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EVALUATING THE ROLE OF ANTHROPOMETRIC VARIABLES IN IDENTIFYING OBESITY AMONG AO NAGA ADULTS IN NORTHEAST INDIA

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ABSTRACT

Anthropometric variables vary in diagnostic utility across populations and sexes, and indigenous Indian communities remain underrepresented in such evaluations. The aim of the study was to assess the sex-specific performance of waist-hip ratio (WHR), waist-to-height ratio (WtHR), mid-upper arm circumference (MUAC), and body adiposity index (BAI) for identifying obesity among Ao Naga adults of Northeast India. A cross-sectional investigation was conducted among 103 adults (53 men, 50 women) in Kohima, Nagaland. Obesity was defined by BMI (WHO-recommended Asian cut-off, ≥ 25 kg/m²) and, as an independent reference standard, the body fat percentage (BF%) measured via bioelectrical impedance analysis (≥ 25% for men; ≥ 35% for women) was used. Sex-specific logistic regression and receiver operating characteristic (ROC) analyses were performed against both reference standards, with the area under the curve (AUC), optimal cut points, sensitivity, and specificity reported for each. Women showed higher BAI and BF%. For BMI-defined obesity, WtHR and BAI showed stronger discrimination than WHR and MUAC in men (AUC 0.850 and 0.805 vs. 0.598 and 0.654) and excellent accuracy in women (AUC 0.977 and 0.907 vs. 0.694 and 0.610). Optimal WtHR cut points were 0.538 in men and 0.564 in women. When compared to directly measured body fat, the ranking remained unchanged, with WtHR and BAI again outperforming WHR and MUAC; WHR performed at the chance level in women. The study found that WtHR and BAI outperformed WHR in identifying both BMI-defined and body fat-defined obesity among Ao Naga adults, particularly in women. The findings highlight the importance of developing population-specific standards that are sensitive to sex and population.

Keywords: *anthropometry; Ao Naga; body adiposity index; mid-upper arm circumference; waist-to-hip ratio; obesity; waist-to-height ratio*

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INTRODUCTION

Anthropometric measurement is a practical and non-invasive technique for assessing body composition, overweight, obesity, and cardiometabolic or chronic disease risks. Global guidelines highlight the importance of anthropometric variables in identifying population-specific risks, monitoring and health interventions in public health and clinical and epidemiological settings [14, 18, 41]. Several studies have reported significant differences in the predictive accuracy of anthropometric indices across ethnicities, age categories, and geographic regions [10, 11, 17, 21, 44]. These differences are particularly evident in Indian populations where anthropometric variables perform differently across ethnic groups [7, 8, 14, 18, 36]. Establishing context-specific cut-offs is therefore imperative to strengthen the predictive value of anthropometric variables for detecting overweight and obesity and metabolic risk factors [10, 14, 41]. Although several methodological approaches and population-specific thresholds have been proposed, questions remain about their reliability and applicability across populations, particularly among groups that have been understudied [20, 39].

Furthermore, the relationship between anthropometric indices and BMI differs significantly by sex, ethnicity, and geographic context [10, 14]. This variation is particularly concerning given the limited research examining alternative anthropometric variables**,** such as waist-to-height ratio (WtHR) and body adiposity index (BAI) in indigenous adult populations in India. Each variable carries well-recognized limitations that bear directly on its suitability for specific populations. Furthermore, BMI does not distinguish between fat mass and lean mass, nor does it account for adiposity distribution patterns such as abdominal versus peripheral adiposity [32, 44]. The WHR, while sensitive to central fat accumulation, is influenced by hip circumference variability and performs inconsistently across populations [4, 20]. The BAI, calculated from hip circumference and height, tends to overestimate body adiposity in individuals with higher lean mass and underestimate it in those with greater body fat percentage (BF%) [5, 6]. MUAC, though practical in field settings, is a direct circumference measurement rather than a derived index and shows weaker associations with total adiposity in adults [19, 33]. These limitations reinforce the importance of population-specific validation before any measurement is adopted for screening purposes.

Further, researchers have consistently indicated that the waist-to-height ratio (WtHR) possesses greater diagnostic accuracy for identifying obesity and cardiometabolic risk, in contrast to the waist-to-hip ratio (WHR), which

demonstrates comparatively unsatisfactory performance [3, 4, 20, 39]. These findings point out the vital role of validating anthropometric variables across diverse populations, as their diagnostic accuracy varies by ethnicity and context. These population-specific validations are necessary for both reliable classification and design of targeted public health strategies [3, 14, 32, 38, 41]. The currently used standardized anthropometric indices, such as BMI, WHR, and WtHR, were largely established using Western populations, with subsequent validation in urban Indian ethnic groups, which raises significant questions about their applicability to rural and tribal ethnic groups who may have different body composition patterns [10, 18, 21]. This concern is particularly acute in Asian populations where standard BMI cut-offs often miss at-risk individuals, as metabolic disorders arise even at comparatively lower BMI levels [32, 41, 44]. Asians, and South Asians in particular, show higher body adiposity at lower BMI values, a pattern that substantially elevates the risks of cardiovascular and metabolic disease in adults [18, 36, 42]. Sex-related disparities in adipose tissue distribution exacerbate these ethnic variations, underscoring the necessity of sex-specific criteria in anthropometric evaluation [12, 17, 45]. The tribal populations in India further demonstrate that conventional cut-off values frequently underestimate cardiometabolic risk in under-represented groups [7, 8, 19, 25, 30].

Due to the constraints of BMI, alternative anthropometric indices like WtHR have been recognized as more reliable predictors of metabolic risks. These indices have received support from WHO recommendations and systematic reviews that advocate for population- and context-specific cut-offs for obesity assessment [41, 42]. This recognition is particularly relevant for South Asian populations, who demonstrate a unique "thin-fat" phenotype characterized by reduced muscle mass, increased fat mass, and elevated abdominal adiposity [32, 36, 44]. This distinctive body composition pattern makes traditional BMI assessments inadequate for accurately identifying metabolic risks in this population. The body composition differences are particularly pronounced in under-represented tribal communities of Northeast India where distinctive patterns of adiposity distribution and metabolic risks diverge from the assumptions underlying conventional public health screening tools [7, 8, 9, 39]. This divergence creates a critical gap in our ability to accurately assess health risks in these populations. Because of this difference, the World Health Organization [41] and the American Diabetes Association [1] have suggested lower BMI limits for Asian populations, with overweight being defined as ≥ 23 kg/m^2 and obesity as ≥ 25 kg/m^2. However, even these adjusted thresholds may be insufficient, as sex differences further complicate risk assessment [6, 12, 31, 41]. Men and

women differ significantly in adiposity patterns, muscle distribution, and metabolic susceptibility. While ethnicity-specific BMI cut-offs represent progress, emerging research suggests that sex-specific standards may also be necessary for truly accurate risk assessment [6, 12].

The Ao Naga tribe, indigenous to Mokokchung, Nagaland, India, exemplifies these challenges as a community with distinctive somatic and cultural characteristics [15]. Preliminary research among Ao adults had already shown that WtHR and waist circumference (WC) were stronger predictors of hypertension than BMI and WHR, implying that recommended anthropometric approaches may misclassify the risk of obesity-related comorbidities or non-communicable disease risks in this population [25]. A community-based survey in rural Mokokchung district also found high prevalence of risk for non-communicable diseases, including obesity, among Ao Naga adults, highlighting an emerging cardiometabolic burden that currently recommended screening tools (e.g., BMI) may not adequately capture [35]. Given the South Asian thin-fat phenotype and the distinct adiposity patterns documented among tribal populations of Northeast India, waist-derived indices such as WtHR and BAI were expected to demonstrate stronger discriminatory performance than WHR in this community. This expectation aligns with broader studies on tribal communities in Northeast India, which have consistently demonstrated the inadequacy of generalized cut-offs and the urgent need for tailored reference standards [7, 8, 9, 18].

