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Mid upper arm circumference cutoffs for identifying underweight and severe underweight among infants less than six months: A Hospital Based Cross-Sectional study

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ABSTRACT

Background: Prevalence of undernutrition among infants <6 months are very high in India. WAZ is the most sensitive predictor of mortality among infants <6 months as compared to other anthropometric parameters. However, taking weight and calculating z-score in the community setting have many challenges. Taking mid upper arm circumference (MUAC) is more feasible in a field setting. **Methodology:** A cross-sectional study was conducted with 419 infants <6 months in a tertiary care hospital in India to identify appropriate MUAC cutoffs for identifying underweight (WAZ<-2) and severe underweight (WAZ<-3) among infants <6 months by calculating sensitivities, specificities and Youden indices. Cohen kappa coefficients were calculated to assess agreements between MUAC and WAZ cutoffs. **Results:** The MUAC cut-offs for underweight and severe underweight were calculated as 11cm (Youden Index: 0.503; sensitivity: 83.4%; specificity: 66.9%) and 10.9cm (Youden Index: 0.504; sensitivity: 76.3%; specificity: 74.1%), respectively. Kappa coefficients to diagnose underweight with MUAC<=11cm was highest at 0.48. **Conclusions:** The MUAC cut-off of 11cm could reliably be used to screen infants <6 months with underweight and severe underweight for providing appropriate care in the Indian settings.

Keywords: Infants <6 months, MUAC, WAZ, Underweight, Severe Underweight

Introduction

Globally, underweight is one of the major causes of morbidity and mortality among children [1, 2]. Throughout the world, around 104 million children were underweight in 2010, and the majority of these children lived in sub-Saharan Africa and South Asia.[3] Moreover, globally around 5.4 million children <5 years die every year. Around half of these child mortalities are directly related to poor nutrition.[4] Infants <6 months face significantly higher risk of morbidity and mortality than older malnourished children.[5]

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In the long-term, these infants also face impaired physical and cognitive development and greater susceptibility to cardiovascular and metabolic non-communicable diseases. [6-10] In India, the most recent national survey estimated that 12.1% infants <6 months were severely underweight and 28.5% were underweight.[5]

Currently, for children aged 6-59 months, growth standards use weight for height z scores (WHZ), weight for age Z-scores (WAZ) and mid-upper arm circumference (MUAC) measurements as independent measures to identify their nutritional status.[11] Current World Health Organization (WHO) guidelines on the 'Management of Severe Acute Malnutrition in infants and children', which also include a chapter focusing on managing infants <6 months recommends using weight-for-length *z*-scores (WLZ) criteria to identify undernourished infants <6 months for admission to treatment programs.[12] However, the guidelines also say that this guidance was not based on direct evidence review but based on conventions used among older children. So, after publication of the 2013 WHO guidelines, there has been growing importance of identifying appropriate anthropometric criteria and cutoff to identify under nutrition among infants <6 months which can best able to predict mortality and morbidity among them.[13, 14] Several studies have found that WAZ≤3 is a better predictor of mortality among infants <6 months when compared to WLZ≤3. [15-18] Studies conducted in India also found that WAZ≤3 is the best predictor of mortality among infants <6 months compared to other anthropometric criteria or their combinations.[19]

In a community setting, MUAC measurement technique is considered to be simpler, feasible, and cost-effective screening method as compared to taking weight. [20] Z-score calculations of WAZ add additional complexity and chances of errors, and further magnify existing errors in taking weight. [21] The WHO 2013 Guideline: Updates on the management of SAM in infants and children also recommended using MUAC for identification of under nutrition among children by community health workers in the community.[12] Different studies have found that MUAC results are highly precise, accurate and require minimal training.[22, 23] MUAC measurement is also acceptable for mothers as infants do not need to be undressed and can remain in caretaker's arms while doing the weight measurement. [24] Therefore, it would be important to identify appropriate MUAC cutoffs for identifying underweight (WAZ≤2) and severe underweight (WAZ≤3) so that the criteria can be used as an alternative to WAZ for screening and identification of underweight or severe underweight cases in the Indian settings. With this background, we conducted the study with the objective to determine the validity of MUAC as compared to WAZ for using it in the Indian settings to assess the nutritional status among infants <6 months.

