Prediction of total body muscle mass from simple anthropometric measurements in young Indian males

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**Background & objectives:** The total body skeletal muscle mass plays a significant role in both health and disease states. Accurate measurement or prediction of muscle mass is useful in physiology, nutrition and clinical medicine. There are many prediction equations derived in the Western populations to estimate skeletal muscle mass, however, regression equations best fit the population they are derived from. There is hence a need to generate predictive equations for the Indian population. The objective of this study was to derive predictive equations for muscle mass from simple anthropometric measurements such as mid-arm circumference (MAC) and triceps skinfolds in a young Indian male population.

**Methods:** Anthropometric measurements of body weight, height, mid-arm circumference and skinfold measurements were carried out on 66 subjects with a wide range of body mass indices. Twenty four hour urine samples were collected over a 3 day period for estimating urinary creatinine excretion, from which the total body muscle mass was inferred. Linear regression was carried out between MAC and corrected arm muscle area (CAMA) with muscle mass obtained from urinary creatinine to derive a prediction equation for muscle mass.

**Results:** The prediction equation obtained for muscle mass (kg) using MAC alone was \((1.641 \times MAC) - 15.580\) \([r=0.72, \text{standard error of estimate (SEE)} = 2.91 \text{ kg}]\), while the equation derived from CAMA alone was \((0.496 \times \text{CAMA}) + 10.183\), \([r=0.62, \text{SEE} = 3.29 \text{ kg}]\).

**Interpretation & conclusion:** A new prediction equation for the measurement of muscle mass was derived in young Indian men using simple anthropometric measurements such as mid-arm circumference and triceps skinfolds.

**Key words** Corrected arm muscle area - creatinine - mid-arm circumference - muscle mass

Skeletal muscle represents the largest component of the metabolically active tissue of the body and accounts for <50 per cent of the body weight. It plays an important role in regulating the physical function in all age groups and in determining energy requirements. In protein-energy malnutrition (PEM) and in periods of starvation or large energy deficits, muscle protein undergoes catabolism and oxidation, thereby reducing in size. In cachexia, a condition associated with chronic infections and malignant conditions, the most obvious change that occurs is the depletion of muscle mass. Depletion of skeletal muscle mass can affect the survival rate of a patient and can also prolong recovery to normal physiological function.

Many methods are available for estimation of whole body and regional muscle mass. Computerized axial tomography (CT) and magnetic resonance imaging (MRI) are now available to measure total body skeletal muscle accurately. Though accurate, these methods
are expensive and labor intensive. In addition, CT method exposes the subjects to radiation. Urinary creatinine excretion method is a very specific method of assessing total body muscle mass.

Equations for predicting skeletal muscle mass have been developed and validated using various methods. They include prediction using total body potassium, dual energy X-ray absorptiometry, creatinine excretion and anthropometry. Simple anthropometric measurements like triceps skinfold thickness and mid-arm circumference (MAC) and corrected arm muscle area (CAMA) can be used to predict bone-free and fat-free arm muscle area as well as total body muscle mass. Anthropometric prediction equations for total body skeletal muscle were developed and cross-validated in independent samples of non-obese and obese Western subjects. The instruments that are needed for anthropometry are portable and inexpensive, and the methods need minimal training and are noninvasive. They can also be used easily in field studies as well as clinical situations to predict the muscle mass of individuals. However, equations that have been derived in the Western population are often not suited for the Indian population. Hence, this study was taken up to derive equations for muscle mass (determined by the creatinine method) based on simple anthropometric measurements such as mid-arm circumference and triceps skinfold for young Indian male population.

Material & Methods

Subjects: Sixty six young male subjects were derived from a population of students and individuals living around the neighboring slums of St. John's Medical College, Bangalore. This was done so that a wide range of body mass index (15.5 to 23.4 kg/m²) was obtained in the subjects. The subjects were recruited through posted flyers and by word of mouth. The inclusion criteria were normal healthy males in the age group of 18-30 yr, and subjects who could refrain from meat for a period of four days and who could collect their urine sample for three days. Subjects with any organ failure were excluded from the study. The physical activity levels of students were sedentary while the slums dwellers were mainly painters, carpenters and plumbers who were getting daily wages. The subjects were mainly from middle class families while the slum dwellers were of lower socio-economic status, living in houses with asbestos roofed houses, and sharing a common toilet. The subjects were made to undergo a complete medical history, physical examination and analysis for blood cell count, routine blood biochemistry and urine analysis. Written consent was obtained from each subject. The Human Ethical Approval Committee of St. John's Medical College had provided their approval for conducting this research project.