The distinctive South Asian diabetes phenotype, combined with the specific findings in Ao Naga communities, further emphasizes the critical need for population-specific approaches in public health assessment [36,40]. However, comprehensive evidence examining multiple anthropometric variables in this population remains limited. The present study aims to address this research gap by examining sex-specific differences in multiple anthropometric variables among Ao Naga adults residing in Kohima, Nagaland. This research examines the associations and diagnostic accuracy of WHR, WtHR, MUAC, and BAI individually for adults, providing practical guidance for an underrepresented population while critically evaluating the relevance of standardized anthropometric variables and their cut-offs for population screening. These findings will contribute to a growing body of evidence advocating for population-specific, sex-sensitive, and culturally contextualized tools for public health assessments.

METHODS

The cross-sectional, community-based study was conducted among the Ao Naga adults living in Kohima, Nagaland. The study was conducted over a 30-day period in December 2023 and included 103 participants (53 males and 50 females) identified through purposive sampling to ensure adequate sex-specific representation. Participants were selected from the localities of Lerie and AG Colony of Kohima, which have high concentrations of Ao Naga residents, and were chosen to ensure cultural homogeneity and community relevance. Considering the absence of locality-specific population data, the sample cannot be precisely quantified as a proportion of the local Ao adult population. The purposive sampling method was employed to ensure adequate sex-specific study representation, and the derived cut-off values should therefore be regarded as preliminary estimates requiring validation in larger population-based research. Eligibility criteria included being at least 18 years old and self-identifying as ethnically Ao. Participants under the age group of 18 years, pregnant or lactating women, and individuals with self-reported physical conditions affecting anthropometric measurements, such as physical deformities or conditions affecting posture and limb dimensions, and those who refused to provide informed consent were excluded.

The Ao people represent one of the major Naga ethnic groups indigenous to Mokokchung District in Nagaland, Northeast India. Their traditional territory extends from the Tsüla Valley in the east to the Tsürang Valley in the west. The community self-identifies as *Aoer*, meaning "those who came", a reference to their migration across the Dikhu River, an origin narrative that has long been recognized as central to their collective identity [26]. The Ao-Naga tribe is not a homogenous unit but is divided into six major clans, which are further subdivided into numerous sub-clans. These six clans include Pongen, Longkumer, and Jamir of the Chungli group, along with Imchen, Walling, and Longchar of the Mongsen group. These clan divisions remain central to the Ao-Naga social organization, even as practices and taboos evolve [22]. According to the *Census of India* (2011), the Ao Nagas number approximately 227,000 in Nagaland, with the majority concentrated in Mokokchung District [27]. However, emigration for education, employment, and administration has led to significant Ao settlements in other parts of the state, particularly in urban centres, such as Kohima and Dimapur. In Kohima, the state capital, the Ao people constitute one of the most visible Naga subgroups, maintaining active cultural and social associations.

Socio-economic and demographic variables collected

Socio-economic and demographic variables collected in the study included age, as younger adults (18–35 years), middle-aged adults (36–55 years), and older adults (56 years and above) were included to capture generational variation; marital status (married, unmarried, divorced/separated/widowed) to reflect household and social roles, and educational attainment, categorized as primary (1–6 years of schooling), middle to higher secondary (7–12 years), and higher secondary and above (12+ years), to assess access to formal education. Occupation was grouped into government employment, private/business/self-employed, and homemaker/student/unemployed to represent economic engagement. Household income was categorized as low (< 10,000 rupees), medium (10,000–40,000), and high (> 40,000) using quartile cut-offs (25th, 50th, and 75th percentiles) derived from the sample distribution.

Collection of anthropometric variables

All anthropometric measurements were performed by a single trained investigator. The anthropometric measurements of stature or height, body weight, waist circumference (WC), hip circumference (HC), and mid-upper arm circumference (MUAC). Stature was measured using a standard anthropometer to the nearest 0.1 cm with participants standing erect without footwear. Body weight was obtained using a portable digital weighing scale to the nearest 0.1 kg with participants in light clothing without footwear. The WC, HC and MUAC were measured using a non-elastic measuring tape to the nearest 0.1 cm following standard landmarks. The BF%, visceral fat, and segmental body composition were measured using a bioelectrical impedance analyser (BIA) (Omron Body Composition Analyzer, Omron Healthcare, Japan). These measurements provide a direct assessment of body composition to supplement the indirect anthropometric indices. Derived anthropometric indices were calculated using the established formulas:

- BMI = weight (kg) / height^2 (m^2)
- WHR = WC / HC
- WtHR = WC / height
- BAI = [(HC / height$^{1.5}$) – 18]

Data were collected with cultural sensitivity, including explanations in the local vernacular when necessary. Written informed consent was obtained from all study participants. The objectives of the study were explained before the

collection of relevant data. Prevalence of obesity status was assessed using the WHO Expert Consultation (2004) Asian cut-offs, which classify overweight as BMI ≥ 23.0 kg/m² and obesity as BMI ≥ 25 kg/m², to account for population-specific risk thresholds. Nutritional status was categorised using Asian-specific cut-offs: underweight (< 18.5 kg/m²), normal weight (18.5–22.9 kg/m²), overweight (23.0–24.9 kg/m²), and obesity (≥ 25.0 kg/m²) [36,41]. In binary logistic regression and ROC analyses, participants with a BMI of ≥ 25.0 kg/m² were categorised as obese, while those with a BMI less than 25.0 kg/m² were classified as non-obese. The study was non-invasive in nature and involved no clinical procedures or biological sampling. It was conducted in accordance with the ethical principles of the Declaration of Helsinki [38]. Written informed consent was obtained from all participants after explaining the study objectives in their preferred language. Participation was voluntary, and participants were free to withdraw at any time without consequence. Data confidentiality and participant anonymity were maintained throughout the study and analysis.

Statistical analysis

Data were analysed using IBM SPSS Statistics Version 30.0 and R Version 4.3.0. Socio-demographic variables were summarized as frequencies and percentages, with 95% confidence intervals estimated using the Wilson scoring method. Continuous variables were expressed as mean and standard deviation, stratified by sex. Associations between BMI and anthropometric variables (WHR, WtHR, MUAC, and BAI) were examined using Pearson's correlation coefficients, and the results were illustrated with heat maps and scatter plots. The univariate logistic regression was performed to estimate odds of obesity (BMI ≥ 25.0 kg/m²; Asian cut-off), and model performance was assessed by receiver operating characteristic (ROC) analysis. For each variable, the area under the curve (AUC), optimal cut-off, sensitivity, and specificity were reported. All four anthropometric variables were entered simultaneously into the logistic regression model to enable direct comparison of predictive strength across variables regardless of individual significance levels. A two-tailed p-value < 0.05 was considered statistically significant. Additionally, BF% was assessed utilizing the bioelectrical impedance analyser, and obesity was classified using the Asian-specific BF% cut-off values of ≥ 25% for males and ≥ 35% for females [11] to establish a direct reference standard for validating ROC and regression outcomes.