Materials and Methods

Study Design: A hospital based cross-sectional study conducted between January 2021 to March 2022 in the pediatric OPD and Immunization clinic of a tertiary care hospital.

Sample Size: The sample size for the study was calculated to using the formula:

Sample Size = $Z^2P(1-P)/d^2$

P= Expected prevalence of underweight infants. As per NFHS-5, prevalence of underweight (WAZ≤ 2) among infants <6 months was 28.5%.[5] It was assumed that the prevalence would be slightly higher among sick infants in the hospital-based setting. Hence the prevalence of underweight for the sample size calculation was assumed to be 50%. Also, at 50% prevalence, the calculated sample size would be more and hence, for any unknown prevalence, prevalence of 50% is taken for the sample size calculation. [25]

With significance level of 5% ($p<0.05$); $Z\alpha$, is 1.96

Level of relative precision; d= 0.05

The sample size for the study using the above parameters and accounting for sampling error of 10% was calculated as 419.

All infants <6 months who visited the pediatric out-patient department (OPD) and Immunization clinic of the hospital during the study period were included in the study. Infants with any known chronic kidney, liver, neurological, respiratory, heart or other chronic diseases were excluded from the study.

Ethical Consideration: Approval of the study protocol was obtained from the Institutional Ethical Committee of the institution (LHMC/IEC/2020/PG Thesis/117). During the data collection, written informed consent was obtained from the parents/guardian of the study subjects.

Data Collection: Each Infant was measured for weight and MUAC. Weight of infant was taken in minimal clothing using digital weighing scale to nearest the 10g (SECA 334: Capacity: 20kg, Graduation: 5g<10kg>10g). MUAC was measured using standard UNICEF MUAC tape in the left arm at a flexed position. Weight and MUAC were taken twice and when the difference in the two measurements were more than the acceptable ranges (100g for weight and 0.2cm for MUAC) then the third measurements were taken and were considered as final. WAZ of infants was calculated using WHO 2006 growth reference. [10] Under the supervision of a research assistant, all measurements were taken by experienced research staff that had been trained by the principal investigator on measuring weight and MUAC. Senior research staff from the hospital conducted quality checks of around 10 percent of data to ensure integrity of the data collected.

Data Analysis: Statistical Package for Social Sciences (SPSS) 23 was used for data analysis (IBM SPSS Statistics 23). MUAC was compared with WAZ for sensitivity and specificity to diagnose underweight (WAZ≤2) and severe underweight (WAZ≤3). The Youden Indices were calculated to determine the ideal MUAC cut-offs for infants <6 months of age for WAZ≤ 2, and WAZ≤3. The Kappa coefficients were also calculated to assess the agreements between MUAC with WAZ for diagnosing underweight and severe underweight. Similarly, we also calculated and compared sensitivities, specificities, and Youden indices of MUAC cut-offs to diagnose underweight (WAZ≤ 2) and severe underweight (WAZ≤ 3) separately for infants <6 weeks and infants 6 weeks to 6 months because Emergency Nutrition Network suggests different MUAC cutoffs for the above age groups of infants.[26] Kappa coefficients were also calculated to assess the agreement between MUAC and WAZ for diagnosing underweight and severe underweight among to two age groups of infants.

Results

As shown in Table-1, for infants <6 months, 36.8% infants had WAZ≤ 2 while 19.3% infants had WAZ≤3. For infants <6 weeks, 39.1% infants had WAZ≤ 2 while 10.9% infants had WAZ≤ 3. For infants aged 6 weeks to 6 months, 36.5% infants had WAZ≤ 2 while 20.4% infants had WAZ≤ 3.

