SENSITIVITY AND SPECIFICITY OF BODY MASS INDEX WITHIN MALE UNIVERSITY SPORT STUDENTS
# Table of Contents

<table>
<thead>
<tr>
<th>Page</th>
<th>Acknowledgements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(i)</td>
</tr>
<tr>
<td></td>
<td>Abstract</td>
</tr>
<tr>
<td></td>
<td>(ii)</td>
</tr>
</tbody>
</table>

## Chapter One

### Introduction

**Chapter Two**

### Review of Literature

- 2.1 The Obesity Epidemic
- 2.2 Aetiology of Obesity
- 2.3 Financial Consequences
- 2.4 Treatments and Prevention
- 2.5 Methods of Measuring Obesity
- 2.6 Sensitivity and Specificity of BMI

**Chapter Three**

### Methodology

- 3.1 Ethical Approval
- 3.2 Measurement of Reliability
- 3.3 Participants and Experimental Sample Size
- 3.4 General Protocol and Data Collection
- 3.5 Anthropometric Measurement Protocol
- 3.6 Data Analysis for Main Study

**Chapter Four**

### Results

- 4.1 Reliability Study
- 4.2 Diagnostic Data
- 4.3 Sensitivity and Specificity

**Chapter Five**

### Discussion

- 5.1 Measurement Reliability
- 5.2 Sensitivity and Specificity

**Chapter Six**

### Conclusion

**References**

**Appendices**

- Appendix A – Informed Consent Form
<table>
<thead>
<tr>
<th>Table</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1.1</td>
<td>The International Classification of adult underweight, overweight and obesity according to BMI.</td>
<td>5</td>
</tr>
<tr>
<td>3.6.1</td>
<td>BMI derived from the WHO (2000) and body fat percentage derived from the ACSM (2006) classifications used within this study</td>
<td>22</td>
</tr>
<tr>
<td>4.1.1</td>
<td>Measurement of reliability study results for BMI and skinfold measurement for male university sport students ($n = 14$).</td>
<td>24</td>
</tr>
<tr>
<td>4.3.1</td>
<td>Level of sensitivity and specificity of BMI for condition one and two.</td>
<td>26</td>
</tr>
</tbody>
</table>
-LIST OF FIGURES-

<table>
<thead>
<tr>
<th>Figure</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0.1</td>
<td>The five levels of human body composition organisation. (Wang et al., 1992, p. 20)</td>
<td>2</td>
</tr>
<tr>
<td>4.2.1</td>
<td>Scatter plot of BMI &gt; 30 kg/m² and percentage body fat &gt; 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.</td>
<td>25</td>
</tr>
<tr>
<td>4.2.2</td>
<td>Diagnosis data of BMI &gt; 24.99 kg/m² and percentage body fat &gt; 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.</td>
<td>26</td>
</tr>
</tbody>
</table>
-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.
-ABSTRACT-

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 (BMI > 30 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 (BMI > 25 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
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.
There is a current epidemic of overweight and obesity not only within Britain but the whole world. ‘Over half of the British population are now overweight. Between 1980 and 1995, the prevalence of obesity in Britain doubled from 8% to 15%’ (Wilding, 1997 p. 998). According to the WHO (2000) throughout most human history, weight gain and fat storage have been viewed as signs of health. Today however, as standards of living continue to rise, weight gain and obesity are posing a growing threat to health in countries all over the world. Clinical evidence of obesity can be dated back as far as Graeco-Roman times, but scientific interest of understanding the condition was not made until the 20th century (WHO, 2000). According to Deurenberg et al. (1998) obesity is a global problem because it is expanding within both developed and less developed countries. ‘As of January 2000, 25% of the adult population classifies as obese, compared with only 14.5% in 1980’ (McArdle et al., 2001 p821).

