

## Special Article - Malnutrition

# Detecting Severe Acute Malnutrition in Children under Five at Scale: The Challenges of Anthropometry to Reach the Missed Millions

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**Objective:** Severe Acute Malnutrition (SAM) interventions aim to detect and treat children at highest risk of death who benefit most from treatment. SAM services reach less than 20% of affected children worldwide, and innovative policy changes are needed to scale up services. This paper discusses anthropometry to diagnose SAM as one pathway to improve the effectiveness coverage of SAM services.

**Results:** WHO defines SAM by either MUAC <115 mm or WHZ <-3 or the presence of nutritional oedema. Both MUAC and WHZ are proxy indicators of a clinical condition, and neither is a gold standard. Because they measure different characteristics of the same illness, MUAC and WHZ identify different SAM populations that overlap differently in different contexts across and within countries. MUAC is a better predictor of mortality and has the practical advantages of simplicity, reliability and accuracy. Using both indicators independently identifies more children and loses sensitivity to risk of death.

**Discussion and Conclusion:** Based on current evidence and operational and policy considerations, using MUAC only for diagnosing SAM with a country-adapted cut-off could feasibly scale up SAM services and improve coverage to reach the millions of missed children. Meanwhile, continued research on the biomedical consequences and policy implications of this approach, as well as innovations such as system dynamics modeling, may contribute to the evidence.

**Keywords:** Anthropometry; Mid-upper arm circumference; Severe acute malnutrition; Weight-for-height z-score; Child malnutrition; Nutrition disorders; Child

**Abbreviations**

MUAC: Mid-Upper Arm Circumference; SAM: Severe Acute Malnutrition; UNICEF: United Nations Children's Fund; WHZ: Weight-For-Height Z-Score; WHO: World Health Organization.

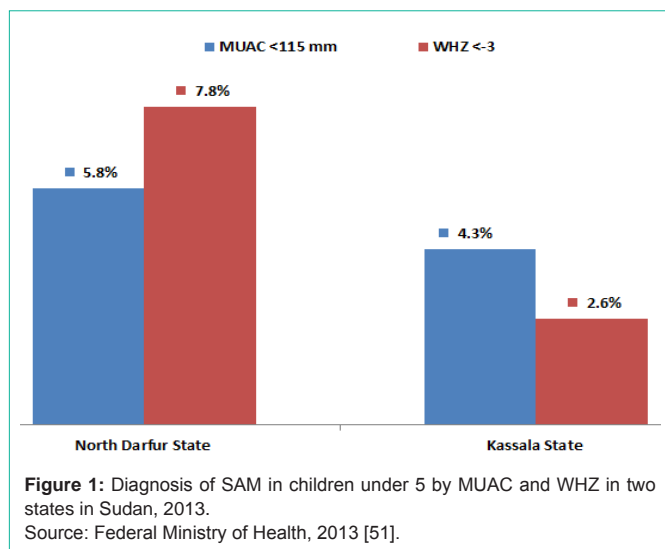
**Introduction**

Worldwide, Severe Acute Malnutrition (SAM) affects about 16 million children under 5 at any time [1] and kills over half a million annually [2]. SAM is a serious illness caused by inadequate food intake or absorption or by infection. SAM alters metabolism, weakening the immune system and making children more susceptible to illness and nine times more likely to die than well-nourished children [3]. Until 2000, few children with SAM were treated, in routine hospital care or temporary emergency centers often far from their homes. The advent of ready-to-use therapeutic food in the 1990s allowed treatment of uncomplicated SAM in decentralized primary care and made scale-up possible [4]. The global annual SAM treatment caseload grew from a few thousand in 2000 to over 3 million in 2014 in about 80 countries [5], but less than 20% of SAM children received care [5]. Scale-up has slowed, and accelerated change is required. One way to reach the millions of missed children with SAM more efficiently is to improve early detection of children at highest risk of death. This paper

discusses the challenges of anthropometry in diagnosing SAM as one pathway to improve the effectiveness coverage of SAM services. The authors examined published literature, policies and practices on the use of Mid-Upper Arm Circumference (MUAC) and/or Weight-for-Height Z-Score (WHZ) to detect SAM for treatment.

