Validation of MUAC Cut-Offs of WHO for Diagnosis of Acute Malnutrition among Children under 5 Years in Karachi, Pakistan

Mehreen Qadri[1], Lubna Ansari Baig[1], Zaeema Ahmer[1,*], Aimen Asim[1] and Syed Moin Aly[2]

[1]*APPNA Institute of Public Health, Jinnah Sindh Medical University, Karachi, Pakistan*

[2]*Institute of Medical Education, Jinnah Sindh Medical University, Karachi, Pakistan*

Abstract: *Objective*: To validate the WHO recommended Mid-Upper Arm Circumference (MUAC) cut-offs for acute malnutrition screening in children younger than five in Karachi, Pakistan.

Methods: A cross-sectional study was conducted, including an anthropometric examination following WHO guidelines. Height was measured using Stadiometer and Infantometer. The link between MUAC and Weight-for-Height-Z score (WHZ) for different cut-offs of MUAC for Moderate Acute Malnutrition (MAM) and Severe Acute Malnutrition (SAM) was shown using Receiver Operator Characteristics (ROC) curves and the Youden index. Sensitivity and specificity of MUAC <11.5 cm and ≥11.5 to <12.5cm were determined using WHZ scores of -3 Standard Deviation (SD) and ≥-3 to <-2 SD for SAM and MAM, respectively.

Results: Among 499 children, as per WHZ score, 9.6% and 27.1% had SAM and MAM, respectively, whereas according to MUAC, 6.4% and 3.6% had MAM and SAM, respectively. At the maximum value of the Youden index of 55.6%, an optimum cut-off of 12.7cm for screening of SAM with MUAC was found compared to the recommended cut-off of 11.5cm. Similarly, at the maximum value of the Youden index of 57.7%, an optimum cut-off of 13.9cm for screening of MAM with MUAC was found compared to the recommended cut-off of 12.5cm.

Conclusion: The current MUAC cut-off of WHO for screening SAM and MAM cases captures only a small percentage of children under five. This needs to be revised to capture children with acute malnutrition for timely treatment in Pakistan.

Keywords: SAM, MAM, MUAC, WHZ-score, children under 5 years, Karachi.

INTRODUCTION

Acute malnutrition is a substantial public health concern worldwide, and highly malnourished children are more likely to die. Malnutrition affects almost 165 million children worldwide, and it accounts for more than half of all childhood deaths [1]. In 2012, globally, 52 million children were affected by acute malnutrition, with 33 million suffering from Moderate Acute Malnutrition (MAM) and 90 million suffering from Severe Acute Malnutrition (SAM) [2]. Globally, SAM affects around 16 million children under five, with more than half a million deaths each year. The National Nutrition Survey of Pakistan 2018 shows the rate of wasting has increased from 15.1% to 17.7% since 2011 [3].

SAM is one of the most critical public health crises impacting children. The risk of mortality and morbidity in these children is nine times higher than in healthy children [5]. In Cambodia, acute malnutrition raises the risk of mortality in children, accounting for 8% of all deaths, with more than half a million deaths each year. Prompt treatments in young children can avoid casualties due to acute malnutrition [4]. In children less than five years of age, early diagnosis is a crucial step in minimizing the risk of growth retardation and mortality due to acute malnutrition [5]. The World Health Organization (WHO) suggested nutritional therapy for children aged 6 to 59 months with Mid Upper-Arm Circumference (MUAC) measurement of 11.5cm or between 11.5 and 12.5cm for SAM and MAM, respectively [6].

With a global goal of correctly identifying children suffering from acute malnutrition, studies in developing countries such as India and Cambodia were conducted to assess the validity of the WHO suggested MUAC cut-off for acute malnutrition identification. The studies indicated that the cut-offs have poor sensitivity and specificity in their populations [5, 6]. To increase the validity of MUAC as a screening tool in the timely diagnosis of SAM and MAM, it is critical to validate WHO cut-offs in the local context.

