# Screening for overweight using mid-upper arm circumference (MUAC) among children younger than two years in the Eastern Cape, South Africa.

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## Abstract

**Background:** The relationship between overweight and under nutrition, particularly in resource-poor settings, poses practical challenges for targeting nutrition interventions. Current anthropometric indicators including weight for height (WHZ) recommended by the WHO may be challenging in community settings.

**Objectives:** The aim of this study was to assess whether MUAC can accurately identify children younger than two years with overweight and obesity.

**Method:** A descriptive, cross-sectional study was used to collect data from a non-probability sample of 397 young South African children from October 2015 to February 2016. MUAC cut-off values were tested using a receivers' operating characteristic and area under the curve (AUC).

**Results:** The prevalence of overweight (WHZ>+2) and obesity (WHZ>+3) was 11% (n=44) and 5% (21) respectively. A MUAC cut off value for identifying male children six to 24 months old with overweight was determined at 16.5 cm (85% sensitivity, 71.4% specificity, AUC=0.821) and female children at 16.5 cm (100% sensitivity, 76.6% specificity, AUC=0.938).

**Conclusions:** MUAC may be an appropriate tool for identifying children younger than two years old with overweight and obesity. The predicted MUAC cut-off values were able to identify infants and young children with overweight accurately.

## Second Abstract

The emerging double burden of disease poses practical challenges for targeting nutrition interventions, particularly in resource-poor settings. Current anthropometric indicators including weight for height (WHZ) recommended by the WHO may be challenging in community settings. MUAC may be an appropriate tool for identifying children younger than two years old with overweight and obesity. The aim of this study was to assess whether MUAC can accurately identify children younger than two years with overweight and obesity.

## Introduction

According to the WHO[1], 42 million children under the age of five years are overweight or obese. The prevalence of stunting and wasting is reducing in low and middle income countries (LMIC), while overweight and obesity is becoming more prevalent among children[2]. Accelerated weight gain in early life may be related to non-communicable disease risk[3]. Overweight at one year old may greatly increase the risk of type 2 diabetes and premature death from cardiovascular disease[4]. High rates of glucose intolerance and pre-hypertension have been observed among rural South African adolescents[5], indicative of the epidemiological transition taking place.

Major changes to the diet as a result of the nutrition transition include increased consumption of refined carbohydrates, added sweeteners, edible oils and animal source foods. These dietary patterns can result in higher rates in overweight and obesity in both children and adults. In Southern African countries, it has been estimated that 72% of people are not meeting the recommendations for vegetable and fruit consumption[6]. Furthermore, while the rate of initiation of breastfeeding is high in SA, the exclusive breastfeeding rate declines rapidly[7]. Early introduction of foods and liquids other than breastmilk before the age of six months is common[7] and may be associated with overweight and obesity later in life[8]. High-sugar fruit juices are being introduced to infants from six months of age[9]. A large proportion of South African infants are consuming foods such as processed meats and crisps on a daily basis by the time they are twelve months old. These less healthy foods are rapidly becoming more affordable, accessible and acceptable to all populations in South Africa, including rural and informal settlements[10].

The effects of these shifts in dietary patterns are already being observed, with as many as 10% of infants overweight at six months of age[11].

The emerging double burden of disease poses significant practical challenges for targeting nutrition interventions, particularly in resource-poor settings. Current anthropometric indicators to identify overweight in children as recommended by the WHO and the World Obesity Federation (WOF)[12], include weight for length (WLZ) or weight for height (WHZ) and BMI for age. Evidence suggests that WHZ and BMI for age yield similar prevalence of overweight and obesity and therefore there is no need to monitor both indicators[13]. However, using the WHZ or BMI for age cut-off values, may be challenging at community and household level due to practical limitations such as carrying bulky equipment by community health workers who may not always have access to transport. Furthermore, in resource-poor settings, a MUAC tape may offer several advantages such as being non-invasive, cheaper and faster to use when compared with the scales, stadiometers and length boards required for determining WHZ. Community health workers and parents or guardians can also easily be trained to use and interpret MUAC measurements as a screening tool and it may even aid in the reduction of errors occurring in anthropometric measurements of children[14].

