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Fat Free Mass and Upper Arm Muscle Area as Measures of Muscularity in Tribal and Non-tribal Indian College Students

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Authors' contributions

This work was carried out in collaboration between all authors. This study was planned and designed by the corresponding author CM and research fellow author SD. Author SC being an expert in anthropometric based studies, helped author SD to procure data by anthropometric measurements. Compilation of data and statistical analysis were undertaken by authors SD, ASD and SC. Authors SD and SC prepared the first draft of the manuscript. Authors ASD and CM prepared the final manuscript. All authors read and approved the final draft.

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Original Research Article

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ABSTRACT

Aims: Primarily, to assess fat free mass (FFM) and upper arm muscle area (UAMA) as measures of muscularity in tribal and non-tribal college students, and secondly, to examine muscularity, as an index of nutritional status, in these two populations.
Study Design: Cross-sectional study.
Place and Duration of Study: Study population was undergraduate students studying at two different colleges in Tripura, India between October, 2011 and March, 2013.

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Methodology: This study was undertaken in young adult college students of two different communities, tribal (n=70; 35 males; 35 females) and non-tribal (n=100; 50 males; 50 females), aged 18 to 21 years. Each subject was measured for height, weight, arm circumference and skin fold thickness at triceps and subscapular region. Mid upper arm muscle area (UAMA) and fat-free mass (FFM) were calculated to predict muscularity and correlated with biochemical (urinary creatinine) and physical muscle (hand-grip dynamometer) variables in both genders.

Results: Among the two anthropometric measures (UAMA and FFM) used in this study for determination of muscularity, FFM was found better correlated with muscularity criterion variables creatinine and grip force in both genders of non-tribes, compared to tribes. Such correlation was found stronger with grip force than creatinine. Correlation coefficient analysis of each of these variables (either creatinine or grip force) with FFM and UAMA revealed that males are better correlated than females in both populations (tribe: male P=0.010; female P=0.014, non-tribe: male P=0.001; female P=0.004). Multiple regression analysis indicates that FFM is the most compatible predictor against both criterion variables in both populations (tribe: grip force-R^2 change 0.028, P<0.001; creatinine-R^2 change 0.165, P<0.01; non-tribe: grip force-R^2 change 0.039, P<0.001; creatinine-R^2 change 0.372, P<0.001). Pitman test confirms that FFM is the estimate with significantly better fit with creatinine in both genders of non-tribal population, when compared with UAMA.

Conclusion: In these two populations of Indian tribal and non-tribal college students, FFM was found more suitable over UAMA in predicting muscularity.

Keywords: Anthropometry; muscularity; nutritional status; community.

1. INTRODUCTION

Anthropometry is an essential feature of determining nutritional status of individuals or communities and may be used to assess overweight, obesity, fat mass gain, adipose tissue redistribution, muscle mass loss, and skeletal health. These indicators are useful to determine the risk for chronic and acute diseases, and guide medical interventions [1-8].

Over the past few decades, many skin fold equations have been developed for predicting specifically percentage of fat mass and fat-free mass (FFM) in children as well as in adults. However, most of these estimates were developed by using multiple skin fold thickness measurements [9-11]. A survey of the current literature revealed that there is few equations which are based on only two skin fold thicknesses and are developed for children or adolescents [12,13]. One such equation is the Slaughter equation, which is recommended for population studies due to its accuracy and simplicity [14]. This has been supported by many other studies where the Slaughter equation for FFM was used for determination of muscularity during growth [15], body-composition assessment [16] and metabolic profile studies in early pubertal to young adult-males [17]. Another widely accepted and clinically practical method for assessing nutritional status and muscle mass in adults [18-20] is the determination of upper arm muscle area (UAMA) [21], which is calculated by using two anthropometric measures - mid upper arm circumference (MUAC) and triceps skin fold. There is however, no set standard for *in vivo* body composition measurements, because all existing methods may include certain assumption which may not hold true in all cases; the best model therefore may be derived by using a combination of different measurements, thereby minimizing the importance of such assumptions [22]. For instance, although UAMA is widely used to assess muscle mass in children, FFM has been shown to predict muscularity better than UAMA in pre-pubescence [15]. However, no information is available on FFM versus UAMA as most suitable measures of muscularity among Indian adults.