In Pakistan, the current WHO cut-offs for acute malnutrition are <11.5cm for SAM and between ≥11.5cm to <12.5cm for MAM. However, research from other South Asian countries has indicated that the criterion mentioned above overlooks many children with acute malnutrition. There are no studies conducted in Pakistan to determine whether MUAC cut-offs are adequate for detecting acute malnutrition and whether an additional instrument is required to detect acute malnutrition. We are using WHZ scores combined with

*Address correspondence to this author at the APPNA Institute of Public Health, Jinnah Sindh Medical University, Rafiqui H.J Road, Karachi 75510, Pakistan; Tel: +92 21 35215572; E-mail: zaeema.ahmer@jsmu.edu.pk

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MUAC in this study to identify missing SAM and MAM children and validate the WHO-recommended MUAC cut-offs for diagnosing acute malnutrition in children under five years in Karachi, Pakistan. The findings of this study will help to enhance long-term nutritional improvement by identifying more severely malnourished children. It will influence the formulation and implementation of nutritional rehabilitation programs in Pakistan and the revision of diagnostic cut-offs for SAM and MAM in Pakistani children.

MATERIALS AND METHODS

Study Design and Sampling

A cross-sectional study was conducted from August 2020 to January 2021 at the Outpatient Department (OPD) of the National Institute of Child Health (NICH) Hospital. NICH is the largest children's tertiary care hospital in Karachi, with the largest turnover of patients in a single day. Children under the age of 5 years, of either gender, presenting were recruited conveniently for the study. In contrast, children with muscular disabilities or if a legal guardian refused to provide written informed consent were excluded from the study. The WHO sample size calculator was used to determine the sample size. With a 95% confidence interval and a 10% margin of error, the sample size was estimated to be 450. Wasting was prevalent in 17.7% of children, with a sensitivity of 50% and specificity of 90.8 percent [3, 9].

Study Variables and Anthropometric Measurements

According to WHO guidelines, a clinical examination for prevalent pitting edema was performed. The participants' demographic and anthropometric data were collected using an interview-assisted questionnaire. The study participants inquired about age, sex, and other socio-demographic characteristics, whereas sensitivity and specificity of WHO MUAC cut-offs for acute malnutrition were estimated. In order to limit measurement error, anthropometric data such as weight, height/length, and MUAC were documented by taking measurements according to WHO standard protocol. The non-flexible measuring tape was used to assess MUAC. Weight was calculated on the Sico weighing scale.

Data Analysis

The SPSS software version 23 was used to perform the analysis. Weight, height, and length were entered into the WHO Anthro 3.2.2 edition. Mean and Standard Deviations (SD) were determined for quantifiable data such as age (months), income (PKR), weight (kg), and height (cm). Percentages and proportions were determined or categorical variables such as gender, parent/guardian education, type of residence, and ethnicity. SAM and MAM were calculated as nutritional indicators of acute malnutrition. The degree of settlement between the MUAC and the WHZ was measured using a Kappa analysis. Youden Index was determined to calculate the optimal cut-off for MUAC intended for diagnosing SAM and MAM.

RESULTS

Demographic Characteristics of Study Participants

A total of 499 children participated in our research. The children's average age in months was 32.60±16.16, and 22.6% of the children were between the ages of 25 and 36 months. Males were 53.3%, comprising more than half of the participants, whereas 29.1% of the study participant's parents had completed matriculation. The monthly income of 78.6% of parents was more than 20,000 PKR. 49.5% of study participants were Urdu speaking, which is the most common language spoken in Karachi, as shown in Table **1**.

Characteristics of Study Participants with Acute Malnutrition

According to WHZ, 9.6% of study participants had SAM in our research, and 27.1% had MAM. However, as per MUAC, 10.4% of study participants had acute malnutrition with 6.4%, and 3.6% had MAM and SAM, respectively, as shown in Table **2**.

