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Accuracy of using mid-upper arm circumference to detect severe malnutrition among children under five years at H. Adam Malik General Hospital

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ABSTRACT

Severe malnutrition in children under 5 years is a global health problem due to higher morbidity and mortality. Mid-upper arm circumference (MUAC) and weight-for-height z-score (WHZ) were assessed to detect severe malnutrition. We compared WHZ and MUAC cut off to identify waste among children under 5 years, and WHZ was the gold standard. A cross-sectional study was conducted on pediatric inpatients and outpatients. A total of 99 children ages 6-59 months were recruited. A trained doctor performed anthropometric measurements. Statistical analysis was done by SPSS; results with p values <0,05 is significant. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV), Likelihood Ratio (LR) were determined by 2x2 tables. We also used the *receiver operator curve* (ROC). The mean age of subjects was 2.0 years. The majority of subjects were born by section Caesarea (78,8%). Subjects were diagnosed with cardiovascular disease (29,3%), infection (20,2%), endocrine disturbance (18,2%), operative (9,1%), and other (6,1%). The prevalence of severe malnutrition based on MUAC <11.5 cm was 49,5% and 34.3% based on WHZ <−3. While moderate malnutrition based on MUAC 11.5 – 12.5 cm was 27,3% and 24.4% based on WHZ (-2) – (-3) SD. Sensitivity, specificity, PPV, NPV, LR (+), LR (-) of MUAC <11,5 cm were 59%, 90%, 85%, 69%, respectively. The total area of the ROC curve was 0.765 with accuracy 74%. The MUAC compared to WHZ has good accuracy to identify severe malnutrition in children under five years. A higher cut-off could improve case identification.

1. Introduction

Malnutrition in children aged <5 years is a global health problem that affects 50.5 million children worldwide in 2017. In Asia, the prevalence of malnutrition in children aged <5 years is 35 million children, 5.2 million of whom come from countries in Southeast Asia [1]. Meanwhile, the prevalence of children aged <5 years suffering from severe malnutrition worldwide is 16.4 million and in Southeast Asia there are 2.5 million children. According to the 2018 Basic Health Research Minister of Health, the proportion of malnutrition in children aged <5 years in Indonesia is 13.8%, of which 31.9% is severe malnutrition [2]. Severe malnutrition is one of the main causes of morbidity and mortality in children aged <5 years in developing countries [3]. Data from the World Health Organization (WHO) states that severe malnutrition causes an increase in death in one in ten children aged <5 years [1]. Children with severe malnutrition will become less productive physically and intellectually in adulthood. This can occur due to disturbances in the morphological and functional development of the central nervous system, thus affecting the cognitive and emotional development of children. Morbidity and mortality in children with severe malnutrition can also occur due to susceptibility to infection and due to various basic diseases. Therefore, an accurate diagnosis of severe malnutrition in children is necessary [4].

The diagnosis of severe malnutrition in children is confirmed by anthropometric examination, that is, if the weight/length-height is <-3 standard deviations (SD) based on the WHO child growth standard curve [5]. Recording and measuring of body weight and length/height and the process of interpreting status nutrition experience various challenges in health services, especially in developing countries. Several guidelines recommend using the mid-upper arm circumference (MUAC) in diagnosing severe malnutrition. The MUAC measurement has advantages because the procedure is simpler, the equipment is minimal, and it is inexpensive. However, the accuracy of this method in diagnosing severe malnutrition in children is still being debated [6]. The use of the cut-off MUAC size in diagnosing severe malnutrition in children aged 6 – 60 months according to WHO is <11.5 cm while in moderate malnutrition it is 11.5 – 12.5 cm. Mid-upper arm circumference size is an indicator to establish severe malnutrition in children when subcutaneous fat and muscle mass decrease. A study in Bangladesh suggested that the MUAC cut off for body weight/length-height <-3 standard deviations based on the WHO curve was <12 cm and for body weight/length-height <-2 standard deviations based on the WHO curve was <12.5 cm. in children aged 6 – 24 months, <12.5 cm and <13.5 cm in children aged 25 – 36 months, and <13.5 cm and <14.0 cm for children aged 37 – 60 months [7]. The cut-off size of MUAC will vary according to population because related to body fat percentage and also health risks in a population [8]. Therefore, researchers conducted a study on the accuracy of MUAC measurements compared to body weight/length-height based on the WHO curve in assessing severe malnutrition in children aged 6 – 60 months in Indonesia. This study was conducted at the H. Adam Malik General Hospital in Medan, North of Sumatera, Indonesia.