To evaluate a population’s percentage of body fatness BMI is mainly used, where weight in kilograms (kg) is divided by height in meters (m) squared, (Gard and Wright, 2005). BMI is an ideal method to calculate fatness quickly to be able to issue recommendations for obesity treatment (Aronne, 2002). The WHO (2000) provide a table of classification of BMI values, showing the overweight cut-off point at 25 kg/m² and obese cut-off point at 30 kg/m², (see Table 2.1.1) but these can vary according to different populations, hence the question marks against the overweight and obese category.
### BMI Classification and Cut-Off Points

<table>
<thead>
<tr>
<th>Classification</th>
<th>Principle Cut Off Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underweight</td>
<td>&lt;18.50</td>
</tr>
<tr>
<td>Normal</td>
<td>18.50 – 24.99</td>
</tr>
<tr>
<td>Overweight</td>
<td>? 25 ?</td>
</tr>
<tr>
<td>Obese</td>
<td>? 30 ?</td>
</tr>
<tr>
<td>Class I</td>
<td>30 – 34.99</td>
</tr>
<tr>
<td>Class II</td>
<td>35 – 39.99</td>
</tr>
<tr>
<td>Class III</td>
<td>? 40 ?</td>
</tr>
</tbody>
</table>

**Source:** WHO (2000)

A debate over recent years has been ongoing trying to establish if there are needs to develop specific BMI cut-off points for different ethnic groups, due to evidence which suggests that BMI, percentage body fat and body fat distribution contrasts across populations (WHO, 2000) and therefore the WHO classification set at 25 kg/m² defining overweight maybe generating health risks. WHO (2000) have standardised cut-off points but do understand that BMI cut-off values for overweight and obesity may not be sensitive and specific enough for every population.

Obesity is an important risk factor for a number of clinical and public health issues that constitute the principal causes of death in England. ‘Obesity is associated with increased risk of heart disease, stroke, type 2 diabetes, coronary heart disease, congestive heart failure, hypertension, dyslipidaemia, gall bladder disease, osteoarthritis, sleep apnea, and certain cancers, such as ovary, breast, and colon’ (Labib, 2003 p.17). Overweight people tend to be at many health disadvantages such as decreased longevity and health insurance expenses. Kopelman (2000) established epidemic studies verify that increases in weight are vital predictors of life expectancy.
Veugelers and Fitzgerald (2005a) describe the tremendous increase of childhood overweight and obesity and that it is a major public health problem throughout industrial nations. Many researchers including LeMura and Maziekas (2001), Strauss and Pollack (2001), Thorpe et al. (2004), and Veugelers and Fitzgerald (2005a and b) feel that childhood overweight and obesity have escalated tremendously over the past decades. Strauss and Pollack (2001) collected and analysed data from a National Longitudinal Survey of Youth (NLSY) to investigate the prevalence of overweight within a national sample of children. It was conducted over a period of 12 years, using a cohort of 8270 children aged 4 to 12 years old. As this study used a longitudinal research method and a very large sample size it has great accuracy in the results, as studying over a long period gives time to identify any gradual changes or consistency within the area. The results display that childhood overweight and obesity prevalence continues to rise rapidly.

In comparison to this Veugelers and Fitzgerald (2005a) did a similar study looking at the prevalence of childhood obesity but by using a different research method. Assessing only half the amount of students at random from within schools that Strauss and Pollack (2001) assessed, measuring height and weight and referring to the NLSY for physical activity statistics, this research could be thought of not being as accurate as Strauss and Pollack (2001) which show a higher rate of obesity prevalence. However, the difference in results may be due to the fact that Veugelers and Fitzgerald (2005a) study was conducted later and as the prevalence of obesity is rising fast then the results do fit the general trend, and suggest both studies to be correct. Overall both studies found that overweight and obesity prevalence within childhood is too high and in need for serious prevention strategies before it is too late.

Being overweight whilst in childhood leads to a decreased quality of life from then and into the future. Veugelers and Fitzgerald (2005b) propose that being overweight as a child it effects self-esteem and generates a negative effect upon cognitive and
Many clinicians believe that obesity should not be considered as a cosmetic problem affecting specific individuals, but an epidemic that threatens global health (Kopelman, 2000). Major progress has been made over centuries, however, the obesity epidemic continues to rise drastically, challenging public health workers and scientists like never before (WHO, 2000). Due to these worldwide increases it has caused the WHO and the International Obesity Task Force (IOTF) to announce a global obesity epidemic (McArdle et al., 2001).