Validity of MUAC for Wasting against WHZ <-2

Out of 499 study participants, MUAC revealed 52 acute malnutrition cases, whereas WHZ diagnosed 26 as wasting. WHZ ranked the remaining 26 cases as normal, whereas MUAC classified them as cases of wasting. WHZ identified 48 cases of wasting, 26 of which were also identified by MUAC; however, MUAC considered the remaining 22 cases normal when assessed by MUAC. Overall, MUAC and WHZ have a moderate level of agreement (Kappa=46.7%, $p<0.01$), with 54.1% sensitivity and 94.2% specificity in diagnosing wasting, and 54% of wasting recognized using both MUAC and WHZ.

A total of 32 cases of MAM were diagnosed using the MUAC tool. Using the WHZ score on these 32

Table 1: Demographic Characteristics of Study Participants (n= 499)

Characteristics		n	%
Age Group (Months)	6 -12	75	15.1
	13 - 24	105	21.2
	25 - 36	112	22.6
	37 - 48	109	22.0
	49 - 60	9	19.2
Age in months (Mean ±SD)		32.60±16.16	
Sex	Male	266	53.3
	Female	233	46.7
Education level of parents	No formal education	76	15.2
	Primary	60	12.0
	Secondary	73	14.6
	Matric	145	29.1
	Intermediate	104	20.8
	Graduate	41	8.2
Monthly Income (PKR) of parents	≥ 20000	107	21.4
	>20000	392	78.6
Ethnicity	Urdu Speaking	247	49.5
	Sindhi	55	11.0
	Punjabi	61	12.2
	Pashto	37	7.4
	Balochi	23	4.6
	Saraiki	20	4.0
	Memon	56	11.2

Table 2: Characteristics of Study Participants with Acute Malnutrition (WHZ & MUAC) (n= 499)

Parameters		Number	Percentage %
WHZ < -3 SD (SAM)	No	451	90.4
	Yes	48	9.6
WHZ < -2 to ≥ -3 SD (MAM)	No	364	72.9
	Yes	135	27.1
Edema 3 plus	No	484	97.0
	Yes	15	3.0
MUAC <12.5 cm (acute malnutrition)	No	447	89.6
	Yes	52	10.4
MUAC between ≥ 11.5 cm to < 12.5cm (MAM)	No	467	93.6
	Yes	32	6.4
MUAC <11.5 cm (SAM)	No	481	96.4
	Yes	18	3.6

children, 23 were classified as MAM. In the 32 cases identified, 9 cases were not considered MAM by the WHZ score. 135 study participants tested positive for MAM when screened by WHZ. Using the MUAC on these 135 participants, 23 were also identified as MAM, and 112 were not classified as MAM. In diagnosing MAM, MUAC and WHZ had a good degree of agreement (19.2%, p<0.01), with a sensitivity of 17.0% and specificity of 97.5%.

MUAC found 18 cases, out of which 15 of these cases were diagnosed as SAM, and 3 were not identified as SAM when screened by WHZ. Using WHZ assessment, a total of 48 cases were identified as SAM. Among these 48 cases, the MUAC tool categorized 15 children as SAM, and the remaining 33 cases were not identified as SAM. In diagnosing SAM, MUAC and WHZ show a moderate agreement (42.4%, p<0.01), with a sensitivity of 31.2% and specificity of 99.3%, as presented in Table **3**.

Sensitivity, Specificity, and Youden Index for MUAC with SAM and MAM

At various MUAC cut-off values, the Youden Index was calculated to establish the optimal MUAC cut-off for the diagnosis of SAM. The WHO MUAC criterion of 11.5cm has a sensitivity of 99.3% and a specificity of 31.3% for diagnosing MAM. The best MUAC cut-off was 12.7cm, with the greatest Youden index of 55.6. At this MUAC cut-off, the sensitivity and specificity were 88.9% and 66.7%, respectively.

Likewise, for diagnosis of MAM, WHO MUAC criteria of 12.5cm had a sensitivity of 97.5% and specificity of 31.9% for diagnosing with a score of 57.7 at the best MUAC cut-off of 13.9cm, at which the Youden index was the highest. This MUAC cut-off sensitivity and specificity were determined to be 70.3% and 87.4%, respectively, as shown in Table **4**.