2. Method

This is a analytical analyses with cross sectional design to determine the accuracy of mid-arm circumference measurements compared to body weight/length-height based on the WHO Z-score curve in assessing severe malnutrition in children aged 6-60 months at H. Adam Malik General Central Hospital Medan. This study was conducted in the pediatric outpatient and inpatient units and the data collection was carried out from June – August 2022. As many as 99 of the 132 total children included met the inclusion and exclusion criteria. Children aged 6 – 60 months who are enrolled in outpatient and inpatient child care units, parents are willing to become respondents by signing the consent form as inclusion criteria. Children with spinal deformities, such as: lordosis, kyphosis, scoliosis, spondylosis; children with signs of fluid retention, such as: edema; children with enlarged organs, such as: hepatomegaly, splenomegaly; and children with bone malignancy were excluded from this study.

2.1 Procedure

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This study was carried out after obtaining approval from the Research Ethics Committee of Universitas Sumatera Utara. Subject search was carried out through patient lists in outpatient units and pediatric inpatient rooms. Data collection was carried out through interviews with the subject's family to obtain data on the subject's characteristics including gender, age of children, number of siblings, birth weight, and mother's age. Body weight was measured using a pre-measured weight scale. The subject is wearing minimal clothing without any weight. The scale shows the number 0. The child is asked to stand in the middle of the scale with his head straight ahead barefoot. If the child cannot stand yet, then the measurement is taken in a sitting position and ensures that the child's entire body is on the scales. Weighing was carried out twice and then the average results were sought.

Children under 2 years are measured for body length in a lying position. Measurements were carried out by two people, namely a measurer and an assistant in a state of pronation with the Frankfurt position. The measuring board is placed horizontally on a flat surface. Hats, socks, shoes and other accessories must be removed. With the help of an assistant, the child's back is affixed evenly to the measuring board with the head located on the end of the part for the head that is fixed, then the assistant places his hands on both the child's ears to make sure the child's head is well attached to the end of the board for the head. The child's eyes are facing forward with the line of sight and the Frankfurt plane forming a 90 degree angle with the surface of the board. Measurements were made with an accuracy of 0.1 cm. Measurements were made twice and then the average was taken from both. Children over 2 years of age are measured with a microtoise placed on a vertical surface such as a wall with a flat floor. Measurements are taken with the child standing upright against the wall with a forward view. The head, back and heels pressed tightly against the wall. Measurements were made twice and then the average was taken from both. Measurement of mid upper arm circumference (MUAC) was carried out using a tape measure with an accuracy of 0.1 cm. The child should stand upright with arms relaxed at their sides. Measurement is taken at the midpoint of the upper arm, midway between the lateral ends of the acromion and olecranon with the hand in a flexed position at a 90° angle. A measuring tape that is flexible and does not stretch is placed perpendicular to the long axis of the arm, tightly wrapped around the arm, and recorded. The measurement was carried out twice and then the average was taken for each respondent.

2.2 Data processing and analysis

Data obtained from all examinations (interviews, physical examinations, and anthropometric examinations) were collected, then data processing was carried out which included editing, coding entry, and cleaning data using a computer. Editing is an activity of checking research variable data whether it is complete, clear, relevant, and consistent. Editing is done manually where the processing includes checking all research forms. Coding is an activity to convert data in the form of letters into data in the form of numbers to facilitate data analysis and speed up data entry. Data entry is data processing that is done by entering data so that it is easy to analyze. Cleaning is an activity that re-checks the data entered whether there are errors or not to ensure the data is clean from errors for analysis.