The use of 24 hour creatinine excretion and grip force as methodologically independent indicators of muscle mass is well-documented [15,23]. Grip force, as a measure of muscle function, reflects body's nutritional status [23,24] and 24 hour urinary creatinine is widely used as an indicator of muscle mass [25– 27].

India is a multiethnic country. As far as social and population background of this particular state of Tripura is concerned, according to Census of India (2011) and Government of Tripura reported Provisional Population Totals (2011), Tripura, which is one of the seven states of North-East

India, has a tribal population of 31% [28,29]. Like all other tribal people of India, tribes of Tripura are also having geographically isolated life-style. In remote villages food shortages cause high prevalence of under nutrition. During the past one or two decades, there is a trend for urban migration among tribal communities of India like other social groups [30] and because of such urbanization young adult tribal population constitutes a sizable proportion of college students who are comparatively in a better socio-demographic settings for education, health and job opportunities. We hypothesized that such urbanization possibly has improved nutritional status and muscularity of tribal population, which although was anticipated, but not verified.

In this cross-sectional observational study, we therefore assessed the muscularity, as an index of nutritional status, of young adult college students (18-21 years) of two diverse socio cultural origin, Kokborok ethno-linguistic group and Bengali ethno-linguistic group by anthropometric measurements, derived indices and methodologically independent indicators of muscle mass. The reason for choosing these age groups were primarily because they were in their late adolescence (18-21 years) and had supposedly completed their linear growth, skeletal mass gain, body weight gain, sexual maturity and psychological and cognitive development [31]. Additionally, urbanization effects on nutritional status and muscularity of young adult tribal college students who were in their late adolescence and their comparison with semi-urbanized non-tribal college students was not verified.

Thus, aim of this research was primarily to assess FFM and UAMA as measures of muscularity in tribal and non-tribal college students, and secondly, to examine muscularity, as an index of nutritional status, in these two populations.

2. MATERIALS AND METHODS

2.1 Subjects

This study was carried out during the period from October 2011 and March 2013. The study area was selected in a semi-urban setting to satisfy the prerequisite and similar socio-demographic background (education, health, job opportunities, and family background) of both the ethnic communities of subjects of this study. The area of this cross-sectional study in undergraduate colleges was intentionally selected because of higher concentration of the two communities of population in a common place with similar educational background. A multi-stage stratified random sampling method was utilized to finally select the subjects of this study [32]. Briefly, sampling of state government district colleges were stratified by urbanization characters, economics, education level and environment. Next, amongst the selected district colleges, a random sampling of colleges was made according to our logistic suitability and availability of subjects. After selection of colleges, random sampling was performed for willing participants in different classes of these colleges. Next, within each class, simple random sampling was conducted for tribal and non-tribal students. In the next stage, subjects of the two communities were generally identified from physical characteristics and surnames. The information provided by the subjects was subsequently verified from official records. In the next stage, further random sampling was employed to select the subjects within the specific age group of this study and the subjects below or above the age (18-21 years) was excluded from the study. The age of the subjects was further verified from official records and/or birth certificates. Next, all such randomly selected subjects were explained the objectivity and protocol of the research. In the subsequent stages, subjects were further screened based on their compliance or non-compliance for all kinds of tests and measurements, healthy or unhealthy, history of chronic disease or chronic medication or consumption of alcohol or tobacco use. Finally only subjects who willingly gave a written consent to participate were included in this study. Thus, by combining different random sampling methods (cluster, stratified, simple), we were able to achieve a rich variety of probabilistic sampling methods (multi-stage stratified random sampling methods) that are commonly used in a wide range of social research contexts [32].

Since prevalence of nutritional status and muscularity in our selected subjects (both males and females taken together) was not known, a prevalence of 50% was taken [33] to calculate the sample size with 95% confidence interval and absolute precision of 5%. So, the minimum sample size estimated was 384 subjects. The final sample size, however, was higher than this number and consisted of two genders. The final sample size of both groups of subjects and their gender match however could not be achieved because of wide variation in ethnicity ratio (69:31) among the studied populations.

