Anthropometric evaluations of body composition of undergraduate students at the University of La Réunion

Evelyne Tarnus and Emmanuel Bourdon

Biology Department, University of La Réunion, Saint Denis de La Réunion, France

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Tarnus, Evelyne, and Emmanuel Bourdon. Anthropometric evaluations of body composition of undergraduate students at the University of La Réunion. Adv Physiol Educ 30: 248–253, 2006; doi:10.1152/advan.00069.2005.—A positive correlation is well established between obesity and the susceptibility to develop metabolic syndrome, a multifactorial disease dramatically associated with an enhanced mortality risk in the developed world. A high prevalence of obesity has recently been described at La Réunion Island, a French department in the Indian Ocean. Anthropometry is generally considered as the single most easily obtainable, inexpensive, and noninvasive method that reflects body composition. At the University of La Réunion, a laboratory course involving students was designed to teach anthropometric measurements for the determination of body composition. Using skin fold thickness equations, students determined the fat and total muscular masses of their body composition. The influences of sex and their physical activity or inactivity on these different parameters were compared and interpreted at the end of the course. Positive and significant correlations were established between the students’ body mass indexes values and their fat mass percentages and between their fat-free and muscular masses as well. A higher fat mass percentage was found in sedentary students compared with more active ones. Therefore, this laboratory makes the students practice and understand the use of classical techniques to evaluate the body composition of a person. It also alerts them to the correlation between a sedentary attitude and higher body fat content. This laboratory course constitutes an active introduction to a following lesson on more recent and actual techniques used to evaluate body composition.

A STRONG CONNECTION is now well established between the development of metabolic syndrome and a higher rate of mortality (2, 5). Metabolic syndrome is characterized by central obesity, hypertension, insulin resistance (Type 2 diabetes), and atherogenic disorders (5). Obesity constitutes one of the primary risk factors for the development of metabolic syndrome apart from genetic factors (9). In young adults, obesity is often associated with poor fitness and can lead to the development of cardiovascular diseases, the leading cause of mortality in Western countries (8, 2, 12).

A strong link between obesity and diabetes is now well established as 70% of diabetic people present as overweight (5). In the Indian ocean, the inhabitants of La Réunion Island, a French overseas department, exhibit an increasing prevalence of Type 2 diabetes and elevated waist-to-hip ratios (W/H), markers of central adiposity (6). La Réunion Island provides an example of rapid urbanization and a drastic change in the way of life over just a few decades (6). In one generation, lifestyle, such as eating habits, has evolved from traditional habits to that of a Western type. The population of the island is much younger than that of the French mainland (Europe). Persons who are <20 yr old represent 37% and 26% of the population of the island and mainland, respectively.

A laboratory course was designed to teach second-year undergraduate students in Physiology the use of anthropometric measurements for the determination of their body composition. Anthropometry is generally considered as the single most easily obtainable, inexpensive, and noninvasive method that reflects body composition (1). Using skin fold thickness equations, a classical technique, students determined their fat and total muscular masses.

Students used statistical analysis of the data obtained by each group to relate body composition to the influence of sex and physical activity or inactivity. This exercise allowed them to use a scientific method to study a real world problem.

LABORATORY COURSE PROCEDURES

Participants

Students in this laboratory were in their fourth semester preparing for a Bachelor’s degree in Biology at the University of La Réunion. During this year of study, they had 42 h of lectures on cardiovascular and digestive physiology in addition to 6 h of classroom exercises related to their laboratory activities. All students signed a consent agreement allowing the use of their anonymous data for publication in the Advances in Physiology Education journal, and the laboratory activity was approved by the Institutional Review Board.

Students in the class ranged in age from 18 to 24 yr old. La Réunion’s population is composed of multiple ethnic groups. Malabars or Tamil of Indian origin represent one-quarter of the island’s inhabitants. About 35% of the population is of African/Malagasy origin. White Europeans make up approximately one-quarter of the population. The remaining 15% of the population is composed of Métis, Vietnamese, and Chinese people. About same percentages were carried over in the classroom.

