SENSITIVITY AND SPECIFICITY OF BODY MASS
INDEX WITHIN MALE UNIVERSITY SPORT
STUDENTS
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-ACKNOWLEDGEMENTS-

I would like to thank my dissertation supervisor Carl Beynon for his guidance and support throughout this study and I would also like to thank all of the male sport students at the University of Wales Institute Cardiff that took part, without you it would not have been possible.
The purpose of the present study was to establish if body mass index (BMI) was sensitive and specific enough to classify overweight and obesity within a male university sport student population.

Male university sport students \((n = 75)\) participated within this study. BMI was calculated using the World Health Organisation (WHO, 2000) standardised cut-off values, obesity defined as BMI > 30 kg/m\(^2\) (condition one) and overweight defined as BMI > 25 kg/m\(^2\) (condition two). Percentage body fat was evaluated with the use of skinfold measurement, using the American College of Sports Medicine standardised values of 25 percent to define obese and 20 percent to define overweight this was used as a criterion to determine sensitivity and specificity levels of BMI. Sensitivity was high \((1)\) for both condition one and two and specificity was also high \((0.93)\) for condition one, but specificity for condition two was low \((0.52)\).

In conclusion, the WHO (2000) standard classification for obesity \((\text{BMI} > 30 \text{ kg/m}^2)\) is an optimal cut-off value to use for a population of male university sport students, however the results of this study propose that the WHO (2000) standard classification for overweight \((\text{BMI} > 25 \text{ kg/m}^2)\) is not an accurate or reliable cut-off value to use when assessing overweight within male university sport students.
students needs to be established, due to obesity being a major growing concern across the entire world, concerning every population. ‘Obesity, defined as an excess accumulation of body fat, is a heterogeneous disorder with a final common pathway in which energy intake chronically exceeds energy expenditure’ (McArdle et al., 2001 p.823). Obesity is in epidemic state and the incidence is a potential for ill health (Afridi et al., 2004).

Being overweight or obese is associated with an increased risk of many diseases and along with the risk of ill health obesity significantly increases the risk of mortality (Labib, 2003). Due to obesity having a high prevalence, Labib (2003) describes that the economic costs have been estimated to be 3-8% of all health care expenditure to treat the associated health risks.

Some may ask what caused the onset of an obesity epidemic and why it is continuing. According to Labib (2003) two major changes directly contribute to the increasing prevalence of obesity. The first factor is a major decrease in energy expenditure due to the impact of technological advancement and the second factor is an increased consumption of unhealthy foods. Along with this, energy expenditure such as physical activity, does not balance with the increased energy intake, suggesting sedentary lifestyle also contributes to obesity.

Obesity does not just occur within adults, but also in childhood. Childhood obesity is a worsening epidemic, involving short and long-term medical consequences (Thorpe et al., 2004). It is said that obesity in childhood tends to persist into adulthood, generating opportunity for great efforts to be made for prevention and intervention of childhood obesity to be reduced (Reilly et al., 2003 and Thorpe et al., 2004). This is why measurement of body composition is so important, to detect the individuals at risk of disease, to cut down the amount of children carrying obesity into adulthood and to help cut down health care costs. Body composition has a very important influence upon athletes’ performance and general health as for all populations. ‘Body
Figure 1.0.1 The five levels of human body composition organisation. (Wang et al., 1992, p. 20)

There are many valid laboratory based techniques that can be used to measure body composition; the gold standard for measuring body composition in a two-compartment model has been underwater weighing (Sarria et al., 1998). Due to time constraints, expenses and the complexity involved in laboratory based methods are not practical when dealing with large numbers; therefore anthropometric techniques are primarily used, such as BMI and skinfold measurement (Hardman and Stensel, 2003). These anthropometric techniques involve the use of predictive equations and produce only an estimate of an individual’s fat mass (FM), which may be inaccurate due to the large and varying population.
estimate of body fatness. Neovius et al. (2004) suggest that even though BMI is used widely throughout the adult population, the use of BMI within the young population is controversial. The accuracy of BMI varies depending on age, sex and maturation (Neovius et al., 2004), and therefore BMI may not be sensitive for subgroups such as sport students, due to the standardized cut-off values being established from data collected from the general population according to Ode et al. (2007).