Precisely, the subjects of the present study were a subgroup of the selected subjects participating in a larger Tripura Central University supported cross-sectional study of our group for investigating the interrelations between nutritional status, health, gender and ethnicity. Thus, the subjects were from two diverse socio cultural origin, Kokborok ethno-linguistic tribal group (n=70; male: 35; female: 35) and Bengali ethno-linguistic non-tribal group (n=100; male: 50; female: 50), aged 18 to 21years.

2.2 Anthropometric Measurements

Each subject was measured for stature, weight, circumference and skin fold thickness at triceps and subscapular region. All anthropometric measurements were made on the right side of the body by trained investigators by using the standard techniques [34,35]. Body weight was taken to the nearest 0.5 kg with minimum clothing by using a standard weighing scale. Standing height was measured to the nearest 0.1 cm in the standard arm hanging position with a Harpenden type Anthropometer. The body mass index (BMI) was calculated by the following formula:

$$\text{BMI (kg/m}^2\text{)} = \text{Weight (kg)/Height (m}^2\text{)}$$

Triceps and subscapular skin folds were measured to the nearest 0.1 mm with a Holtain skin fold caliper (Holtain Ltd.), and mid upper arm circumferences was measured with a metal tape, with the right arm hanging relaxed at the subject's side. For the estimation of FFM, the percentage body fat was calculated by using Slaughter et al.*'s* [12] skin fold thickness equations for adult males and for all females. These equations are:

% body fat (male) = 1.21 (triceps skin fold+ subscapular skin fold) - 0.008 (triceps skin fold + subscapular skin fold)^2 - 6.8

% body fat (female) = 1.33 (triceps skin fold + subscapular skin fold) - 0.013 (triceps skin fold + subscapular skin fold)^2 - 2.5

FFM (kg) = body weight-(% body fat × body weight) / 100

UAMA was calculated by using the following equation of Jelliffe and co-workers [36,37].

UAMA = [arm circumference – (π X triceps skin fold)]^2 / 4 π

All measurements were taken by two of the authors (SD and SC). Differences between intra-observer and inter-observer measurements were calculated for testing the coefficient of reliability(R) of the measurements using the technical error measurement (TEM) [38]. Accuracy of measurements were determined by recording different measurements separately from a certain percentage of participants from both communities by SD and SC. TEM analyses showed very high R values (>0.96 -0.97) for both intra-observer and inter-observer measurements. As the obtained range of R values were within the cut-off value of 0.95 as suggested earlier [38], the measurements recorded by the two authors (SD and SC) were considered reliable and reproducible. TEM was calculated by using the following formula:

$$\text{TEM} = \sqrt{(\sum D^2/ 2N)}$$

Where, D=difference between the measurements, N=number of individuals measured.

2.3 Grip Force

Maximal isometric grip force of the non-dominant hand was determined with a standard adjustable–handle Jamar dynamometer as described earlier [15,23,39]. Briefly, the handle was adjusted so that the line of the subject's proximal inter-phalangeal joints rested exactly on top of the adjustable handle. The subject was told to put maximum force on the dynamometer. The maximal reading of 2 attempts was recorded. The grip force was expressed in Newtons (N) by multiplying the dynamometer reading in kilograms by a factor of 9.81.

2.4 Physiological Measurements

Systolic (SBP) and diastolic (DBP) blood pressures were measured with the help of sphygmomanometer and stethoscope. Resting heart rate (HR) and respiratory rate (RR) were taken respectively by measuring the pulse rate at the left radial artery by palpating for 1 min [40,41], and visual observation of breathing per minute [42] with a stop watch.