RESULTS

Table 1 presents the socio-demographic characteristics of the Ao Naga adults (N = 103). The age distribution was broadly comparable between men and women, with around one-third in the 18–35 age group (34.0% males; 40.0% females) and a similar proportion in the oldest group (56 + years). Most participants were married (56.6% of men and 54.0% of women), while unmarried individuals comprised about two-fifths of the study participants. Educational attainment was relatively high, as nearly half of both sexes had studied beyond the higher secondary. Occupational status showed distinct sex differences where the majority of men (67.9%) were classified primarily as students or unemployed, whereas women were more frequently engaged in private business or were self-employed (36.0%). This pattern likely reflects women's greater involvement in small-scale business and informal economic activities, while a larger share of men were 'students' or not in paid employment. Household income patterns also differed, with men predominantly concentrated in the middle-income group (50.9%), while the majority of women's households were in the low-income bracket (56.0%).

Table 2 presents the sex-stratified descriptive anthropometric characteristics, including BF% measured by BIA, indicating that men were taller and heavier than women, consistent with general sex-based differences in body size, although BMI values were comparable between groups (24.93 kg/m² in men vs. 24.59 kg/m² in women, $p > 0.05$). Despite similar BMI, the body composition indicators showed notable variation: men had larger MUAC and higher WHR, reflecting greater central adiposity, while women exhibited a higher body adiposity index, suggesting relatively greater body fat accumulation. The WtHR was nearly identical between sexes, indicating that abdominal adiposity distribution relative to stature was broadly similar. Mean BF% was 27.96 ± 5.49% in males and 32.89 ± 6.41% in females, reflecting higher overall adiposity in women despite comparable BMI values. These findings demonstrate that sex-specific anthropometric patterns are not always adequately captured by BMI alone, highlighting the importance of using multiple variables when assessing obesity and body composition in adults. The correlations between BMI, height, body weight, and the anthropometric variables are presented in Figure 1. In both sexes, BMI correlated most strongly with WtHR and BAI, while WHR showed the weakest associations, particularly with height. The scatterplots illustrate these relationships, showing steeper regression slopes for WtHR and BAI than for WHR and MUAC in Figure 2.

Table 1. Sex-Specific sociodemographic background of the Ao Naga adults

Variables	Male (n = 53) n (%, 95% CI)	Female (n = 50) n (%, 95% CI)
Age Groups		
18–35	18 (34.0%; 22.7–47.4)	20 (40.0%; 27.6–53.8)
36–55	20 (37.7%; 25.9–51.2)	15 (30.0%; 19.1–43.8)
56+	15 (28.3%; 18.0–41.6)	15 (30.0%; 19.1–43.8)
Marital Status		
Married	30 (56.6%; 43.3–69.0)	27 (54.0%; 40.4–67.0)
Unmarried	20 (37.7%; 25.9–51.2)	20 (40.0%; 27.6–53.8)
Divorced/Separated/Widowed (D/S/W)	3 (5.7%; 1.9–15.4)	3 (6.0%; 2.1–16.2)
Education		
Primary (< 6)	8 (15.1%; 7.9–27.1)	9 (18.0%; 9.8–30.8)
Middle school / higher secondary (6–12)	20 (37.7%; 25.9–51.2)	16 (32.0%; 20.8–45.8)
Higher secondary and above (12 +)	25 (47.2%; 34.4–60.3)	25 (50.0%; 36.6–63.4)
Occupation		
Government	14 (26.4%; 16.4–39.6)	11 (22.0%; 12.8–35.2)
Homemaker/Student/Unemployed	36 (67.9%; 54.5–78.9)	21 (42.0%; 29.4–55.8)
Private/Business/Self-employed	3 (5.7%; 1.9–15.4)	18 (36.0%; 24.1–49.9)
Income		
Low Income (< 10,000)	16 (30.2%; 19.4–43.5)	28 (56.0%; 42.3–68.8)
Middle Income (10,000–40,000)	27 (50.9%; 37.9–63.9)	15 (30.0%; 19.1–43.8)
High Income (40,000 +)	10 (18.9%; 10.6–31.4)	7 (14.0%; 7.0–26.2)

Note. n = number of subjects; % = percentage; CI = confidence interval.

Table 2. Sex-stratified descriptive anthropometric characteristics of Ao Naga adults

Variable	Male (n = 53) Mean ± SD	Female (n = 50) Mean ± SD
Age (years)	45.91 ± 17.99	43.90 ± 16.72
Height (cm)	165.97 ± 8.29	157.65 ± 5.41
Weight (kg)	67.49 ± 10.62	61.45 ± 12.24
BMI (kg/m^2)	24.93 ± 3.09	24.59 ± 4.42
Body Fat (%)	27.96 ± 5.49	32.89 ± 6.41
WHR	0.95 ± 0.06	0.90 ± 0.07
WtHR	0.540 ± 0.059	0.535 ± 0.079
BAI	26.11 ± 4.73	29.40 ± 6.46
MUAC (cm)	30.40 ± 3.64	29.49 ± 4.57

Note. SD = standard deviation; BMI = body mass index; WHR = waist-to-hip ratio; WtHR = waist-to-height ratio; BAI = body adiposity index; MUAC = mid-upper arm circumference. Body fat % measured by BIA.



Figure 1. Sex-stratified correlation matrix of BMI, height, body weight, and anthropometric variables (WHR, WtHR, BAI, and MUAC) among Ao Naga adults.

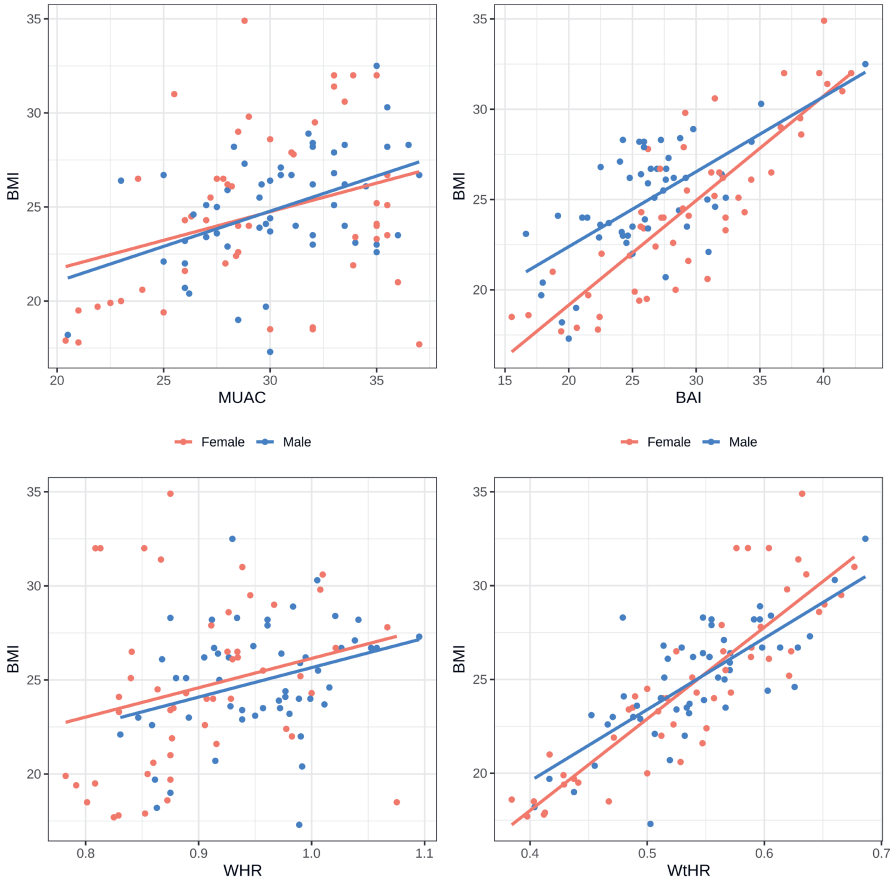


Figure 2. Scatterplots of BMI against MUAC, BAI, WHR, and WtHR, stratified by sex, with fitted linear regression lines.