There is still no standard classification system for obese adolescents according to Mei et al. (2007). In comparison to the general population, a young male sporting population has a large muscle mass, which BMI does not consider and this may influence the standard of sensitivity and specificity of BMI leading to misclassification, labelling athletic individuals as overweight. Skinfold measurement assesses percentage body fat and has been widely used to calculate body composition in the past. Mei et al. (2007) suggests that skinfold measurement provides additional information on excess body fat than what BMI can present. Ode et al. (2007) suggests that percentage fat is a better tool to use when calculating obesity within athletes than BMI.

Therefore the purpose of this study is to determine the level of sensitivity and specificity of BMI as a measure of excessive body fatness in male university sport students.
3.1 Ethical Approval
When the question and procedure was decided for this particular study ethical approval was applied for, by submitting a research proposal to the Cardiff School of Sport Research Ethics Sub-Committee. Ethical clearance was gained to ensure that the study did not detrimentally affect the physical, psychological or social well being of any participants involved. Ethical behaviour was maintained throughout the study by respecting participants, constant professionalism, informed consent used to gain permission to perform the study and confidentiality was maintained.

3.2 Measurement of reliability
‘Reliability can be defined as the consistency of measurements, or of an individual’s performance, on a test or the absence of the measurement error’ (Atkinson and Nevil, 1998 p. 219). Before any study that collects measurements can take place the level of reliability needs to be established, this then provides how accurate and valid the results are for the general studies in hand. When skinfold site’s are repeatedly measured the data may vary due to the inconsistency of the technique (Norton and Olds, 1996).

To establish if the anthropometrist was accurate for this study a measurement of reliability test was carried out before the main experiment took place. According to Hopkins (2000) a typical reliability study would perform several trials on a sample using the same equipment and the same rater. The reliability test involved within this study used the exact method adopted in the main anthropometric measurements protocol explained below. Two measurements of each individual variable (Stature, body mass, and four anatomical landmarks) were taken from the reliability study participants ($n = 14$), using of the same equipment and rater throughout. The data was then processed to calculate whether the anthropometrist was reliable.
for each repeated variable on the programme SPSS (11.1 Windows). The repeated one-way ANOVA was to check that there was no significant difference ($P > 0.05$) between the test and retest, by measuring the variability between the means of the set of scores from each individual variable.

Following this, measurement of reliability was established by calculating the intraclass correlation coefficient (ICC), to check if there was a significant relationship ($P < 0.05$) and to assess the degree of relationship between the test and retest, which was provided on a scale of zero to one. An ICC of 0.00 indicates no relationship between the sets of data suggesting the scores are unreliable, whereas an ICC of +1.00 indicates a perfect relationship suggesting reliable scores. Norton and Olds (1996) describe that ICC is always expressed as a positive number with no units. The acceptable value used within this study for ICC was ICC $> 0.8$, which was established from Atkinson (2003).

$$\text{ICC} = \frac{\text{MSs} - \text{MSe}}{\text{MSs}}$$

Where:
- ICC = intraclass correlation coefficient
- MSe = Error mean square
- MSs = mean square between participants

(Norton and Olds, 1996 p. 85)
can be expressed in absolute and relative terms, where absolute is expressed in the actual units of the current variable and relative gives the error as a percentage of the overall mean and has no units. To be able to compare the TEM of different variables it may be beneficial to calculate absolute TEM into relative TEM (Norton and Olds, 1996). The acceptable value used within this study for relative TEM was %TEM < 5 percent, which was established from Atkinson (2003).

\[
\text{TEM} = \sqrt{MSe}
\]