The area under the ROC curves was used to evaluate the efficacy of MUAC in predicting SAM when compared to WHZ. ROC curves for sensitivity and specificity of multiple MUAC cut-offs were plotted to find the new SAM cut-off. The cut-off value of 12.7cm was chosen because it had 88.9% sensitivity and 66.7% specificity. MUAC missed a lot of the SAM cases. (As illustrated by the green line in Figure **1**), however, WHZ recognized a significant number of SAM cases (As illustrated by the blue line in Figure **1**). According to ROC, there was 85.5 percent area under the curve, with p<0.01 and C.I (0.79, 0.91) as presented in Figure **1**.

ROC curves for sensitivity and specificity of multiple MUAC cut-offs were plotted to establish the new MAM cut-off. Increasing the cut-off point enhanced MUAC

Table 3: Validity of MUAC for Different Parameters of Wasting, MAM, and SAM against WHZ

MUAC <12.5	WHZ<-2		Total
	Positive	Negative	
Positive	26	26	52
Negative	22	425	447
Total	48	451	499
Sensitivity = 54.1% and Specificity =94.2% and Kappa= 46.7%			
MUAC Between ≥ 11.5 to < 12.5cm	**WHZ**		**Total**
	Positive	**Negative**	
Positive	23	9	32
Negative	112	355	467
Total	135	364	499
Sensitivity =17.0% and Specificity =97.5% and Kappa= 19.2%			
MUAC <11.5	**WHZ**		**Total**
	Positive	**Negative**	
Positive	15	3	18
Negative	33	448	481
Total	48	451	499
Sensitivity = 31.2 % and Specificity =99.3% and Kappa= 42.4%			

Table 4: Sensitivity, Specificity, and Youden Index at Various Cutoff Values of MUAC for Optimal Point for SAM and MAM

SAM				MAM			
MUAC	Sensitivity	Specificity	Youden Index (SEN+SPE)-100	MUAC	Sensitivity	Specificity	Youden Index (SEN+SPE)-100
11.5	99.3	31.3	30.6	12.5	97.5	31.9	29.4
11.6	99.1	33.3	32.4	12.6	96.4	43.7	40.1
11.7	98.7	35.4	34.1	12.7	95.1	47.4	42.5
11.8	98.4	37.5	35.9	12.8	94.5	49.6	44.1
11.9	98.2	43.8	42.0	12.9	92.9	51.1	44.0
12.0	98.0	43.8	41.8	13.0	92.0	51.1	43.1
12.1	96.9	47.9	44.8	13.1	88.2	59.3	47.4
12.2	96.2	50.0	46.2	13.2	87.9	63.7	51.6
12.3	95.8	52.1	47.9	13.3	84.6	68.1	52.8
12.4	95.3	54.2	49.5	13.4	82.4	71.1	53.5
12.5	94.2	54.2	48.4	13.5	81.9	71.9	53.7
12.6	90.9	64.6	55.5	13.6	75.3	79.3	54.5
12.7	88.9	66.7	55.6	13.7	74.2	83.0	57.1
12.8	87.8	66.7	54.5	13.8	72.3	85.2	57.4
12.9	86.0	66.7	52.7	13.9	70.3	87.4	57.7
13.0	85.4	66.7	52.0	14.0	69.0	87.4	56.4
13.1	80.3	70.8	51.1	14.1	60.7	91.9	52.6
13.2	78.7	70.8	49.5	14.2	60.2	91.9	52.0
13.3	74.9	72.9	47.9	14.3	55.5	91.9	47.3
13.4	72.3	72.9	45.2	14.4	53.0	93.3	46.4
13.5	71.8	75.0	46.8	14.5	50.5	93.3	43.9
13.6	65.2	83.3	48.5	14.6	44.8	94.8	39.6
13.7	63.4	85.4	48.8	14.7	43.1	95.6	38.7
13.8	61.4	87.5	48.9	14.8	40.7	95.6	36.2
13.9	59.4	89.6	49.0	14.9	38.2	95.6	33.7
14.0	58.3	89.6	47.9	15.0	36.5	95.6	32.1
14.1	51.0	95.8	46.8	15.1	28.6	95.6	24.1
14.2	50.6	95.8	46.4	15.2	27.5	95.6	23.0
14.3	46.8	95.8	42.6	15.3	23.1	96.3	19.4
14.4	44.3	95.8	40.2	15.4	22.0	97.0	19.0
14.5	42.4	95.8	38.2	15.5	21.7	97.0	18.7