2.2 Aetiology of Obesity
Kopelman (2000) explains that obesity is a heterogeneous group of conditions having many causes and suggests that it is not just a single disease. Furthermore Kopelman (2000) describes that body weight is influenced by an interaction between three factors, such as genetic, environmental and psychosocial, these act on physiological mediators of energy intake and expenditure. Even though genetics are of importance, Kopelman (2000) suggests that the development of obesity is still related to behavioural and environmental changes due to technical advances. Most cases of obesity are mainly considered as poor dietary habits and inactivity of the developing world and according to Kopelman (2000) many other clinicians consider obesity to be a self-inflicted condition of little medical significance. The IOTF (No Date) identify that obesity can be seen as a result of changes in diet, physical activity, health and nutrition, generally known as the 'nutrition transition'. Urban areas tend to experience higher rates of obesity than rural areas, because the city lifestyle usually involves less physical activity, such as working in an office, a wider variety of foods being provided and normally at a lower price (IOTF, No Date).
Almost all experts agree that reductions in daily physical exertion have contributed significantly to the current obesity epidemic. Prentice and Jebb (1995) identify that the implication of obesity is that levels of physical activity are lower, and therefore energy needs have declined. The average recorded energy intake in Britain has declined substantially as obesity rates have escalated. Evidence suggests that modern inactive lifestyles are at least as important as diet in the aetiology of obesity and perhaps represent the major factor Prentice and Jebb (1995). The National Audit Office Report (2001) also suggest, even though complete data on trends of levels of physical activity in the population are not available, the upward trend for obesity appears to have an equivalence drop in physical activity and a rise in sedentary behavior. This could be due to many reasons such as greater use of cars, energy saving devices such as lifts and escalators, reduction in the amount of physical education provided in schools and inactive pass times such as television, computer games and internet (The National Audit Office Report, 2001).

2.3 Financial Consequences
Referring to the National Audit Office Report (2001) obesity does not only cause a great financial cost to health care organisations but causes a large human cost by contributing to the onset of disease and premature mortality. Though there are doubts in quantifying the link between obesity and associated disease, estimates show that it costs at least half a billion pounds a year in treatment costs to the National Health Service (NHS), and possibly in excess of two billion pounds to the wider economy (The National Audit Office Report, 2001). Obesity has serious financial consequences for the NHS and the economy are increasing because around 20 percent of the population is now classified obese, and the upward trend over the last twenty years is continuing. With regard to The National Audit Office Report (2001) obesity puts great pressure on the NHS not only to treat obesity alone including consultations, drugs and treatment of disease attributable to the condition, but also to treat the number of consequences that result from obesity. Indirect costs for treating the consequences of obesity actually cost the NHS more than it does to treat obesity
2.4 Treatments and Prevention

The main aim is to prevent obesity from occurring but if it does happen to arise then treatment and control is the next option. Fox (2005) identified, there are several studies that have monitored activity and weight over periods of 5 or more years, which consistently show even though assessment errors may weaken effects, high levels of physical activity or becoming fitter over a period of years reduces the chances of gaining substantial amounts of weight.

According to Afidi et al. (2004) there are five major approaches to treat and control obesity. These are dietary, exercise, behavior, combination and pharmacy therapies. Afidi et al. (2004) explain these approaches as the following, dietary therapy involves three different types of diet according to the individuals needs, low-calorie diet, which provides 800 to 1500 kcal of energy a day, very-low-calorie diet, which provides 250 to 800 kcal of energy a day usually including protein enriched liquid, and an energy-restricted or Hypo Caloric diet, which is based on the individual daily energy requirements. Exercise therapy involves individuals to take part in 30 to 45 minutes of physical activity regularly but preferably daily, such as walking, cycling or housework. Behavior therapy is improved in conjunction with dietary and exercise therapy taking place. Behavioral therapy is a short-term modification and involves overcoming barriers to identify dietary habits in need of change and setting specific goals to ensure physical activity levels are increased, and pharmacy therapy is the use of drugs and medicines to help very serious states of obesity, and should be the last approach of treatment and control.
being direct methods and some indirect, all of which have advantages and disadvantages. Direct methods are the most effective and accurate to establish the balance of morphological characteristics of a human but they are not suitable for most studies, McArdle et al. (2005) describe them as very intensive and tedious. Direct methods are chemical solution, which dissolves the body to establish the fat and fat-free component, the other direct method involves dissection of fat and fat-free adipose tissue, muscle and bone; this has not been used often within research. Indirect measurements, which are more realistic, consist of hydrostatic weighing, skinfold thickness and girth measurements, dual energy x-ray absorptiometry (DEXA), total body electrical impedance, near-infrared interactance, and magnetic resonance imaging (McArdle et al., 2005).

