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Mid-upper arm circumference (MUAC) performance versus weight for height in South African children (0–59 months) with acute malnutrition

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Introduction

Malnutrition in both children and adults is a major public health concern.1 Approximately 45% of mortality in children under five years of age in developing countries is due to under nutrition, which increases the mortality risk resulting from compromised immune systems. In assessing nutritional status, anthropometry indicators for acute malnutrition include mid upper arm circumference (MUAC) and weight for height (W/H) which measure wasting.2 Moderate acute malnutrition (MAM) is an important focus that is often given less prominence yet it is more prevalent than severe acute malnutrition (SAM). According to Cogill,3 the classification of malnutrition based on z-scores is as follows: +1 SD is normal; <1 SD and ≥ -2 SD is mild malnutrition; < -2 SD and ≥ -3 SD is moderate malnutrition; and, < -3SD is severe malnutrition. However, MAM also increases the risk of morbidity and mortality.4 Identification of SAM is critical and requires urgent medical and nutritional support.3 Both W/H and MUAC serve as nutritional status proxies, in their use as a screening tool for SAM, but the underlying concepts differ. In wasted children MUAC has often been used as a pre-screening tool, while W/H requires the measuring of weight and height, as well as a reference table, while using MUAC requires only the use of a tape measure with a fixed cut off.2 MUAC is regarded as a useful screening tool in community interventions and a better predictor of mortality in children.10 However, the discrepancies regarding MUAC and W/H include age, sex, as well as body shape.3 W/H and MUAC z-scores have been shown to identify different child populations with SAM, with only a small level of overlap.11

Of the approximately 45% mortality in children under the age of five due to undernutrition, a large portion of the mortality is due to diarrhoea.12 Often diarrhoea and undernutrition manifest concurrently in children. Children with diarrhoea present with decreased weight gain, with undernourished children being more susceptible to diarrhoea.12 Although a bidirectional relationship between diarrhoea and malnutrition exists, the impact of hydration status on malnutrition assessment in children is not well documented.13-15 As the weight of a child can decrease due to dehydration, anthropometric measures such as W/H in children with diarrhoea can be confusing.16 From the data collected over the last decade and a half, measurements for MAM and SAM have been restricted to specific age groups in infants and young children.17 However, data are lacking for the 0–6 month age group in South Africa. According to Lopriore et al.,18 infants less than six months old are commonly excluded from studies, resulting in miscalculating the undernutrition prevalence in children less than five years old. Therefore, the objective of this study was to compare MUAC and W/H as indices of acute malnutrition in children aged 0–59 months in South Africa.
Method
Setting and design
The study was a randomised community-based cross-sectional household survey undertaken in iLembe district, KwaZulu-Natal (KZN). The study population included children aged 0–59 months, and their mothers/caregivers. The study was conducted over a 21 week period between April and September 2014.

Sampling
Based on the Statistics South Africa 2011 database, in a weighted cross-sectional study a randomised community survey was carried out in iLembe district, stratifying households by the four subdistricts, then by ward \( n = 32 \) and enumerator areas \( 4 \) per ward, \( n = 120 \). A total of 1199 households in iLembe district were randomly selected using geographic positioning systems (GPS), of which 484 households were identified with children under age five, and 415 households \( 85.7\% \) consented to participate in the study. A total of 615 children under age five were enrolled in the study from these 415 households.

Measures
Basic anthropometry was performed on children aged 0–59 months measuring weight, height/length and MUAC.

Weight: The weight of the child was taken using a portable Philips® digital bathroom scale-model HF340/00, with measurements taken to the nearest 0.1 kg for accuracy. The participants were weighed with minimal clothing, without shoes and preferably with an empty bladder. Children less than 24 months of age were weighed together with the mother and the weight of the mother was subtracted to obtain the weight of the child. Weight measurements were taken in duplicate for accuracy and a correct average.

Height/length: The height of the child was determined using a Scales® 2000 moveable stadiometer for ages 2–5 years or length mat to the nearest 0.1 cm to accuracy. The participants were required to stand with their legs straight, heels and the height measure touching at the back, arms straight, shoulders, with chin level to ground and looking straight ahead. With infants, participants were placed in a supine position, using the length mat to the nearest 0.1 cm for accuracy. The participants were measured using the length mat for children less than two years old. Measurements were taken in duplicate for accuracy and a correct average.