Table 3 presents the binary logistic regression analyses of anthropometric variables for predicting BMI-defined obesity (BMI ≥ 25.0 kg/m²) in men and women. In males, WtHR was the strongest predictor, with each unit increase associated with 36% higher odds of obesity (OR = 1.36, p < 0.001). The BAI was also significant (OR = 1.43, p = 0.010), while MUAC showed only a borderline association (p = 0.063), and WHR did not reach significance. Among females, both WtHR (OR = 2.09, p = 0.003) and BAI (OR = 1.57, p < 0.001) were robust predictors of obesity, while WHR also demonstrated a significant, though weaker, association (OR = 2.62, p = 0.034). Collectively, these results emphasize the predictive strengths of WtHR and BAI across sexes, with the added value of WHR being observed in females but not in males.

Table 3. Binary logistic regression analysis of anthropometric variables for predicting BMI-defined obesity

Predictor	B	SE	p-value	OR	95% CI
Male (n = 53)					
WHR	0.704	0.483	0.145	2.02	0.79–5.21
WtHR	0.309	0.090	<0.001	1.36	1.14–1.63
MUAC	0.156	0.084	0.063	1.17	0.99–1.38
BAI	0.354	0.111	0.010	1.43	1.15–1.77
Female (n = 50)					
WHR	0.964	0.456	0.034	2.62	1.07–6.40
WtHR	0.737	0.245	0.003	2.09	1.29–3.38
MUAC	0.099	0.067	0.136	1.10	0.97–1.26
BAI	0.450	0.131	<0.001	1.57	1.21–2.03

Note. B = unstandardized regression coefficient; SE = standard error; OR = odds ratio; CI = confidence interval. Obesity defined as BMI ≥ 25.0 kg/m² (Asian cut-off).

Table 4 presents the AUC-ROC analyses of anthropometric variables for identifying BMI-defined obesity in adults. Among males, WtHR demonstrated the strongest diagnostic performance (AUC = 0.850), followed closely by BAI (AUC = 0.805). Both indices showed high sensitivity and specificity at their respective optimal cut-offs, whereas WHR yielded a much lower AUC (0.598), reflecting limited predictive value. In females, the discriminative ability of WtHR was even stronger (AUC = 0.977), reaching near-perfect diagnostic accuracy, while BAI also performed excellently (AUC = 0.907). By contrast, WHR (AUC = 0.694) and MUAC (AUC = 0.610) were weaker indicators of obesity in women. Collectively, these findings underscore the superior diagnostic utility of WtHR and BAI across sexes, with particularly pronounced accuracy among females. The AUC values of the anthropometric variables with confidence intervals and the corresponding ROC curves for identifying obesity using BMI are depicted in Figure 3 and Figure 4, respectively.

Table 4. Receiver operating characteristic (ROC) curve analysis of anthropometric variables for identifying BMI-defined obesity

Predictor	AUC (95% CI)	p-value	Cut-off	Sens.	Spec.	Youden
Male (n = 53)						
WHR	0.598 (0.443–0.753)	0.216	1.01	25.0	100.0	0.25
WtHR	0.850 (0.741–0.959)	<0.001	0.538	82.1	84.0	0.66
MUAC	0.654 (0.505–0.804)	0.043	30.25	64.3	68.0	0.32
BAI	0.805 (0.682–0.928)	<0.001	25.27	85.7	85.7	0.58
Female (n = 50)						
WHR	0.694 (0.541–0.847)	0.013	0.909	68.2	75.0	0.43
WtHR	0.977 (0.945–1.000)	<0.001	0.564	86.4	96.4	0.83
MUAC	0.610 (0.452–0.767)	0.172	27.10	90.9	42.9	0.34
BAI	0.907 (0.829–0.985)	<0.001	30.15	77.3	89.3	0.67

Note. AUC = area under the curve; CI = confidence interval; Sens. = sensitivity; Spec. = specificity. Youden index = Sensitivity + Specificity - 1.

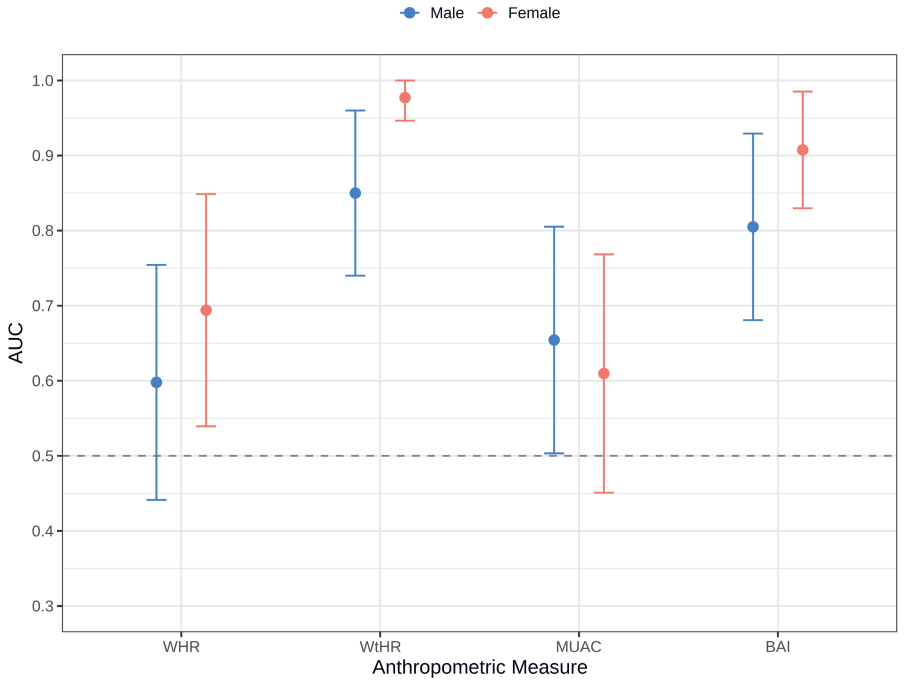


Figure 3. Area under the curve (AUC) values with 95% confidence intervals for anthropometric variables identifying BMI-defined obesity, stratified by sex. The segmented line indicates the reference (AUC = 0.50) with no discrimination.