Research has begun to establish that MUAC can be effective in identifying overweight and obese children[15]. The rate of increase in arm circumference has also been reported parallel to the rate of weight gain in children[14]. There is currently no formal recommendation for a single cut-off value for MUAC to identify overweight and obese infants and children in the same way that cut-off values are available for identifying acute malnutrition. The WHO MUAC field tables available can be cumbersome to use; rely on the age of the child and undermine the simplicity of MUAC as a screening tool. There is also a lack of data relating to children younger than two years as many of the studies available, which assess the ability of MUAC to identify obese children, focus on children older than two years[15,16]. Therefore, the aim of this study was to predict MUAC cut-off values to identify overweight and obese infants and children younger than two years old within a specific population.

## Methods

This descriptive study was undertaken using a cross sectional design. Ethical approval was obtained from the Research Ethics Committee (Human), Nelson Mandela University, as well as the Eastern Cape Department of Health (ref. no H15-HEA-002). Inclusion in the study required written informed consent from the primary caregiver of the participant. Data on weight, length and MUAC was collected from infants and young children living in a South African resource-poor peri-urban settlement, aged from birth to two years (n=408) between October 2015 and February 2016. Date of birth and date of measurement were recorded and participant age calculated as an age in decimals. Procedures for obtaining anthropometric data followed protocols described by the Centres for Disease Control and Prevention[17]. Weight was measured in kilograms (kg) with a Nagata BW 2010 infant scale (capacity 20 kg x 10 g) and recorded to the nearest 0.01 kg. Length was measured in centimetres (cm) using a Seca infantometer to the nearest 0.1 cm. Non-stretch MUAC tapes were used to measure arm circumference in cm to the nearest 0.1cm. Scales were calibrated before measurements were taken, and measurements were taken at eye level to avoid parallax errors. Measurements were taken by trained fieldworkers. Fieldworkers were registered dietitians and dietetic students who received training before commencing data collection and throughout the data collection period. Fieldworkers collected data under direct supervision of the principle investigator. Anthropometric data were used to calculate Z-scores for weight for age (WAZ), height for age (HAZ), weight for length (WLZ) using WHO Anthro software (WHO, Switzerland). Data cleaning criteria were applied according to WHO guidelines[18].

Descriptive statistics were used to describe the outcomes. As absolute MUAC was expected to increase from younger to older age groups, tests for significance in MUAC between age groups was performed using a Scheffe test. A p-value of $<0.05$ was considered significant. A receiver's operating characteristic (ROC) curve was generated using SPSS software (v25) and used to calculate the area under the curve (AUC) to assess the performance of MUAC as a diagnostic test when using WLZ as the criterion for overweight and obesity. WLZ was used as the standard criterion as it is the recommended indicator of overweight and obesity[19]. An AUC value of $>0.8$ was considered an accurate test[20]. The Youden index (J) is the difference between the true positive rate (sensitivity) and the false positive rate with: 1 indicating a perfect test, and 0 a useless test. It signifies the optimal sensitivity and specificity values yielding the maximum sums from the ROC curves. The J-value was used to inform the optimal MUAC cut-off values.

## Results

Eleven records were removed from the sample as they had implausible Z-scores. The final sample (n=397) was homogenously (100%) of African ethnicity. The sample was made up of 50% (n=197) male participants, and 50% (n=200) female participants. The mean participant age was 9.78 months (SD=6.13). There was no significant difference between the ages of male and female participants (p=0.53).

The mean WLZ was 0.83 (SD=1,28). The prevalence of overweight (+2<WLZ<+3) and obesity (WLZ>+3) was 11.8% (n=47) and 5% (n=21) respectively. There were no significant differences observed between genders for WLZ (p=0.367), as shown in Table 1.