Mid-Upper Arm Circumference (MUAC): MUAC was measured using colour-coded non-stretch measuring tapes to the nearest 1 mm.

The tape was able to fit tightly but not so as to restrict blood flow or dent the upper arm. The left arm was bent at the elbow. The point of measurement was the distance between the bony prominence at the top of the shoulder (superiorly) and the point of the elbow being bent. To measure the MUAC, the middle of this above-mentioned distance was marked on the arm, and then the MUAC was measured at this midpoint. The MUAC was also done in duplicate. If the measurements were discrepant by more than 0.5 cm then a third observation was taken and the two similar measurements were used.

Procedures
The study was approved by the University of KwaZulu-Natal (UKZN) Biomedical Research Ethics Committee (REF No BE099/14). The data were collected by five teams \( 1 \) male and \( 1 \) female per team \( \) who underwent 2 months of training in anthropometry. During training fieldworkers completed anthropometric measurements using the same children, as well as children in the same age group. Therefore, no inter-observer significant difference between the fieldworker teams for anthropometry was found. During the pilot study this was also observed as each fieldworker in a team completed measurements to verify accuracy.

Data analysis
Data were processed and analysed using Stata 13.0 (StataCorp. 2013. Stata Statistical Software: Release 13. College Station, TX: StataCorp LP).

Anthropometric z-scores for age for MUAC, weight and height data were calculated against the 2006 World Health Organisation (WHO) growth standards for children. This was performed using the “zscore06” and “zanthro” anthropometric add on modules available for Stata. Differences in mean anthropometric z-score by gender were analysed using the 2-sample independent t-test. Comparison of mean W/H versus MUAC z-score within each gender were analysed using the paired t-test.

The overall malnutrition prevalence was estimated for each index, compared using a Kappa statistic and further compared by stratifying on age and sex. The malnutrition prevalence for each metric by age group and sex are presented with 95% confidence intervals. Comparison of prevalence frequencies by age and gender as well as other categorical characteristics were assessed using a survey weighted Chi-square \( \chi^2 \) test. A \( p\)-value of \( < 0.05 \) was considered statistically significant.

Results
Demographic details of children:
There were 615 children 0–5 years participating in the study, 46.9% \( n = 300 \) were male and 52.4% \( n = 310 \) were female. Data regarding the sex of five children was missing. Over half of the children \( 63.1\% \) were between ages 1–4 years (Table 1). Most of the children were from the 3–4 year group \( 20.3\% \), with the 4–5 year group being the smallest \( 16.8\% \).

| Age Groups (months) | Male | Female | Total |
|--------------------|------|--------|-------|
| < 1 year           | 58 (20.5%, 95% CI: 15.3, 26.9) | 63 (19.9%, 95% CI: 14.6, 26.4) | 121 (20.1%; 95% CI: 16.1, 24.9) |
| 1–2 years          | 57 (19.0%, 95% CI: 14.5, 24.4) | 72 (22.5%, 95% CI: 17.9, 34.7) | 129 (22.2%; 95% CI: 17.4, 27.9) |
| 2–3 years          | 60 (20.3%, 95% CI: 15.8, 25.7) | 64 (21.1%, 95% CI: 16.1, 27.3) | 124 (20.6%; 95% CI: 17.2, 24.4) |
| 3–4 years          | 77 (25.0%, 95% CI: 19.6, 30.8) | 53 (16.3%, 95% CI: 11.0, 23.4) | 130 (20.3%; 95% CI: 16.7, 24.5) |
| 4–5 years          | 48 (15.4%, 95% CI: 11.3, 20.6) | 58 (17.3%, 95% CI: 12.4, 23.7) | 106 (16.8% 95% CI: 13.9, 20.1) |
| Total              | 300  | 310   | 610   |

Table 1: Weighted Demographics of children aged 0–5 years old by sex in iLembe district \( n = 615 \)
Anthropometric characteristics of the children