Anthropometric measurements: Anthropometric and skinfold measurements were carried out on the subject on the next day after recruitment. Subjects were weighed in minimal clothing, using a digital load cell balance, (Soehnle, West Germany), which had a precision of 0.1 kg. The height of the subjects were recorded, without footwear, using a vertically mobile scale (Holtain, Crymych, UK) and expressed to the nearest 0.1 cm. Body mass index (BMI) was calculated from the height and weight as follows; BMI = weight (kg)/height² (m). The mid-arm circumference (MAC) was measured with the subject standing erect. The subject's elbow was flexed to 90° and the midpoint between the tip of acromion and olecranon process was located. The tape was placed around the arm at the midpoint, with the arm relaxed and elbow extended and the circumference was recorded to the nearest 0.1 cm.

Skinfold measurements were carried out in triplicate in the standing position and the mean taken for further calculation: biceps, triceps, subscapular and suprailiac. The biceps skinfold thickness was measured as the thickness of a vertical fold raised on the anterior aspect of the arm, over the belly of the biceps muscle. The triceps skinfold was measured in the midline of the posterior aspect of the arm, over the triceps muscle, at a point midway between the lateral projection of the acromion process of the scapula and the inferior margin of the olecranon process of the ulna. The subscapular skinfold was picked up on a diagonal, inclined inferolaterally approximately 45° to the horizontal plane in the natural cleavage lines of the skin. The site is just inferior to the inferior angle of the scapula. The suprailiac skinfold was measured in the midaxillary line immediately superior to the iliac crest. An oblique skinfold is grasped just posterior to the midaxillary line following the natural cleavage of the skin. It is aligned inferomedially at 45° to the horizontal. All measurements were standardized.
Muscle mass = 18.9 Cr (g/day) + 4.1, where Cr is the 24 h urinary creatinine excretion.

Statistical analysis: Linear regressions were carried out in the whole group (n=66) between muscle mass estimated from urinary creatinine and MAC and CAMA to develop prediction equation. Multiple regressions were also performed of muscle mass with additional other anthropometric variable such as height and weight. Age was not included into this analysis because of the small age range of the present group of subjects. Paired t-test analysis was also carried out between the muscle mass obtained from urinary creatinine and the muscle mass derived from MAC and CAMA, and differences were deemed to be significant at \( P < 0.05 \). In order to test the homogeneity of the data, the entire original data set (n=66) was randomly divided into two sets of data. One set comprising of about half the data (n=33) was used to develop the prediction equation (prediction set), while the remaining (n=33) was used to validate the equation (validation set). The difference in the muscle mass obtained by the prediction equations of MAC and CAMA were compared against the muscle mass obtained from the urinary creatinine method\(^{19}\). The appropriateness of the muscle mass obtained by a western equation\(^{12}\) was also assessed against the muscle mass measured from urinary creatinine\(^{19}\).

Results

The subjects were normal healthy subjects from the student population and from the neighboring slums of St. John's Medical College Hospital. The mean age of the entire group of 66 subjects was 20.5±2.0 yr, while the mean body weight, height, body mass index, mid-arm circumference and muscle mass from creatinine was 50.3±8.3 kg, 164.1±6.4 cm, 18.5±2.0 kg/m\(^2\), 24.4±1.8 cm and 24.4±4.2 kg respectively. The entire group of subjects was then separated into two groups of slum dwellers (n=38) and students (n=28) to check for any differences in their physical characteristics. Significant differences were observed in the age, body weight, height, body mass index, mid-arm circumference, percent body fat, and muscle mass obtained from creatinine excretion (Table I). We recruited subjects with wide range of body weight and body composition, as we wanted to derive the equation on subjects with a wide range of muscle mass.

The skinfold measurements were carried out to the nearest 0.2 mm using skinfold calipers (Holtain, Crymych, and UK). The logarithm of the sum of the four skinfolds was used in age and gender specific equations\(^{15}\) to obtain the body density, from which estimates of percentage of body fat were made\(^{16}\).

**Calculation of muscle mass:** The mid-arm circumference (cm) and triceps skinfold measurements (mm) were used to calculate corrected arm muscle area (CAMA). The calculation of CAMA in males was as follows\(^{12}\):

\[
\text{CAMA} = \frac{(\text{MAC} - (\pi \times \text{TSF}))^2}{4\pi} - 10
\]

where, TSF is the triceps skinfold, MAC is the mid arm circumference (cm) and the term 10 refers to the correction for bone area in males.

Total body muscle mass (kg) was calculated from CAMA using a prediction equation that related CAMA and height to muscle mass\(^{12}\).

Muscle mass (kg) = Height x (0.0264 + (0.0029 x CAMA)).

