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Research Article

Accuracy of new CIMDER tapes and the standard MUAC tape for screening nutritional status in children

Abstract

Background: The mid-upper arm circumference (MUAC) to assess children nutritional status under 5 years of age, has been used since late fifties.

Methods: The study was conducted to assess the accuracy in classifying the nutritional status of children under 5 years of age using the new CIMDER tapes compared to the new standard MUAC tape S0145620, distributed by UNICEF, taking weight-for-age as gold-standard from WHO multicenter study. Results.

Results: The new CIMDER tapes developed for boys and girls in different age groups, yielded better results than the new standard MUAC tape for all accuracy indicators used.

Conclusions: These results warrant that the new CIMDER tapes can be used for screening nutritional status in children under 5 years of age with improved accuracy compared to the standard MUAC tape. New CIMDER tapes also screen for overweight, but the standard MUAC tape does not.

Introduction

The nutritional status of children is defined by anthropometric measurements including age, weight, length, height and mid-upper arm circumference (MUAC). In the late 1950´s, Jellife reported the use of MUAC in community surveys and later in the 1960´s proposed standards for MUAC as an indicator of nutritional status in children under 60 months of age [1]. In 1974, Shakir and Morely proposed a three color cord for measuring MUAC [2], with a cut-off point at 11.0 cms for classifying severe malnutrition (>11.0 cms) and moderate malnutrition between 11.1 and 12.0 cms. Based on this simple tool, CIMDER (Center for *M*ultidisciplinary *R*esearch in Development.) developed two tapes for measuring malnutrition in children from 3 to 72 months old according to age [3,4]. The design was more precise including three colored bands (green for well nourished, yellow for mild malnutrition and red for moderate and severe malnutrition) with a slot as the 0 of the scale and for inserting the plastic tape to wrap around the mid arm. Serfaz also proposed in 1975 an "insertion tape" with the same three colors [5]. In 1986, World Health Organization (WHO) recommended MUAC for screening the nutritional status of children around the world, with a cutoff point of <11.0 cms for severe malnutrition [6]. Both pro and con arguments for their use have been expressed since then. However, WHO developed an important multicenter study to establish worldwide standard values for the nutritional status of children under 60 months of age [7]. This multicenter study indicates how all children should grow worldwide when adequate nutrition is guaranteed together with environmental health conditions and practices. In 2009, WHO and United Nations Children's Fund (UNCEF) endorsed MUAC cutoff point of <11.5 cms (previously <11.0 cms) as an independent admission criterion for the treatment of severe acute malnutrition (SAM) around the world [8].

A consultation of operational agencies and academic specialists concluded among other things, that "Neither MUAC nor weight for height reveal themselves to be ideal predictors of mortality; however, of the two indicators, MUAC appears to show consistently better predictive power. Until now, MUAC is the best anthropometric predictor of mortality currently available" [9-12].

A recent systematic literature review [13], concluded that applying a standard set of criteria (simplicity, acceptability, cost, independence of age, reliability and accuracy) to determine

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which is the most appropriate measure or index, MUAC stands out strongly as the best measure in nutritional surveillance systems to detect short term changes in the nutritional status of a population.

Fiorentino et al., [14], addressed the issue of including gender and age with MUAC measurements, and CIMDER developed two new tapes, one for boys and the other for girls each with specific age groups between 6 and 60 months of age. These new CIMDER tapes were designed taking the WHO reference standards for age and weight and tested for accuracy in 1283 children in urban poor boroughs of Cali, Colombia [15]. The new CIMDER tapes showed high accuracy values when compared to weight for age with WHO child growth standards.

These findings encouraged the proposal of comparing the accuracy of the new CIMDER tapes with the MUAC standard tape (S0145620) for screening the nutritional status in children under 60 months of age.

Methods

The study was designed to compare the accuracy of MUAC measurements with two different instruments: the new CIMDER tapes and new MUAC standard tape* in a population of 2198 children (boys and girls) 3-60 months of age. Previous consent form parents or caregivers, the children were recruited from Growth and Development programs conducted in Cali in a period of 4 months. Basic data collected were: (1) age in months using birth certificate or civil registry; (2) weight in kilograms to the nearest 100gr, using a MB130 digital DETECTO scale transformable into infant scale (with known tare); (3) length in cms using a wood infant meter; height in cms using a Tall A-2000 DETECTO; and (4) MUAC, using the new MUAC standard tape and the new CIMDER tapes.