2.5 Collection of Urine Samples and Analysis

Daily creatinine excretion was determined in 24 hour urine samples. For this, the participants were given materials, oral and written guidance for home completion of 24 hour urine collection. They were instructed to consume modified diet free from meat for 1 week. Urine sample was collected on the 7th day after completion of this diet schedule. Subjects were further instructed to be free of any unusual physical or mental stresses on the day of collection. Briefly, on the day of the collection, participants discarded their first urine void, recorded the time, and then collected all subsequent voids for 24 hour including a void at the recorded time the following morning. Samples reported to be incomplete were excluded. Urine samples were collected in polyethylene bottles containing 10 mL of 6N HCl as a preservative, sampled and stored at frozen temperature until the analysis was made. Urinary creatinine was measured according to the method as described by Nath and Nath [43].

All equipments and tests were standardized before data collection.

2.6 Statistical Analysis

Data are presented as mean±standard deviation (SD). Pearson correlations and simple linear and multiple regression analyses were performed. Before regression was undertaken, the variables were checked for normality. To check for gender and population differences, in addition, unpaired *t*-tests were included. The Pitman test [44] was used to determine the model with the better fit. Briefly, residuals of the regressions of each criterion variable with both $FFM_{Slaughter}$ (A) and UAMA (B) were calculated. The sum (A+B) and the difference (A-B) were calculated for each criterion variable and then A+B was correlated with A-B. Each correlation was checked to see if it was significantly different from zero. In such case, the residual with the smaller SD was the model with better fit. All tests were two-tailed, and the level of statistical significance was set at $P<0.05$. All statistical analyses were undertaken using the SPSS statistical package (version 11.50).

3. RESULTS

Mean values for age, physical and physiological characteristics, anthropometric measurements, body composition and urinary creatinine excretion of the two populations are presented in Table 1. As far as height (cm) and weight (kg) were concerned, these characteristics were found significantly higher for males ($P<0.001$) in both populations, compared to females. No significant difference in BMI (kg/m^2) was observed between males and females of both populations. Systolic blood pressures (mm Hg) were found significantly higher only for tribal males ($P<0.001$), than females, whereas, in both populations, diastolic pressures (mm Hg) were found significantly higher in males (non-tribal, $P<0.05$; tribal, $P<0.001$) than females. A significant variation in heart rate (beats/min) was found only between males and females of non-tribal population ($P<0.01$), whereas for respiratory rate (cycles/min), there was no significant difference between males and females of both populations.

Skin fold measurement namely triceps fat fold thickness (mm) were significantly higher for females than for males in both populations. The significance level for triceps for tribes and non-tribes respectively were $P<0.01$ and $P<0.001$. Subscapular fat fold thickness (mm) was significantly higher only for tribal females ($P<0.05$), than males. $FFM_{Slaughter}$ (kg) and the methodologically independent muscle variables, grip force (N) and urinary creatinine (mmoL/24 hour), all were significantly higher for males, than females in both populations, except for creatinine in tribal population ($P=0.134$). Although there was no significant difference in arm circumference (cm) between males and females of non tribal population, but, this was found significant in tribal population ($P<0.02$).

When all these data were further analyzed for intergroup comparison between the males and females, it was observed that no variables could reach at significant level.

Pearson's correlation coefficients of 24 hour urinary creatinine excretion and grip force with $FFM_{Slaughter}$ and UAMA in both populations are shown in Table 2. Data show that, irrespective of gender and population, grip force (N) was significantly correlated with both $FFM_{Slaughter}$ and UAMA. However, such correlation was stronger in non-tribal subjects than tribal. Results further indicate that, in case of non-tribal male, significant correlation for $FFM_{Slaughter}$ was strongest (0.446; $P<0.01$), while in females, this value was marginally less (0.399; $P<0.01$). For UAMA, these significant correlation values in non-tribal males and females respectively were 0.352 ($P<0.02$) and 0.375 ($P<0.01$). In case of tribal subjects, such correlations for grip force also were significant and in males and females values for $FFM_{Slaughter}$ and UAMA respectively were 0.430 (*P*<0.02) and 0.412 (*P*<0.02), and 0.438 (*P*<0.01) and 0.417 (*P*<0.02).