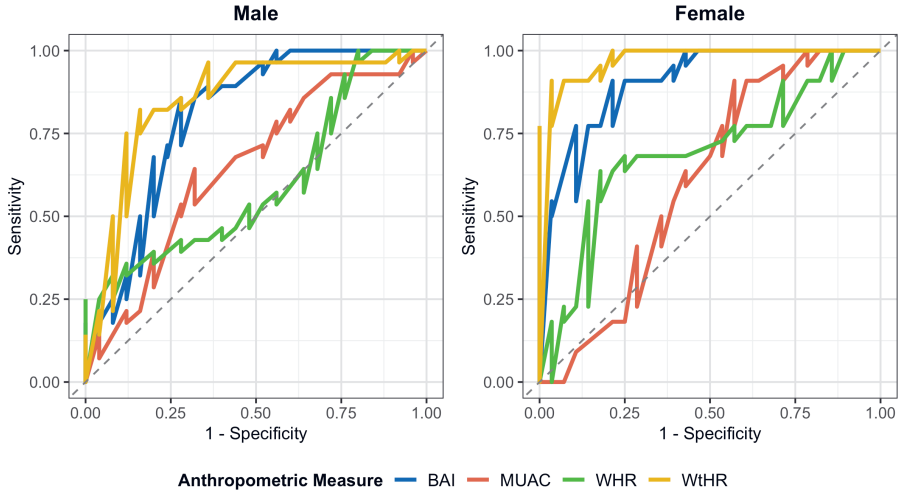


Figure 4. Receiver operating characteristic (ROC) curves of anthropometric variables (WHR, WtHR, BAI, MUAC) for identifying BMI-defined obesity, stratified by sex. The segmented line indicates the reference (AUC = 0.50) with no discrimination.

Diagnostic performance was additionally assessed against directly measured BF%, with obesity defined as ≥ 25% in males and ≥ 35% in females [11]. Obesity was classified using Asian-specific BF% cut-offs of ≥ 25% for males and ≥ 35% for females [11]. Based on these criteria, 39 males (73.6%) and 20 females (40.0%) were classified as obese by BF%, compared to 28 males (52.8%) and 22 females (44.0%) classified as obese by BMI. The discordance was particularly pronounced among males where BMI underestimated obesity prevalence by approximately 21 percentage points relative to body fat-based classification, suggesting that BMI may substantially misclassify the obesity burden in Ao Naga men.

The ROC curve analysis using body fat-defined obesity further confirmed these patterns (Table 5). WtHR demonstrated good discriminatory accuracy both in males (AUC = 0.822, 95% CI: 0.700–0.945, $p < 0.001$) and females (AUC = 0.836, 95% CI: 0.719–0.952, $p < 0.001$). BAI also performed well in males (AUC = 0.794, 95% CI: 0.639–0.949, $p < 0.001$) and females (AUC = 0.888, 95% CI: 0.796–0.981, $p < 0.001$). WHR showed poor performance in males (AUC = 0.619, $p = 0.151$) and performed at chance level in females (AUC = 0.487, $p = 0.874$), with its confidence interval crossing the 0.50 threshold, indicating negligible discriminatory ability for body fat-defined obesity in Ao Naga women (Figures 5 and 6). MUAC remained consistently weak in both sexes (males: AUC = 0.583, $p = 0.347$; females: AUC = 0.592, $p = 0.256$) (Table 5). The ranking of anthropometric variables was identical across both reference standards, where WtHR and BAI consistently outperformed WHR and MUAC, strengthening confidence in their diagnostic utility for this population (Figures 5 and 6).

Table 5. Receiver operating characteristic (ROC) curve analysis of anthropometric variables for identifying body fat-defined obesity

Predictor	AUC (95% CI)	p-value	Cut-off	Sens.	Spec.	Youden
Male (n = 53)						
WHR	0.619 (0.457–0.781)	0.151	99.31‡	30.8	92.9	0.24
WtHR	0.822 (0.700–0.945)	<0.001	–0.601†	89.7	64.3	0.54
BAI	0.794 (0.639–0.949)	<0.001	–0.297†	79.5	78.6	0.58
MUAC	0.583 (0.410–0.757)	0.347	26.30	89.7	28.6	0.18
Female (n = 50)						
WHR	0.487 (0.322–0.651)	0.874	92.07‡	45.0	66.7	0.12
WtHR	0.836 (0.719–0.952)	<0.001	0.323†	80.0	83.3	0.63
BAI	0.888 (0.796–0.981)	<0.001	0.529†	65.0	100.0	0.65
MUAC	0.592 (0.434–0.750)	0.256	26.65	85.0	33.3	0.18

Note. AUC = area under the curve; CI = confidence interval; Sens. = sensitivity; Spec. = specificity. Body fat obesity is defined as ≥25% for males and ≥35% for females (Gallagher et al. 2000). † WtHR and BAI cut-offs are in standardized Z-score units. ‡ WHR cut-offs are in WHR × 100 units.

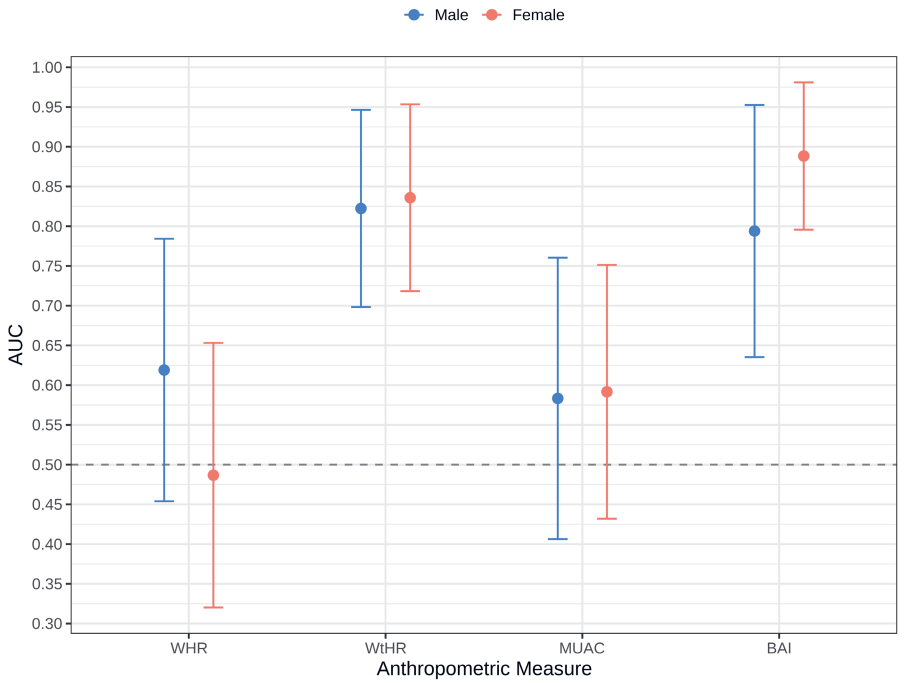


Figure 5. Receiver operating characteristic (ROC) curves of anthropometric variables (WHR, WtHR, BAI, MUAC) for identifying body fat-defined obesity, stratified by sex. The segmented line indicates the reference (AUC = 0.50) with no discrimination.

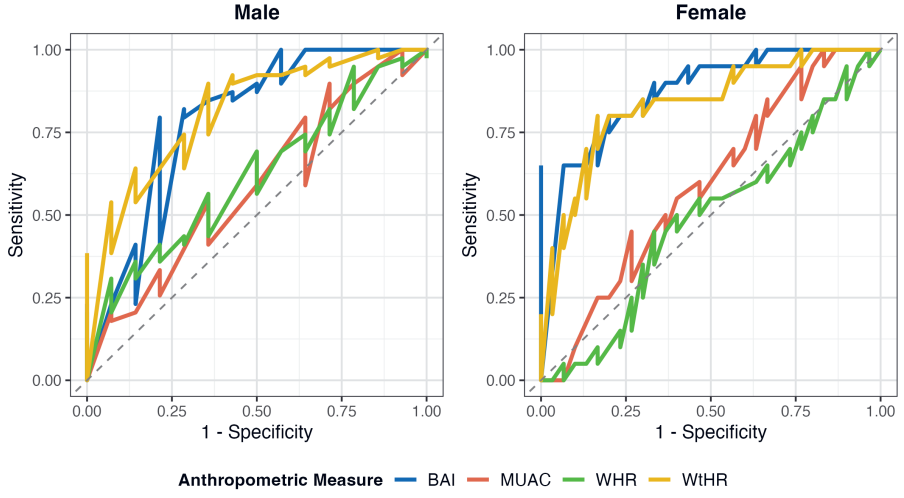


Figure 6. Area under the curve (AUC) values with 95% confidence intervals for anthropometric variables identifying body fat-defined obesity, stratified by sex. The segmented line indicates the reference (AUC = 0.50) with no discrimination.