Where: 
- \(\text{TEM}\) = Absolute technical error of measurement
- \(MSe\) = Error mean square

\[
\%\text{TEM} = \frac{\text{TEM}}{\text{Mean}} \times 100
\]

Where: 
- \(\%\text{TEM}\) = Relative technical error of measurement

(Norton and Olds, 1996 p. 85)

### 3.3 Participants and Experimental Sample Size
Participants were male undergraduate students studying a full time sports degree at the University of Wales Institute Cardiff (UWIC). Participants assessed \(n = 75\) had a mean body mass (kg) of \(82.1 \pm 11.8\), mean stature (m) of \(1.80 \pm 0.07\), mean BMI (kg/m\(^2\)) of \(25.33 \pm 2.98\) and a mean percentage fat of \(13.41 \pm 3.57\). The assessment of participants took place December 2007, at UWIC, based in Cardiff, Wales.
participants prior to any volunteered commitments. Before BMI and skinfold measurement’s were taken informed consent forms (see appendix A) were given out stating the aims and nature of the investigation, the duration, their personal rights and reassuring that participants information would be kept anonymous and confidential. Participants willing to take part then read and signed the form. Each participant reported to UWIC when requested, dressed correctly wearing minimal clothing such as t-shirt and shorts. Data was collected in a quiet room, which was pre-booked to ensure measurement was not interrupted. Data was then transferred into a document on SPSS ready for the statistical analysis to be carried out.

3.5 Anthropometric Measurements Protocol

Body Mass
Body mass measurements were obtained using SECA digital weighing scales (SECA, Model 770, Vogel & Halke Hamburg, Germany) calibrated in kilograms. Participants stood barefoot, whilst looking straight ahead and standing in the centre of the scales. Body mass was measured to enable BMI to be calculated.

Stature
Stature was measured using a portable anthropometric stadiometer (Leicester height measurer, SECA, Model 214, Vogel & Halke Hamburg Germany) calibrated in millimetres. Participants stood barefoot and upright, with heels together and in contact with the stadiometer, whilst arms hanging naturally by their sides. Stature was also measured to enable BMI to be calculated.
relative percentage of body size in English speaking countries (Gard and Wright, 2005). BMI was calculated by measuring the stature and body mass of all participants and then put into an equation, body mass (kilograms) divided by stature (meters) squared, (Gard and Wright, 2005).

\[
\text{BMI} = \frac{\text{Body mass (kg)}}{\text{Stature (m)}^2}
\]

(Gard and Wright, 2005 p. 92)

**Skinfold Measurement**

Skinfold measurement has been used from as early as 1921, where Matiegka invented an equation to calculate body fat from measuring the thickness of skinfold sites of the human body (Durnin and Rahaman, 1967). Skinfold measurement is an easy and non-invasive method to assess body composition this explains the reason for its wide range of use (De Lorenzo et al., 1998).

The standardised procedure used to mark up and measure the skinfold of participants was from the ACSM (2006), the measurements were obtained using a Harpenden Skinfold caliper (Holtain Ltd, Crosswell, Crymych, Pembrokshire), calibrated in 0.2 mm intervals. Four identified sites were measured, being the triceps, bicep, suprailliac and subscapular, on the right hand side of the body, although according to Durnin and Wormersley (1974) there has not been any statistical difference found from either side of the body. Four sites were measured due to the recommendation of Durnin and Rahaman (1967) suggesting that measuring four anatomical sites is more accurate than two sites. A pen was used to mark designated anatomical landmarks to ensure the measurements were as accurate as possible. A double fold of skin and the subcutaneous fat was firmly grasped between the thumb and index finger at the marked anatomical land mark, whilst placing the callipers directly upon the skin surface, 1 cm away from the thumb and finger, perpendicular to the skinfold and halfway between the crest and the base of the fold. The fold of skin was maintained
- **Triceps skinfold**
  Triceps skinfold measurement’s were obtained by measuring the vertical skinfold on the posterior mid-line of the upper arm, at the marked point between the acromion and olecranon landmark, with the arm held freely at the side of the body.

