A practice focused overview of methods to assess obesity before arthroplasty

Ladan Sahafi, BSci, MEngSci a,b,c
Donald Bramwell, BSc (Hons)(ExpThPhys), BSc (Elec Eng), GradDip SciComms c
Melanie Harris, PhD, MEd a
Jegan Krishnan, MBBS, PhD, FRACS b
Malcolm Battersby, PhD, FRANZCP, FACHAM, MBBS a

a Flinders Human Behaviour and Health Research Unit, Flinders University, Adelaide, Australia
b Department of Orthopaedics, Flinders Medical Centre, Flinders Drive, Adelaide, Australia
c International Musculoskeletal Research Institute, Daw Park, Adelaide, Australia

Corresponding author’s e-mail: ladan.sahafi@flinders.edu.au
Abstract

Obesity is associated with poorer outcomes after hip and knee arthroplasty. Body mass index is the most commonly used measure of obesity, but it does not reliably assess body composition. This paper reviewed the literature to provide a practice focused overview of existing approaches to measure obesity and discussed their suitability in informing decisions for hip and knee arthroplasty. We found that measures of obesity that are practical in clinical settings and high utility when making decisions on arthroplasty could be clustered into three groups: reliable but costly; inexpensive and assessing body composition; and inexpensive without body composition assessment. Measures of obesity of value to surgeons’ decision making could be drawn from a combination of the first or second group measures with the third group.

Keywords: Obesity, body composition, BMI, fat distribution, arthroplasty

Introduction

Obesity is increasing in developed and developing countries. According to the latest World Health Organization (WHO) report, there were 300 million obese adults worldwide in 2000. This figure grew to over 500 million by 2008 and then to over 900 million by 2014 (World-Health-Organization, 2014a, World-Health-Organization, 2014b).

Obesity has many adverse health consequences, including increasing the risk of osteoarthritis and accelerating the progress of the disease. The increasing prevalence of osteoarthritis each year leads to increasing demand for hip and knee replacements, the most effective treatment for severe osteoarthritis (Duren et al., 2008, Dowsey et al., 2013).

Obesity in hip or knee arthroplasty patients is associated with poorer outcomes including increased infection (Kerkhoffs et al., 2012), and lower functional improvements (Singh et al., 2009, Dowsey et al., 2013). Outcomes are worse for morbidly obese patients (Singh et al., 2009, Waters, 2014), deterring some surgeons from operating on morbidly obese patients, with a Body Mass Index (BMI) of 40 or above (Amin et al., 2006).

BMI is almost the only index used for evaluating obesity in the literature on hip and knee arthroplasty whereas many other indices and instruments have been developed to assess obesity and body composition. Some of these are accepted and used in monitoring diseases such as cardiovascular disease (Lee et al., 2008, De Souza et al., 2013).

While BMI offers a viable approach to categorise individuals based on body mass and height, its use to indicate
individuals’ obesity has a number of limitations, including an inability to distinguish between fat mass and fat-free mass (Okorodudu et al., 2010, Wickel, 2013). Muscle mass can substantially contribute to a higher BMI in leaner individuals of the same height (Vasarhelyi et al., 2012). In osteoarthritis patients, in particular, decreased muscle mass resulting from inactivity can reduce a patient’s BMI without providing clinically relevant information (Bölgen Çimen et al., 2004).

An assessment of body composition that provides information about anatomical fat and fat distribution can be useful in anticipating risks during and after arthroplasty (Wang et al., 2009). Given that BMI fails to accurately determine body composition (Wang et al., 2009), it might be important to consider other approaches.

The exclusive use of most of these instruments potentially generates biased results (Wakabayashi, 2013). It is therefore possible that a combination of methods for quantifying obesity could compensate for the drawbacks of using BMI as the sole source of information on an obese patient’s suitability for arthroplasty. We therefore aimed to review the literature to present an overview of existing approaches to obesity measurement and assess their suitability in informing decisions for hip and knee arthroplasty.

**Method**

We searched the Medline database, combining terms for obesity with terms for measurement methods and techniques. As this review aimed to describe current obesity measurement methods, our search covered the period 2000-2014. Further articles were identified from reference lists of selected papers and literature already known to authors.

We then selected a range of criteria relevant in the context of arthroplasty practice. These criteria include practicality, simplicity, reliability, cost and overall utility. **Practicality**, in this paper, signifies practicality in clinical settings, in terms of equipment which are suitable for use in clinics, considering, also, the time and expertise required for operating measuring equipment. **Simplicity** indicates simplicity of the measuring process, and little requirement for highly trained personnel. **Reliability**, refers to the accuracy of the measure in determining body composition and identifying obesity, rather than the formal statistical meaning of the word. **Cost** includes the cost of the equipment required for measurement, as well as the time taken to obtain a measure of obesity. Finally, from these, an overall judgement of utility was made.