sensitivity and specificity for MAM screening, according to the ROC curve. The 13.9cm cut-off point was chosen because it has a sensitivity of 70.3% and a specificity of 87.4%. ROC revealed an 85.7% area under the curve with $p<0.01$ and C.I. (0.82, 0.89), as presented in Figure **2**. Many MAM children were not diagnosed as MAM cases by MUAC (As illustrated by the green line in Figure **2**). However, WHZ detected a significant number of MAM cases (As illustrated by the blue line in Figure **2**).

DISCUSSION

Due to the high prevalence of malnutrition in children, it is vital to effectively identify and utilize

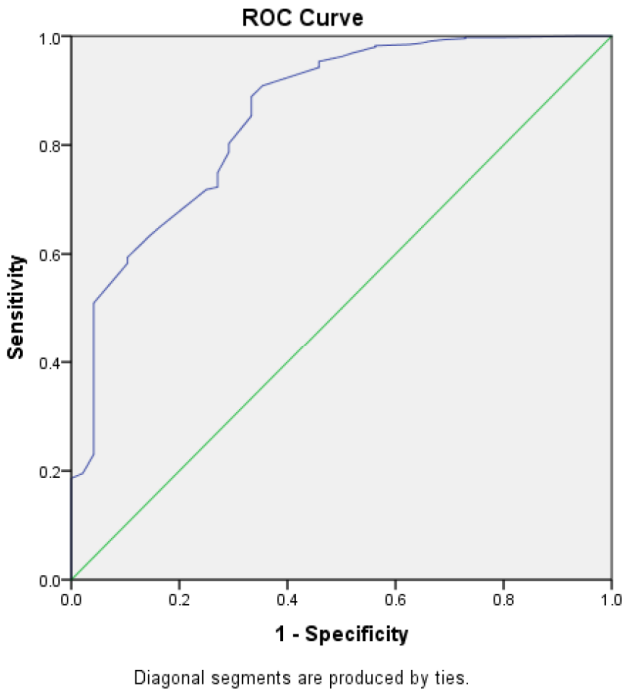

Figure 1: Receiver's Operating Characteristic Curve of MUAC for SAM against Weight for Height.

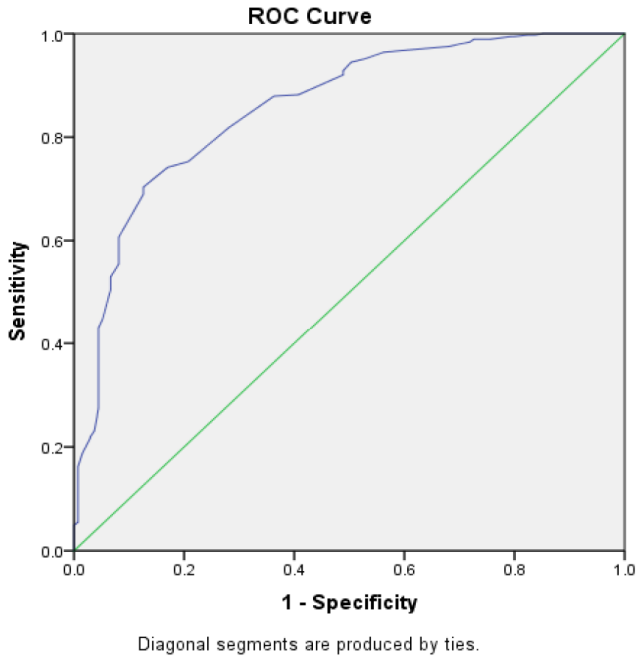

Figure 2: Receiver's Operating Characteristic Curve of MUAC for MAM against Weight for Height.