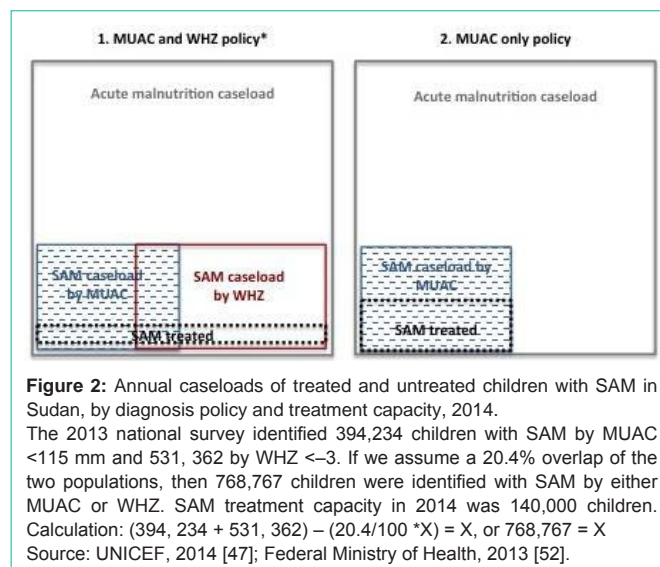
**Detecting sAM for treatment**

The World Health Organization (WHO) defines SAM as MUAC less than (<) 115 mm or WHZ < minus 3 standard deviations of the median value of the 2006 WHO Child Growth Standards or the presence of bilateral pitting (nutritional) oedema [6]. Both MUAC and WHZ are proxy indicators of the clinical condition of SAM and are more practical in resource-poor environments than biomarkers such as hormonal and metabolic changes, but neither is a gold standard. Late detection of SAM or presentation for treatment increases the risk of medical complications requiring intensive inpatient care [7]. Early detection prevents development of complications and allows early start of treatment in primary healthcare, making treatment cheaper [7] and easier to scale up and integrate [8]. This improves health outcomes and maximizes effectiveness coverage (the proportion of children with SAM who recovered after treatment, the key outcome indicator of effective care) [9].



MUAC detects loss of subcutaneous fat and muscle mass in wasted children [10,11]. MUAC tapes are inexpensive, portable and easy to use with training and supervision [6]. Measurement requires placing the tape correctly and reading and recording measurements accurately. MUAC is influenced by age, sex and body composition of lean mass. MUAC <115mm in children 6-59 months detects younger children (with smaller arms than older children) and more girls (with smaller arms than boys) [11]. Child populations with more central fat, e.g., thin-fat phenotypes in South Asia, have lower MUAC readings than those with more peripheral fat [12] indicating MUAC's sensitivity to fat distribution. Though using a single MUAC cut-off for all children 6-59 months has been questioned, as MUAC is age and gender dependent [13,14], using MUAC-for-age or MUAC-for-height did not improve predictive value of mortality [11,15].

WHZ is a composite indicator of weight relative to length (for children under 2) or height (for children over 2). Expressed in standard deviations, it describes how far and in what direction a child's weight deviates from the median weight of a child of the same length or height in the WHO Child Growth Standards. WHZ requires good training and regular supervision and involves weighing and measuring length or height using scales and length/height boards that are not easily available and must be functional and calibrated for accuracy. In practice, children are rarely weighed naked, and measurements are often imprecise because the moving piece of the measuring board is incorrectly placed. WHZ also involves finding the intersection of height and weight on separate reference tables for boys and girls with either upper limits or ranges of cutoffs [16] and classifying nutritional status by z-scores. Because WHZ is more likely to identify boys than girls with SAM (the WHO SAM cutoff for girls at any given height is at a lower weight than for boys [17], so girls must have lower weight to be eligible for treatment) some researchers and policy makers recommended a unisex table based on the tables for boys to avoid discriminating against girls [18]. As WHZ compares ponderal growth with linear growth, child populations with larger heads, chests and abdomens and greater central body fat distribution [19], stunted growth or shorter legs generally have higher WHZ (or lower prevalence of wasting) [20,21]. Longer legs typically translate into lower WHZ (or higher prevalence of wasting), though linear growth reflects good health [22].