The new standard MUAC tape: This tape measures the MUAC in children between 6-60 months of age without discriminating boys or girls nor age within 6-60 months. The child nutritional status is *classified using the following cut-off points and colors: <11.5 cms for acute severe malnutrition as red; between 11.5 and 12.5 cms for moderate malnutrition as yellow; and >12.5 cms for well- nourished as green. Overweight is not measured with the new MUAC standard tape. The new standard tape (S0145620) was created for supporting implementation of new WHO child growth standards. (See UNICEF´s 2019, Technical Bulletin N°13. Revision 2).

New CIMDER tapes: The two new CIMDER tapes, one for boys and one for girls, have specific cutoff points for four age groups (3–6; 6.1–18; 18.1–36 and 36.1–60 months) using WHO MUAC Z-scores.[14] The child nutritional status is classified as follows: red for moderate to severe malnutrition; yellow for mild malnutrition; green for well nourished; and grey for overweight.

Training: Two experienced nurses in conducting growth and development programs were trained to reduce measurement errors when collecting age, weight, length, height and MUAC data. The training covered assessment of the child's age using exact date of birth, accurate weighing using a digital scale, precise MUAC measurements and warnings about sources of error in using the tapes. A nurse used only the new MUAC standard tape and the other used the new CIMDER tapes, without knowing the other nurse measurements.

Data collection and quality control. The child's age, weight, length, and height were recorded; next, two independent measurements on the same child (in separate rooms) using new MUAC and new CIMDER tapes were recorded. Nutritional status based on weight-for-age Z-scores was translated to colors later to avoid bias when reading the new MUAC and new CIMDER tapes. A supervisor verified that measurements were being conducted correctly, and checked data for inconsistencies (e.g. classification in the group 3–6 months when the child was 7 months old) [14].

Analysis

The nutritional status with the new MUAC and new CIMDER tapes was classified as follows: red, for scores <-2 standard deviations (SD); yellow, for scores between -2 and -1 SD; green, for scores between -1 and +2 SD; and grey for scores >+2 SD. Statistical analysis was conducted using SAS 9.4 and SPSS 24.0 software. Accuracy analysis included sensitivity, specificity and predictive values (positive and negative), and was expressed as follows: 100-85% 'very good'; 84–70% 'good'; 69–55% moderate and ≥55% 'weak'. Two indexes for interpreting concordance correlation between new MUAC and new CIMDER tapes: Youden index and the Kappa test [16,17].

The concordance strength for Youden and Kappa values was expressed as follows: 0.81–1.00 "very good", 0.61–0.80 "good"; 0.41–0.60 moderate; and ≤0.40 "weak". The receiver operation curve (ROC) was also estimated to compare the probability area under both curves for new CIMDER and new MUAC tapes. The ROC curve has an advantage over the other measures because it integrates sensitivity and specificity into a single measure [18].

Likelihood ratios are an alternative for assessing the performance of a diagnostic instrument. The likelihood ratio indicates how many times more (or less) likely a test result is to be found in people with the attribute compared with people without it [19]. Finally, the accuracy test measures the proportion of true positives plus true negatives over all possible results.

Results

Age and weight were used to assess the global nutritional status according to the WHO Z-score standard in 1133 boys, and 1065 girls, for a total of 2198 children. Results indicate that 6.9% of the children were moderately to severely malnourished (red), 17.4% mildly malnourished (yellow), 63.0% well nourished (green), and 12.7% overweight (grey) (Tables 1-3).

Discussion

Several studies analyzed the appropriateness of MUAC to

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diagnose malnutrition in children less than 5 years old [20,21], Wieringa et al., [22], found that MUAC increases about 1cms for boys and 1.5 for girls between 1 and 5 years and recommend to raise MUAC cut-off with the increase of children´s age. The accuracy of the new CIMDER tapes compared with the new MUAC standard tape is clearly superior as shown by all accuracy measurements in our study (Tables 4,5).

The percentage of red green and grey groups detected with new CIMDER tapes differed slightly from the percentage of WHO Z-score standards. The percentage in yellow detected with new CIMDER tapes was substantially higher than with new MUAC standard tape. Noteworthy, 13% of overweight detected with the WHO Z-score and 8.3% with new CIMDER tapes were higher than the 6.9% and 7.1% in red, that is, there are more overweight than malnourished children among the 2198 study subjects.

