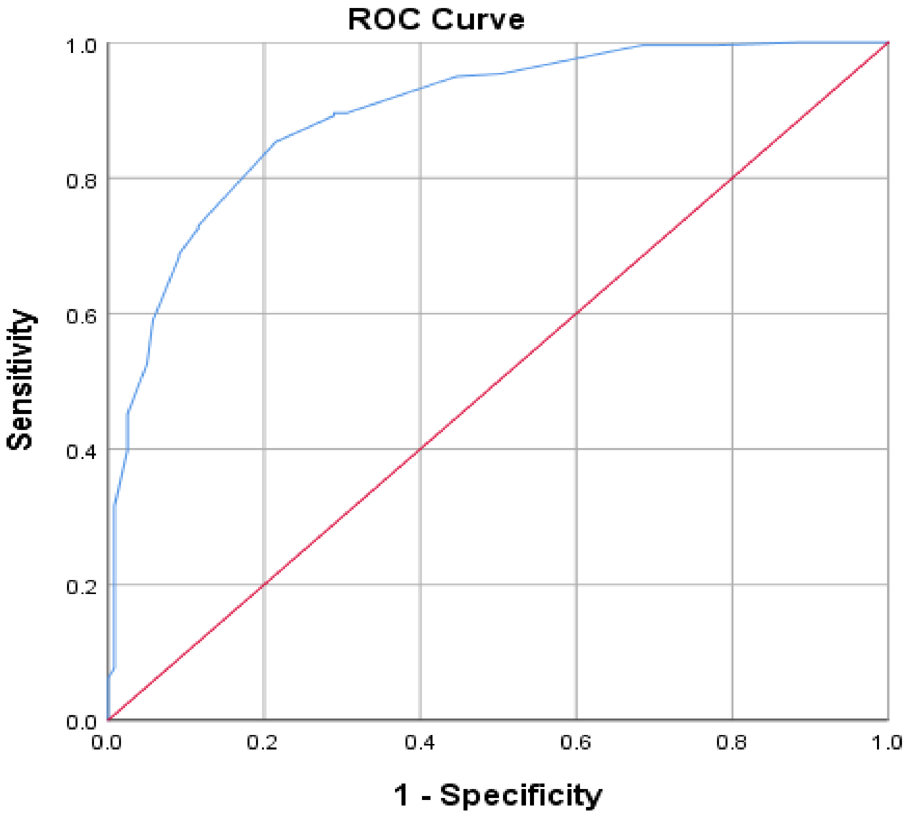

Figure 3. Characterization curve MUAC ability to determine low nutritional status in adolescents