Pre- and Postlaboratory Settings

The laboratory course started with a 1-h lecture session to acquaint the students with the objectives and methods of the exercise. All the principles of body composition evaluation using anthropometric measurements were explained, including a description of the tools used for anthropometric measurements. The formulas were written on the blackboard and explained in the same terms used below (cf. formulas used). Students were taught basic statistics (means and SDs, Student’s t-coefficients, and P values) through a simple example.
Explanations were provided to students regarding the scientific report they were going to write from data obtained from the whole group (~20 students/group). A few weeks after the laboratory course and after the students’ reports had been reviewed, the students’ results were discussed with them during a 2-h lecture. After the laboratory activity, students were also taught other classical methods used for evaluation of body composition, including hydrostatic densitometry and K^40 calculation techniques. More contemporary techniques, such as nuclear magnetic resonance and tomodensitometry, were also studied in the lecture classroom.

**Anthropometric Measurements in the Laboratory**

The anthropometric evaluation of body composition constituted a 3-h practical exercise. Sixty-six students were randomly divided into four groups. Students selected a partner with whom to take the measurements. At the end of the session, students wrote their personal data, which remained anonymous, on the blackboard.

For the following week, students individually prepared written reports including an interpretation of group results and statistics. The reports averaged 8–10 pages in length. It was very important to stress that because the laboratory course dealt with anthropometric measurements, students were told that there was no obligation to report their own body composition and that they would in no way be evaluated from their personal measurements. Only their scientific report with calculations of anonymous data from their whole group would be evaluated. In May 2006, of the ~200 students who participated in this laboratory course, only 1 pregnant student did not do the measurements, but she enthusiastically helped with the skin fold measurements of her classmates.

**Body mass index.** Body height was measured to the nearest 0.01 m with the subject standing with their back to a wall-mounted stadiometer and in bare feet. Weight was measured to the nearest 0.1 kg with calibrated scales. The body mass index (BMI; in kg/m^2) was calculated as weight (in kg) divided by height (in m^2).

**Ideal body weight.** Ideal body weight (IBW) was determined with Lorentz’s formula (9) as follows:

For a woman: IBW (kg) = height (cm) − 100

\[- \left\{ \frac{\text{height} (\text{cm}) - 150}{2} \right\} \]

For a man: IBW (kg) = height (cm) − 100

\[- \left\{ \frac{\text{height} (\text{cm}) - 150}{4} \right\} \]

This formula should only be used for people older than 18 yr of age who range in height from 140 to 220 cm (9). In our case, the formula could be applied to all participants.

When we introduced this formula, we explained that the IBW should not be considered as an absolute value but rather as a zone of weight where mortality/morbidity risks are at their minimum rates. Figure 1A was drawn on the blackboard to educate students about the strong link between mortality and being either overweight or underweight. Based on current federal guidelines released by the National Heart, Lung, and Blood Institute (7), ideal weight is defined as a BMI between 18.7 and 24.9 for all adults regardless of age. Students were informed that the optimum BMI tends to be higher for older adults compared with the young.

**Waist-to-hip ratio.** Waist, hip, and upper arm circumferences were measured using a measuring tape.

Waist and hip circumferences were measured at the umbilici and at the widest buttock level, respectively. The pictures shown in Fig. 1B were drawn on the blackboard. We then showed to the students that pear-shaped obesity is more common in women, whereas men develop preferentially a trunkal obesity (apple shape). Also, the latter is dramatically associated to a higher incidence of cardiovascular diseases and diabetes.

**Skin fold measurements.** Skin folds were measured using portable electronic Harpenden skin fold calipers. Six digital skin fold meters (model DMV250) from Moretti (www.morettispa.com) were used during this course. The Harpenden skin fold caliper has been modified to give a simple digital display or an output that may be entered directly to more
sophisticated equipment (e.g., a digital computer or x-y plotter) for further analysis (10).

The photograph shown in Fig. 2A shows the use of the electronic Harpenden caliper by the students. Figure 2, B and C, represent the different localizations of the skin folds. The values for the bicipital (BS), tricipital (TS), subscapular (SS), and suprailiac skin folds (IS) were obtained in millimeters. One student pinched the skin at the appropriate site to raise a double layer of skin and the underlying adipose tissue but not the muscle. The calipers were then applied 1 cm below and at right angles to the pinch, and a reading was taken a few seconds later. Students measured each skin fold at least three times and
and following Siri’s formula (13):

\[
\text{Fat mass} \% = 100 \times \left(1 - \frac{d}{0.0720 \times \log_{10}(\text{BS} + \text{TS} + \text{SS} + \text{IS})} \right)
\]

For a man: \(ABM_c = ABM - 6.5\)

For a woman: \(ABM_c = ABM - 10\)

Finally, the total muscular mass (TMM) was obtained with the following equation:

\[
\text{TMM (kg)} = \text{Height (cm)} \times \left[0.0264 + (0.0029 \times ABM_c)\right]
\]

**Statistics**

Data are expressed as means ± SD, and variances were compared using Student’s t-test for unpaired samples and by using a \(P\) value of 0.05 as the threshold of significance.