Brodie et al. (1998) discuss four areas for measuring body composition, such as chemical, electrical, physical and anthropometric. Hydrodensitometry and anthropometry are techniques that have been used for decades and bioelectrical impedance is a more recent method. The two other alternative approaches mentioned near-infrared interactance and DEXA are gaining more popularity for body composition.

Sarria et al. (1998) propose that when measuring body composition using a two-compartment model underwater weighing is the gold standard. Underwater weighing also referred to as hydrostatic weighing is used to determine body volume, from the difference between body mass measured in the air and body weight measured during water submersion (McArdle et al., 2005). Brodie et al. (1998) supports Sarria et al. (1998) suggesting that hydrostatic weighing is the most accurate and reliable method when estimating body composition, and due to its high reliability it is often used as a measurement criteria for techniques that are doubted.
and the impedance (Brodie et al., 1998). BIA tends to over predict body fat in lean individuals and also predicts body fat less accurately than girths and skinfolds (McArdle et al., 2005).

Another method being near-infrared interactance is based on light absorption and reflection. The light beam is placed over the bicep and the reflected energy is monitored and then put into an equation with other anthropometric measurements for body composition to be predicted (Brodie et al., 1998). The final method that can be considered is DEXA, which is very technical and quantifies fat and non-bone lean body mass including the bodies deep bone structure (McArdle et al., 2005).

Finally, anthropometry, a set of standardised techniques for systematically taking measurements of the body or body parts, such as skinfold thickness and girth measurements are used in conjunction with equations to predict body density and converted to body fat percentage. 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).

The use of skinfolds has become one of the most common laboratory and field anthropometric technique to assess body composition (Brodie et al., 1998). The main purpose of the skinfold measurement is to estimate general percentage fatness from the measurement of subcutaneous fat (McArdle et al., 2005). Skinfold measurement’s are simple and less expensive than hydrostatic weighing or other laboratory-based techniques for body composition analysis but reliability does vary depending on tester-to-tester and the amount of experience gained (Mei et al., 2007). McArdle et al. (2005) suggests that skinfold scores are useful as they provide reasonably consistent and reliable results for percentage body fat distribution. The suggestion from McArdle et al. (2005) implies that even thought skinfold measurement is an inexpensive method and does not require expert supervision, it is still a very accurate method.
Therefore, there is population specific mathematical equations to predict body density and percentage body fat, which prove accurate for participants of similar age, gender, training status, fatness and race (McArdle et al., 2005). When using the skinfold method as a prediction of percentage body fat Durnin and Rahaman (1967) recommend that four skinfold sites are measured, as they are more representative of the distribution of fat than a smaller number of sites and also a single small error in measurement would be less important.

2.6 Sensitivity and Specificity of BMI

It is generally thought that the most important and most used measurement of body composition is body mass index (BMI), which is widely used for the classification of adult obesity, and is calculated as body mass (kilograms) divided by height (meters) squared (Ode et al., 2007). BMI was devised by Quetelet over 150 years ago and is widely used to calculate the relative percentage of body size in English speaking countries, but it can be argued that it is not an accurate predictor for every ethnic group and variation of physique (Gard and Wright, 2005). Kopelman (2000) and WHO (No Date) supports this suggesting, that every population has different body proportions and therefore BMI may not correspond when using standardised cut-off values to the same degree of fatness.

In relation to the International classifications of adult underweight, overweight and obesity according to BMI (see Table 2.1.1), overweight in adults is classed as BMI > 25 kg/m² and BMI > 30 kg/m² for obese. The classifications of overweight and obesity in Table 2.1.1 have question marks against them due to, BMI values being age-independent and the same for both sexes. As proposed by Ode et al. (2007) BMI may not be a reliable predictor for athletes and young adults, due to them having a large muscle mass, which may lead to them being misclassified as overweight or obese, as BMI does not consider muscle mass.
Similar studies have been carried out trying to establish if BMI is an accurate predictor for different ethnic groups and also for college athletes and non-athletes previously. A study by Ode et al. (2007) was carried out to establish the relationship between BMI and percentage body fat via a BOD POD and also to determine the accuracy of BMI as a measure of percentage fat in college athletes \((n = 226)\) and non-athletes \((n = 213)\). This study concluded that when classifying fatness in college athletes and non-athletes BMI should be used with care and that BMI needs specific classifications for different populations (Ode et al., 2007).