Data analysis was performed using the Statistical Package for Social Science (SPSS) version 20.0. The characteristics of research subjects with nominal and ordinal scales were analyzed descriptively and presented in the form of n (%). Ratio scale data were analyzed descriptively to find out the mean and standard deviation (SD). Then analyzed with the Kolmogorov Smirnov test to determine whether the data is normally distributed or not, and presented in the form of mean ± SD if normally distributed ($p \geq 0.05$). However, if not, it is presented in median (minimum-maximum) form. The diagnostic test was performed by calculating the sensitivity and specificity of the mid-upper arm circumference to the body weight/height Z score on the WHO curve. Receiver operator curve (ROC) is determined based on the intersection point between sensitivity and specificity. Calculations of positive predictive value (PPV), negative (NPV), and likelihood ratio (LR) were also performed.

3. Results

A total of 132 children aged 6-60 months were given an explanation about the research and then their parents asked for consent to become research subjects. There were 10 children who were not willing to be research subjects. Then the subjects were analyzed based on inclusion and exclusion criteria. There were 11 subjects with incomplete data, 7 subjects with edema, and 5 subjects with organ enlargement. Male subjects 57.6%. The mean age of the study subjects was 2.0 ± 1.2 years with the majority of children (60.6%) being in the age range of 6-24 months. The mean age of the mother during pregnancy was 27.3 years, with the youngest being 19 years and the oldest being 40 years. The characteristics showed in table 1.

Table 1. Subjects Characteristics

Characteristics	n = 99
Sex, n (%)	
Male	57 (57,6)
Female	42 (42,4)
Age (Years), Mean± SD	2.0 ± 1,2
Category of age, n (%)	
6-24 months	61 (61,6)
>24 months	38 (38,4)
Mothers age (Years), Mean± SD	27,3 ± 4,1
Numbers of Siblings, Mean± SD	2,6 ± 1,0
The history of labor, n (%)	
Spontaneous	21 (21,2)
Sectio Caessaria	78 (78.8)
Birth Weight (gr), Mean± SD	2,8 (0,5)
≥2500 g	80 (80,8)
<2500 g	19 (19,2)
Diagnose, n (%)	
Cardiovascular	29 (29,3)
Neurology	17 (17,2)
Infection	20 (20,2)
Surgery	9 (9,1)
Endocrine	18 (18,2)
Others	6 (6,1)

Anthropometry performed was body weight, height, body mass index, and mid-upper arm circumference and its result showed in table 2.

Table 2. Anthropometric Measurements

Anthropometry	n = 99
Weigt (kg), Mean± SD	8,0 ± 2,8
Height/Length (cm), Mean± SD	77,4 ± 13,0
Nutritional status based on WHO weight/length-height curve Z score, n (%)	
Severe Malnutrition	49 (49,5)
Moderate Malnutrition	27 (27,3)
Well Nourished	23 (23,2)
Mid-upper arm circumference	11,6 ± 1,2
Nutritional status based on Mid-upper arm circumference, n (%)	
Severe Malnutrition	34 (34,3)
Moderate Malnutrition	42 (42,4)
Well Nourished	23 (23,2)

In this study, researchers tested the diagnostic value of mid-upper arm circumference examination to diagnose malnutrition in children aged 6 – 59 months in table 2x2 that shown in table 3. Next, an analysis was performed using the ROC shown in Figure 1. The area under curve (AUC) value obtained was 76.5% with a 95% confidence interval, namely 66.9%-86.1%, and p<0.01.

