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LITERATURE REVIEW
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Mid Upper Arm Circumference (MUAC) Accuracy in Detecting Acute Malnutrition in Children under 5 Years: A Literature Review

Akurasi Mid Upper Arm Circumference (MUAC) dalam Mendeteksi Malnutrisi Akut pada Anak di bawah 5 Tahun: A Literature Review

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ABSTRACT

Background: Fast and accurate detection of acute malnutrition is important to prevent death. The use of Mid Upper Arm Circumference (MUAC) can be an alternative but its accuracy is still being explored because many differences in research results are found.
Objectives: This literature aimed to identify the accuracy (sensitivity and specificity) and optimal MUAC cut-off in detecting acute malnutrition in children under 5 years.
Methods: Search for articles using Google Scholar and Pubmed with the keywords "MUAC" "children" "acute malnutrition". Selection based on the question "How is the sensitivity and specificity of MUAC in detecting acute malnutrition in children under 5 years" with inclusion criteria articles for the last 10 years, fully accessible and free of charge. Excluding non-English articles and type review articles. Six articles were found that further review.
Discussion: The sensitivity of the MUAC indicator by World Health Organization in detecting acute malnutrition is smaller than its specificity. The lowest sensitivity of MUAC in detecting severe (<11.5 cm) and moderate (11.5-12.5 cm) acute malnutrition is in Nepal, namely 13.6% and 21% respectively. Based on the results of analysis using the ROC curve in each article, it was found that the optimal MUAC cut-off varied in detecting cases of acute malnutrition.
Conclusions: The MUAC cut-off accuracy recommended by the World Health Organization to identify severe and moderate acute malnutrition is not optimal. Therefore, further studies are needed in each country to determine the optimal cut-off that is appropriate for the region according to the age group and problem classification.

INTRODUCTION

Acute malnutrition arises from an abrupt reduction in food intake, illness leading to weight loss, or the development of oedema. Children suffering from acute malnutrition have stunted growth, resulting in a lower body weight relative to their height[1]. Acute malnutrition or wasting is responsible for more than 50% of mortality in children under the age of 5[2].

According to the 2020 predictions from the United Nations International Children's Emergency Fund (UNICEF), there are around 45.4 million children under the age of five worldwide who are suffering from acute malnutrition (wasting). The majority of these children are located in regions affected by humanitarian conflicts, poverty, and inadequate access to nutritional and healthcare services. The South Asia region has the highest prevalence of acutely malnourished children under the age of five, with a rate of 14.7%. Indonesia has a prevalence of acute malnutrition in around 6.2 million children under the age of five, accounting for 10.2% of the population in that age group. This places Indonesia as the third-highest Country in Asia regarding acute malnutrition rates[3].

Acute malnutrition can be categorized into two types: severe acute malnutrition, which is characterized by a weight-for-height z-score <-3 or a mid-upper arm circumference (MUAC) < 11.5 cm, and moderate acute malnutrition, which is defined by a z-score between -2 and -3 or a MUAC between 11.5 and 12.5 cm[4]. Prompt identification of acute malnutrition is crucial to avert mortality in children aged 5[5]. Anthropometric assessments primarily facilitate the early identification of acute malnutrition cases by employing non-invasive and cost-effective methods to assess the nutritional status of

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individuals and populations[6]. MUAC and weight-for-height z-score are suggested metrics for assessing acute malnutrition[7].

The weight-for-height z-score is the most reliable method for recognizing acute malnutrition. Nevertheless, measuring weight and height and then graphing the data on a development chart can be arduous and challenging, particularly when evaluating within a community setting[8]. Thus, employing MUAC with uncomplicated chromatic bands is a substitute for timely identification in identifying instances of acute malnutrition. Expanding the availability of MUAC in household and community settings can enhance the reach of diagnosing and treating acute malnutrition cases, leading to increased coverage[9].

Precision in a diagnostic test, as determined by measurement markers like MUAC, is crucial for unbiased identification. A measurement is considered more accurate than others if it has a smaller error margin. The diagnostic test's accuracy can be determined by sensitivity and specificity[10]. An optimal diagnostic test can accurately detect all individuals tested, regardless of whether they have the disease or not [11]. Various studies have reported varying accuracy values [12,13,14,15], for MUAC indicators using predetermined cut-offs. These values are often expressed in sensitivity and specificity percentages [16]. Furthermore, disparities differ according to age, gender, and geographical location [17].

