Original Article:
Mid-Upper Arm Circumference: An Alternative to BMI for Screening Overweight and Obesity Among the Khiamniungan Tribal Children and Adolescents of Nagaland, Northeast India

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Abstract: Background: Body mass index (BMI) is recommended globally as the optimal, straight forward measure of obesity. Nonetheless, in a resource-poor setting, Mid-upper-arm circumference (MUAC) is considered as a key indicator for overweight and obesity. Objective: The present study is an attempt to determine the accuracy of MUAC for the assessment of overweight and obesity among children and adolescents of Khiamniungan tribe. Methods: This is a cross-sectional study which includes 960 Khiamniungan tribal children and adolescents of both sexes aged 5-16 years. All the somatometric measurements were assessed objectively. Result: MUAC was found to be strongly correlated with height, weight, waist circumference and body mass index in both children (r≥0.617; p<0.001) and adolescents (r≥0.74, p<0.001). The MUAC cut-off to identify BMI-defined overweight/obesity among children 16.50 cm and adolescents’ 21.50 cm. AUC results were ‘fair’ for children and ‘excellent’ for adolescents (0.75 and 0.95, respectively). Conclusion: MUAC can be preferred over conventional BMI as an alternative screening tool in a resource-poor setting as it is simple, inexpensive, easy to use, and non-invasive method.

Key Words: Children, Adolescents, Overweight, Obesity, Mid-upper arm circumference

Introduction:
The ever increasing trend of overweight and obesity is evident in many of the developed and developing countries (1–4) which have become pandemic globally (5–7). The global prevalence of obesity increased threefold since 1975 with an estimate of about 671 million adults and 124 million young people (5-19 years) in the year 2016 (8). Childhood or adolescent overweight and obesity are the principal risk factors for stroke, coronary heart disease, diabetes, hypertension, mortality and premature death (9). Childhood obesity affects various aspects of physical and mental health (10,11) and have higher risk for adult obesity (12). Maternal overweight and obesity are associated with increased risks of pregnancy complications, preterm birth, stillbirth, gestational diabetes mellitus (GDM), pre-eclampsia, congenital malformation, long term risk of childhood obesity and metabolic dysfunction (13–19). Body mass index (BMI)-for-age is recommended internationally as the optimal, straight forward measure of obesity for public health surveillance and clinical applications in children and adolescents (20). However, in resource-poor settings where equipment and training are limited, BMI evaluation may be unreliable and not feasible for use in field studies with many subjects (21). Previous studies have suggested that mid-upper arm circumference (MUAC) is an important indicator for overweight including obesity and can be used for assessing nutritional status which is easy, quick, cost-effective and more practical alternative to BMI (22,23).

The aim of the present study is to determine the accuracy of MUAC for the assessment of overweight and obesity (defined on the basis of BMI-for-age) among children and adolescents.

Materials and Methods
Participants
This is a cross-sectional study carried out among the Khiamniungan tribal children (5-9yrs) and adolescents (10-16yrs) of both the sexes. A total sample of 960 individuals was collected from three randomly selected high-schools at Noklak, Tuensang district, Nagaland, India. Prior to the collection of the data, permission was obtained from the principals of all the schools. Information was given to the students beforehand and consent was taken from all the participants and their parents. The accuracy of their age was determined from the school records. This study was approved by the ethical committee of the Department of Anthropology, University of Delhi, Delhi.