- **Biceps skinfold**
  Biceps skinfold measurement’s were obtained by measuring the vertical skinfold on the anterior aspect of the arm over the centre of the biceps muscle, 1 cm above the level used to mark the triceps site.

- **Suprailliac skinfold**
  Suprailliac skinfold measurement’s were obtained by measuring the diagonal skinfold in line with the natural angle of the iliac crest taken in the anterior axillary line immediately superior to the iliac crest.

- **Subscapular skinfold**
  Subscapular skinfold measurement’s were obtained by measuring the diagonal skinfold held at an oblique angle, at a 45-degree angle, 1 to 2 cm below the inferior angle of the scapular.

Once the four skinfold measurement’s were collected body density for each participant was derived using the linear regression equation for 17-19 year old males modified by Durnin and Wormersley (1974), and the outcome of body density was then converted into percentage body fat using the Siri equation (Siri, 1956).
Body Density = 1.1620 – [0.0630(\log_{10} \text{SUM OF ALL FOUR SKINFOLDS})]
(Durnin and Wormersley, 1974)

The Siri Equation
\[
\text{FAT \%} = \frac{[(4.95) - 4.5]}{\text{BD}} \times 100
\]
(Siri, 1956)

3.6 Data Analysis for Main Study
Once BMI and percentage body fat was calculated, each participant’s data was labelled with a classification of fatness referring to the WHO (2000) cut-off values, such as normal (BMI = 18.50 – 24.99), overweight (BMI > 25) or obese (BMI > 30). The data was then sort into the number of true positives (TP), true negatives (TN), false positives (FP) and false negatives (FN), this means for example TP would be the number of participants that were actually obese according to the skinfold measurement criteria and also classified obese by BMI, whereas a FP would actually not be classified as obese according to the criteria, however BMI suggests that the individual is obese.

Sensitivity and specificity was assessed for the classification of BMI in male sport students. Both sensitivity and specificity was calculated for two different categories, using the specified cut off points (see Table 3.6.1). First category being the individuals classified as obese (condition 1) obtaining body fat 25 percent and above according to ACSM (2006) and also test positive with a BMI larger than 30 kg/m² according to WHO (2000). The second category calculated was all the individuals classified as overweight (condition 2) obtaining body fat of 20 percent and above according to ACSM, (2006) and also the test positive individuals of a BMI above 24.99 kg/m² according to WHO (2000).
<table>
<thead>
<tr>
<th>Classification</th>
<th>BMI (kg/m²)</th>
<th>Body Fat (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>18.50 – 24.99</td>
<td>15 – 19.99</td>
</tr>
<tr>
<td>Obese</td>
<td>30+</td>
<td>25+</td>
</tr>
</tbody>
</table>

Body fat percentage calculated from skinfold measurement used the cut off values derived from the American College of Sports Medicine (2006), classifying overweight as 20-25 percent body fat and obese as over 25 percent body fat. Although generally BMI greater than 24.99 kg/m² is defined as overweight and body fat of 20-25 percent is defined as over-fat, within this study both of these classifications are referred to as overweight to ensure that confusion is avoided.

**Sensitivity** = \(rac{\text{Number who are both condition 1 and/or 2 positive and test positive}}{\text{Number who are condition 1 and/or 2 positive}}\)

**Specificity** = \(rac{\text{Number who are both condition 1 and/or 2 negative and test negative}}{\text{Number who are condition 1 and/or 2 negative}}\)

Where:  
**Condition 1** = Obese: (BMI > 30 kg/m² and 25 + % body fat)  
**Condition 2** = Overweight: (BMI > 24.99 kg/m² and 20 + % body fat)  
(Bland, 1995, p.273)