The univariate logistic regression analysis using body fat-defined obesity as the reference standard confirmed the superiority of WtHR and BAI in both sexes (Table 6). Among males, WtHR (OR = 5.045, 95% CI: 1.833–13.882, p = 0.002) and BAI (OR = 4.980, 95% CI: 1.783–13.912, p = 0.002) were significant predictors, while WHR (p = 0.180) and MUAC (p = 0.256) were found not significant. Among females, BAI demonstrated the strongest association (OR = 13.794, 95% CI: 3.127–60.851, p < 0.001), followed by WtHR (OR = 4.964, 95% CI: 1.949–12.645, p < 0.001), with WHR (p = 0.670) and MUAC (p = 0.198) again being non-significant.

Table 6. Univariate logistic regression analysis of anthropometric variables for predicting body fat-defined obesity

Predictor	B	SE	p-value	OR	95% CI
Male (n = 53)					
WHR	0.073	0.054	0.180	1.076	0.967–1.197
WtHR†	1.618	0.516	0.002	5.045	1.833–13.882
BAI†	1.605	0.524	0.002	4.980	1.783–13.912
MUAC	0.100	0.088	0.256	1.105	0.930–1.311
Female (n = 50)					
WHR	–0.018	0.041	0.670	0.982	0.906–1.066
WtHR†	1.602	0.477	<0.001	4.964	1.949–12.645
BAI†	2.624	0.757	<0.001	13.794	3.127–60.851
MUAC	0.086	0.067	0.198	1.090	0.956–1.243

Note. B = unstandardized regression coefficient; SE = standard error; OR = odds ratio; CI = confidence interval. Each predictor entered separately in univariate models. † OR represents odds change per one standard deviation increase (Z-score).

DISCUSSION

The present study compared the sex-specific accuracy of WHR, WtHR, MUAC, and BAI for identifying obesity and adiposity among Ao Naga adults, using both BMI and directly measured BF% as reference standards. The socio-economic profile of research participants differed by sex, particularly in occupation and income, with most women's households falling in the lower-income group (Table 1). Similar socio-economic patterns in obesity risks have been reported in national surveys and tribal research studies [20,26,42]. These differences may contribute to variation in body composition and support the need for population-specific reference standards. Although men and women had similar

BMIs, women showed greater adiposity, reflected in higher BAI and higher measured BF% (Table 2). This indicates that BMI alone does not completely capture sex-specific differences in body adiposity and that indices such as WtHR and BAI added useful information. When overweight and obesity were combined, nearly three-quarters of participants were above the healthy BMI range, pointing to a shift toward overweight or obesity. This pattern was found to be consistent with other Naga and Northeast Indian populations. In the neighbouring Angami Naga of Kohima district, overweight and obesity were similarly high in both sexes despite comparable BMI [28], while a survey of the rural tribal population of Mokokchung, Nagaland, documented a rising prevalence of overweight alongside a high burden of hypertension and other NCD risk factors [35].

Across the regression and ROC analyses, waist-based indices, particularly WtHR and BAI, were consistently the strongest predictors of obesity in both sexes, while WHR was found to be the weakest predictor (Tables 3 and 4). The discriminatory accuracy of WtHR was found to be high, especially in women (AUC = 0.977) (Figures 3 and 4). This exceeds the pooled value of 0.704 reported by Browning et al. [4] across 78 studies and was found to be consistent with evidence from a large sample of South Asian adults, in whom WtHR showed higher accuracy than BMI, WC, and WHR, with higher values in women than men [16]. Reviews have similarly noted that MUAC, though moderately related to BMI, is unreliable as a stand-alone variable [21, 38]. These results extend earlier work in Ao adults, where waist-based variables predicted hypertension more effectively than BMI or WHR [27]. The present study showed the same advantage for identifying obesity. Comparable use of these indices to derive cut-off points in the Chiru tribe of Northeast India further supports their applicability in tribal populations [34].

A key strength of this study is that the findings were tested against a direct measurement of body composition rather than against BMI alone. When BF% was used as an independent reference standard, the order of the variables did not change, with WtHR and BAI again outperforming WHR and MUAC (Figures 5 and 6). Since WtHR and BAI performed best whether obesity was defined by BMI or by body fat, but their strong performance is unlikely to depend on BMI alone. Notably, body fat-based classification identified considerably more obesity in men (73.6%) than BMI (52.8%), suggesting that BMI may underestimate adiposity in Ao Naga men. WHR performed not performed well than chance for body fat-defined obesity in women (AUC=0.487), confirming its limited value in this group compared to conventionally used anthropometric adiposity measures (Figure 6).

The correlation analysis helped explain these differences (Figure 1). WHR showed almost negligible relationship with height (r = 0.03 in men), indicating that it reflects little about overall body size, whereas WtHR was closely tied to weight, particularly in women, matching its high accuracy. BAI was strongly and negatively related to height, reflecting its known dependence on stature. In short, the variables that account for body size, WtHR and BAI, aligned most closely with both BMI and the body fat findings, while WHR did not (Figure 2). BAI performed well in this population, and an Indian study has likewise reported that BAI is associated with body fat in both sexes [13]. However, its performance is not consistent across populations and BAI has been shown to underestimate body fat compared with bioelectrical impedance [29], and it should therefore be applied with caution.

This study also showed the value of analysing men and women separately, as the relative performance of the variables differed by sex [5, 12, 22, 39]. Ignoring such differences may hide important health patterns. More broadly, anthropometric standards in India are often based on urban or non-tribal groups, with limited validation in indigenous populations, as observed in the distinctive adiposity patterns reported among other tribal groups [35]. Large surveys, such as the Longitudinal Ageing Study in India, may offer useful data for future validation [2]. Tribal groups such as the Ao Naga have distinct genetic, dietary, and environmental backgrounds, yet remain underrepresented in the evidence used to guide policy.

This study has limitations, including a relatively small, purposively selected group of research participants. Even so, the consistency of the results across correlation, regression, and ROC analyses and across both reference standards strengthens confidence in the findings. Beyond the statistics, this study is a reminder that good public health depends on accurate measurement. For populations such as the Ao Naga, measurement should be sex-specific, population-specific, and culturally relevant; without this, health policy risks being both inaccurate and unfair.

CONCLUSION

This study demonstrated that WtHR and BAI showed greater diagnostic accuracy for identifying BMI-defined obesity than WHR and MUAC among Ao Naga individuals in Kohima, a conclusion that remained consistent when BF% was used as an independent direct reference standard. The advantage of WtHR and BAI was most apparent among women, where both indices aligned

closely with both reference standards and demonstrated high diagnostic accuracy. In contrast, WHR performed weakly across sexes, suggesting that its utility in routine screening warrants reconsideration. These findings show that measurement is context-dependent; cut-offs that work in one population may not work in another. The results also reveal that nearly three-fourths (71.8%) of Ao Naga adults were classified as overweight or obese based on Asian BMI cut-offs, reflecting a population undergoing nutritional and lifestyle transition. The superior predictive power of WtHR and BAI highlights increasing central and peripheral adiposity, particularly among women, aligning with broader national and tribal patterns reported in India. By looking carefully at sex differences and population variation, the findings emphasize the need to continue developing reference standards appropriate for India's tribal populations. Although modest in scale, it provides early empirical evidence of a post-transition phenotype among Ao Naga adults characterized by increased adiposity, consistent with broader nutritional transition patterns documented across tribal communities in Northeast India [7, 8, 16]. Collectively, the findings emphasize the value of adopting population- and sex-sensitive anthropometric tools to ensure accurate assessment and inclusive public health strategies for Indigenous communities in Northeast India.