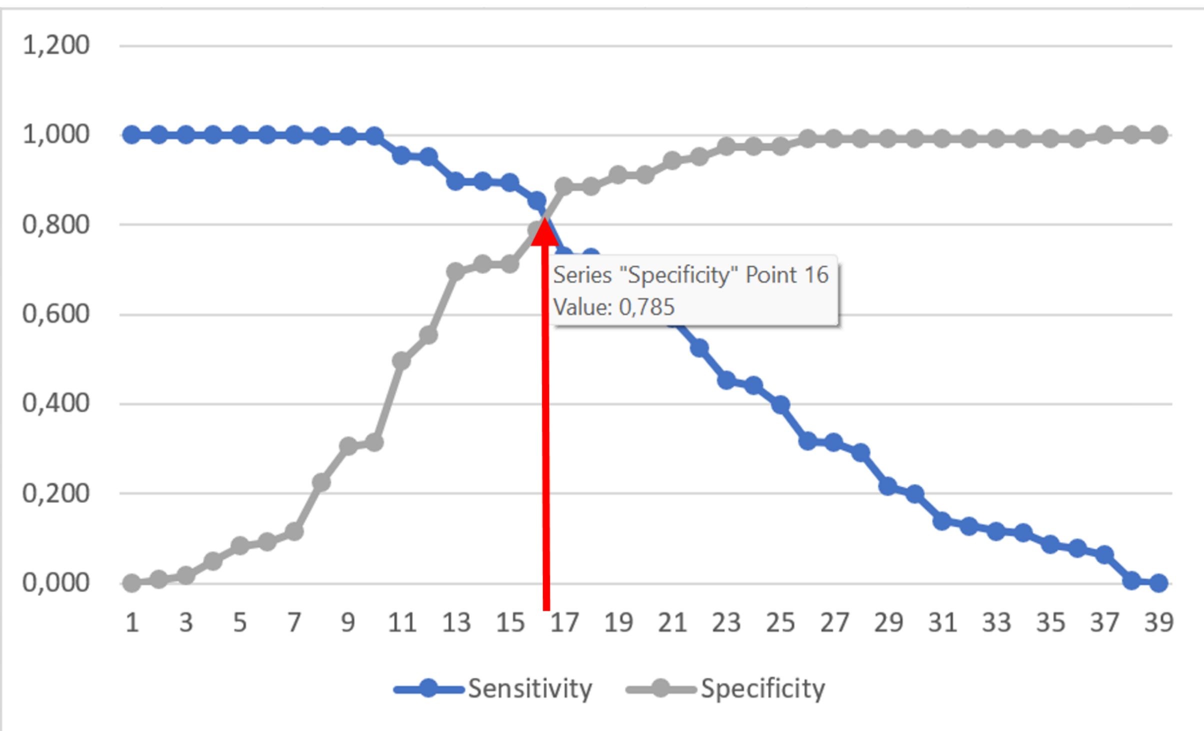

Figure 4. Cutoff values based on MUAC sensitivity and specificity distributions for determining undernutrition status in adolescents

Table 2. Sensitivity and specificity calculation results

No	MUAC	Sensitivity	Specificity	1 - Specificity	Youden Index
1	16.000	1.000	0.000	1.000	0.000
2	17.500	1.000	0.008	0.992	0.008
3	18.500	1.000	0.017	0.983	0.017
4	19.500	1.000	0.050	0.950	0.050
5	20.100	1.000	0.083	0.917	0.083
6	20.350	1.000	0.091	0.909	0.091
7	20.750	1.000	0.116	0.884	0.116
8	21.250	0.996	0.223	0.777	0.219
9	21.550	0.996	0.306	0.694	0.302
10	21.800	0.996	0.314	0.686	0.310
11	22.250	0.954	0.496	0.504	0.450
12	22.750	0.950	0.562	0.438	0.512
13	23.100	0.896	0.702	0.298	0.598
14	23.250	0.896	0.711	0.289	0.606
15	23.350	0.896	0.719	0.281	0.615
16	23.450	0.892	0.719	0.281	0.611
17	**23.750**	0.853	0.785	0.207	**0.647**
18	24.150	0.730	0.893	0.107	0.622
19	24.400	0.726	0.893	0.107	0.618
20	24.600	0.687	0.917	0.083	0.605
21	24.850	0.683	0.917	0.083	0.601
22	25.250	0.591	0.950	0.050	0.541
23	25.750	0.525	0.950	0.050	0.476
24	26.150	0.452	0.975	0.025	0.427
25	26.400	0.440	0.975	0.025	0.415
26	26.750	0.398	0.975	0.025	0.373
27	27.100	0.317	0.992	0.008	0.308
28	27.350	0.313	0.992	0.008	0.304
29	27.750	0.290	0.992	0.008	0.281
30	28.250	0.216	0.992	0.008	0.208
31	28.750	0.197	0.992	0.008	0.189
32	29.250	0.139	0.992	0.008	0.131
33	29.750	0.127	0.992	0.008	0.119
34	30.250	0.116	0.992	0.008	0.108
35	30.750	0.112	0.992	0.008	0.104
36	31.250	0.085	0.992	0.008	0.077
37	31.750	0.077	0.992	0.008	0.069
38	32.500	0.062	1.000	0.000	0.062
39	33.500	0.004	1.000	0.000	0.004
40	35.000	0.000	1.000	0.000	0.000

Table 3. Conversion of clustering in the Epidemiological Survey model between MUAC and BMI of adolescent girls in Metro City

Observe			TRUE		FALSE		Total		
Positive			232		35		267		
Negative			27		86		113		
Total			259		121		380		
Cutt Off	**Youden Index**	**AUC**	**Sensitivity**	**Specificity**	**1 - Specificity**	**PPV**	**NPV**	**LR+**	**LR-**
23.75	0.647	0.899	0.896	0.711	0.289	0.869	0.761	3.097	0.407

It appears that the intersection point between the two lines is between the values of 16 and 17, so according to Table 2, it can be concluded that the cut-off value of the MUAC value is between 23.45 and 23.75. However, based on the calculation of the Youden index of 0.647, the cut-off value is 23.75.

Table 3 presents the calculation results based on the epidemiological survey model. A cut-off value of 23.75 is based on the Youden index of 0.647, sensitivity of 0.896, specificity of 0.711, and AUC value of 0.899. While the FPR was 0.289, the PPV was 0.869, and the NPV was 0.761. The LR+ value is 3.097, the LR- is 0.407, and the accuracy value is 83.68%.