Table 2. further depicts that urinary creatinine excretion (mmoL/24 h) of males of both populations were significantly correlated with $FFM_{Slaughter}$ and such correlation was better seen in non-tribal subjects (0.760; *P*<0.001) than tribal (0.424; *P*<0.05). However, females of both populations showed variable pattern of correlation with $FFM_{Slaughter.}$ Tribal females although failed to show any significant correlation with $FFM_{Slaughter}$ (0.321; *P*=0.118), but non-tribal females showed significant correlation (0.437; *P*<0.05). Females of both populations, however, failed to show any correlation with UAMA.

Stepwise multiple regression analysis of all subjects with grip force and 24 hour creatinine excretion as the dependent variables according to gender and population are shown in Table 3. Results of multiple regression analyses (with $FFM_{Slaughter}$, UAMA, age, and gender as potential predictors) demonstrated that $FFM_{Slaughter,}$ irrespective of population, is the most compatible predictor for both criterion variables (grip force and creatinine), with values for R^2 change ranging from 0.028 to 0.039 for grip force and 0.165 to 0.372 for creatinine. Age and UAMA did not show any influence. However, in both populations, gender showed a significant influence as a potential predictor for grip force only and the values for R^2 change ranging from 0.784 to 0.840.

In non-tribal population, the Pitman test yielded significantly smaller SDs of the residuals for the regression of FFM on creatinine in males and females when compared with UAMA. All other residual SDs for FFM and UAMA in both populations were not significantly different.

4. DISCUSSION

The present study was undertaken in a semi-urban setting to satisfy the prerequisite and similar socio-demographic background (education, health, job opportunities, family background) of both the ethnic communities of subjects of this study. To make an assessment of nutritional status, physical and physiological characteristics of the participants of two communities, certain measurements were included (Table 1) in this study. Data generated on anthropometric characteristics of two different ethnic groups of students (Table 1) suggest that there exists a wide gender variation in measures of different variables. Such variations in anthropometric characteristics between two different ethnic groups of diverse origin have been reported earlier by many workers [45-47]. However, the physiological characteristics (B.P., heart rate, respiratory rate) and nutritional status (BMI) of participants of both the communities were either normal or near to normal reference range, suggesting that the subjects of both the communities, irrespective of gender, were both nutritionally normal and physiologically healthy.

Several earlier reports had suggested for a frequently used simple alternative for the evaluation of nutritional status, which is the determination of UAMA [18-20]. The advantage of determination of this anthropometric value is that this requires only two anthropometric measures (triceps skin fold thickness and upper arm circumference) to yield quickly an index of muscularity. Likewise, equations of Slaughter et al. [12] for estimation of FFM, which require two anthropometric measurements (triceps and sub scapular or triceps and suprailiac) have long been recommended for population studies for their accuracy and simplicity [14].

However, an earlier report had indicated that there is no set standard for body composition measurements *in vivo* because each and every method may include certain assumption that may not hold true in all cases, and the best model can be derived by using a combination of different measurements, thereby minimizing the importance of such assumptions [22]. In fact, in one previous study in healthy children and adolescents it was shown that FFM estimate was a better predictor for muscularity than UAMA before puberty although UAMA is widely used in children and adults to assess nutritional status and muscle mass [15]. This prompted us to undertake this study to verify which one of these simpler anthropometric estimates of nutritional status may be superior in predicting muscularity in our selected populations who were healthy young adult college students of two different communities and ethnic backgrounds.

Grip strength was considered in this study because it represents a well-established measure of muscle function indicating fairly well the nutritional status of an individual [24]. Another non-invasive and biochemical measure included in this study was 24 hour urinary creatinine, which is widely used as an indicator of muscle mass [25–27].

Table 1. Age, physical characteristics, anthropometric measurements, body composition of the subjects according to ethnic background and gender