The new MUAC standard tape has a very high capacity for detecting boys and girls in the green group, but very low in the other groups. It detected only 1% in red and 2.3% in yellow, compared with the 6.9% and 17.4% respectively using age for weight WHO Z-score standards; the new CIMDER tapes detected 7.1% in red and 24% yellow, closer to the age for weight WHO Z-score standards. These measurements are critical because they include or reject malnourished children for treatment. In the case of well-nourished children, new MUAC standard tape detected 96.7% in green, much higher than the 63% detected

Table 1: Nutritional status of 2198 children by age and sex using WHO Z-score standards for weight, age and sex. Cali, 2018.

Age group (Months)	Red		Yellow		Geen		Grey		Total	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
3-6	16	20	18	14	70	85	17	16	121	135
6.1-18	32	15	45	61	178	179	47	45	302	300
18.1-36	18	22	54	59	202	172	42	31	316	284
36.1-60	14	14	77	56	263	235	40	41	394	346
Subtotal	80	71	194	190	713	671	146	133	1133	1065
Total	151 (6.9%)		384 (17.4%)		1384 (63.0%)		279 (12.7%)		2198	

Table 2: Nutritional status of 2198 children by age and sex using the new CIMDER tapes. Cali, 2018.

Age group (Months)	Red		Yellow		Green		Grey		Total	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
3-6	13	17	17	16	69	90	24	10	123	133
6.1-18	17	12	43	51	203	197	44	35	307	295
18.1-36	18	25	96	91	190	150	17	12	321	278
36.1-60	26	27	123	95	229	200	18	23	396	345
Subtotal	74	81	279	253	691	637	103	80	1147	1051
Total	155 (7.1%)		532 (24.2%)		1328 (60.4%)		183 (8.3%)		2198	

Table 3: Nutritional status of children 2198 by age and sex assessed with new MUAC standard tape. Cali, 2018.

Age group (Months)	Red		Yellow		Green		Total	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
3-6	6	11	13	14	102	110	121	135
6.1-18	1	3	7	12	294	285	302	300
18.1-36	0	0	2	2	312	284	314	286
36.1-60	0	1	0	1	392	346	392	348
Subtotal	7	15	22	29	1100	1025	1129	1069
Total	22 (1.0)		51 (2.3)		2125 (96.7)		2198	

Table 4: Accuracy and concordance of the new CIMDER and UNICEF tapes, for assessing nutritional status among boys.

Age (Months)	Red		Yellow		Green		Gray	
	CIMDER	UNICEF	CIMDER	UNICEF	CIMDER	UNICEF	CIMDER	UNICEF
3-6.								
Sensitivity%	73.3	25	50	55.5	79.4	97.1	84.2	--
Specificity%	99	100.0	93	81.6	76	47.1	90.1	--
Predictive value + %	91.7	100.0	56.3	34.45	81.8	69.3	58.3	--
Predictive value - %	96.2	89.7	91.2	91.3	73.1	64.9	97.8	--
Youden	72.3 24.0	24.0	43	37.2	55.4	34.2	72.5	--
Kappa	79.1 36.6	36.6	45.1	29.6	55.1	35.9	61.9	--
Likelihood Ratio	271.5 32.9	32.9	13.2	5.5	12.3	6.0	41.6	--
ROC	70.0 58.3	58.3	68.8	78.3	75.2	66.45	83.1	--
Accurate test	86.2 62.5	62.5	71,5	68.6	77.7	72.1	87.2	--
6.1-18								
Sensitivity%	31.3	3.1	25.6	11.1	83.5	98.9	60.9	--
Specificity%	97.4	100.0	88.2	91.8	60.3	20.2	93.6	--
Predictive value + %	58.8	100.0	26.8	19.2	75.4	64.0	63.6	--
Predictive value - %	92.1	89.7	87.5	85.5	71.6	92.6	36.4	--
Youden	28.7	0.03	13.8	0.03	43.8	0.19	54.5	--
Kappa	36	5.5	14	3.6	45	0.22	55.5	--
Likelihood Ratio	0.71	0.98	2.6	1.4	0.3	0.05	0.42	--
ROC	52.7	50	59.6	56.7	73.9	55.9	79.5	--
Accurate test	64,4	51.6	56.9	51.5	71.9	59.6	77.3	--
18.1-36								
Sensitivity%	44.4	ND	65.4	5.6	71.5	99.0	33.3	--
Specificity%	93.7	ND	76.5	97.3	63.4	7.0	98.9	--
Predictive value + %	50	ND	35.8	30	77.7	65.1	82.4	--
Predictive value - %	96.6	ND	91.7	83.2	55.5	80.0	90.5	--
Youden	41.7	ND	41.9	0.03	34.9	0.1	32.2	--
Kappa	44	ND	31.5	4.2	33.8	7.5	43	--
Likelihood Ratio	28.8	ND	6.2	2.1	4.3	7.6	45.2	--
ROC	74.3	ND	72	53.7	69.7	53.5	66.5	--
Accurate test	69.1	ND	71	51.5	67.5	53.0	66.1	--
36.1-60								
Sensitivity%	46.2	ND	53.3	1.8	68.3	99.6	38.5	--
Specificity%	94.9	ND	73.9	98.6	63.8	4.5	93.5	--
Predictive value + %	24	ND	32.8	20.2	79.6	68.4	88.2	--
Predictive value - %	98.1	ND	86.9	89.7	49.4	83.3	93.8	--
Youden	28.4	ND	27.2	4	32.1	4.0	37.9	--
Kappa	28.4	ND	22	6	29.9	5.3	50.6	--
Likelihood Ratio	15.9	ND	3.2	1.3	3.4	11.6	103.5	--
ROC	71.7	ND	63.4	50.2	65.5	50.5	71.3	--
Accurate test	70.6	ND	63.6	50.2	66.1	52.1	66	--