Our study targeted children 0–59 months but when visiting households we were not able to always obtain both MUAC and W/H measurements if the child was restless. Field workers were also instructed not to insist on obtaining the anthropometric measurements if the children were restless or crying. Thus, of the 615 child participants, measurements were only obtained using both indices for 529 children. Using both the weight for height z-score ($n=564$) and the MUAC z-score ($n=536$) male and female children had similar low mean scores for each measure, 0.88 (SD 1.46) and 0.87 (SD 1.38) for males and females respectively for W/H z-score ($p$-value = 0.856) and 0.61 (SD 1.25) and 0.60 (SD 1.15) for males and females, respectively, for MUAC z-score ($p$-value = 0.901). Comparing mean W/H with MUAC z-scores within each gender indicated significant differences for both sexes ($p<0.001$).

Table 2 presents the agreement between W/H and MUAC z-scores categories. There was ~54.0% agreement between the two indices when categorised in standard deviation (SD) bands and the Kappa statistic value of 0.27 constituted fair agreements for the 529 children for whom valid z-scores were estimated against the WHO 2006 standards.

Based on W/H, 44 children were identified as malnourished and were categorised as follows: 31 had mild malnutrition; eight had MAM; and five had SAM. In comparison, using MUAC, 38 children were malnourished: 30 children had mild malnutrition; six children had MAM; and two children had SAM. More male children, (2.8% and 1.5% for W/H and MUAC, respectively) were detected as malnourished in comparison to female children (1.8% and 1.5%, respectively). Using W/H SAM was detected in 1.1% males and 1.1% females, MAM was 2.0% in males and 1.0% in females, and mild malnutrition was detected in 6.0% males and 5.5% females. In comparison, using MUAC as a measure, SAM was detected in 0.5% males and 0.3% females, MAM in 1.5% males and 0.8% females, and mild malnutrition in 6.1% males and 4.4% females. In children aged 0–6 months using W/H, five children were identified with mild malnutrition, two were moderately malnourished and three were severely malnourished. In comparison using MUAC, only one child was identified with SAM.

Table 2 presents the agreement between W/H z-scores and MUAC z-scores. There is a significant positive correlation between the two indices ($r=+1; p<0.001$). However, there are outlying points for children at risk of mild, moderate and severe undernutrition indicating the lack of consensus between the measures concerning the nutritional status of the children.

Discussion and recommendations

While MUAC is considered an appropriate diagnostic screening tool for nutritional status, minimal changes in children aged 1–5 years old have been observed. This study identified W/H (7.7%) as a more sensitive measure of child malnutrition and measured more than double for the children with SAM compared to MUAC. W/H also appeared as a
more sensitive measure in children less than a year old compared to MUAC but from ages 3 to <5 years a divergence appeared whereby MUAC was a more sensitive measure than W/H as the child's age increased. There was no report of oedema in the children of this study. While SAM identification was low in our study, W/H was a sensitive measure to identify more children with MAM (3.0%). Although the level of wasting was low in our study, as per the global trend, at the primary healthcare (PHC) level there is a need for attention to malnutrition in the iLembe district. Although the debate about using W/H and MUAC is ongoing, our study confirmed wasting in children aged 0–59 months at a sub district level, requiring that children's weight be monitored throughout the district to target more interventions.

In South Africa, children face a multiple burden of disease as reported by the District Health Barometer (DHB) 2014/15. The disease burden profile indicated diarrheal disease as the leading cause of child mortality. According to Modi et al., previous research reported that W/H measurements had variations based on the severity of a child's dehydration status, while dehydration status did not significantly affect MUAC measurements. Thus, in undernutrition W/H was considered as a poor indicator in children that also had diarrhoea. This study diagnosed more children with MAM and SAM using W/H measurements compared to MUAC.

Two previous studies in SA reported low wasting prevalence using W/H as a measure that was consistent with the current study. The findings of both studies followed the trend that exists in SA that acute malnutrition levels were low in comparison to high chronic malnutrition levels.

To assist in addressing the current child malnutrition burden in South Africa, the Guidelines on the Integrated Management of Acute Malnutrition (IMAM) in KwaZulu-Natal was compiled in 2014. The IMAM guidelines aims to detect and treat SAM in children before any life threatening complications occur. As of 2014, nutrition advisors and dieticians have been instituted in all clinics to detect malnutrition cases as well as provide follow-up and counselling on malnutrition status at a community level.