RECOMMENDATIONS

Based on the findings, study recommend that national and regional health agencies prioritize the development of population-specific anthropometric cut-offs to improve diagnostic accuracy among tribal communities, such as the Ao Nagas. Due to their high predictive accuracy, WtHR and BAI should be suggested as standard screening tools in field settings. Future research must incorporate sex-disaggregated analyses to capture physiological differences and avoid obscuring health disparities. There is a need for larger, multisite studies across Naga tribes to validate and refine these measurements by incorporating cultural and lifestyle dimensions. Finally, strengthening primary care capacity to monitor simple variables like WtHR and MUAC, alongside culturally competent health policies, will be essential to improve early detection and equitable health outcomes in indigenous populations.

LIMITATIONS

As with most community-based studies, certain limitations are acknowledged. The relatively small and purposively selected sample may not fully represent the broader Ao Naga population, and the cross-sectional design limits causal interpretation. The derived cut-off values should therefore be regarded as preliminary estimates requiring validation in larger groups of research participants. Nevertheless, the internal consistency of the findings across sexes and variables lends confidence to the observed patterns. It should also be noted that all anthropometric variables evaluated, including BMI, are indirect proxies for body fat; although BF% measured by BIA was used as a direct reference standard, this technique has its own measurement limitations. Prior studies involving Ao Naga adults have demonstrated that WtHR predicts hypertension with greater accuracy than BMI [25], indicating possible clinical benefits beyond mere measurement convenience. Future research should extend this validation to other cardiometabolic endpoints to determine whether WtHR and BAI improve upon BMI's ability to predict actual health risk in this population.

AUTHORS' CONTRIBUTION

Temsutola Pongen conceptualized the study, conducted fieldwork, performed statistical analysis, and prepared the first draft of the manuscript. Nitish Mondal supervised the research design, critically reviewed and edited the final manuscript. Both authors read and approved the final version of the manuscript.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

1. American Diabetes Association (2015). Standards of medical care in diabetes-2015: Summary of revisions. Diabetes Care, 38, Suppl 1, S4. https://doi.org/10.2337/dc15-S003
2. Arokiasamy P., Bloom D., Lee J., Parasuraman S., Sekher T. V., Mohanty S. K., et al. (2022). Cohort profile: the Longitudinal Ageing Study in India (LASI). International Journal of Epidemiology, 51 (4), e167–e176. https://doi.org/10.1093/ije/dyab266
3. Ashwell M., Gibson S. (2016). Waist-to-height ratio as an indicator of 'early health risk': simpler and more predictive than using a 'matrix' based on BMI and waist circumference. BMJ Open, 6 (3), e010159. https://doi.org/10.1136/bmjopen-2015-010159.
4. Browning L.M., Hsieh S.D., Ashwell M. (2010). A systematic review of waist-to-height ratio as a screening tool for the prediction of cardiovascular disease and diabetes: 0.5 could be a suitable global boundary value. Nutrition Research Reviews, 23 (2), 247–269. https://doi.org/10.1017/S0954422410000144
5. Cancela-Carral J. M., Bezerra P. (2023). Degree of association between the body mass index (BMI), waist-hip ratio (WHR), waist-height ratio (WHtR), body adiposity index (BAI) and conicity index (CI) in physically active older adults. Clinical Nutrition ESPEN, 56, 171–176. https://doi.org/10.1016/j.clnesp.2023.10.007
6. Castle A., Hoeppner S., Manne-Goehler J., et al. (2023). Identifying sex-specific anthropometric measures and thresholds for dysglycemia screening in an HIV-endemic rural South African population. PLOS Global Public Health, 3, e0001698. https://doi.org/10.1371/journal.pgph.0001698
7. Chaudhuri R., Das P., Sarkar P., Chatterjee D., Bandyopadhyay A. R. (2020). Estimation of optimal obesity cut-offs among Tripuri and Halam women of Tripura, Northeast India. Papers on Anthropology, 29 (2), 83–91. https://doi.org/10.12697/poa.2020.29.2.07
8. Das P., Ghosh K., Bose A., et al. (2023). The role of anthropometric variables in assessment of obesity among Tripuri women of North-East India. Papers on Anthropology, 32 (2), 59–67. https://doi.org/10.12697/poa.2023.32.2.04
9. Das S., Chatterjee P. (2025). Comparative assessment of anthropometric and body composition parameters among tribal adults in Northeast India. Wisdom Journal of Science and Technology, 1 (1), 36–43. https://doi.org/10.64848/WJST.1.1.2025.36-43

10. Deurenberg P., Deurenberg-Yap M., Guricci S. (2002). Asians are different from Caucasians and from each other in their BMI/body fat percent relationship. Obesity Reviews, 3 (3), 141–146. https://doi.org/10.1046/j.1467-789x.2002.00065.x
11. Gallagher D., Heymsfield S. B., Heo M., Jebb S. A., Murgatroyd P. R., Sakamoto Y. (2000). Healthy percentage body fat ranges: an approach for developing guidelines based on body mass index. American Journal of Clinical Nutrition, 72 (3), 694–701. https://doi.org/10.1093/ajcn/72.3.694
12. Górnicka A., Szewczyk K., Białkowska A., et al. (2022). Anthropometric indices as predictive screening tools for obesity in adults; the need to define sex-specific cut-off points. Applied Sciences, 12 (12), 6165. https://doi.org/10.3390/app12126165
13. Gupta S., Kapoor S. (2014). Body adiposity index: its relevance and validity in assessing body fatness of adults. International Scholarly Research Notices, 2014, 243294. https://doi.org/10.1155/2014/243294
14. Islam M., Chowdhury A., Siraj M., et al. (2024). Anthropometric indices in predicting 10-year cardiovascular risk in South and Southeast Asia: analysis of 12 WHO STEPS survey data. The Lancet Regional Health – Southeast Asia, 29, 100481. https://doi.org/10.1016/j.lansea.2024.100481
15. Jamir T., Ditamulu D., Tetso D., Venuh Z., Mushrif-Tripathy V., Pokharia A. K. (2014). Archaeology of Naga ancestral sites. Vol 1. Heritage Publishing House, Dimapur.
16. Jayawardana R., Ranasinghe P., Sheriff M. H., Matthews D. R., Katulanda P. (2013). Waist to height ratio: a better anthropometric marker of diabetes and cardio-metabolic risks in South Asian adults. Diabetes Research and Clinical Practice, 99 (3), 292–299. https://doi.org/10.1016/j.diabres.2012.12.013
17. Karastergiou K., Smith S. R., Greenberg A. S., et al. (2012). Sex differences in human adipose tissues: the biology of pear shape. Biology of Sex Differences, 3 (1), 13. https://doi.org/10.1186/2042-6410-3-13
18. Kshatriya G. K., Acharya S. K. (2016). Triple burden of obesity, undernutrition, and cardiovascular risk among Indian tribes. PLoS One, 11 (1), e0147934. https://doi.org/10.1371/journal.pone.0147934
19. Kshatriya G. K., Chakraborty R., Mondal N., Bose K. (2021). Validating mid-upper arm circumference (MUAC) cut-off points as indicators of nutritional status among nine tribal populations of India. Anthropological Review, 84 (3), 301–315. https://doi.org/10.2478/anre-2021-0018
20. Lam B. C. C., Koh G. C. H., Chen C., Wong M. T. K., Fallows S. J. (2015). Comparison of Body Mass Index (BMI), Body Adiposity Index (BAI), Waist Circumference (WC), Waist-To-Hip Ratio (WHR) and Waist-To-Height Ratio (WHtR) as predictors of cardiovascular disease risk factors in an adult population in Singapore. PLoS One, 10 (4), e0122985. https://doi.org/10.1371/journal.pone.0122985