**RESULTS AND DISCUSSION**

Values obtained by the students are summarized in Table 1. Means and SDs were calculated for the entire group’s data and also after the data had been categorized according to students’ sex and their physical exercise status.

The first discussion dealt with comparing the students’ values with the guidelines for determining obesity and thus metabolic syndrome susceptibility. The criteria used were those defined by the European Group for the Study of Insulin Resistance (1999), the World Health Organization (1999), and the National Cholesterol Education Program’s Adult Treatment Program’s Adult Treatment (2001) (5). According to these societies, obesity is characterized by a BMI of over 30 or a waist-to-hip ratio superior to 0.9 for a man or to 0.85 for a woman.

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**Table 1. Values determined by students in the anthropometric measurement laboratory class**

<table>
<thead>
<tr>
<th></th>
<th>(n)</th>
<th>Body Mass Index, kg/m(^2)</th>
<th>Ideal Body Weight, kg/m(^2)</th>
<th>Waist-to-Hip Ratio</th>
<th>Fat Mass, %</th>
<th>Total Muscular Mass, kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total students</td>
<td>66</td>
<td>21.9 ± 3.8</td>
<td>61.6 ± 7.8</td>
<td>0.81 ± 0.07</td>
<td>30.7 ± 8.3</td>
<td>18.2 ± 7.2</td>
</tr>
<tr>
<td>Men</td>
<td>23</td>
<td>22.5 ± 2.6</td>
<td>70.6 ± 6.1</td>
<td>0.84 ± 0.06</td>
<td>22.3 ± 4.8</td>
<td>24.2 ± 7.8</td>
</tr>
<tr>
<td>Women</td>
<td>43</td>
<td>21.6 ± 4.3</td>
<td>56.8 ± 2.4</td>
<td>0.80 ± 0.01</td>
<td>34.8 ± 6.6</td>
<td>15.0 ± 4.4</td>
</tr>
<tr>
<td>Sportive men</td>
<td>14</td>
<td>22.3 ± 2.5</td>
<td>72.9 ± 5.9</td>
<td>0.82 ± 0.05</td>
<td>22.1 ± 5.2</td>
<td>25.4 ± 7.6</td>
</tr>
<tr>
<td>Nonsportive men</td>
<td>9</td>
<td>22.8 ± 2.9</td>
<td>67.0 ± 4.5</td>
<td>0.86 ± 0.07</td>
<td>24.3 ± 3.8</td>
<td>22.2 ± 8.3</td>
</tr>
<tr>
<td>Sportive women</td>
<td>22</td>
<td>20.7 ± 3.7</td>
<td>56.8 ± 2.8</td>
<td>0.78 ± 0.06</td>
<td>33.7 ± 7.7</td>
<td>14.9 ± 4.2</td>
</tr>
<tr>
<td>Nonsportive women</td>
<td>21</td>
<td>22.4 ± 4.7</td>
<td>56.7 ± 2.0</td>
<td>0.81 ± 0.07</td>
<td>35.9 ± 5.3</td>
<td>15.1 ± 4.7</td>
</tr>
</tbody>
</table>

Results are means ± SD; \(n\), no. of students. \(a, b, c, d, e\) Numbers with identical letters correspond to values that are significantly different (\(P < 0.05\)) compared one with the other using Student’s t-test for unpaired samples.
Influence of Sexual Dimorphism

Students were asked in their reports to compare values obtained for two different populations (women and men or active and sedentary). During the interpretation of the results, a special emphasis was put on the differences observed between the values of fat mass obtained by women and those obtained by men (Table 1). The waist-to-hip ratio reflects whether the body fat distribution is gynoid or android. The upper limit for the waist-to-hip ratio for obesity is higher for a man than for a woman. This comes naturally from the fact that a female silhouette is characterized by a wider hip. In the case of obesity, an elevated waist-to-hip ratio is synonymous with central obesity or android-type obesity, which is directly linked to the development of metabolic syndrome (5).