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Table 3. Table 2x2 Diagnostic test

Nutritional Status Based on MUAC	Nutritional Status Based on WHZ Severe Malnutrition (+)	Severe Malnutrition (-)	Sens	Spes	PPV	NPV	LR (+)	LR (-)	Accuracy
Severe malnutrition (+)	29	5	59%	90%	85%	69%	5,9	0,45	74%
Severe malnutrition (-)	20	45							

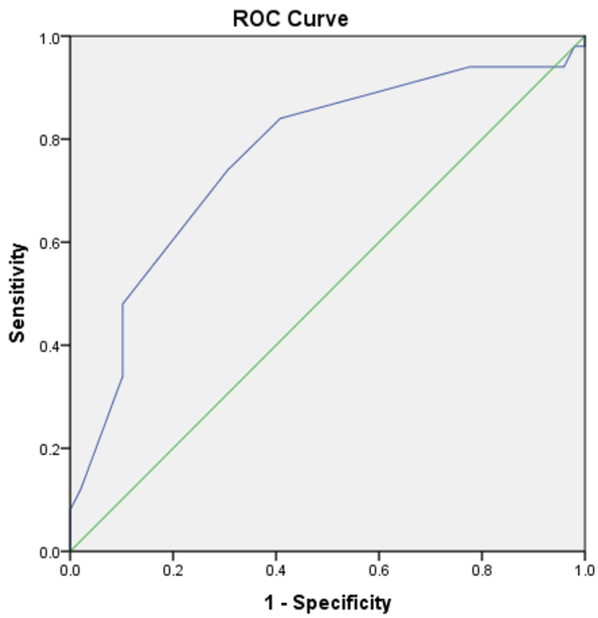

Figure 1. ROC Curve

4. Discussion

The results of this study indicate the accuracy of the mid-upper arm circumference measure in assessing severe malnutrition in children aged 6 – 60 months. Most of the subjects of this study were male. This is in line with research by [8] in India which was conducted in government hospitals where the proportion of male subjects was reported at 54.8%. Meanwhile, according to a community study in Ethiopia, it was also reported that the largest proportion of male subjects was 53.7 % [9]. Research on children aged 6-59 months in Indonesia also reported a greater proportion of male subjects [10]. The mean age was 2 years where more than half of the subjects were in the age range of 6 – 24 months. Another study in 17 regions in Nepal reported different results, where the highest proportion of severe malnutrition was in the age range 24-59 months 54.2% [11]. The number of siblings is significantly associated with the risk of severe malnutrition where according to research conducted in South Asia, children those with 2 sisters had a higher risk of malnutrition than single children (adjusted odds ratio [adj OR]=1.36, 95% CI=1.07, 1.73) [12].

According to the Indonesian Ministry of Health, the mean age of the mother during pregnancy was 15-49 years. In this study, the lowest maternal age was 19 years and the largest was 40 years. Most (78.8%) of the subjects of this study were born via SC surgery. SC surgery is associated with fetal distress, delayed labor, history of previous operations, amniotic fluid disorders, hypertensive disorders, malpresentations, and various other diseases during pregnancy [13]. Various abnormalities during pregnancy can interfere with fetal growth and inhibit it, causing low birth weight. Children with low birth weight (<2500 g) have a greater risk of experiencing malnutrition (OR 1.35, 95% CI 1.2 – 1.38) [14].

Severe malnutrition can occur due to lack of food intake or increased daily nutritional needs [15]. This is associated with comorbid diseases. Subjects in this study suffered from congenital heart disease / CHD (29.3%), infections (20.2%), hormonal disorders (18.2%), and neurological disorders (17.2%). A study in Uganda reported a 6-fold increase in the risk of malnutrition in children aged 0-5 years with CHD, associated with the incidence of heart failure and anemia [16]. Changes in left-right shunt cause right heart failure and increase in systemic venous pressure resulting in edema of the mucosal surface of the wall. intestine thereby interfering with nutrient absorption and lymphatic flow [17]. Other factors that cause malnutrition in children with CHD are shortness of breath, fatigue, and respiratory tract infections in heart failure patients.35 Children with severe malnutrition generally experience anemia associated with bone marrow hypoplasia, deficiency of iron, vitamin B12, vitamin A and folic acid [18].