Variables	Tribal		Non-tribal		*P-value			
	Male(I) (n=35)	Female(II) (n=35)	Male (III) (n=50)	Female (IV) (n=50)	I vs. II	III vs. IV	I vs. III	II vs. IV
Age (yr)	19.49±0.92	19.06±0.94	19.48±0.65	19.30±0.71	0.058	0.187	0.976	0.813
Height (cm)	164.79±5.38	151.75±4.74	167.16±4.46	152.20±6.35	<0.001	<0.001	0.036	0.706
Weight (kg)	58.60±9.04	49.02±6.73	58.44±11.18	50.68±9.55	<0.001	<0.001	0.942	0.351
BMI (kg/m^2)	21.51±2.62	21.32±2.98	20.87±3.60	21.85±3.80	0.771	0.192	0.334	0.477
Systolic blood pressure (mm Hg)	121.93±7.13	112.90±6.40	119.52±9.89	115.96±9.05	<0.001	0.063	0.196	0.071
Diastolic blood pressure (mm Hg)	80.46±7.26	73.10±5.05	79.00±7.77	76.16±5.77	<0.001	<0.05	0.377	0.011
Heart rate (beats/min)	78.47±5.40	78.57±4.96	77.42±5.42	79.92±5.17	0.936	<0.01	0.381	0.229
Respiratory rate (cycles/min)	19.51±1.17	19.10±1.26	20.20±7.37	19.88±1.85	0.154	0.767	0.521	0.022
Grip force (N)	268.88±52.93	72.44±31.48	285.55±72.97	60.10±42.77	<0.001	<0.001	0.228	0.129
UAMA (cm^2)	37.12±5.33	31.28±7.29	37.72±8.68	33.42±8.15	<0.001	<0.02	0.696	0.211
$FFM_{Slaughter}$ (kg)	52.67±6.24	40.37±4.96	51.57±7.49	41.00±6.53	<0.001	<0.001	0.461	0.614
Creatinine excretion (mmoL/24 hour) (n=25)	11.52±3.90	9.91±3.59	11.39±3.02	9.32±3.99	0.134	<0.05	0.887	0.582
Arm circumference (cm)	23.38±1.84	22.06±2.39	23.52±2.76	22.83±2.71	<0.02	0.210	0.786	0.171
Triceps fat fold thickness (mm)	5.84±2.03	7.48±1.91	5.99±2.01	7.91±3.06	<0.01	<0.001	0.731	0.429
Subscapular fat fold thickness (mm)	9.40±3.17	11.03±2.90	10.77±4.28	12.11±3.06	<0.05	0.073	0.094	0.100

*BMI, body mass index; UAMA, Mid-upper arm muscle area; $FFM_{Slaughter}$, fat-free mass according to Slaughter et al. 1988 [12]; All the values are expressed as mean ± SD. * Differences between genders were examined by unpaired t-tests*

Table 2. Pearson's correlation coefficients of grip force and 24 hours urinary creatinine excretion with fat free mass (FFM) and mid upper arm muscle area (UAMA) in subjects according to ethnic background and gender

	Tribal				Non-tribal			
	$FFM_{Slaughter}$ (kg)	*P*-value	UAMA (cm^2)	*P*-value	$FFM_{Slaughter}$ (kg)	*P*-value	UAMA (cm^2)	*P*-value
Grip force (N)								
Males	0.430	<0.02	0.438	<0.01	0.446	<0.01	0.352	<0.02
Females	0.412	<0.02	0.417	<0.02	0.399	<0.01	0.375	<0.01
Creatinine excretion (mmoL/24h)								
Males	0.424	<0.05	0.357	0.080	0.760	<0.001	0.480	<0.02
Females	0.321	0.118	0.395	0.051	0.437	<0.05	0.119	0.571

$FFM_{Slaughter}$, fat-free mass according to Slaughter et al. (1988) [12]; UAMA, mid-upper arm muscle area

Table 3. Stepwise multiple regression analysis of all subjects with grip force and creatinine excretion as the dependent variable

	Grip force (N)			Creatinine excretion (mmoL/24 hour)		
	R^2 change	Coefficient	*P*-value	R^2 change	Coefficient	*P*-value
Tribal	(n = 70)			(n=50)		
$FFM_{Slaughter}$	0.028	3.247	<0.001	0.165	0.214	<0.01
UAMA			>0.05			>0.05
Age			>0.05			>0.05
Gender	0.840	-156.485	<0.001			>0.05
Non-tribal	(n = 100)			(n=50)		
$FFM_{Slaughter}$	0.039	3.595	<0.001	0.372	0.308	<0.001
UAMA			>0.05			>0.05
Age			>0.05			>0.05
Gender	0.784	-187.468	<0.001			>0.05

$FFM_{Slaughter}$, fat-free mass according to Slaughter et al. (1988) [12]; UAMA, Mid-upper Arm Muscle Area.