In other words, ‘sensitivity is the proportion of true positives that are correctly identified by the test and specificity is the proportion of true negatives that are correctly identified by the test’ (Bland, 1994 p. 273). Therefore the sensitivity and specificity statistics provided how many people were classified correctly with the use of BMI and those that were not, in comparison to the skinfold measurement criteria. The sensitivity and specificity results suggest how trustworthy the specific cut-off values used for BMI are for a male sporting population.
4.1 Reliability Study

Table 4.1.1 shows the mean ± SD for each variable in test one and two of the reliability study, mean difference ± SD, ANOVA significance, intraclass correlation coefficient, 95% confidence intervals lower and upper bound, intraclass correlation coefficient significance and the technical error of measurement in relative and absolute terms for the measurement of reliability study, of BMI and skinfold measurements.

With regards to table 4.1.1 all variables within the reliability study show no significant difference (P > 0.05), values ranging from 0.13 to 1. ICC for all variables provides great reliability ranging from 0.99 to 1, which is perfect. ICC significance also suggests a perfectly significant relationship between test one and two for every variable (P < 0.05). A high precision was demonstrated by % TEM (relative) being very low. All this suggests that the rater was reliable to gain accurate and valid results for the main study.
Table 4.1.1 Measurement of reliability study results for BMI and skinfold measurement for male university sport students \((n = 14)\)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Test One Mean ± Std</th>
<th>Test Two Mean ± Std</th>
<th>Mean Difference ± Std</th>
<th>ANOVA Sig</th>
<th>ICC</th>
<th>95% CI Lower Bound</th>
<th>95% CI Upper Bound</th>
<th>ICC Sig</th>
<th>TEM</th>
<th>%TEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stature</td>
<td>180.0 ± 6.4</td>
<td>180.1 ± 6.2</td>
<td>0.1 ± 0.1</td>
<td>0.23</td>
<td>1.00</td>
<td>1</td>
<td>1</td>
<td>0.00</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Body Mass</td>
<td>68.0 ± 9.8</td>
<td>68.0 ± 9.8</td>
<td>0 ± 0.0</td>
<td>1.00</td>
<td>1.00</td>
<td>1</td>
<td>1</td>
<td>0.00</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Bicep</td>
<td>6.7 ± 2.4</td>
<td>6.8 ± 2.4</td>
<td>0.2 ± 0.0</td>
<td>0.13</td>
<td>0.99</td>
<td>0.96</td>
<td>1</td>
<td>0.00</td>
<td>0.3</td>
<td>3.7</td>
</tr>
<tr>
<td>Triceps</td>
<td>11.2 ± 4.6</td>
<td>11.1 ± 4.2</td>
<td>0.1 ± 0.4</td>
<td>0.46</td>
<td>0.99</td>
<td>0.98</td>
<td>1</td>
<td>0.00</td>
<td>0.4</td>
<td>3.2</td>
</tr>
<tr>
<td>Subscapular</td>
<td>13.7 ± 4.6</td>
<td>13.8 ± 4.5</td>
<td>0.2 ± 0.1</td>
<td>0.26</td>
<td>0.99</td>
<td>0.98</td>
<td>1</td>
<td>0.00</td>
<td>0.4</td>
<td>2.7</td>
</tr>
<tr>
<td>Suprailliac</td>
<td>10.8 ± 3.4</td>
<td>10.8 ± 3.3</td>
<td>0.0 ± 0.1</td>
<td>0.82</td>
<td>1.00</td>
<td>0.99</td>
<td>1</td>
<td>0.00</td>
<td>0.2</td>
<td>1.4</td>
</tr>
</tbody>
</table>
4.2 Diagnostic Data

Figure 4.3.1 and 4.3.2 show the diagnosis data for both condition one and two, illustrating the number of TP, TN, FN and FP. The number of participants misclassified by BMI as overweight (condition 2) was a lot higher than the misclassification by BMI as obese (condition 1). Figure 4.2.1 shows only 5 participants were misclassified as obese (BMI > 30 kg/m\(^2\)) by BMI, falling into the FP quadrant, as a result the specificity is high (specificity = 0.93), whereas figure 4.2.1 shows that 34 participants were misclassified falling into the FP quadrant when detecting overweight (BMI > 24.99 kg/m\(^2\)) by BMI, therefore resulting in a low specificity of 52%. There were not any participants within the FN quadrant in either of the conditions, resulting in perfect sensitivity (1).