Anthropometric measurements
Somatometric measurements such as height (cm), weight (kg), waist circumference (cm), mid upper arm circumference (cm), and skinfold thickness (mm) of triceps and biceps were taken. Body height was measured barefoot, with the participant’s head in the Frankfort horizontal plane. Weight was measured...
with the subject barefoot, minimal clothing, standing in
straight posture and hands by the side of their body. Height
and weight were measured to the nearest 0.1 cm and 0.1 kg
respectively. Waist circumference was accurately measured
at the level midway between the lowest rib and at the top of
the iliac crest at the end of normal expiration. MUAC was
measured at the midway between the olecranon and acromial
process on the upper right arm while hanging the arm loosely
on the side of the body (normal arm hanging position). All
measurements were taken thrice and mean of the three
measurements were accepted. The measurements were taken
following the International Society for the Assessment of
Kinanthropometry (ISAK), international standards for
anthropometric assessment (24). A portable digital weighing
machine, Anthropometer, steel tape and Harpenden Skinfold
caliper were used for the measurements. BMI was defined as
weight (kg)/height (m2). BMI z-scores were computed using
age and sex specific reference data from the World Health
Organization. Participants were classified as overweight and
obesity (BMI z-score >+1 standard deviation (SD)) (25).

Statistical analysis
All the statistical analyses were conducted using Microsoft
Excel and SPSS version 20.0 (IBM). Descriptive
characteristics of children and adolescents are presented by
mean and standard deviations (SD). Pearson correlation
coefficients were calculated to determine the strength of the
linear relationship between MUAC and other somatometric
variables. Receiver operating characteristic (ROC) curve
analysis was used to test the ability of MUAC to determine
those children and adolescents classified as overweight
including obesity by BMI-for-age. The area under the curve
(AUC) is considered as the predictor variable which represents
the trade-off between the correct identification of high-risk
overweight (including obese) individuals (sensitivity) and the
correct identification of low-risk (non-overweight/obese)
individuals (specificity). An AUC of 1 indicates the ability to
perfectly distinguish between overweight/obese and non-
overweight/obese participants, whereas an AUC of 0.5
indicates no greater predictive ability than chance alone. The
categories used to summarize accuracy in ROC analysis were
as follows: excellent (0.9–1), good (0.8–0.9), fair (0.7–0.8),
poor (0.6–0.7) and fail (0.5–0.6). A test with an AUC ≥0.85 is
generally considered an accurate test (26). Youden’s index that
approaches 1 indicates higher authenticity to be used as a
diagnostic or screening tool (27).

Results
Descriptive characteristics of the participants are presented in
Table 1. All the somatometric variables were found to be
statistically significantly (p<0.001) between children and
adolescents.

Table 1: Characteristics of study participants (n=960)

<table>
<thead>
<tr>
<th>Somatometric Variables</th>
<th>Children (5-9yrs) n=400</th>
<th>Adolescents (10-16yrs) n=560</th>
<th>t-test; p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (cm)</td>
<td>115.42 (9.22)</td>
<td>146.05 (11.47)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>19.27 (3.40)</td>
<td>36.80 (9.13)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BMI</td>
<td>14.38 (0.91)</td>
<td>16.94 (2.25)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BMI Z-score</td>
<td>-0.68 (0.41)</td>
<td>0.48 (1.02)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>MUAC (cm)</td>
<td>16.05 (1.14)</td>
<td>20.64 (2.77)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>WC (cm)</td>
<td>51.15 (2.81)</td>
<td>60.70 (5.73)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Triceps (mm)</td>
<td>6.39 (1.43)</td>
<td>7.48 (2.91)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Biceps (mm)</td>
<td>3.04 (0.80)</td>
<td>3.58 (1.34)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Pearson correlation coefficients between MUAC and
somatometric variables for boys and girls are shown in Table
2. MUAC found to be strongly correlated with weight,
body mass index and waist circumference among children
(r=0.617; p<0.001) and strongly correlated with height,
weight, body mass index and waist circumference among
adolescents (r=0.74, p<0.001).