Table-1: Mothers and Infants Health and Nutritional Characteristics

Infants Nutritional Status		No.	%
Infants <6 Months	WAZ≤ 2 (Underweight)	154	36.8
	WAZ≤ 3 (Severely underweight)	81	19.3
Infants <6 Weeks	WAZ≤ 2 (Underweight)	18	39.1
	WAZ≤ 3 (Severely underweight)	5	10.9
Infants Aged 6 Weeks to 6 Months	WAZ≤ 2 (Underweight)	136	36.5
	WAZ≤ 3 (Severely underweight)	76	20.4

Infants <6 Months

The MUAC cut-offs for underweight and severe underweight were calculated as 11cm (Youden Index of 0.503 with 83.4% sensitivity and 66.9% specificity) and 10.9cm (Youden Index of 0.504 with 76.3% sensitivity and 74.1% specificity), respectively. As Youden indices were more than 50% for identifying underweight and severe underweight, MUAC cutoff of <11cm and <10.9cm can be reliably used to identify infants with underweight and severe underweight respectively (Table-2).

Table-2: Sensitivity, specificity and Youden index of different MUAC cut-offs for Underweight (WAZ≤2) and Severe Underweight (WAZ≤3) for infants <6 months.

	Underweight (WAZ≤2)			Severe Underweight (WAZ≤3)		
Positive if Less Than or Equal To[a]	**Specificity (%)**	**Sensitivity (%)**	**Youden Index**	**Specificity (%)**	**Sensitivity (%)**	**Youden Index**
10.7cm	87.17	57.79	0.450	79.88	67.90	0.478
10.8cm	86.42	61.04	0.475	78.40	70.37	0.488
10.9cm	84.91	64.94	0.498	76.33	74.07	0.504
11.0cm	83.40	66.88	0.503	74.26	74.07	0.483
11.1cm	79.25	69.48	0.487	70.71	77.78	0.488
11.2cm	78.49	69.48	0.480	70.12	77.78	0.479

Infants <6 Weeks: For infants aged <6 weeks, MUAC cut-offs for underweight and severe underweight were 9.9cm (Youden Index of 0.325 with 71.4% sensitivity and 61.1% specificity for underweight and Youden Index of 0.66 with 65.9% sensitivity and 100% specificity. So, MUAC cutoff of <9.9cm can reliably be used to identify severe underweight among infants aged <6 weeks as its Youden index is more than 50% (Table-3).

Table-3: Sensitivity, specificity and Youden index of different MUAC cut-offs for Underweight (WAZ ≤2) and Severe Underweight (WAZ ≤3) for infants <6weeks

	Underweight (WAZ ≤2)			Severe Underweight (WAZ ≤3)		
Positive if Less Than or Equal To[a]	**Specificity (%)**	**Sensitivity (%)**	**Youden Index**	**Specificity (%)**	**Sensitivity (%)**	**Youden Index**
9.5cm	79.6	44.4	0.23	70.7	40.0	0.11
9.7cm	75.0	50.0	0.25	68.3	60.0	0.28
9.8cm	71.4	50.0	0.21	65.9	60.0	0.29
9.9cm	71.4	61.1	0.33	65.9	100.0	0.66
10.0cm	67.9	61.1	0.29	63.4	100.0	0.63
10.1cm	64.3	61.1	0.25	61.0	100.0	0.61
10.2cm	60.7	61.1	0.22	58.5	100.0	0.59

Infants Aged 6 Weeks to 6 Months

For infants aged 6 weeks to 6 months, MUAC cut-offs for underweight and severe underweight were 11cm (Youden Index of 0.54 with 88.6% sensitivity and 65.4% specificity) and 10.9 cm (Youden Index of 0.532 with 80.8% sensitivity and 72.4% specificity) respectively. So, MUAC cutoffs of <11cm and <10.9cm can reliably be used to identify underweight and severe underweight among infants aged 6 weeks to 6 months as their Youden indices are more than 50% (Table-4).