This study aimed to determine the precision of Mid Upper Arm Circumference (MUAC) in detecting acute malnutrition in children under five years based on a comprehensive evaluation of existing literature. The assessment of the precision and reliability of MUAC in detecting acute malnutrition relies on evaluating its sensitivity and specificity, with the weight-for-height z-score serving as the benchmark for comparison. The study determined the precise MUAC cut-off point for accurately detecting acute malnutrition in children under 5 years old.

METHODS

Research Design and Article Search Strategy

This article is a literature review to determine the precision of Mid Upper Arm Circumference (MUAC) to identify acute malnutrition in children aged five and below. The article search technique using the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) methodology on two electronic databases: Google Scholar and Pubmed. The search terms used were "MUAC", "children", and "acute malnutrition", yielding 427 articles on Google Scholar and 224 papers on Pubmed. Figure 1 displays the flowchart illustrating the process of article search using PRISMA.

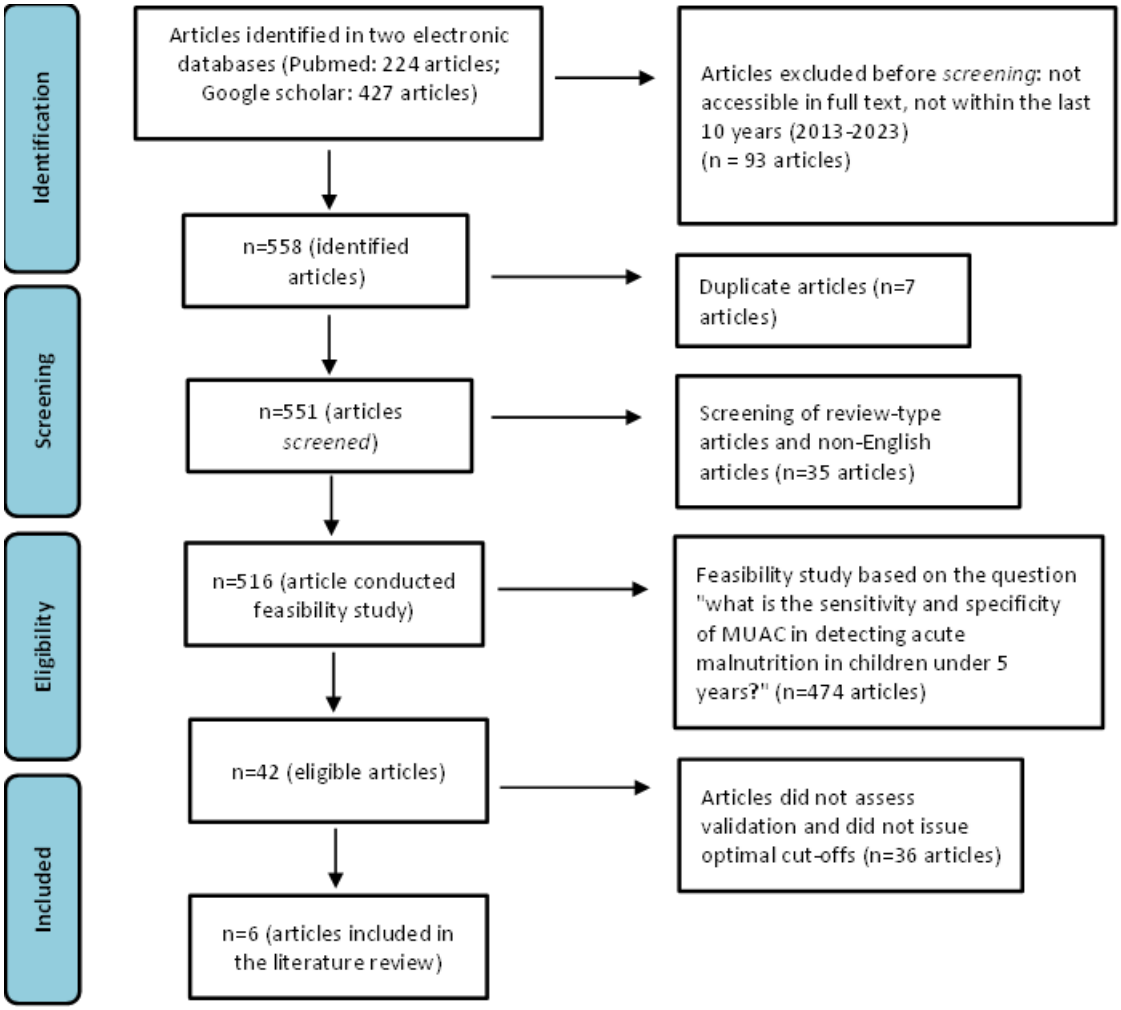

Figure 1. Flowchart of literature search PRISMA method

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Article Selection

The articles were selected based on the inclusion criterion of being published within the past 10 years (2013-2023) and being completely available and free of charge. This study excluded redundant articles from two databases, namely six articles. The exclusion criteria for article selection in this study include non-English research and review papers or review research.

Data Extraction and Presentation

The primary author autonomously evaluated articles suitable for incorporation in the literature review. The eligibility criteria were determined by screening the title/abstract and assessing the content of the publication. The screening was conducted to determine the sensitivity and specificity of Mid-Upper Arm Circumference (MUAC) in identifying acute malnutrition in children under 5. Furthermore, the eligibility selection process involved removing articles that needed to incorporate the optimal MUAC cut-off in their research. The articles that have completed the data extraction stage and eligibility selection are displayed in a table. The article's attributes, such as the author, year of publication, purpose, study design, sample size, and findings, are presented in Table 1.

DISCUSSION