Table 2: Age group relationship between mid-upper arm
circumference and other somatometric variables (n=960)

<table>
<thead>
<tr>
<th>Somatometric Variables</th>
<th>Children (5-9yrs) n=400</th>
<th>Adolescents (10-16yrs) n=560</th>
<th>r</th>
<th>p</th>
<th>r</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (cm)</td>
<td>0.496</td>
<td>&lt;0.001</td>
<td>0.744</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>0.708</td>
<td>&lt;0.001</td>
<td>0.921</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI</td>
<td>0.669</td>
<td>&lt;0.001</td>
<td>0.897</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WC (cm)</td>
<td>0.617</td>
<td>&lt;0.001</td>
<td>0.857</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triceps (mm)</td>
<td>0.317</td>
<td>&lt;0.001</td>
<td>0.431</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biceps (mm)</td>
<td>0.239</td>
<td>&lt;0.001</td>
<td>0.504</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The results of the ROC curve analyses are presented in Table
3. The ROC-AUC results were ‘fair’ among children 0.75 and
‘excellent’ 0.95 for adolescents. The MUAC cut-off points to
identify BMI-defined overweight including obesity were
16.50 cm (95% CI, 0.39-1) for children and 21.50 cm (95%
CI, 0.93-0.97) for adolescents.

Youden’s index for children was low 0.15 and for adolescents
0.75. Sensitivity and specificity were low for the optimal age-
group specific cut-points for children (50-65.3%) and high
optimal age-group specific cut-points for adolescents (80.2-
94.8%) respectively. The positive predictive value and
negative predictive value for children and adolescents were
(0.71 and 99.6%). The prevalence of overweight and obesity
was 0.50% for children and 27.67% for adolescents. The
accuracy to correctly identify children and adolescents with
overweight and obesity were 65.3% and 84.28% respectively.

Table 3: Results of Receiver Operating Characteristics (ROC) curve analyses for the association between mid-upper arm circumference and
overweight (including obesity) in children and adolescents (n=960)

<table>
<thead>
<tr>
<th>Age group</th>
<th>n</th>
<th>AUC (95% CI)</th>
<th>Youden Index</th>
<th>Cutoff (cm)</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>+PV (%)</th>
<th>PV (%)</th>
<th>Prevalence (%)</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children</td>
<td>400</td>
<td>0.75 (0.39-1.00)</td>
<td>0.15</td>
<td>16.50</td>
<td>50.00</td>
<td>65.30</td>
<td>0.72</td>
<td>99.60</td>
<td>0.50</td>
<td>65.30</td>
</tr>
<tr>
<td>Adolescents</td>
<td>560</td>
<td>0.95 (0.93-0.97)</td>
<td>0.75</td>
<td>21.50</td>
<td>94.80</td>
<td>80.20</td>
<td>64.75</td>
<td>97.59</td>
<td>27.67</td>
<td>84.28</td>
</tr>
</tbody>
</table>

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Discussion

There are very few studies across India to examine if MUAC can be a useful, alternative and practical screening tool for overweight including obesity among children and adolescents. There is no literature in existence examining overweight/obesity among the Nagas using MUAC and this is the first among the Khammungan tribal children and adolescents.

The findings of the present study demonstrate the ability of the MUAC to correctly identify overweight including obesity among the Khammungan children (5-9) years and adolescents (10-16) years. The MUAC was strongly associated with height, weight, waist circumference, and body mass index in both the age-groups. The area under the ROC curve was ‘fair’ for children (0.75) and ‘excellent’ for adolescents (0.95). This indicates that MUAC has the ability to identify overweight including obesity among children and adolescents classified according to the standard accepted WHO BMI Z-scores. The sensitivity and specificity were in the range of 50.0-65.3% for children and 80.2-94.8% among adolescents. The Youden index was weak (0.15) for children, this could be due to the fact that there were only 2 (two) overweight/obese individuals and for adolescents (0.75) which is closer to 1 indicating high authenticity of MUAC which can be adopted as a diagnostic tool apart from the conventional BMI.

Waist circumference is considered as the best indicator of abdominal obesity, which is associated with metabolic syndrome, insulin resistance, and biomarkers of vascular smooth muscle dysfunction in children (28,29). However, in certain circumstances where measurement of waist circumference is not feasible, which is affected by respiratory movements and postprandial abdominal distension. The measurement of MUAC is independent of all these factors and therefore can be an alternative and reliable index (30,31).