Table-4: Sensitivity, specificity and Youden index of different MUAC cut-offs for Underweight (WAZ≤2) and Severe Underweight (WAZ ≤3) for infants ≥ 6weeks

Positive if Less Than or Equal To[a]	Specificity (%)	Sensitivity (%)	Youden Index	Specificity (%)	Sensitivity (%)	Youden Index
10.6cm	---	---	---	86.5	60.5	0.47
10.7cm	91.6	56.6	0.48	84.2	65.8	0.50
10.8cm	91.1	60.3	0.51	82.8	68.4	0.51
10.9cm	89.5	64.0	0.53	80.8	72.4	0.53
11.0cm	88.6	65.4	0.54	79.5	72.4	0.52
11.1cm	84.8	68.4	0.53	76.1	76.3	0.52
11.2cm	84.0	68.4	0.52	75.4	76.3	0.52
11.3cm	80.6	72.1	0.53	---	---	---

Moreover, the degree of agreement as shown by Kappa coefficients between different MUAC cut-offs identified above to diagnose underweight and severe underweight among infants <6 months were 0.48 and 0.35, respectively though still not excellent. For infants aged <6 weeks, the degree of agreement between WAZ ≤2 and MUAC <=9.9cm was 0.28 and for infants aged 6 weeks to 6 months, the degree of agreement between WAZ ≤2 and MUAC <=9.9cm was 0.27. The above analyses show that level of agreement was highest between WAZ ≤2 and MUAC <=11 cm for infants <6 months (Table 5).

Table-5: Kappa values showing agreement between MUAC with WAZ to diagnose underweight and severe underweight in infants <6 months, infants <6 weeks and infants aged 6 weeks and 6 months.

Infants Age Category	MUAC Cut-offs	Nutritional Status	Kappa Coefficient (K)
Infants <6 Months	MUAC <=11cm	WAZ≤2	0.48
	MUAC <=10.9cm	WAZ≤3	0.35
Infants <6 Months	MUAC <=9.9cm	WAZ≤2	0.28
Infants Aged 6 Weeks to 6 Months	MUAC <=9.9cm	WAZ≤2	0.27

Discussion

The study found that prevalence of underweight (WAZ≤3) was 36.8% and severe underweight (WAZ≤2) was 19.3% in the infants <6 months which are higher than the national average.[5] The study showed moderate correlation and possible clinical role to define underweight and severe underweight among infants <6 months using MUAC among sick babies, who were visiting the hospital. Other studies have also suggested statistically optimal cut-off values ranged from 11.5 to 10.5 cm to assess the burden of infants with severe malnutrition for a treatment programs. [16-17]

Unfortunately, we currently have limited evidence for comparison with our study findings with relevant published data. Unless the evidence base is widened and MUAC as a screening and diagnosing tool for underweight and severe underweight among infants <6 months are rigorously compared with current standards and its advantages and disadvantages are evaluated carefully, questions on its potential usage as an indicator of severe malnutrition among young infants will remain unanswered. However, some of the benefits highlighted above and evidence suggest that MUAC should be included to assess nutritional status of infants <6 month in order to improve efficiency, coverage and effectiveness of identification. It is already recommended by the recently updated MAMI (Management of small & nutritionally At-risk Mothers and Infants) Care Pathway.[26]

Limitations and Future Research

We recognize the limitations of our work. The selection of the present hospital for the study was purposive and hence the sample is not be representative of the entire infant <6 months population. However, as this is a large government-run hospital for children in the country, the study sample represents a wide range of population and the findings can therefore be generalized for the hospital setting. Though looking at the heterogeneity of India's population, a large-scale population-based multicentric study with large sample size needs to be conducted in future to assess the most appropriate MUAC cut-off for identifying underweight and severe underweight among infants <6 months in India. Future research should also explore how MUAC cut-offs predict these longer-term risks and how it is associated with body composition.

Conclusion

In a resource-constraint setting like India with a high burden of cases of severe malnutrition and where measuring weight or calculating z-score may not be feasible, the MUAC cut-off of 11cm could reliably be used to screen underweight and severe underweight in infants <6 months for providing appropriate care in India.

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