**Diet and experimental protocol:** The subjects were fed a weight-maintaining meat-free diet for a period of four days. The total daily food intake was consumed as three, isoenergetic, isonitrogenous meals. The same diet prescription was adopted by all the participants. The subjects were housed in the metabolic ward of the department, in which they were supervised for the entire 24 h period, and were allocated to a physical activity pattern that matched their habitual physical activity. The meals were standardized and provided for the subjects in the metabolic kitchen, and consumed under supervision.

All the other nutrients were provided in the form of supplements in adequate amounts.

Complete 24 h urine collections were made throughout the dietary feeding period. Urinary creatinine (g/day) excretion was estimated using Jaffe’s method\(^{17}\). The mean creatinine estimation of day 2,3 and 4 were used to compute values of muscle mass from the equation\(^{18}\).
The characteristics of subjects in the prediction and validation data sets were compared. The two data sets were comparable and there were no significant differences in terms of age, body weight, height, body mass index, MAC, CAMA and muscle mass by creatinine estimation (Table II).

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Slum dwellers (n=38)</th>
<th>Students (n=28)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>21.3±1.8</td>
<td>19.4±1.6*</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>44.3±3.3</td>
<td>58.5±6.6*</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>160.6±2.8</td>
<td>168.9±6.6*</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>17.1±0.7</td>
<td>20.5±1.5*</td>
</tr>
<tr>
<td>Mid-arm circumference (cm)</td>
<td>23.2±1.1</td>
<td>25.9±1.4*</td>
</tr>
<tr>
<td>Per cent body fat</td>
<td>10.4±2.6</td>
<td>17.1±4.3*</td>
</tr>
<tr>
<td>Muscle mass from creatinine (kg)</td>
<td>22.1±2.2</td>
<td>27.6±4.2*</td>
</tr>
</tbody>
</table>

*P<0.001 compared to slum dwellers. Values are mean ± SD

Table II. Comparison of the characteristics of the prediction and validation data sets

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Prediction set (n=33)</th>
<th>Validation set (n=33)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>20.7±1.9</td>
<td>20.3±2.0</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>49.5±8.3</td>
<td>51.1±8.3</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>164.1±7.0</td>
<td>164.1±5.7</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>18.3±1.9</td>
<td>18.8±2.1</td>
</tr>
<tr>
<td>Mid-arm circumference (cm)</td>
<td>24.2±1.8</td>
<td>24.6±1.9</td>
</tr>
<tr>
<td>Corrected arm muscle area (cm²)</td>
<td>28.2±4.4</td>
<td>29.1±6.0</td>
</tr>
<tr>
<td>Muscle mass from creatinine (kg)</td>
<td>23.8±3.6</td>
<td>25.0±4.6</td>
</tr>
</tbody>
</table>

All values are in means±SD.

No significant differences between groups

Fig. 1. Linear regression between the muscle mass estimates of mid-arm circumference and corrected arm muscle area Vs estimates of urinary creatinine in the whole group (n=66).

Linear regression was carried out in the whole group between both MAC and CAMA against muscle mass obtained from urinary creatinine in order to obtain predictive equations for muscle mass (Fig. 1). The prediction equation obtained for muscle mass (kg) using MAC was \((1.641 \times \text{MAC}) - 15.580\) \([r=0.72, \text{standard error of estimate (SEE) = 2.91 kg}]\), while the equation derived from CAMA was \((0.496 \times \text{CAMA}) + 10.183\) \([r=0.62, \text{SEE = 3.29 kg}]\). The mean muscle mass estimate obtained by urinary creatinine method was 24.4±4.2 kg, while it was 24.4±3.0 kg when predicted from MAC and 24.4±2.6 kg from CAMA. Paired t-test analysis showed no significant differences between the estimates of muscle mass from different methods. The mean difference for muscle mass from urinary creatinine was -0.01 ± 2.88 kg for the MAC derived equations and 0.002±3.26 kg for the CAMA derived equations. The application of an exponential or quadratic fit to the MAC or CAMA data gave very small improvements in the r value (by about 0.01 in all comparisons) and therefore the linear equations were used as they are the easiest to use in practice.
In order to assess whether anthropometric variables improved the prediction equation, height and weight were entered into the regression of MAC and CAMA in a stepwise fashion. Height was excluded in the stepwise regression during the analysis, as it was not significant. The resultant equations using weight and MAC was

\[
\text{Muscle mass (kg)} = [(0.265 \times \text{weight}) + (0.672 \times \text{MAC})]-5.314
\]

\[r=0.79, \text{SEE}=2.62 \text{ kg}\]