The MUAC cut-off value of 23.75 is close to the concept of the normal value of MUAC to determine nutritional status criteria, so MUAC prediction of BMI can be concluded to be good. This is supported by the high AUC value above 0.7 as well as the high sensitivity and specificity values above 0.7. The LR+ value is between the values of 2 and 6, and the LR- value is between the values of 0.2 and 0.5, so the MUAC prediction of BMI is fair, which means it is reasonable enough to be used even though it is not in the good or excellent category.

3.2. Discussion

These studies found that MUAC can detect underweight with moderately strong or strong discriminative performance, with an AUC of 0.899 [34], [35]. The ideal MUAC cut-off point obtained was 23.7 cm with a sensitivity of 89.6% and specificity of 71.1%. The results of this study also show that MUAC has high sensitivity and is specifically able to diagnose malnutrition. Finally, MUAC is large enough or strong enough to distinguish adolescents with or without malnutrition status.

The results of this study are supported by research in India which states that there is a positive correlation between MUAC and BMI in adolescents aged 15 to 19 years (sensitivity = 86.1%, specificity = 93.1%, AUC = 0.934) [36]. Another study in Addis Ababa showed that emaciation and severe emaciation in Ethiopia reached 9,5% (95% CI 7-7, 11-7%), the AUC was 0.91 (95% CI 0-88, 0-93), and the cutoff value was 23.3. This indicates a high sensitivity of 100% and specificity of 88.2% [13]. A recent study in Eastern Sudan yielded sensitivity = 86.0%, specificity = 80.0%, YI = 0.66, AUC = 0.87 [23].

Based on the recommended cut-off point of 23.7 cm from the results of this study, MUAC has an NPV of 0.761 and a PPV of 0.869. PPV indicates that 86.9% of adolescents identified as malnourished by MUAC are actually malnourished, while NPV indicates that 76.1% of adolescent girls identified as not malnourished by MUAC are actually not malnourished [37].

The sensitivity value generated from this study was at a value of more than 0.7, and these results prove that MUAC is very well used as a tool to diagnose malnutrition in adolescents, especially adolescent girls. However, in reality, MUAC has not been used as the main screening method for detecting malnutrition in adolescents. This condition is due to the variety of cutoff values from each research result, namely in India, which is 21.6 cm [36], in Ethiopia at 22.6 cm [13], in Sudan at 21,2 cm [23], while in this study it was 23.7 cm.

The varying cutoff values of each study may be due to variations in the population of the study. Each country has diverse population characteristics, such as different environments and lifestyles, including genetics. Both of these factors affect the physical condition of the individual and can influence the test results. In addition, the use of samples and testing methods, including the interpretation of results, varies greatly in each country, which ultimately affects the sensitivity and specificity of the measurement results and impacts the determination of the cutoff value [38]. This condition ultimately causes MUAC not to be universally applied.

Behind the advantages of BMI in assessing nutritional status, it has several disadvantages. The BMI formula applied cannot measure body fat directly. In addition, BMI does not apply to children in the growth period (adolescents), pregnant women, and athletes or individuals who are actively exercising, even though they are over 18 years old [39]. Another limitation of applying BMI values to predict nutritional status is that it requires more than one tool and one assessment stage to obtain results. BMI calculations require calibrated scales and stadiometers to obtain valid results [11], [16]. After measuring weight and height, BMI assessment still requires a calculation process using a formula. The results of this calculation are then interpreted using a reference chart. Of course, this stage requires more time and the ability to calculate [3], [13], [16].

The MUAC method is easier to use and cheaper than the

BMI calculation method. With high sensitivity results and good specificity, the MUAC method is a good alternative for identifying undernutrition status in adolescents [10], [11], [40].

3.2.1. Strengths and Limitations

The implementation of quality control and monitoring during anthropometric data collection is a major factor in this study. This step is to reduce errors in measurement thus ensuring the validity of the data obtained. But we need to mention the limitations that exist in this study. The relatively small sample size is a limitation of the study. Therefore, the use of a large sample size is recommended for future research.

4. Conclusions

The results of this study show that MUAC has a strong correlation with BMI, with high sensitivity and specificity in adolescent girls aged 15 to 19 years. This study also produced a cutoff value that was not much different from 23.7 compared to the previous cutoff value used to determine malnutrition in adult women, which was 23.5. Based on these results, MUAC can be recommended for early assessment in the detection of malnutrition in adolescents. The shortcoming of this study is the relatively small sample size. In the future, it is recommended to use a larger sample size by considering ethnic diversity, environment, and lifestyle.

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