Since the first publications on MUAC [23] and WHZ [24] to diagnose malnutrition in pre-school children, their use has expanded and their popularity fluctuated. A first comparative study (1975) of anthropometric methods to diagnose 'protein calorie malnutrition' showed close agreement between the two indicators in the same population [24]. A major review of untreated SAM in the community found MUAC better at identifying children at risk of mortality [25]. Further comparative studies found MUAC less prone to error than WHZ [26], better able to detect children with nutritional oedema and as effective as WHZ in identifying SAM children with medical complications [26]. No difference was found in clinical and laboratory characteristics and treatment outcomes in children with SAM identified by either indicator [27]. A 2011 Kenya study recommended routine MUAC measurement as part of child hospital admissions in sub-Saharan Africa [28]. A 2013 Bangladesh study found that community health workers achieved 90% error-free case management of children identified with uncomplicated SAM by MUAC [29]. A 2015 Niger study found that mothers detected SAM in children using MUAC with good sensitivity and specificity [30]. A 2014 Kenya study found weight, length and height measurements reliable under controlled conditions but less so when combined into WHZ, risking failure to detect SAM [31]. A 2015 Bangladesh study found that WHZ misdiagnosed 12–14% of children with SAM, compared with only 1%–2% misdiagnosed by MUAC [32]. MUAC's validity has been challenged [33] by comparing its sensitivity and positive predictive value to that of WHZ instead of mortality, mistakenly assuming that WHZ is the definitive standard for identifying SAM.

Different body shapes (which influences WHZ), stunting level and fat distribution (which influences MUAC) mean that MUAC and WHZ identify different children with SAM [11,19,26,34]. A 2016 study of anthropometric surveys from 47 countries found that on average, 52.7% of children were classified as SAM based on MUAC and 63.7% based on WHZ, with an overlap of 16.5% [35]. SAM prevalence based on either MUAC or WHZ and overlap of SAM child populations varied within and across countries, showing that the relationship between MUAC and WHZ was more complex than previously thought.

## Improving effectiveness coverage of SAM services

Policy changes and innovative strategies are needed to break the deadlock of sustained low coverage and improve health outcomes when they are less severe and less costly to treat. Self-referral, active and routine detection of SAM by informed communities and health workers and better access to care are key to expanding coverage. Persistent barriers to treatment access, initiation, adherence and retention are understanding of the illness and treatment pathway, availability of services, transport costs, out-of-pocket expenditures and opportunity costs for carers [36], [37]. Improving SAM treatment access and uptake will increase coverage and reduce health costs and financial risk for carers. A 2015 Sierra Leone study found that using MUAC only for admission of SAM children significantly increased coverage (71%) over using WHZ (55%) and resulted in similar recovery rates (83% for MUAC and 71% for WHZ) [38].

Using MUAC only to detect SAM may improve coverage because of its ease of use, reliability and ability to identify children at risk of mortality. Its effectiveness has been studied in several contexts [39], and some countries have adopted it fully (Ghana, Somalia) or partially (Sierra Leone, South Sudan, Sudan). SAM detection and care based on MUAC enabled adding SAM to Integrated Community Case Management (iCCM) of diarrhoea, malaria and pneumonia in Bangladesh [29], Mali, Pakistan and South Sudan [40]. Moreover, MUAC only may reduce workload and improve planning and resource allocation [41], thus health outcomes. While MUAC only may detect SAM children at highest risk of death, arguments against such a policy underlined the risk of missing SAM children identified by WHZ who also have increased risk of death, although lower than by MUAC [28]. A counter-argument suggested increasing the MUAC cut-off to include more children with SAM identified by WHZ [42] who might otherwise be left out and would benefit from treatment. If SAM treatment capacity increases so that all cases of SAM identified by MUAC access treatment, then cases of SAM identified by WHZ that were not yet identified by MUAC should be targeted.