Further, in order to check the homogeneity of the data, the whole group of subjects (n=66) was randomly divided into group 1 (n = 33, prediction group) and group 2 (n = 33, validation group). Linear regression was carried out in the prediction group between muscle mass estimated by urinary creatinine against MAC and CAMA. The prediction equation so obtained for MAC was

\[
\text{Muscle mass (kg)} = (1.442 \times \text{MAC}) - 11.065
\]

\[r = 0.71, \text{SEE} = 2.57 \text{ kg}\]

while it was

\[
(0.50 \times \text{CAMA}) + 9.623
\]

\[r = 0.61, \text{SEE} = 2.90 \text{ kg}\]

The total body muscle mass derived by the MAC and CAMA predictive equations were compared to the estimates of muscle mass from urinary creatinine by measuring the difference between them in the validation set of subjects (Fig. 2). The mean difference for the muscle mass from the predictive equation of MAC was 0.64 ± 3.25 kg, while it was 0.78 ± 3.62 kg obtained from CAMA predictive equation. Paired t-test analysis show no significant differences in the estimates of total body muscle mass between the different methods.

In order to assess whether the Western equation for muscle mass derived by Heymsfield et al.\textsuperscript{12} produces accurate results in this young Indian population, the muscle mass estimated by the Western equation was compared to those values estimated by urinary creatinine. The mean difference that was obtained was 6.4±3.0 kg and the difference significantly correlated with the magnitude of the measurement (Fig. 3).

BMI was correlated with both muscle mass and per cent body fat (% fat) in this group of young male subjects. Both these indices correlated well with the BMI, with \[r = 0.71 (P<0.001)\] and \[r = 0.70 (P<0.001)\] for correlates of BMI and muscle mass and fat respectively.

**Discussion**

Loss of muscle mass leads to an impairment of an individual's mobility and in severe cases will cause death.\textsuperscript{20} The common symptoms in chronic organ diseases are muscle weakness and early fatigue and the
intensities of symptoms and exercise intolerance seem to be related to muscle wasting and alterations in peripheral skeletal muscle in these patients.\textsuperscript{21}

Sarcopenia, the age-related loss of muscle mass, strength, and oxidative capacity in the elderly is a common problem.\textsuperscript{22-24} A lower total body muscle mass, which has an independent effect on insulin sensitivity and glucose disposal,\textsuperscript{25,26} could also determine the risk for developing insulin resistance. In young individuals, it was observed that both muscle and fat correlated well with BMI suggesting that both play a role in the magnitude of the BMI or body size, unlike in older subjects where the body fat is more closely related to BMI than muscle.\textsuperscript{27} When multiple regression with other anthropometric measurements such as weight and height was done, the regression with height was not significant, while weight showed a good relationship. It could be because in young individuals body weight correlated well with muscle, which may not be the case in older subjects.

Of the various techniques available for estimating total skeletal muscle mass, urinary creatinine excretion method is theoretically one of the most specific indices because creatine, the precursor of creatinine, is mainly present in the skeletal muscle, although a small amount is produced in smooth muscle, brain, and other organs.\textsuperscript{9} However, the creatinine excretion varies on a day to day basis depending on the diet and also, at least 3 days of urine collection needs to be made.\textsuperscript{28} Hence, the urinary creatinine method is difficult and laborious, and unsuitable for clinical and field studies. The fit of data in the muscle mass - MAC or CAMA relationship was similar when linear, exponential or quadratic fits were applied, and hence only the linear equation was chosen because of its ease of use.

In this study we chose subjects with a wide range of BMI, as we wanted to derive an equation that worked across a wide range of muscle mass. In a previous study\textsuperscript{29} carried out to develop and cross-validate predictive equations for estimating skeletal muscle mass using bioelectrical impedance analysis, the BMI range of the subjects was 16-48 kg/m\textsuperscript{2}. When the whole data set of the present study was divided into slum dwellers (n=38) and students (n=28), significant differences were observed between the two groups in body weight, height, body mass index and per cent body fat.

The large difference that was observed in comparisons of the measured muscle mass with the western equation could be due to various reasons. The subjects in the Western study included both healthy male and female subjects as well as subjects with protein energy malnutrition secondary to cancer, gastrointestinal diseases, and anorexia nervosa, while the present study was on young, healthy Indian male subjects. The age range of the subjects in the previous study\textsuperscript{12} was 20 to 70 yr, while our subjects ranged from 17 to 25 yr. It must also be remembered that regression equations would best fit the populations that they are derived from and may not be applicable for other populations.

The limitations of this study were that it was only conducted in young Indian men. The calculation of CAMA required a correction for bone mass, which was taken from the literature on Western subjects. There may be different relationships between bone and skeletal muscle mass in Indians. Since muscle mass is appendicular, it seems reasonable to propose that the addition of a calf or upper leg girth would have strengthened the prediction equation.

In conclusion, the present study documented a prediction equation for the measurement of muscle mass.
in young Indian men, based on simple anthropometric measurements.

References


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