The sensitivity number represents the percentage of individuals with the ailment correctly identified as sick. In contrast, the specificity value represents the percentage of healthy individuals correctly identified as healthy[18]. The study demonstrates that the MUAC indicator when using a predetermined cut-off, had a low sensitivity value in detecting acute malnutrition. This means that the indicator failed to identify acute malnutrition cases in children under five years old who were malnourished according to the BW z-score. The low sensitivity percentage indicates the number of false negative cases where the MUAC indicator incorrectly classified children as not acutely malnourished. The lack of precision in the diagnostic test may be attributed to using non-standardized measurement instruments, leading to varying measurements in each region[19].

Further study revealed that by adhering to the existing World Health Organization threshold of 115 mm for identifying severe acute malnutrition, a total of 23 children who would have been classified as severely malnourished based on their Body Weight/Total Body z-scores would be overlooked[20]. The MUAC cut-offs of <11.5 cm and 11.5 - 12.5 cm are still being used for identifying acute malnutrition in children under five. Consequently, the failure to recognize instances promptly will lead to a significant number of children suffering from acute malnutrition issues not receiving the best possible care[21]. The majority of children under the age of five who have mild acute malnutrition can be effectively treated at home through targeted nutrition interventions, such as parental counselling and ensuring that the household has access to enough food. Nevertheless, in instances of severe acute malnutrition, it is advisable to seek optimal care from healthcare experts in order to prevent the occurrence of more severe consequences that may result in fatality[22].

These findings align with the results of a meta-analysis, which emphasized that the body weight indicator is crucial in identifying severe acute malnutrition. Identifying such instances leads to suboptimal medical intervention and attention administration. Therefore, employing both MUAC and BW/TB is a superior approach[23]. These two indicators are regarded as mutually exclusive; MUAC is being used for the first assessment in the community setting, while both MUAC and WHZ (weight-for-height z-score) are measured in primary healthcare units[20].

Unlike other research findings, a comprehensive analysis revealed that the measurement of (MUAC) was deemed superior to WHZ in determining the risk of mortality in undernourished children[24]. A separate study examined different approaches for diagnosing severe acute malnutrition in children aged 6-59 months. Specifically, it assessed the effectiveness of combining Upper Arm Length (UAL) and MUAC measurements. The findings revealed that the MUAC-UAL indicator had a higher sensitivity (39.43%) than the MUAC indicator (17.98%)[25].