diagnostic tools to identify at-risk populations. MUAC 11.5cm, WHZ<-3, and/or edema are currently recommended by WHO as extensively recognized independent diagnostic criteria for diagnosis of acute malnutrition [2]. Several international studies have suggested increasing the MUAC cut-off for timely diagnosis [1-5, 10, 14]. This is conceivably the first study that validates WHO MUAC cut-offs among Pakistani children younger than five years. The study identified different cut-offs of MUAC for diagnosing SAM and MAM. It was found that a higher MUAC cut-off is a better indicator in diagnosing SAM and MAM, whereas WHZ has slightly better diagnostic ability than MUAC. Furthermore, WHZ scores identify the prevalence of SAM and MAM better than MUAC. This is in line with studies conducted in South Asian countries, which recommend using WHZ scores to identify SAM and MAM children [4, 7-9, 16, 17].

Globally, multiple studies have shown the application of WHZ and MUAC criteria to detect children with acute malnutrition [6, 13, 15, 16]. Our findings of higher MUAC cut-offs were consistent with other global studies indicating the concern of revision of cut-offs [4, 7-10]. However, our study found the frequency of MAM detected by WHZ and MUAC as 27.0% and 22.4%, respectively. The frequency of SAM detected by WHZ and MUAC was 9.61% and 6.61%, respectively, and the overall agreement between MUAC and WHZ was moderate.

Our study showed the new MUAC cut-off for diagnosing SAM and MAM. Comparable findings have also been reported by other existing literature, indicating the revision of the cut-off [3, 4, 8-10]. A study in Cambodia indicated the ideal MUAC cut-off as 13.3cm for the diagnosis of SAM [3]. Our findings support a multi-centric 39 nutritional survey, which recommended changing the MUAC cut-off value from 11.0cm to 11.5cm and recommending a cut-off of 13.5cm for improved diagnosis of SAM [4].

Other existing literature results suggesting a higher cut-off value reveal that MUAC is a poor sign of undernutrition at a cut-off of less than 13.5cm but a very sensitive indicator at 15.5cm [8]. Similar findings from India reported MUAC 11.5cm as a poor indicator of sensitivity and specificity. They further suggested cut-offs of 12.8cm and 13.6cm for SAM and MAM, respectively [9]. A similar study recommended a cut-off of 14.7cm for diagnosing malnutrition and found that the prevalence of SAM was 3.4% by WHZ and 1.5% by MUAC, respectively [10].

Anthropometric analysis of five nutrition surveys conducted in Ahmedabad revealed that the MUAC criterion for SAM and MAM for 6 to 24 months was 12.0cm and 12.5cm, respectively, and 12.5cm and 13.5cm for children aged 25 to 60 months [14]. WHZ was a more sensitive indicator at the facility level, but MUAC was recommended as a quick and easy testing method at the household level in research on South

African children aged 6-59 months. This also supports both anthropometric methods to assure that malnutrition is appropriately detected in all age groups [13].

Similar findings have also been reported from other studies at the global level showing WHZ scores being more specific in detecting acute malnutrition. The frequency of SAM with WHZ scores was 84.5%, while with MUAC, it was 38.5%. Furthermore, MAM and SAM were diagnosed in more than 95% of children with WHZ scores, but only 33% were diagnosed using MUAC [14]. A similar investigation was carried out in Jabalpur's rural and urban areas of India, suggesting median MUAC of 13.5cm and 13.2cm for the rural and urban populations. Findings revealed that the prevalence of malnutrition according to MUAC and WHZ in a rural setting was 14.3% and 19.7%, respectively. While in an urban setting, the prevalence of malnutrition, according to MUAC and WHZ, was 14.4% and 18.9%, respectively [15]. For SAM and MAM diagnosis, MUAC cut-offs of 12.5cm and 13.5cm were proposed for children aged 25 to 36 months and 13.5cm and 14.0cm for children aged 37 to 60 months [17]. A hospital-based study of Bangladeshi children indicated that if the current WHO MUAC criterion had been applied instead of the WHZ cut-off, a vast number of children would not have been classified as severely or moderately malnourished if they had been.