## The challenge of scaling up SAM services, the case of Sudan

The complexity of decision-making is illustrated by Sudan, which has a high burden of SAM and a weak health system. The government received support for SAM services in war-affected zones (about 20% of the country) [43] in 2015 expanded services to another 35% of health facilities with its own resources [44] but struggled to scale up further or integrate SAM case management into routine primary health care. The 2015-2017 national health plan proposed using MUAC only for SAM diagnosis and treatment [45] to accelerate scale-up [46] but faced resistance because of the lack of international guidance or clear evidence.

With 5.2 million children under 5 in 2010 and a SAM prevalence defined by WHZ of 5.3%, Sudan had an average of 275,600 children with SAM [47] and an annual caseload of 716,560 children (applying the global 1.6 incidence conversion factor) [48]. The real caseload was probably higher because the prevalence did not include SAM cases defined by MUAC or oedema and the incidence conversion factor was probably higher [49]. When applying the SAM treatment capacity in 2010 of 52,064 children [50], only one out of 14 children were admitted for treatment (coverage was probably lower because

the caseload did not count children with SAM identified by either MUAC or oedema).

Sudan has diverse ethnic groups with different body shapes (e.g., pastoralist populations tend to have longer legs and hence higher sitting to standing height ratio than agrarian populations). A 2016 study suggested that on average, the SAM population identified by either MUAC or WHZ overlaps by 20.4% and twice as many SAM children are identified by WHZ as by MUAC [35]. However, in 2013, North Darfur State had a SAM prevalence of 5.8% based on MUAC and 7.8% based on WHZ, while Kassala State had a SAM prevalence of 4.3% based on MUAC and 2.6% based on WHZ [51] (Figure 1), suggesting a different overlap of the two populations.

The estimated SAM caseload based on population estimates in 2014 [52] and the prevalence rate from a 2013 survey, was 394,234 children identified by MUAC and 531,362 identified by WHZ [51]. The survey results did not indicate how much the SAM populations overlapped, but assuming 20.4% [35], 768,767 children would have been identified by either MUAC or WHZ (Figure 2). Thus, 51.3% of SAM children (394,234 with low MUAC/768,767) were at higher risk of death. In 2014, Sudan's SAM treatment capacity was 140,000 children. With the current policy and treatment capacity, one child in five (18.2% or 140,000/768,767) identified by either MUAC or WHZ (or oedema) accessed treatment. There was no guarantee that the one child who accessed treatment was identified with SAM by MUAC and thus was at higher risk of death. With a MUAC only policy and the 2014 treatment capacity, one child in three (35.5% or 140,000/394,234) with a high risk of death would have accessed treatment.

Increasing SAM service coverage would require major increase in capacities and resources. A MUAC only policy would double coverage and save more lives by targeting children at highest risk of death. This example raises the question whether saving the lives of more serious SAM cases and treating less serious cases with less costly interventions (75% to 90% of SAM children may recover spontaneously [53]) may be more effective for overall health outcome.

## Conclusion

This paper discussed the challenges of anthropometry in diagnosing SAM and ways to improve the effectiveness coverage of SAM. Innovative practices have been piloted to increase early detection and treatment of SAM children, but the clinical unknowns of the missed children resisted policy change. Simple and reliable anthropometry for early diagnosis could increase the number of children accessing treatment. But because of incomplete biomedical evidence, researchers are unlikely to agree soon on using MUAC only. This uncertainty is a serious barrier to decision-making for policy change to accelerate coverage of more effective, feasible and sustainable quality services at scale.

Based on current evidence and policy considerations, using MUAC only for diagnosis shows promise for closing the capacity gap to scale up services to reach missed children with SAM. Meanwhile, with so many children's lives at risk, more and innovative research is needed on the biomedical consequences and policy implications of this approach. Effectiveness studies of SAM-specific health outcomes from implementation of various policies will fill in part of the picture.

Systems thinking can help explain why and how SAM policies work in complex and rapidly changing settings [54]. For example, mathematical modeling [55] and dynamic systems modeling over time [56] could compare the (cost-) effectiveness of different SAM policies in specific contexts. This paper calls for better understanding of the impacts of policy changes and for real-world decisions without making SAM children wait for treatment.

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