Management of heart failure in CHD such as fluid restriction can reduce intake and diuretics can cause metabolic alkalosis resulting in anorexia and hypokalemia which inhibit protein anabolism [17]. Severe malnutrition is usually found in CHD patients before undergoing surgical correction with a prevalence of 24.8% (95% CI, 19.3-31.3) according to a meta-analysis of 39 studies [19]. Delayed surgery for heart defect correction is associated with severe malnutrition and patients will experience catch-up after undergoing heart defect correction surgery [16]. The prevalence of severe malnutrition in acyanotic and cyanotic CHD children is 67.5% and 50% (p=0.039). Acyanotic lesions are associated with acute malnutrition, namely severe malnutrition, while cyanotic lesions are associated with chronic malnutrition, namely stunting [19]. The presence of an infectious disease increases the risk of severe malnutrition (OR 6.00) in children aged 24-60 months, especially in rural communities [20]. Conversely, children with severe malnutrition can increase the incidence, severity and death from infection because it can cause dysbiosis and colonization. pathogens as precursors of infection [21]. In addition, severe malnutrition can cause enteric dysfunction in the form of malabsorption, dysregulation of nutrition and metabolism, inflammation and bacterial translocation associated with infection [20].

A study in Turkey reported a proportion of severe malnutrition of 17.1% where most severely malnourished children had a diagnosis of cerebral palsy (CP), short stature, suboptimal positioning, oromotor dysfunction, and emotional stress in caregivers who feed them [22]. Severe malnutrition in children with CP increases the risk of comorbidities (relative risk [RR] 2.4 95% CI 1.7 – 3.4) which is associated with incidence of pneumonia, pressure ulcers, and pathological bone fractures [23]. Nutritional support resulted in a reduction in the presentation of severely malnourished patients and a significant improvement in the WHO weight/length-height curve score [24]. The prevalence of malnutrition based on the WHO weight/length-height curve is greater than that based on the MUAC measurement in several studies. A study in Nepal reported that the prevalence of severe malnutrition was 2.1% and 0.4%, respectively, while moderate malnutrition was 8.5% and 2.7% in children aged 6-59 months [11]. A study in India reported the prevalence malnutrition based on the WHO weight/length-height curve was 19.7% and based on the MUAC measurement 14.3% in rural areas, while 18.9% and 14.4% in urban areas [25]. A study in Ethiopia reported the prevalence of malnutrition based on the WHO weight/length-height curve 11.0% and based on the MUAC size 11.2%%, while based on the two methods it was 61.2% [9]. The study in Indonesia on 30 posyandu, reported a prevalence of severe malnutrition of 2.8 % and moderate malnutrition of 8.3% in children aged 6-59 months based on the WHO weight/length-height curve [10].

Several cases of severe malnutrition were detected by both methods based on the WHO BB/PB-TB curve and the MUAC measure [6]. A study in Bangladesh reported 1,996 moderately malnourished children, detected by the WHO curve (63.5%), MUAC (15.1%), both (21.4%), and 353 severe malnutrition, detected by WHO curve (65.4%), MUAC (19.3%), both (15.3%) [26]. Multi-ethnic study in Sudan, Philippines, Chad, and Bangladesh reported moderate malnutrition prevalence of 23.1%, of which 28.5% were detected

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with a MUAC size <12.5 cm and a WHO weight/length-height Z curve score <-2 SD [27]. Severe malnutrition in children occurs due to an imbalance in calories which can be caused by a lack of food intake and/or an increase in daily nutritional needs [15]. This will stimulate expenditure of the body's calorie reserves thereby reducing muscle mass and fat mass which can be assessed from the MUAC measure [28]. Guidelines WHO provides a MUAC limit of <11.5 cm and a MUAC curve of body weight/length-height <-3 SD for severe malnutrition, while 11.5 – 12.5 cm and -2 – (-3) SD for underweight [29]. This study concluded that a MUAC measurement <11.5 cm could indicate 59% of subjects who were severely malnourished based on the WHO BB/PB-TB curve, while an ALL size >11.5 cm could indicate 90% of subjects who were not severely malnourished based on WHO weight/length-height curve. If a person has a MUAC size <11.5 cm then that person has an 85% chance of suffering from severe malnutrition, while if a MUAC size is >11.5 cm it shows a 69% chance that someone is not suffering from severe malnutrition.