![Figure 4.2.1](image)

**Figure 4.2.1** Scatter plot of BMI > 30 kg/m\(^2\) and percentage body fat > 25% (condition 1). The four quadrants labelled FN, TP, TN, and FP to illustrate the correct classifications and misclassifications that occurred. The fit line is shown for all male university sport students.
Figure 4.2.2 Diagnosis data of BMI > 24.99 kg/m² and percentage body fat > 20% (condition 2). The four quadrants labelled FN, TP, TN, and FP to illustrate the correct classifications and misclassifications that occurred. The fit line is shown for all male university sport students.

4.3. Sensitivity and Specificity

Sensitivity and specificity for condition one and two is presented below in table 4.3.1. BMI proves to be highly sensitive providing the value of 1 within both conditions, suggesting BMI can identify all overweight and obese male university sport students, whilst specificity demonstrates to be lower in condition two than condition one, 0.52 and 0.93 respectively. Specificity values in both conditions suggest that BMI tends to misclassify those that are not overweight or obese according to the criterion measurements. However, condition one is still classed as high specificity and acceptable.

<table>
<thead>
<tr>
<th></th>
<th>Condition One</th>
<th>Condition Two</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensitivity</strong></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Specificity</strong></td>
<td>0.93</td>
<td>0.52</td>
</tr>
</tbody>
</table>
6.0 Conclusion

From the results gathered within this study it reveals that sensitivity and specificity of BMI for male university sport students is acceptable when classifying obesity (BMI > 30 kg/m²), however BMI is unacceptable when classifying overweight (BMI > 25 kg/m²), as the results suggest that BMI tends to misclassify normal weight male sport students with regard to the skinfold criteria as overweight due to a high muscle mass. Therefore when using BMI > 25 kg/m² within male university sport students it would be advised to use an additional anthropometric tool to ensure precise classification. Finally it can be concluded that the WHO (2000) standardised cut-off values used to classify obesity are sensitive and specific for a male university sport students, but the standard cut-off values used for overweight are not accurate predictors as specificity was low for this specific population.
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for BMI, triceps skinfold thickness, and arm girth for obesity screening in


Dear Participant

I am a Level 3 undergraduate student in the School of Sport at the University of Wales Institute Cardiff. I am required, as part-fulfilment of my degree program, to submit a dissertation. As such I have elected to conduct an investigation into the accuracy of BMI measurements in comparison to skinfold measurements in determining weight classification within a population of male university sports students. In order for me to conduct this research your help as a participant would be very much appreciated.

As a participant, you will have your height, weight, and four skinfold sites being triceps, bicep, sub scapular and supra iliac measured. There are no risks involved in the measurements to be used, and as participation is entirely voluntary, you would be free to withdraw at any stage of the research process.

Participant confidentiality will be upheld at all times. Individual participant data will remain private to myself, as principle investigator, and my dissertation supervisor only. No reference will be made to any individual at any stage of the writing–up process. If you are willing to participate, then please read the slip below carefully, and sign. If you have any queries, do not hesitate to contact me via email at gracebeth@hotmail.com or by telephone 07841470752.

Should you decide to help with my study, I will contact you via email to arrange for us to meet.

Thank you. I look forward to hearing from you.

Beth Grace

I have read and understood the request to be a participant in the above research. I understand there are no risks involved. I understand that participation is voluntary, and that withdrawal is possible at any time. I understand my individual data will remain anonymous at all times. I agree to participate.

Signature……………………………………    Date……………………….

Email Address………………………………………………………………..