*Table 1: Anthropometric indicators in male and female participants (n=397). Values=Mean (SD)*

| **Anthropometric indicator** | **Sex** | **n** | **Mean (SD)** | **p-value** | **Cohen's D** |
|---|---|---|---|---|---|
| **Weight (kg)** | Male | 197 | 9.19 (2.59) | 0.018* | 0.24 |
| | Female | 200 | 8.58 (2.49) | | |
| **Height (cm)** | Male | 197 | 70.83 (8.86) | 0.049* | 0.20 |
| | Female | 200 | 69.04 (9.12) | | |
| **WLZ** | Male | 197 | 0.77 (1.40) | 0.367 | 0.09 |
| | Female | 200 | 0.88 (1.15) | | |
| **MUAC (cm)** | Male | 197 | 15.59 (1.74) | 0.017* | 0.24 |
| | Female | 200 | 15.17 (1.75) | | |

*Denotes statistically significant at p<0.05

Infants younger than six months had significantly different MUAC measurements compared with children older than six months, but there was no statistically significant difference observed among children between six and 24 months old. This resulted in the decision to test a single MUAC for children six to 24 months old as these children were found to be comparable.

The AUC for identifying overweight males 0-6 months old (n=58) was 0.766. The MUAC cut-off value at 14.5 cm had a sensitivity of 88.9% and specificity of 63.3% (J=0.542). Female children 0-6 months old had an AUC of 0.788 for overweight. The MUAC cut-off with the highest J-value (J=0.585) was 14.2 cm (100% sensitivity, and 58.5% specificity).

Data obtained from males aged six to 24 months (n=139) generated ROC curves with AUC of 0.821 for overweight (+2<WLZ<+3) and 0.905 for obesity (WLZ>+3), presented in Table 2. The MUAC cut-off value of 16.5 cm had the highest J-value (0.589) and a sensitivity of 85% and specificity of 71.4% for identifying overweight. The optimum MUAC cut-off value for identifying obesity among males six to 24 months old was 17.2 cm (88.9% sensitivity, 80.8% specificity, J=0.697). As presented in Table 3, a MUAC cut-off for identifying overweight female children aged six to 24 months (n=130) was determined at 16.5 cm (AUC=0.938). This cut-off value had a sensitivity of 100% and specificity of 76.7% (J=0.767). The optimum MUAC cut-off value for identifying obesity was 17.0 cm (J=0.758).

*Table 2: Potential MUAC cut-off values for identifying overweight and obesity in males six to 24 months old, compared with WLZ (n=139)*

| **+2<WLZ<+3 Male 6-24 months** | | **AUC=0.821** | **N=139** | **WLZ>+3 Male 6-24 months** | | **AUC=0.905** | **N=139** |
|---|---|---|---|---|---|---|---|
| **MUAC (cm)** | **Sensitivity** | **Specificity** | **Youden Index** | **MUAC (cm)** | **Sensitivity** | **Specificity** | **Youden Index** |
| 16.3 | 0.850 | 0.664 | 0.522 | 16.8 | 0.889 | 0.731 | 0.620 |
| 16.4 | 0.850 | 0.672 | 0.564 | 16.9 | 0.889 | 0.738 | 0.627 |
| **16.5** | **0.850** | **0.714** | **0.589** | **17.0** | **0.889** | **0.762** | **0.650** |
| 16.6 | 0.850 | 0.739 | 0.573 | 17.1 | 0.889 | 0.792 | 0.681 |
| 16.7 | 0.800 | 0.773 | 0.582 | 17.2 | 0.889 | 0.808 | 0.697 |

*Table 3: Potential MUAC cut-off values for identifying overweight and obesity in females six to 24 months old, compared with WLZ (n=130)*

| **+2<WLZ<+3 Female 6-24 months** | **AUC=0.938** | **N=130** | **WLZ>+3 Female 6-24 months** | **AUC=0.938** | **N=130** |
|---|---|---|---|---|---|

| MUAC (cm) | Sensitivity | Specificity | Youden Index | MUAC (cm) | Sensitivity | Specificity | Youden Index |
|---|---|---|---|---|---|---|---|
| 16.3 | 1.000 | 0.717 | 0.717 | 16.8 | 0.900 | 0.833 | 0.733 |
| 16.4 | 1.000 | 0.742 | 0.742 | 16.9 | 0.900 | 0.850 | 0.750 |
| **16.5** | **1.000** | **0.767** | **0.767** | **17.0** | **0.900** | **0.858** | **0.758** |
| 16.6 | 0.900 | 0.792 | 0.692 | 17.1 | 0.800 | 0.867 | 0.667 |
| 16.7 | 0.900 | 0.833 | 0.733 | 17.2 | 0.800 | 0.883 | 0.683 |