**Findings: Measures of obesity**

Obesity is defined as excessive body fat accumulation (World-Health-Organization, 2014a). It can, therefore, be
measured through assessment of body composition to determine the percentages of fat, bone and muscle (Duren et al., 2008, Beechy et al., 2012, Vasarhelyi et al., 2012). Measures of obesity can be categorised into three groups based on cost and reliability.

1- **Group one**

This group includes inexpensive and simple methods of measuring obesity which are not particularly reliable as they do not provide body composition assessment. They are, however, useful for categorisation. This group is comprised of measures of body dimensions, such as height, weight and circumferences of waist and hip, which are fed into standardised regression equations to calculate an index to quantify obesity (Ralston et al., 2012).

Body Mass Index (BMI) is the most widely used index to identify obesity and is defined as $\frac{\text{weight (kg)}}{\text{height (m)}^2}$ (Bray, 2004, Okorodudu et al., 2010). The World Health Organization terms individuals who have a BMI of 30 kg/m$^2$ or greater as obese. There are three classes of obesity: Class I for a BMI between 30 and 34.9 kg/m$^2$; Class II (‘severely obese’) for a BMI between 35 and 39.9 kg/m$^2$; and Class III (‘morbidly obese’) for a BMI of 40 kg/m$^2$ or greater.

Central obesity, commonly represented by waist circumference (WC), contributes to greater risk of metabolic diseases (Browning et al., 2010). In terms of osteoarthritis risk, studies comparing WC and BMI show conflicting results, with some researchers concluding that WC is a better indicator than BMI (Huxley et al., 2010). WHO defines WC cut-offs of 102 cm and 88 cm for men and women, respectively, as obese (Pimentel et al., 2010, Dahlén et al., 2013). Body composition varies with age, gender and ethnicity (Lopez et al., 2011, Wickel, 2013). With aging, a greater proportion of fat tends to accumulate centrally (Rolfe et al., 2010). It is, therefore, recommended that specific BMI and WC cut-off points relevant to the body composition of different gender, age and ethnic groups (Lopez et al., 2011) might compensate for this limitation.

Waist-to-height ratio (WHtR), calculated as waist (cm)/height (cm), can be considered WC corrected by height (Wakabayashi, 2013). Some studies suggest that WHtR is a more sensitive index to fat, as compared with BMI, and has the potential to rectify the misclassification of BMI (Kagawa et al., 2008, Browning et al., 2010). One of the advantages of WHtR is the use of the same cut-off point for men and women (0.5) (Browning et al., 2010, Ravensbergen et al., 2014).

Sagittal Abdominal Diameter (SAD) represents an alternative index of abdominal obesity. This measure describes the external distance between the front of the abdomen and the small of the back at the iliac level line, taken using a calliper.
while lying straight. Some studies have shown that SAD correlates with risks of metabolic disease more strongly than BMI, WC and WHtR (Dahlén et al., 2013).

All these methods are practical in clinical settings, as they involve simple and quick measurements, without particular training or large equipment. These measures do not assess body composition and are thus, not highly reliable, although they may be useful for categorisation. These practical, low cost methods have high utility for making a decision before knee or hip arthroplasty.

2- **Group two**

This group consists of relatively inexpensive methods of body composition assessment, which provide more reliable measures as compared with the previous group. Bioelectrical Impedance Analysis (BIA) is a widely used method for estimating body composition. In BIA small electrical currents are passed between electrodes, connected from one leg to the other, or to the arm, in order to form a circuit and measure the voltage drop and determine impedance and, therefore, total body water. Since the water content of different tissues varies, they have varying resistance, with fat tissue being a poor conductor of the current due to its low water content and fat-free tissue, which has higher water content, being a good conductor (Beechy et al., 2012, Mialich et al., 2014). Multiple-frequency Bioelectrical Impedance Analysis (MF-BIA) and segmental BIA which transmit currents at wide ranges of frequencies through various parts of body fall into this group. In these methods, the low frequencies measure extracellular water and high frequencies measure intracellular water, allowing total body water and fat-free mass to be determined (Brock et al., 2013, Mialich et al., 2014).

The size and cost of equipment for these methods make them practical in clinical settings. These methods require low operator training, and are simple to use. These methods are reliable and relatively inexpensive (Abbate et al., 2006, Beechy et al., 2012), with high utility for assessing obesity before a knee or hip replacement.

3- **Group three**

The third group includes reliable and costly methods of body composition assessment, including ADP, DEXA and CT-Scan. In Air-Displacement Plethysmography (ADP), body volume is determined by measuring air displacement, allowing body fat percent to be calculated (McGuire et al., 2010).

Dual-Energy X-ray Absorptiometry (DEXA) and Computed Tomography Scanning (CT-Scan) assess body composition by sending X-rays through the body and measuring differential attenuation of the X-rays (Minocci et al., 2005, Duren et
al., 2008). CT-Scans at the whole body level involve high radiation exposure (Duren et al., 2008, Beechy et al., 2012). These methods are practical in clinical settings. They require operator training and time-consuming procedure, and are, therefore, not simple. On the other hand, these methods provide reliable estimates of percent body fat and, thus of obesity. Overall, these techniques have the potential to have high utility for body composition assessment before knee or hip replacements.