The principal findings of this study was that, irrespective of populations, muscularity as an index of nutritional status is better predicted in male and $FFM_{Slaughter}$ is the better predictor of muscularity over UAMA (Table 3). Results suggested that there exists reasonably close associations irrespective of genders and populations between $FFM_{Slaughter}$ and UAMA and different indices of muscularity. Analyses of data further suggested that, in case of non-tribal population, irrespective of genders, $FFM_{Slaughter}$ correlated better with the two independent criterion variables, grip force and creatinine, than tribal population. However, a comparison between creatinine and grip force revealed that grip force correlated more strongly with $FFM_{Slaughter}$. Results of comparison of correlation coefficient of each muscularity criterion variable (grip force and creatinine) with both $FFM_{Slaughter}$ and UAMA suggested that male, particularly non-tribe, showed better correlation than females of both populations (Table 2).

In multiple regression analysis (with $FFM_{Slaughter}$, UAMA, age and gender as potential predictor), calculation of the corresponding values of R^2 change explained variability for both criterion variables (creatinine and grip force) and $FFM_{Slaughter}$ was proved to be the most compatible predictor in both groups of populations. On the other hand, gender, as a potential predictor, explained a small portion of variability only for grip force in both groups of populations. In 2 out of 8 possible comparisons in both groups of populations, the Pitman test showed that $FFM_{Slaughter}$ was the estimate with significantly better fit with creatinine in both genders of non-tribal population, when compared with UAMA. However, as far as grip force is concerned, the reason why the model fit of $FFM_{Slaughter}$ was not significantly better than that of UAMA was not clear. Nevertheless, the fact that most of the comparisons between populations of tribal and non-tribal community are significantly in favour of $FFM_{Slaughter}$ suggests for its superiority over UAMA in determining muscularity, which corroborates well with an earlier observation [15]. The fact that body mass index (BMI) has no significant correlation with body fat in leaner subjects but that Slaughter et al*'s* model strongly does [48], again emphasizes that $FFM_{Slaughter}$ et al*' s* equations are a reasonable predictor of nutritional status [15]. In the present study, muscularity was better predicted in male population of both communities suggesting their better nutritional status and growth [49], compared to female populations, which, however, could not be envisaged from our insignificant results of BMI (Table 1). This proposition finds its direct support from our results of heights and weights in Table 1, which suggest a significantly better growth in males of both populations because heights and weights of adults represent what can be attained by an individual with normal growth [50].

In agreement with these findings, $FFM_{Slaughter,}$ in the present study has proved to be more useful in predicting muscularity in our studied populations than the other rapid and easy alternative, UAMA; and muscularity, as an index of nutritional status and growth [49], was better predicted in male populations of both communities suggesting that a gender difference of nutritional status and growth exists in the studied populations. Thus, in the present study, muscularity, as an index of nutritional status and growth, was better predicted in male populations of both communities suggesting a gender difference of nutritional status in the studied populations.

However, it must be mentioned here that a limitation of the present study may be its unequal sample size, particularly for tribal group. But investigators had no alternative in this issue because (i) the total tribal population of the state is only 31%, (ii) only a smaller fraction of this population usually enrolls for college level education, and finally (iii) many subjects of this group were either discarded or dropped during the multi-stage stratified sampling method.

5. CONCLUSION

In conclusion, among the two anthropometric measurements used, FFM was found more suitable in predicting muscularity over UAMA and there exists a gender difference of muscularity and growth in both groups of studied population. Such micro level community-based study is first of its kind among two communities of young adult college students of different ethnic backgrounds of North-East India, which has helped in predicting an appropriate anthropometric estimate to determine nutritional status and muscularity in the studied population.

ETHICAL APPROVAL

Ethical approval for human studies was obtained from the Advisory Committee of the Institutional Human Ethics Committee.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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