### Table 3: Percentage of children by anthropometric score and age group, iLembe district

| Metric | Range  | <1 yr old | 1–1.99 yrs old | 2–2.99 yrs old | 3–3.99 yrs old | 4–4.99 yrs old | Overall |
|--------|--------|-----------|----------------|----------------|----------------|----------------|---------|
| W/H z-score | –3 or less | 4.30% | 0.77% | 0.00% | 0.00% | 0.00% | 1.08% |
|         | –2 to 2.99 | 5.04% | 0.64% | 1.21% | 0.00% | 0.00% | 1.91% |
|         | –1 to –1.99 | 7.47% | 4.60% | 6.65% | 4.03% | 6.10% | 5.97% |
|         | –0.99 to +0.99 | 50.61% | 39.84% | 40.41% | 59.94% | 62.54% | 46.03% |
|         | +1 to +1.99 | 17.43% | 27.83% | 36.74% | 25.13% | 17.44% | 27.00% |
|         | +2 to +2.99 | 10.04% | 18.35% | 12.40% | 8.01% | 9.12% | 12.66% |
|         | +3 or more | 5.10% | 7.98% | 2.59% | 2.89% | 4.69% | 5.35% |
| MUAC z-score | –3 or less | 0.90% | 0.00% | 0.92% | 0.00% | 0.00% | 0.45% |
|         | –2 to 2.99 | 0.00% | 1.86% | 2.28% | 0.00% | 1.08% | 1.50% |
|         | –1 to –1.99 | 3.01% | 0.54% | 5.77% | 6.07% | 12.52% | 6.14% |
|         | –0.99 to +0.99 | 47.20% | 52.92% | 54.47% | 74.63% | 65.09% | 58.64% |
|         | +1 to +1.99 | 26.68% | 29.18% | 28.31% | 15.70% | 15.26% | 23.05% |
|         | +2 to +2.99 | 13.43% | 11.62% | 6.89% | 3.60% | 4.97% | 7.00% |
|         | +3 or more | 8.78% | 3.87% | 1.37% | 0.00% | 1.08% | 3.23% |
Growth monitoring of children is important and the Road to Health Booklet is a critical tool that can monitor the progress of child growth. Nursing staff at clinics should be retrained or undergo refresher training to keep the booklet updated. Mothers should also be assisted by PHC staff and community caregivers for better understanding of the booklet. The burden of undernutrition requires urgent attention. Therefore nursing staff at PHC level should be trained on how to identify these conditions in young children. Ward-based outreach teams are also important for follow-up of identified children.

The results of this study relate closely to the previous South African studies and national surveys indicating that careful monitoring is required when using W/H and MUAC in detecting malnutrition rates. The debate about using W/H as the indicator of choice in child malnutrition is ongoing. At a global level there have been discrepancies between the uses of these two indicators, whereby acute malnutrition rates were sometimes identified as similar, or where one measure indicated a higher prevalence of malnutrition over the other.27 National surveys in the Philippines found malnutrition prevalence to be greater using W/H in comparison to MUAC measurements.10 A systematic review, conducted to assess acute malnutrition using W/H, reported W/H alone as a recommended anthropometric tool but its reliability in the context of a setting called for further investigated.28 Thus, the WHO has recommended that where differences exist between W/H and MUAC, both measures should be considered.10

According to Young, age plays a significant role in MUAC and W/H discrepancies, as it is associated with food insecurity.29 In young children, wasting is indicative of disease together with poor feeding practices, while wasting is indicative of food insecurity in older children. Thus, Bern suggests that during a period of food insecurity, older children are likely to experience malnutrition in older children. Thus, Bern suggests that during a period of food insecurity, older children are likely to experience malnutrition.27 Poor feeding practices, while wasting is indicative of food insecurity in young children, wasting is indicative of disease together with malnutrition. Thus, Bern suggests that during a period of food insecurity, older children are likely to experience malnutrition.

Limitations
Dehydration status and diarrheal disease were not included as criteria that may impact on W/H measurements and misclassify children with SAM.

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