Mean values of fat mass obtained during the laboratory class were quite similar to those determined by Peterson et al. (13), whose group used a new skin fold thickness equation with a 4-compartment model. Adult women presented a mean fat mass percentage of about 30%. Overweightness is generally established for a woman whose fat mass is higher than 40%. Adult men presented with a mean fat mass of 20%. For a man, overweightness is established when this value is higher than 30%.

From the results in Table 1, the students observed that the men presented a higher muscular mass than the women, who had an elevated fat mass. The role of the influence of sex steroids was briefly explained by the teacher. Female hormones like estrogens and progesterone have a positive influence on the quantity and distribution of fat. Unlike women, men have a high muscular mass, the development of which is stimulated by the anabolic hormone testosterone.

Influence of Physical Activity

Students were asked whether or not they regularly practiced sports during at least 1 h/wk. This was the criterion used in this laboratory course to determine the activity status of the students. More precise criteria could have been used to determine this status, but the one we chose appeared to be sufficient for our demonstration. We observed (Table 1) lower BMI values, lower percentages of fat, and higher muscular masses for the students (women or men) who practiced sports regularly than for those who did not, but the differences were not significant in this group, probably because we defined “active” as only 1 h of sports activity per week.

Carnethon et al. (2) reported a direct effect of the intensity of physical exercise on BMI. They observed decreases in BMI values for young women and men who were used to prolonged physical activity (time on a treadmill) compared with those who were used to doing a shorter time (2). It was mentioned to the students that a very low fat mass percentages (about 10%) can be measured in athletes practicing intensive sports like marathons or body building.

Correlations

The association of BMI and obesity was demonstrated to the students by the establishment of a positive correlation between their obtained data of BMI and their fat mass percentages (Fig. 4A). It was mentioned to the students that several investigators reported that BMI tends to overestimate fatness in athletic individuals (15). The students were taught that body composition can be divided into two parts, fat mass and fat-free mass, consisting of the muscular mass, water, and minerals. Students determined their fat-free mass content (in %) by subtracting their fat mass percentage from 100. The data of all participants showed a positive correlation (Fig. 3B) between the fat-free weight percentage and total muscular weight. These two correlations were used as a practical illustration of the link between BMI and fat composition and between nonfat mass and muscular composition.

Conclusions

This laboratory course was conducted to make students understand the use of anthropometric tools to assess their body composition. Efforts were done to stimulate student involvement, interest, and personal investment as these qualities are essential to any successful teaching laboratory (11). This laboratory allowed the students to engage the following three
main goals of the anthropometric evaluation of body composition.

1 Why should one’s evaluate the nutritional status? A special emphasis was made during the prelaboratory lecture on the strong link existing between obesity and metabolic syndrome. The two teachers involved in this class were also researchers working on the interaction between inflammation and adipocytes in Type 2 diabetes/obesity pathophysiology (3), and they used recent scientific data to illustrate the link between Type 2 diabetes/obesity and enhanced morbidity.

2 How can body composition be evaluated? The major part of the laboratory consisted of students using both classical tools and contemporary methods, such as electronic skin fold calipers, for the acquisition of data concerning their body composition. Students received precise instructions for the correct measurements, which were also used for clinical purposes.

3 How can experimental data obtained during the laboratory be analyzed? This exercise provided students with the opportunity to collect data, evaluate it using statistical analysis, and interpret their results in a report containing graphs and all parts of a classical report, namely, the introduction, results, and interpretations.

For future laboratory classes, we intend to expand the methods used to include two impedance metric balances, which allow the indirect determination of fat mass using electrical conductibility properties of electrolytes contained in the fat-free mass.

Student reactions to this lab were very positive. Students all participated very actively, even those who could be considered overweight. The quality of their written reports was, in most of cases, outstanding. This laboratory course was set up by E. Bourdon when he started his position as an assistant professor at the University in 2004, and such a positive experience with students has constituted a wonderful source of motivation for a beginner teacher to develop physiology laboratories further.

ACKNOWLEDGMENTS

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