A study conducted in Vietnam revealed similar results, recommending that the MUAC cut-off of 13.5cm be used for improving SAM status in children under the age of five [18]. A cross-sectional investigation in 24 villages of a Primary Health Centre in Maharashtra's Wardha district recommended a 12.8cm cut-off for SAM [21]. A cross-sectional investigation in 77 Nepalese districts discovered that the SAM and MAM had the best MUAC cut-offs of 12.5cm and 13.2cm, respectively [22]. A similar study conducted in Uganda pediatric assessment center observed that MUAC had better sensitivity at a 13.6cm cut-off in terms of diagnosis [23].

A MUAC value of 14cm was shown to be suitable for community-level screening of SAM in children under the age of five in an Indonesian study. The WHO cut-off values for identifying malnourished children in the community and providing early referrals to avoid SAM may be too low. The current MUAC cut-off values (12.5cm) have limited sensitivity for detecting MAM in children. Children who would benefit from intervention are missed during malnutrition screening. This is a critical issue in countries where growth monitoring activities rely mainly on MUAC because of its simplicity and low cost. For boys and girls less than two years, a revised MUAC cut-off value may aid in MAM [25].

On the contrary, the lack of studies conducted in Pakistan has indicated that MUAC cut-off has a better ability to detect SAM and MAM. As a result, more research is needed to understand the difference in body shape and muscle mass in the Pakistani context. Further studies on validating MUAC cut-offs and discrepancies of anthropometric tools, including MUAC and WHZ, can pave the way for significant evidence. This, in turn, can be used to create policies and public health interventions to improve the diagnostic ability of anthropometric criteria for timely referral of malnourished children for nutritional rehabilitation.

The current study is the first of its category that was conducted in a Pakistani hospital setting regarding the validation of MUAC cut-offs. The operational criteria followed during anthropometric data collection, which is critical for validity investigations, are the strength of this study. Measurements were taken at a single time point and by a professional nutritionist using calibrated equipment in accordance with a globally recognized, standardized technique. Despite validating cut-offs in the Pakistani context, the current study has a few limitations. Firstly, based on the cross-sectional nature of this study, it would be difficult to interpret any causal relationships between the various nutritional factors and their role in developing acute malnutrition. Second, a small fraction of an age estimate was necessary because the accurate day of birth could not be verified. In addition, subjects from only one hospital were included, so they did not represent the entire population. In the future, community-based studies with larger geographic representation are required to test the usefulness of both MUAC and WHZ.

CONCLUSION

The present study's findings demonstrate MUAC had better performance at a cut-off of 12.7cm and 13.9cm for SAM and MAM, and therefore it is recommended for screening in children aged less than 5 years in a hospital context. The findings of this study are vital for the early detection of SAM cases in the community, as well as the successful management of nutritional rehabilitation programs in Pakistan. Furthermore, combining MUAC and WHZ may have a greater influence on SAM children's therapeutic feeding programs. Regardless of the need for further studies

regarding validation and use of both MUAC and WHZ, this study presents a platform for health policymakers and other relevant stakeholders to improve their approach toward nutrition-based interventions regarding diagnosis in order to reduce the burden of malnutrition.

ETHICS APPROVAL

Ethical approval was taken from the Institutional Review Board of Jinnah Sindh Medical University via proposal no JSMU/IRB/2018/-130

CONSENT TO PARTICIPATE

Consent was taken from the parents of the study participants to be a part of the study.

CONFLICT OF INTEREST

No conflict of interest to report.

FUNDING

No funding was obtained for the study.

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AVAILABILITY OF DATA AND MATERIALS

The data can be made available from the corresponding author upon reasonable request.

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