21. Lear S. A., Humphries K. H., Kohli S., Birmingham C. L. (2007). The use of BMI and waist circumference as surrogates of body fat differs by ethnicity. Obesity, 15 (11), 2817–2824. https://doi.org/10.1038/oby.2007.334
22. Longchar R., Imchasenla (2017). Taboos of the Ao-Nagas: change and continuity. IRA-International Journal of Management & Social Sciences, 8 (1), 46–52. https://doi.org/10.21013/jmss.v8.n1.p5
23. Lu Y., Liu S., Qiao Y., Qiao Y., Li G., Wu Y., Ke C. (2021). Waist-to-height ratio, waist circumference, body mass index, waist divided by height$^{0.5}$ and the risk of cardiometabolic multimorbidity: A national longitudinal cohort study. Nutrition, Metabolism and Cardiovascular Diseases, 31 (11), 2644–2651. https://doi.org/10.1016/j.numecd.2021.05.026
24. Luhar S., Mallinson P. A. C., Clarke L., Kinra S. (2018). Trends in the socioeconomic patterning of overweight/obesity in India: a repeated cross-sectional study using nationally representative data. BMJ Open, 8 (10), e023935. https://doi.org/10.1136/bmjopen-2018-023935
25. Maken T., Varte L. (2013). Anthropometric indicators as predictors of high blood pressure among the Ao tribe of North-East India. Asian Journal of Medical Sciences, 4 (3), 14–22. https://doi.org/10.71152/ajms.v4i3.3301
26. Mills J.P. (1926). The Ao Nagas. Macmillan & Co, London.
27. Office of the Registrar General & Census Commissioner, India (2011). Census of India 2011: Primary Census Abstract. Ministry of Home Affairs, Government of India. New Delhi.
28. Peseyie V., Ghosh S. (2022). Prevalence of obesity and hypertension among the adult Angami Naga of Nagaland, Northeast India: High prevalence of hypertension in an Indian indigenous population. Human Biology and Public Health, 1, 1–14. https://doi.org/10.52905/hbph2022.1.27
29. Ramírez-Vélez R., Correa-Bautista J. E., González-Ruíz K., et al. (2017). The role of body adiposity index in determining body fat percentage in Colombian adults with overweight or obesity. International Journal of Environmental Research and Public Health, 14 (10), 1093. https://doi.org/10.3390/ijerph14101093
30. Saha S., Sil S. K. (2019). A comparative study on fat pattern between tribal and non-tribal girls of Tripura, North-East India. The Indian Journal of Pediatrics, 86 (6), 508–514. https://doi.org/10.1007/s12098-019-02879-7
31. Seyedhoseinpour A., Barzin M., Mahdavi M., et al. (2023). BMI category-specific waist circumference thresholds based on cardiovascular disease outcomes and all-cause mortality: Tehran Lipid and Glucose Study (TLGS). BMC Public Health, 23, 16190. https://doi.org/10.1186/s12889-023-16190-w.
32. Sweatt K., Garvey W., Martins C. (2024). Strengths and Limitations of BMI in the Diagnosis of Obesity: What Is the Path Forward? Current Obesity Reports, 13, 584–595. https://doi.org/10.1007/s13679-024-00580-1

33. Tang A. M., Dong K., Deitchler M., et al. (2013). Use of Cutoffs for Mid-Upper Arm Circumference (MUAC) as an Indicator or Predictor of Nutritional and Health-Related Outcomes in Adolescents and Adults: A Systematic Review. Washington (DC): FHI 360/FANTA.
34. Thanglen H., Zimik U., Thanglen R., Pemmichon R. M., Chanak M., Bose K. (2024). Anthropometric markers and their cut-off point for the prediction of hypertension with lifestyle as a risk factor among Chiru tribe of North East India. Ethnicity & Health, 29 (4–5), 505–522. https://doi.org/10.1080/13557858.2024.2342326
35. Tushi A., Rao S. R., Pattabi K., Kaur P. (2018). Prevalence of risk factors for non-communicable diseases in a rural tribal population of Mokokchung, Nagaland, India. The National Medical Journal of India, 31 (1), 11–14. https://doi.org/10.4103/0970-258X.243405.
36. Unnikrishnan R., Anjana R. M., Mohan V. (2014). Diabetes in South Asians: Is the phenotype different? Diabetes, 63 (1), 53–55 https://doi.org/10.2337/db13-1592
37. Venkatrao M., Nagarathna R., Majumdar V., Patil S. S., Rathi S., Nagendra H. (2020). Prevalence of Obesity in India and Its Neurological Implications: A Multi-factor Analysis of a Nationwide Cross-Sectional Study. Annals of Neurosciences, 27 (3–4), 153–161. https://doi.org/10.1177/0972753120987465
38. Wang J., Thornton J., Russell M., Burastero S., Heymsfield S., Pierson R. N. Jr (1994). Asians have lower body mass index (BMI) but higher percent body fat than do whites: comparisons of anthropometric measurements. American Journal of Clinical Nutrition, 60 (1), 23–28. https://doi.org/10.1093/ajcn/60.1.23
39. Wells J. C. K., Shirley M. K. (2016). Body composition and the monitoring of non-communicable chronic disease risk. Global Health, Epidemiology and Genomics, 1, e18. https://doi.org/10.1017/gheg.2016.9
40. World Health Organization Regional Office for South-East Asia. (2015). Nutrition in South-East Asia: a regional overview. New Delhi: WHO SEARO.
41. World Health Organization. (2004). Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. The Lancet, 363 (9403), 157–163. https://doi.org/10.1016/S0140-6736(03)15268-3
42. World Health Organization. (2011). Waist circumference and waist-hip ratio: Report of a WHO expert consultation. Geneva: World Health Organization.
43. World Medical Association. (2013). World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. JAMA, 310 (20), 2191–2194. https://doi.org/10.1001/jama.2013.281053.
44. Zhu L., Yang W.J., Spence C.B., Bhimla A., Ma G.X. (2021). Lean Yet Unhealthy: Asian American Adults Had Higher Risks for Metabolic Syndrome than Non-Hispanic White Adults with the Same Body Mass Index: Evidence from NHANES 2011–2016. Healthcare, 9 (11), 1518. https://doi.org/10.3390/healthcare9111518

45. Zwierzchowska A., Kantyka J., Rosołek B., Nawrat-Szółtysik A., Małecki A. (2022). Sensitivity and Specificity of Anthropometric Indices in Identifying Obesity in Women over 40 Years of Age and Their Variability in Subsequent Decades of Life. Biology, 11 (12), 1804. https://doi.org/10.3390/biology11121804.

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