The capability of BMI was also researched by Nevill et al. (2006) in comparison to skinfold measurement, upon athletic and non-athletic groups \((n = 478)\), again it illustrated the inability of BMI to effectively represent adiposity in athletic populations. Deurenberg et al. (1998) supports Nevill et al. (2006), and Ode et al. (2007) analysing the relationship between BMI and body fat percentage and evaluated the validity of BMI cut-off points in different ethnic groups, such as American Blacks, Caucasians, Chinese, Ethiopians, Indonesians, Polynesians and Thais \((n = 11,924)\) from 32 studies. Deurenberg et al. (1998) identified that the relationship between percentage body fat and BMI differs in ethnic groups due to the variance of energy intake, level of physical activity and body build across ethnic populations. It was suggested that it might be necessary to use population specific cut-off points to ensure obesity is not over or underestimated.

Mei et al. (2007) produced a detailed study to determine if skinfold measurement added any more information than what BMI could verify, specifically related to age \((5 – 18 \text{ years}, \ n = 1,196)\). It was found that, skinfold measurements do provide additional information for excess body fat and generate higher specificity for pediatric participants ages 5 to 18 years with BMI-for-age 25 – 30 kg/m\(^2\) but not for those with BMI-for-age > 30 kg/m\(^2\). All these studies show that there are more accurate methods of measuring body composition than BMI, although it is a very
Many studies have tried to establish BMI standards for defining overweight, but this present study is going to evaluate the diagnostic accuracy of BMI. Sensitivity and specificity will be established for the BMI classification system proposed by the WHO (2000), for detecting excess fatness in male university sport students, in comparison to a skinfold measurement criterion established by ACSM (2006). Sensitivity for fatness is defined as the true positive rate (Fawcett, 2006), the proportion of positively overweight and obese participants who are also test positive (Bland, 1995). Specificity for fatness is defined as the true negative rate, (Fawcett, 2006), the proportion of participants who are negatively overweight or obese who are also test negative (Bland, 1995).

Neovius et al. (2004) researched the sensitivity and specificity of BMI classification systems for detecting excess fat within adolescents ages 17 years \( n = 474 \) and found from the study that specificity was very high, resulting in very few cases of adolescents being mislabeled and sensitivity being fairly high for males (0.72 – 0.84), however, sensitivity was established to be very low in female adolescents, therefore many females that are overweight could be missed in intervention programs that use proposed international BMI cut offs as a selection criteria. Due to BMI being age, gender and populations specific (Neovius et al., 2004), different classifications for each specific group measured may be in need.
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).

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

Where:

- $ICC = \text{intraclass correlation coefficient}$
- $MSe = \text{Error mean square}$
- $MSs = \text{mean square between participants}$

(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).

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

Where: \( \text{TEM} = \) Absolute technical error of measurement  
\( \text{MSe} = \) 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 ± 11.8, mean stature (m) of 1.80 ± 0.07, mean BMI (kg/m\(^2\)) of 25.33 ± 2.98 and a mean percentage fat of 13.41 ± 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
nearest 0.2 mm.

- **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).
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 sorted 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** = Number who are both condition 1 and/or 2 positive and test positive  
Number who are condition 1 and/or 2 positive

**Specificity** = Number who are both condition 1 and/or 2 negative and test negative  
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>
<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/m²) 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/m²) 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-url)

**Figure 4.2.1** Scatter plot of BMI > 30 kg/m² 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 4.3.1 Level of sensitivity and specificity of BMI for condition one and two |
|---------------------------------------------|---------------------------------------------|
| **Condition One** | **Condition Two** |
| Sensitivity | 1 | 1 |
| Specificity | 0.93 | 0.52 |
5.0 Discussion