In addition, this study found that it was 0.45 times more likely that a MUAC size <11.5 cm would occur in a population that was severely malnourished than in a population that was not malnourished, whereas it was 5.9 times more likely that a MUAC size >11.5 cm would occur in population is severely malnourished compared to a population that is not suffering from severe malnutrition. The AUC value obtained by the ROC method is 76.5%, classified as moderate. This value indicates that if the MUAC examination is carried out on 100 patients, then this examination will provide the correct conclusion in determining the presence or absence of severe malnutrition in 76 patients. A study in Nepal reported that the sensitivity and specificity of the MUAC measure compared to the WHO curve of body weight/length-height for severe malnutrition was 13.6% and 99.7% with an AUC of 0.53, while for moderate malnutrition it was 21.0% and 91.2% with an AUC of 0.56 [11]. Another study in Indonesia reported a sensitivity, specificity, PPV and NPV of the MUAC measure of 16.7%, 99.6%, 57%, and 97.6% compared to the WHO weight/length-height curve body [10]. A community study in India reported the sensitivity and specificity of the MUAC measure in the diagnosis of severe malnutrition of 13.6% and 99.3% while moderate malnutrition was 23.7% and 97.5% [30].

The accuracy of the MUAC measure varies in different age groups. A study in Pakistan reported the highest sensitivity of the MUAC size <11.5 cm in the age group 12-24 months, while the highest specificity was in the group 6-12 months [31]. In children aged 6-24 months, the sensitivity of the MUAC size for moderate malnutrition was greater. than severe malnutrition 79% and 57%, while the specificity is lower, namely 84% and 97% [32]. The sensitivity and specificity values of the MUAC size <11.5 cm in various age groups are 66% and 92% (6-12), 88 % and 79% (12 – 24), 79% and 80% (24 – 48), and 10% and 81% (48 – 60) [48]. The mid-upper arm circumference measurement can be used as a simpler, more effective, and more efficient test in detecting severe malnutrition.6 However, the sensitivity value of the MUAC measure based on the WHO guideline cut-off is quite low in several studies [10], [11], [30]. Therefore, it is necessary to recommend a MUAC size cut-off with the best sensitivity and specificity values that can be applied. According to a study of 3,169 children aged 6-60 months in 77 districts in Nepal, the best MUAC size limits for severe malnutrition and moderate malnutrition were 12.5 cm and 13.2 cm [11]. The study was conducted in 30 posyandu, Central Java get the best limit of ALL size for screening for malnutrition in the community is 14 cm to get the sensitivity, specificity, PPV, and NPV 95.8%, 80.3%, 12.4%, and 99.9% [10].

MUAC measurements in Indonesian posyandu are usually assisted voluntarily by trained community members, usually called cadres. One study reported that there was a significant difference between MUAC measurements examined by cadres compared to those carried out by trained health workers [10]. Therefore, even though it can be done simply, periodic training in anthropometric measurements, especially MUAC measurements, is needed to detect early occurrence of malnutrition. burden on the child so that appropriate efforts can be made immediately. This study was conducted in a tertiary teaching hospital with a different type of diagnosis so that it has a wide variety of subjects. This study also has advantages in data collection, because anthropometric data is carried out by educated and trained medical personnel. Subject diagnoses varied and were taken from outpatients and inpatients. The research limitation lies in the small number of subjects due to limited time. The research also did not examine the relationship of other factors that might cause severe malnutrition such as food intake and family socioeconomic conditions.

5. Conclusion

The MUAC compared to WHZ has good accuracy to identify severe malnutrition in children under five years. A higher cut-off could improve case identification.

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