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Table 1. Study summary

Author, Year	Country	Objective Research	Research Design	Sample Characteristics	Findings
Lamsal *et al*., (2021)[12]	Nepal	Comparing the cut off weight-for-height z-score and Mid Upper Arm Circumference (MUAC) to identify acute malnutrition in children aged 6-59 months.	Cross-sectional, secondary data	3,169 children aged 6-59 months	The sensitivity of severe acute malnutrition (MUAC < 115 mm) was 13.6% with a specificity of 99.7%. While the sensitivity of moderate acute malnutrition (MUAC ≥ 115 to <125 mm) was 21% with a specificity of 91.2%. The Area Under Curve (AUC) was 0.53 for MUAC cut-off in identifying severe acute malnutrition and 0.56 for moderate acute malnutrition. The optimal MUAC cut-offs for severe and moderate acute malnutrition were 125 mm and 132 mm, respectively.
Sougaijam *et al*., (2019)[26]	India	Review the MUAC cut-off used to identify severe acute malnutrition.	Cross-sectional, primary data	2,650 children aged 6-59 months	The sensitivity and specificity of MUAC < 11.5 cm were 23.5% and 99.7%, respectively. The optimal cut-off to identify severe acute malnutrition was < 13 cm with a sensitivity of 74.5% and specificity of 92.7% with an AUC of 0.88.
Thi Hai *et al*., (2020)[27]	Vietnam	Determination of the optimal MUAC cut-off to improve the accuracy of MUAC indicators in SAM screening of children aged 6-59 months.	Cross-sectional, secondary data	4,764 children aged 6-59 months without medical complication	The optimal MUAC cut-off of 13.5 cm with a sensitivity of 65% and specificity of 72% and AUC of 0.72 was used to identify severe acute malnutrition status in children under 5 years old.
Zehra *et al*., (2021)[14]	Pakistan	Assess the frequency of severe acute malnutrition and determine the validity of MUAC compared to the weight-for-height z-score	Cross-sectional, primary data	540 infants ≤ 6 months	Severe acute malnutrition was found in 13.6% of infants. MUAC ≤ 11.5 cm with a sensitivity of 59.5% and specificity of 71.4% with an Area Under Curve (AUC) of 0.70 to identify severe acute malnutrition in infants in a low-income developing country like Pakistan.
Chand & Shah (2015)[28]	India	Identifying the most suitable MUAC cut-off for the diagnosis of severe acute malnutrition in infants 1-6 months	Cross-sectional, primary data	302 infants 1-6 months	MUAC ≤11.0 cm yielded the highest Youden Index of 0.63 and had sensitivity (82.5%) and specificity (80.3%).
Khan et al., (2022)[29]	Bangladesh	Evaluating the accuracy of MUAC in detecting acute malnutrition compared to the weight-for-height z-score in children aged 6-59 months.	Cross-sectional, primary data	239 children aged 6-59 months	The sensitivity of MUAC with the WHO recommended cut-off < 125 mm was 61% and specificity 85.4%. The best MUAC cut-off to detect more moderate acute malnutrition was <128mm with a sensitivity of 75.6% and specificity of 74.4% and Area Under Curve of 0.816.

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Optimal Cut-off in Detecting Severe Acute Malnutrition

According to the study findings, 5 articles examined the precision of MUAC in identifying severe acute malnutrition in young children. A cross-sectional study conducted in Nepal examined 3169 children between the ages of 6 and 59 months, the study found that the sensitivity to severe acute malnutrition, as indicated by a mid-upper arm circumference (MUAC) <115 mm, was 13.6%, while the specificity was 99.7%. The identified threshold for detecting severe acute malnutrition in Nepal was < 125 mm, yielding an Area Under Curve (AUC) of 0.53[12]. Consistent with a study in India, the MUAC exhibited a specificity of 99.7% and a sensitivity of 23.5%. The optimum threshold for detecting severe acute malnutrition in India was less than 130 mm [26]. In Vietnam, a study involving 4764 infants aged 6-59 months without medical issues found that the ideal MUAC cut-off point was less than 135 mm. This cut-off point had a sensitivity of 65% and specificity of 72%, with an AUC (area under the curve) value of 0.72[27].

Aside from the 6–59-month age range, this study also discovered two publications identifying severe acute malnutrition in children aged 1-6 months. These articles determined that the ideal mid-upper arm circumference (MUAC) cut-off point to identify such cases in Pakistan is ≤ 11.5 cm. This cut-off point's sensitivity was 59.5%, with a specificity of 71.4% and an area under the curve (AUC) of 0.70[14]. Nevertheless, in India, the most effective MUAC threshold for detecting severe acute malnutrition in the same population was ≤ 11.0 cm, with a sensitivity of 82.5% and specificity of 80.3%. The area under the curve (AUC) was calculated to be 0.63[28]. The findings of this research are consolidated in Table 2.