5.1 Reliability Study

It is important to ensure that measurements taken for part of research in sports medicine are reliable and valid (Atkinson and Nevill, 1998). The relative reliability of a study could be analysed using a variety of tests such as a Pearson correlation test or an intra-class correlation test (one-way ANOVA for repeated measures). However, although the use of a Pearson correlation test does estimate relative reliability, it has a limitation that it is not sensitive to disagreement between methods and tests due to systematic bias, resulting in an over estimation of relative reliability. Therefore intra-class correlation has an advantage over Pearson correlation as it is sensitive to the presence of systematic bias in the data and is univariate therefore if more than one repeated measure needed to be analysed it is capable of this, unlike the Pearson correlation that is bivariate and not capable of this (Atkinson and Nevill, 1998).

Whilst a one-way ANOVA for repeated measures is capable of providing an estimate of relative reliability, referring to the intra-class correlation coefficient (ICC) it does not provide the accuracy of the data in absolute terms. The calculation of technical error of measurement (TEM) provides relevant information demonstrating the amount of variability in repeated measures in actual units of measurement (absolute precision), which can also be expressed in relative terms as a percentage of TEM. There will always be a certain amount of error within anthropometric studies due to the ability of the rater and also the accuracy of apparatus used, therefore acceptable limits of reliability have to be agreed, within the present study acceptable limits are chosen from Atkinson (2003).

The results obtained from the measurement of reliability within this study, (see Table 4.1.1 p. 24) suggests that the rater has the ability to collect repeated anthropometric measures at a high standard of reliability and precision, according to the acceptable values (ICC > 0.8) suggested by Atkinson (2003). Within this study intra-class correlation coefficient values ranged from ICC = 0.99 to ICC = 1 for repeated skinfold measurements and ICC = 1 for repeated measures of both body mass and
stature. All obtained intra-class correlation coefficients were statistically significant (P < 0.05), these ICC values show perfect reliability.

Absolute TEM values for the present study ranged from TEM = 0.2 cm to TEM = 0.4 for skinfold measurements and for body mass and stature calculated as TEM = 0.2 kg and 0.2 cm respectively, these show very low TEM in relation to the specific units. Relative TEM values (%) obtained in the present study ranged from TEM = 1.4 percent to 3.7 percent for skinfold measurements and TEM = 0.1 percent for both body mass and stature. TEM (%) values established by Perini et al. (2005) ranged from TEM = 1.7 percent to TEM = 9.0 percent for skinfold, which show that the values in the present study are much lower. The relative TEM results of this study according to Atkinson (2003) fall below the values considered acceptable (TEM < 5%), suggesting that the rater used within this study has an acceptable TEM for collecting anthropometric measures. The results suggest very high precision, which corresponds to very low variability within repeated measures, this should therefore provide the most accurate data set for the actual study.

5.2 Sensitivity and Specificity

BMI was evaluated within this study to establish the diagnostic accuracy for detecting excess fat, within male university sport students. Sensitivity and specificity of BMI was assessed using the classification recommended by the WHO (2000), and results were compared to skinfold measurement’s using the recommended percentage body fat criterion by the ACSM (2006).

The results for this present study illustrate that BMI is highly sensitive and can identify all overweight and obese male university sport students but specificity indicates that BMI tends to misclassify individuals that are not overweight or obese, in comparison to the measurement criteria. Sensitivity for both condition one (BMI > 30 kg/m²) and two (BMI > 25 kg/m²) was perfect, suggesting all obese and overweight individuals can be distinguished. Specificity for condition one was also very high indicating that most individuals that are of a normal weight are correctly classified, but specificity for condition two was low implying that BMI misclassifies normal individuals as overweight too often, according to the measurement criteria.
Due to the lack of an established percentage fat criterion and limited studies reporting the sensitivity and specificity of BMI in comparison to skinfold as a measure of body fatness, it is not easy to evaluate the results of this current study with the available field of research. Ode et al. (2007) also raised this point suggesting a shortage of research and the differences in study design made it hard to compare the results of their study to previous research. However, Ode et al. (2007) did illustrate that a high BMI does not always suggest an athletic population should be classified as overweight.

Nevil et al. (2006) has assessed the accuracy of BMI already, the study investigated if BMI was a valid anthropometric technique for athletic and non athletic adults, in relation to skinfold measurements, stature and body mass. The study revealed that BMI was not capable of classifying adiposity correctly within an athletic population, with reference to analysing relationships between techniques.