Many scientific papers have suggested that screening for overweight and obesity among children and adolescents can be done using somatometric indicators such as BMI, WC and MUAC; nonetheless there are no established specific cut-off values for WC and MUAC which is accepted internationally (32). The results of the present study are consistent with the earlier research findings. Mazicioglu and et al. found the AUC ranging from 0.64 to 0.94 for both children and adolescents (6-17) years (32). A study by Lu and et al. among the Han children aged 7-12 years reported the AUC ranging between 0.93 and 0.98 for MUAC predicting overweight and obesity (30). Tchounwou and et al. and Chapug and et al. showed similar ROC-AUC values 0.97 and 0.98 for MUAC to accurately identify obesity among the Black South African children and adolescents, however the country specific cut-off showed some variation (21)(23). Also, Jaiswal and et al. (33) showed an excellent AUC value (0.92-0.98) for both children (5-9) years and adolescents (10-14) years from Bareilly, Uttar Pradesh. Finally, Rerkspuppaphol S & Rerkspuppaphol L found high accuracy level (0.92-0.99) of MUAC for identifying obesity among the Thai school children aged 6-13 years (34). Previous literature revealed variations in the optimal MUAC cut-off values for children and adolescents ranging from 17.9 cm to 25.7 cm in the age group of 5-17 years.

The utilization of MUAC has been a feasible surrogate for undernutrition; however the findings of the present study indicate the potency of MUAC to hold a subsequent prospective for public health in monitoring overweight and obesity, and as a screening tool for children and adolescents needing further assessment of overweight/obesity and its associated comorbidities. Parallel studies should be conducted across different age groups to determine the optimal MUAC thresholds. The influence of maturation on body composition during pubertal development in older children is conspicuous and therefore remodelling of the approach is imperative for the interpretation of results. Obesity is associated with the development of comorbidities such as Type-2 diabetes and cardiovascular disease; subsequent studies should contemplate on MUAC to pragmatic outcomes.

There are limited literatures on the use of MUAC as an indicator for the assessment of overweight and obesity among children and adolescents in India. The strength of this study is that it lays a primary foundation on the use of MUAC as a screening tool for overweight/obesity among children and adolescents of the Khammungan tribal people in particular and the Naga community in general. All the data was collected by a single investigator following highly standardized measurement protocol, the employment of unbiased measurements and meticulous quality control programme to ensure high caliper data. The use of MUAC in this particular study exclusively examined one tribal community. Therefore, the optimal MUAC cut-off values need to be cross-validated with different tribal groups to establish itself as a screening tool for overweight/obesity among children and adolescents.

Conclusion

The present study authenticates the use of MUAC measurement, which is simple, inexpensive, easy to use, and non-invasive as a prospective surrogate for BMI to accurately identify overweight/obesity among children and adolescents. The findings of this study lay the basic foundation on the utilization of MUAC among the Khammungan tribal children and adolescents. Future research should be able to assess the practical end results of MUAC to accurately determine obesity and its associated metabolic risk factors such as diabetes and cardiovascular disease among different ethnic communities.

Conflict of Interest: The authors declare that they have no conflict of interests.

Ethical Approval: This article does not contain any studies with human participants or animals performed by any of the authors.

Informed Consent: Informed consent was obtained from all individual participants included in the study.

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List of Abbreviations:

AUC Area Under the Curve
BMI Body Mass Index
CI Confidence Interval
GDM Gestational Diabetes Mellitus
MUAC Mid-upper Arm Circumference
ISAK International Society for the Assessment of Kinanthropometry
ROC Receiver Operating Characteristic
SPSS Statistical Package for the Social Sciences
WC Waist Circumference
PV Positive predictive value
-PV Negative predictive value

References