Table 2. Summary of MUAC optimal cut-off research results in detecting severe acute malnutrition

Author/Year/Country	Age Group	Optimal Cut-off	Sensitivity/Specificity	Area Under Curve
Lamsal et al., (2021), Nepal	6-59 months	< 125 mm	-	0.53
Sougaijam et al., (2019), India	6-59 months	< 130 mm	74.5%/92.7%	0.88
Thi Hai et al., (2020), Vietnam	6-59 months	< 135 mm	65%/72%	0.72
Zehra et al., (2021), Pakistan	1-6 months	≤ 115 mm	59.5%/71.4%	0.70
Chand & Shah (2015), India	1-6 months	≤ 110 mm	82.5%/80.3%	0.63

In Bangladesh, a study was conducted utilizing secondary data from a sample of 27,767 infants. The study determined that the ideal MUAC limit for severe acute malnutrition in children aged 6-24 months is 120 mm. The study also indicated that this limit had a sensitivity of 72.9% and a specificity of 84.7%. For children aged 25-36 months, the ideal threshold was determined to be 125 mm, with a sensitivity of 55% and specificity of 92.8%. For children aged 37-60 months, the recommended MUAC threshold for severe acute malnutrition is 135 mm. This threshold has a sensitivity of 71.4% and a specificity of 84.6%[30]. The sensitivity of MUAC measuring less than 11.5 cm was found to be at its maximum in the age group of 12-24 months and decreased in the age group of 24-48 months. On the other hand, the specificity was highest in the age group of 6-12 months[31]. The ideal threshold value rises with age, with males having a higher threshold than girls, except for the age range of 8-11 years. The sensitivity of MUAC in detecting acute malnutrition improves when divided into smaller age groups[4].

Two characteristics linked to the occurrence of malnutrition were exclusive breastfeeding and the educational level of mothers; it was observed that illiterate mothers had a significantly higher frequency of severe acute malnutrition (53.3%) [15]. According to the classification of acute malnutrition difficulties, it was discovered that the specificity of MUAC was higher in detecting moderate acute malnutrition (12.5 cm) at a rate of 79%, compared to severe acute malnutrition (11.5 cm) at a rate of 57%[32]. Implementing a MUAC-specific screening programme in Ethiopia with a cut-off of 115 mm would be unethical because it would result in a large number of undiagnosed and untreated children. A more appropriate cut-off of around 125 mm could be optimal for screening severe acute malnutrition[8].

Screening malnourished children who are at the highest risk of mortality can effectively decrease the number of deaths caused by severe acute malnutrition. A retrospective study conducted in Cameroon compared MUAC and weight-for-height z-scores (WHZ) as predictors of mortality in children with severe acute malnutrition. The study found that MUAC was a better predictor of mortality, with a sensitivity of 95.5% and specificity of 25.0%, compared to WHZ, with a sensitivity of 86.4% and specificity of 21.4%.)[2]. MUAC is a more accurate indicator of mortality compared to WHZ; when MUAC is less than 11.5 cm, there is a balance between sensitivity and specificity in predicting mortality during hospitalisation. Including a BW z-score < 3 and/or MUAC < 11.5 cm did not yield a significant enhancement in prediction accuracy compared to the individual assessment of MUAC/WHZ[33]. Nevertheless, a meta-analysis study demonstrated that there is no discernible disparity in the mortality risk between severely acutely malnourished children diagnosed solely based on MUAC <115 mm and those diagnosed solely based on WHZ -3. Consequently, this study does not provide evidence to justify the elimination of WHZ as a crucial independent diagnostic criterion for severe acute malnutrition. Failure to accurately identify children in such situations will lead to suboptimal treatment and an increased risk of mortality[34].

Optimal Cut-off in Detecting Moderate Acute Malnutrition

Moderate acute malnutrition is characterized by MUAC measures more significant than 115 mm and less than 125 mm. Two articles in this study examined the precision of MUAC in identifying patients with moderate

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acute malnutrition. The study done in Bangladesh yielded an Area Under Curve (AUC) MUAC value of 0.816 for identifying mild acute malnutrition. The sensitivity and specificity rates were 61% and 85.4%, respectively. The optimal MUAC cut-off for detecting additional instances was <128mm, with a sensitivity of 75.6% and specificity of 74.4%29. In Nepal, the prevalence of moderate acute malnutrition, defined as a mid-upper arm circumference between 115 mm and 125 mm, was 21%. The ideal threshold value for identifying identical cases was <132mm[12]. The findings of studies about the most effective threshold for detecting moderate acute malnutrition are consolidated in Table 3.