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with the WHO-Z score standards. New CIMDER tapes detected 60.4% in green, close to the 63.0% detected wit weight for age WHO Z-score standards. Again, this measurement is critical because with the new MUAC standard tape it might contain many false negatives, that is, children classified as well-nourished when they have mild malnutrition. Another weakness, given the current epidemiological world situation, is that the new MUAC standard tape does not have a cut-off for detecting overweight among children (grey) whereas new CIMDER tapes detected 8.3% overweight compared with 13% detected with the WHO Z-scores standard.

Among boys, indicators for the new CIMDER tapes behave better than the new MUAC tape in all age groups, as shown by concordance indicators Youden, Kappa, Likelihood ratio, accuracy ROC and Accurate test, except for ROC in yellow for group 3-6 months of age. Data for red with New MUAC standard tape in all age groups was not considered in estimating accuracy because it is well known that when the estimate is based on less than 10 observations, the true sensitivity, specificity, and predictive value, both positive and negative, could be as low as 45% and as high as nearly 100%, by chance alone. Overall, the results indicate that accuracy in measuring nutritional status of boys less than 5 years of age with the new CIMDER tapes, is higher than the new MUAC standard tape (Table 4).

Among girls, the new CIMDER tapes also behave better than UNICEF tapes in all age groups, and on indicators such as Youden, Kappa, accuracy Likelihood, ROC and Accurate test. Again, UNICEF data in red for all age groups should be considered with caution because cells with less than 10 observations use to yield imprecise results. These results indicate that assessment of nutritional status of girls less than 5 years of age with the new CIMDER tapes, overall, is better than the UNICEF tape. The good accuracy and concordance scores suggest that CIMDER tape is a reliable instrument for classifying the nutritional status of girls aged less than 5 years (Table 5).

Several errors have been identified in obtaining accurate nutritional status when plotting age and weight data and interpreting the growth charts. Also, interpretation of growth charts can be difficult even for some graduate health professionals [23] and 'road to health' charts are not appropriate tools for educating parents or caregivers of children. Furthermore, measurements involving height and weight may not offer any additional benefit over MUAC when used for screening childhood malnutrition and identifying risk of death in malnourished children [24,25].

This study has a weakness due to the small numbers of boys and girls in the group 'severely/moderately malnourished' that may threat the accuracy of the new MUAC and CIMDER tapes for this group. Constraints of time and place hindered finding enough numbers of moderately to severely malnourished children. However, we put special attention in estimating sensitivity and specificity independently of how the true diagnosis was assessed to avoid introducing bias on measurements; also, bias was reduced by having the two nurses making independent measurements unaware of the child nutritional status based on WHO Z-score standards and being blind about the other.

Table 5: Accuracy and concordance of the new CIMDER and UNICEF tapes, for assessing nutritional status among girls.