Previous studies have used various methods for measuring percentage body fat, such as air-displacement plethysmography with a BOD POD (Neovius et al., 2004) and (Ode et al., 2007), dual energy x-ray absorptiometry (De Lorenzo et al., 1998), underwater weighing (Sarria et al., 1998) and skinfold measurements (Nevil et al., 2006). Along with different methods being used, different cut off points for percentage body fat and BMI have also been used. Deurenberg et al. (1998) established that the use of different cut-off points are needed for ethnic groups as dietary patterns, physical activity, and body build all vary, which effect the diagnostic tool BMI. A stocky person is likely to have more muscle mass and connective tissue than a slender person with the same body height, therefore having the same BMI would suggest the slender person has more body fat, an additional anthropometric tool may be beneficial to improve the quality of BMI as an indicator of body fatness (Deurenberg et al., 1998).
This present study confirms based on BMI, it is associated with perfectly high sensitivity (100%) for both condition one and two, and therefore will not identify any overweight or obese individuals as normal if used clinically as a screening tool. Specificity on the other hand for condition two was low (52%), this presents a situation of almost a 50 / 50 chance of identifying non-overweight athletes as overweight, in comparison to the skinfold measurement criterion. However, condition one showed very high specificity (93%), providing evidence that BMI will identify very few non-obese athletes as obese.

The results produced by Mei et al. (2007) found that BMI-for age 25 – 30 kg/m² (overweight) did not have very high specificity in comparison to skinfold measurements but those with BMI-for-age > 30 kg/m² (obese) it was highly specific in comparison to skinfold measurements, this support the results from the present study suggesting that BMI is capable of classifying those that are not obese (BMI < 30 kg/m²) but BMI is not always capable of classifying those that are not overweight (BMI < 25 kg/m²).

In both this present study and the research carried out by Mei et al. (2007) the results may be due to the age or level and type of sport played within the population sample that was tested. BMI-for age 25 – 30 kg/m² may not be very specific for children or male university sport students due to having a high muscle mass and being very lean, which leads to a higher body mass, therefore resulting in an elevated BMI, causing the misclassification of overweight to occur.

However, when discussing BMI < 30 kg/m² within this present study, if the population tested was an International rugby team or a rowing team for example then it would be expected that BMI < 30 kg/m² would also be an inaccurate anthropometric tool due to the exceedingly high muscle mass, however within the study population (male university sport students) this was not the case due to only four of the seventy five participants having an exceptionally high muscle mass. Therefore, for this specific population BMI < 30 kg/m² is considered an accurate tool.
Barlow and Dietz (1998) explain that any anthropometric tool suitable for clinical use must have high specificity to avoid unnecessary treatment of non-overweight or non-obese individuals, this supports condition one suggesting BMI may be suitable to use as a screening tool for detecting obese athletes (BMI > 30 kg/m²), as the specificity is high. However, Smalley et al. (1990) contradicts Barlow and Dietz (1998) and argues that an under prediction of obesity would actually be considered a greater error than over predicting, as it may put individuals at risk of diseases associated with obesity, due to not having treatment. Therefore according to Smalley et al. (1990) a low specificity may be acceptable misclassifying normal individuals as overweight, as long as sensitivity was high identifying all overweight and obese individuals, as unnecessary treatment is better than not identifying needed treatment. If this is the case then it suggests that condition two within this study would be classed as acceptable.

Ode et al. (2007) also studied the accuracy and validity of BMI as a measure of percentage body fat, in male and female athletes and non-athletes, using the same cut off values for overweight as the present study, but using a BOD POD for percentage fat estimation. Ode et al. (2007) also found that sensitivity was perfectly high (100%) and specificity was very low (27%) for male athletes. Therefore, BMI > 25 kg/m² incorrectly classified 73% of normal male athletes as overweight. This supports the current study, finding very similar results; BMI was perfect at classifying male sport students that are overweight but not very accurate at classifying those that are of a normal weight. Ode et al. (2007) found specificity a further 21% lower than in the current study, this difference maybe due to different sample sizes, Ode et al. (2007) assessed 149 male athletes and only 75 were assessed within this study or it maybe due to more subjects having a high muscle mass in the population assessed by Ode et al. 2007.
Having a low specificity for condition two suggests that the prevalence of overweight would be overestimated within a male university sporting population. The reason for a low sensitivity according to Sardinha et al. (1999) maybe due to the fact BMI is an equation of weight and height and when changes occur in lean body mass it cannot be recognised from changes in body fatness, whereas changes in skinfold thickness and percentage body fat are less vague and may provide greater confidence for epidemiological studies.