Table 3. Summary of MUAC optimal cut-off research results in detecting moderate acute malnutrition

Author/Year/Country	Age Group	Optimal Cut-off	Sensitivity/Specificity	Area Under Curve
Khan et al., (2022), Bangladesh	6-59 months	< 128 mm	75.6%/74.4%	0.816
Lamsal et al., (2021), Nepal	6-59 months	< 132 mm	-	0.56

A study was undertaken in Ethiopia, with 915 children under the age of five, to assess the effectiveness of MUAC in detecting moderate acute malnutrition in three distinct regions. The findings revealed that the sensitivity of MUAC, when the measurement was less than 125 mm, was 20.6%. The receiver operating characteristic (ROC) analysis determined that the ideal (MUAC) cut-off value for diagnosing mild acute malnutrition in the Gambella and Amhara regions was 138.5 mm. The sensitivity of this cut-off value was found to be 99% in the Gambella region and 100% in the Amhara region. However, the most effective threshold for the Somali region was determined to be 137.5 mm, resulting in a sensitivity rate of 98%. The current cut-off criteria lack the necessary sensitivity to accurately identify cases of mild acute malnutrition in Ethiopia, given the Country's varied ethnic groups with varying body structures and environmental circumstances[35]. The best MUAC cut-off for identifying moderate acute malnutrition was determined by considering the geographical region and the different age groups. The most effective measurement for children aged 6-24 months was a MUAC cut-off of 125 mm, with a sensitivity of 63.2% and specificity of 85%. For children aged 25-36 months, the most effective threshold was shown to be 135 mm, with a sensitivity of 71.7% and specificity of 78.8%. Additionally, for children aged 37-60 months, the recommended MUAC threshold is 140 mm, with a sensitivity of 70.4% and specificity of 80.3%[30].

The estimate of the caseload for mild acute malnutrition using the WHZ and MUAC, considering oedema, yielded fewer children than the calculation that used both markers together [36]. According to a study conducted in India, the WHZ accurately identified 96% of cases of mild acute malnutrition. In comparison, only 28.4% of the same cases were diagnosed using a different method. The z-scores of weight-for-heights had a significant impact on the categorization of acute malnutrition (severe/moderate) for children under 24 months (AOR = 2.4, $\rho < 0.0001$) and stunted children (AOR = 1.7, $\rho < 0.0001$). However, gender did not have any effect on this classification[36]. A study carried out in Cambodia discovered that gender was linked to the threshold value used to classify cases of acute malnutrition. Furthermore, the sensitivity of MUAC in identifying acute malnutrition increased from 49% to 76% when the age groups were divided into smaller categories for mild acute malnutrition[4].

A randomized controlled trial conducted in Nigeria sought to evaluate the precision of maternal utilization of MUAC tape in identifying instances of acute malnutrition in children. The findings revealed that the maternal use of MUAC tape demonstrated superior accuracy in detecting cases of moderate acute malnutrition, with a sensitivity of 90% and a specificity of 80%. When comparing, the ability to detect severe acute malnutrition has a sensitivity of 73% and a specificity of 98%[38].

The findings of this literature review are constrained to South and Southeast Asia. Nevertheless, research on this subject is concentrated in these specific areas, and the findings are presumed to apply to just certain places, such as Indonesia. The methodology of this literature review employed stringent inclusion criteria, which excluded factors such as research design and location. Consequently, it posed challenges in identifying suitable studies. This literature study solely categorized papers on classifying acute malnutrition issues, specifically severe and moderate cases. This research evaluation has the benefit of identifying the accuracy (sensitivity and specificity) of MUAC in detecting acute malnutrition and determining the best cut-off of MUAC based on the various publications studied.

CONCLUSIONS

The precision of MUAC thresholds endorsed by the World Health Organization (WHO) for detecting severe and moderate acute malnutrition might be enhanced. In general, the specificity of the MUAC indicator was higher than its sensitivity. This indicates that the MUAC indicator may accurately identify children who are not acutely malnourished among a group of children who are not acutely malnourished, using weight-for-height z-score measurements as a gold standard. The most effective cut-off for diagnosing acute malnutrition differed based on the geographical region and age group. Hence, it is imperative to do additional research in each Country to ascertain the optimal threshold for their specific location, considering age groups and the categorization of acute malnutrition issues.

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