## Discussion

The proposed MUAC cut-off values of 16.5 cm for overweight (+2<WLZ<+3) males and females, and 17.2 cm for identifying obesity in males and 17.0 cm for females correctly classified an acceptably high number of children. The simplicity of MUAC measurements could assist with identifying infants and young children who are clinically overweight or obese early on in community and household settings. MUAC is simple to use. It also could potentially allow for screening for over and under nutrition with a single tool reflecting different cut-off values.

The results of this study demonstrate that MUAC may be an appropriate tool for identifying children younger than two years old as overweight and obese. The area under the curve for all groups tested was found to have a very good diagnostic value. Research so far has not addressed the need for a suitable MUAC cut-off value for identifying overweight among children younger than two years. Investigations into the use of MUAC as a screening tool for overweight and obesity have largely focused on children of school-going age. Chaput *et al*.[21] demonstrated a high level of sensitivity and specificity for identifying overweight and obesity among nine to eleven year-olds using novel MUAC cut-offs. Craig *et al*.[22] conducted a study that showed similar results using MUAC in South Africa, but again this research focused on children and adolescents older than five years. The areas under the curve for the current study for females and males were both greater than 0.8, considered the threshold for an acceptably accurate test[20].

Some of the challenges in nutrition screening such as accurately estimating a child's age[23] are avoided using MUAC and weight for height indicators. Weight for height still requires trained fieldworkers and equipment[19], and time available to spend on training fieldworkers may be limited due to overloading roles with tasks and large geographic coverage diluting trained fieldworkers[23]. Additionally, health workers are capable of measuring and interpreting weight but can be uncomfortable with weight and length measurements in combination, therefore weight for height interpretations may not be performed routinely in the field[24]. According to the results of this study, MUAC is capable of accurately identifying overweight and obese infants and young children. The simplicity of MUAC may also be advantageous in the emerging problem of childhood overweight and obesity as it should help to minimise resource allocation to growth charts, anthropometric equipment, training materials and workshops[18] in community settings.

Kim, Lee and Sungwon[6] report that overweight and obesity between ages two and six years is significantly associated with developing adult metabolic syndrome, while the association between overweight and obesity before the second birthday and development of metabolic syndrome in adulthood exists but is not significant. This may suggest that a window for intervention exists before the second birthday that might have a significant impact on future chronic disease risk. Given that the first 1000 days is such a crucial time for development, identifying overweight and obesity in this age group could potentially prevent future problems associated with the global double-burden of disease. Hawkes *et al.*,[25] have recently suggested that as all forms of malnutrition have common drivers, health workers should aim to simultaneously prevent under and overnutrition, under the term "double-duty actions". Potential double-duty actions include redesigning the existing growth monitoring programmes including weight for height in primary care settings and interpreting overweight where feasible[25]. A MUAC cut-off value for overweight and obesity could aid in expanding this action to community and household screening for referral.

This study is limited as the average age of the participants was 9.78 months, creating a bias toward younger children. The study was conducted in primary care facilities and crèches, therefore excluding children who do not attend these facilities. A further limitation of the study was the cross-sectional approach. A longitudinal study would have yielded more information in relation to the dynamic growth of children, however longitudinal data can be impractical to collect. This study must be repeated with a larger sample size in urban, peri-urban and rural South African communities in order to validate the use of the tool.

## Conclusion

MUAC has the potential to identify children with overweight and obesity in South African communities, where community health workers lack adequate access to growth monitoring equipment. Referrals to health services made during the crucial stage of childhood development before the second birthday can potentially reduce the later risks of overweight and associated chronic diseases of lifestyle in adolescence and adulthood.

To our knowledge, this is the first work to address a MUAC cut-off value for identifying overweight and obesity among children younger than two years. However, further research is needed, using larger samples from different South African contexts to provide better insight into its standardized use.

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