Ode et al. (2007) developed optimal cut off points for each population examined within the study, along with analysing the sensitivity and specificity of BMI. For male athletes ROC analysis suggested that the optimal cut off point should be BMI > 27.9 kg/m² for overweight, which is higher than the standardised value for overweight presented by WHO (2000). This may be suitable for the population sample in this present study as BMI > 25 kg/m² proves to be inaccurate. When the consensus panel for the health implications of obesity used BMI > 27.9 kg/m² for the classification of male athletes to define overweight, it proved to be more accurate (Ode et al., 2007). The reason for this cut off point being more accurate for male athletes is partly due to the higher muscle mass being taken into consideration and assisting BMI to disguise its incapability of distinguishing the difference between fat mass and fat free mass. Nevill et al. (2006) supports this suggesting muscular males are more likely to be misclassified as a false positive, due to the huge limitation of BMI, furthermore also explaining that there appears to be little research into whether BMI is a valid and reliable tool for detecting body fatness across athletic populations.

The effectiveness of this present study conducted a measurement of reliability test before the proper study data was collected, this is a great strength of the study to ensure the rater was accurate enough to produce reliable results for the actual data collection. The same rater was used throughout the study to ensure that error was kept to a minimum. Finally, standardised skinfold measurement techniques were used adopted from the ACSM (2006) upon four anatomical sites of the body, due to Durnin and Rahaman (1967) suggesting that four sites is the most accurate procedure of establishing percentage body fat.
Due to BMI being age, gender and population specific (Neovius et al., 2004) a limitations to this study was that only a male population was assessed, which does not add the field of research for female university sport students, and only one age category was considered (18 to 19 years), which again does not reflect much use to individuals younger or older than this.

Another potential limitation for the study was that although the population used were male university sport students the study failed to establish the actual levels of physical activity each student performed, therefore some students may not be active and only studying a sports degree out of interest, which in this case may mean they fall into the general population leading to invalid results for the labelled population being tested.

Future research for this area of study should consider all strengths from previous research and compare a wide range of percentage body fat techniques to BMI, due to previous research using only one or two techniques per study making it hard to compare results between studies and establish standardised cut-off values for BMI within male sport students. A wide range of cut-off points need to be analysed to determine which is most effective at detecting the actual overweight individuals, whilst also correctly classifying those that are of a normal weight. This research would establish two issues, in order of priority the most to the least accurate predictor of percentage fat techniques and most importantly set accurate standardised cut-off values for BMI specific for a male university sport student population.

Looking into data sets for specific sports would allow further information to be obtained within this area of research. Specific sports competitors and their individual data information could be compared to other competitors within their chosen sport and also between competitors from different sports, this would give an interesting insight into BMI levels within a sporting population. Further to this national level sportsmen and women could also be compared to lower ability levels to see how the level of training affects BMI.
With regard to the results found within this research BMI can be used but with great awareness for male university sport students when using the overweight classification as used in condition two (BMI > 25 kg/m²) within this study. This is suggested, as people considered normal by skinfold measurement are at almost a 50 percent chance that they will be misclassified as overweight, according to BMI. This would therefore cause an over estimation of overweight individuals, which are actually perfectly healthy, this is supported by Ode et al. (2007) concluding that BMI > 25 kg/m² should be used cautiously when classifying athletes and non-athletes. However, using a classification of BMI > 30 kg/m² within male university sport students as performed in condition one within this study BMI suggests to be a reasonably safe tool, as only 7% of people were misclassified as obese. Therefore, when using BMI > 30 kg/m² within this population it is a perfectly reliable tool. However, BMI should not be the only technique used when using BMI > 25 kg/m² cut off point within a male university sport student population as BMI over estimate the fat mass, causing many individuals to be misclassified.
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.
References


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………………………………………………………………….