Age (Months)	Red		Yellow		Green		Gray	
	CIMDER	UNICEF	CIMDER	UNICEF	CIMDER	UNICEF	CIMDER	UNICEF
3-6.								
Sensitivity%	73.7	30.0	28.6	28.6	87.8	84.7	53.3	--
Specificity%	97.3	100.0	90.5	79.00	66.7	52.0	98.3	--
Predictive value + %	82.4	100.0	26.7	12.1	81.8	75.0	80	--
Predictive value - %	95.6	89.1	91.3	90.2	76.2	66.7	94.2	--
Youden	71	30	19.1	4.6	54.5	36.7	51.6	--
Kappa	74.2	42.2	18.5	2.9	55.9	38.4	60.3	--
Likelihood Ratio	101.1	42.3	3.8	1.3	14.4	6.0	65.4	--
ROC	80	87.5	54.4	59.6	76.1	60.1	82.6	--
Accurate test	85.5	65.4	59.6	52.3	77.3	68.4	75.8	--
6.1-18								
Sensitivity%	30.8	6.7	43.3	23.00	84.5	96.1	51.2	--
Specificity%	97.1	100.0	89.6	93.3	58.6	19.8	95.5	--
Predictive value + %	33.3	100.0	52	46.7	75.4	63.9	66.7	--
Predictive value - %	96.8	95.3	85.8	82.6	71.6	77.4	91.8	--
Youden	27.9	5.7	33.9	16.3	43.1	15.9	46.7	--
Kappa	28.9	11.9	35.1	20.1	44.4	18.1	51.7	--
Likelihood Ratio	22.3	7.1	6.9	4.1	7.7	6.0	22.4	--
ROC	62	50	71.8	63.1	73.6	60.0	74	--
Accurate test	64	53.4	66.5	58.2	71.6	58.0	73.4	--
18.1-36								
Sensitivity%	55.4	ND	70.2	15.3	71.3	15.3	5.5	--
Specificity%	94.9	ND	77.3	95.6	71.8	17.0	99.6	--
Predictive value + %	48	ND	44.4	47.4	79.3	65.2	91.7	--
Predictive value - %	96	ND	90.9	81.3	62.2	100.0	92.5	--
Youden	49.4	ND	47.5	10.9	43.1	0.7	35.1	--
Kappa	46.5	ND	39.1	14.5	42	19.9	47.9	--
Likelihood Ratio	22.3	ND	7.9	3.9	6.3	1.7	136.6	--
ROC	65	ND	76.6	59.00	75	58.6	70.8	--
Accurate test	75.2	ND	73.8	55.5	71.6	16.2	52.6	--
36.1-60								
Sensitivity%	69.2	7.1	58.9	1.8	71.2	99.6	52.5	--
Specificity%	94.5	100.0	78.7	98.6	70.6	4.5	99.3	--
Predictive value + %	33.3	100.0	35.1	20.0	83.8	68.4	91.3	--
Predictive value - %	98.7	96	90.7	83.7	53.5	83.3	94	--
Youden	63.7	5.7	37.6	0.4	41.8	4.0	51.8	--
Kappa	34.2	12	29.5	0.6	38.6	5.3	63.6	--
Likelihood Ratio	38.1	7.1	5.3	1.3	5.9	11.65	156.3	--
ROC	73	55.6	71.1	51.2	70.3	51.2	69	--
Accurate test	81.9	53.6	68.8	50.2	70.9	52.1	75.6	--

Conclusion

All indicators used in this study showed a better performance of the new CIMDER tapes compared to the New MUAC tape. Particularly, the new MUAC standard tape detects many false negatives in red, that is, moderate and severe malnourished children that will not receive treatment. In addition, the new CIMDER tapes accurately discriminate the undernourished and overweight children, both, a worldwide growing public health problem.

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There is also a need for instruments that can be simple, reliable and easy to use by nonprofessional personnel such as health auxiliaries and promoters, community health volunteers and eventually, by parents. Parental use of the new CIMDER tapes can enable them to continuously track their children physical development at home to a great advantage especially in disperse rural areas, as frequent measurements might encourage parental action to improve their feeding practices in order to move or maintain their children in the 'green group'. Moving the primary responsibility for monitoring the children nutritional status to parents is a way of democratizing knowledge and making real the community participation on public health programs.

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Conflict of interest

One of the authors who designed and tested the CIMDER tapes before (Echeverri O, 2016), did not participate in field operations nor statistical procedures to avoid bias on data gathering and processing.

Ethical issues

The protocol was approved, in accordance with the Declaration of Helsinki, by the Ethics and Research Committee of the ESE Tomas Uribe Uribe Hospital. Tuluá, Valle del Cauca, Colombia.

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