4- Others

There are a number of other methods of measuring obesity which are not further reviewed due to their high cost, impracticality or unreliability. Although reliable, direct methods of body composition assessment including dilution technique, total body potassium and neutron activation, and Hydrostatic Weighing, are impractical in clinics (Beechy et al., 2012). Methods such as Waist-to-Hip Ratio, Body Adiposity Index, Skinfold, Near-Infrared Interactance, Ultrasound and Single-Frequency-BIA are highly unreliable (Beechy et al., 2012). Due to its high cost, Magnetic Resonance Imaging (MRI) has poor utility before arthroplasty (Beechy et al., 2012, Vinknes et al., 2013).

Discussion

The review of measures of obesity shows the use of numerous instruments and techniques which vary in terms of practicality in clinical settings, simplicity of use, reliability, cost and utility to arthroplasty. There is no one best method in all respects for quantifying obesity before arthroplasty. Table 1 compares measures of obesity judged to be clinically practical. In this table, ✔✔ implies ‘highly’, ✔ signifies ‘moderately’, and ✗ indicates ‘inadequately’.

Table 1: Comparison of obesity measured judged to be clinically practical

<table>
<thead>
<tr>
<th></th>
<th>Simplicity</th>
<th>Reliability</th>
<th>Cost</th>
<th>Overall Utility</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI</td>
<td>✔✔</td>
<td>✔</td>
<td>✔✔</td>
<td>✔</td>
</tr>
<tr>
<td>WC</td>
<td>✔✔</td>
<td>✔</td>
<td>✔✔</td>
<td>✔</td>
</tr>
<tr>
<td>WHR</td>
<td>✔✔</td>
<td>✗</td>
<td>✔✔</td>
<td>✗</td>
</tr>
<tr>
<td>WHtR</td>
<td>✔✔</td>
<td>✔</td>
<td>✔✔</td>
<td>✔</td>
</tr>
</tbody>
</table>
The clinically practical methods of measuring obesity outlined in this paper can be categorised into three groups from the utility perspective (as listed in Table 2).

Table 2: Groups of obesity measures based on cost, reliability and practicality

<table>
<thead>
<tr>
<th></th>
<th>Group one</th>
<th>Group two</th>
<th>Group three</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple and inexpensive, but no body composition</td>
<td>Relatively reliable and inexpensive, with body composition assessment</td>
<td>Reliable, but costly</td>
<td></td>
</tr>
<tr>
<td>WHtR</td>
<td>MF-BIA</td>
<td>ADP</td>
<td></td>
</tr>
<tr>
<td>WC</td>
<td>Seg-BIA</td>
<td>DEXA</td>
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</tbody>
</table>
**Recommendations**

If accuracy plays a prominent role in decision making before arthroplasty, regardless of the cost, ADP, DEXA and CT-Scan provide appropriate options, although CT-Scan involves exposure to radiation and is not safe to be performed repeatedly.

If a trade-off between cost and accuracy is required for evaluating obesity before arthroplasty, the options consist of MF-BIA and Seg-BIA. These methods provide relatively reliable and inexpensive estimations of body composition assessment.

The indices based on body measurements form simple and inexpensive, yet not highly reliable, methods of measuring obesity. These indices provide an adequate base for categorisation of patients before arthroplasty. Among these measures, all except WHtR require cut-off points based on gender, and sometimes age and ethnicity. Measures of central obesity provide good complements to BMI in order to form a simple but practical approach in categorising individuals. As Wakabayashi et al showed, however, the exclusive use of one central obesity measure potentially generates biased results (Wakabayashi, 2013). A combination of central obesity indices, therefore, affords a more reliable complement to BMI for categorisation. Figure 1 displays the reliability of the simple and inexpensive measures in evaluating obesity including decision making before arthroplasty.

Since there is no one superior measure, a combination of multiple assessment techniques, particularly when selected from different groups may afford a better estimation of obesity. Examples of combined techniques are numerous, for example BMI in conjunction with BIA (Duren et al., 2008), or the use of ADP with BIA methods to predict percent body fat in an obese population (Smith-Ryan et al., 2014).
Conclusion

When assessing patients for a knee or hip replacement, it is sometimes necessary to evaluate obesity and body composition of patients in order to minimise the risk of complications during and after the procedure. This review assessed methods for measuring obesity in terms of practicality in clinics, simplicity, reliability, cost and overall utility to arthroplasty. We found that clinically practical obesity measures that have high utility to decision making before arthroplasty could be classified into three groups: inexpensive without body composition assessment (including WHtR, SAD, WC, and BMI); inexpensive with body composition assessment (including MF-BIA and Seg-BIA); and reliable but costly (including DEXA, CT-Scan and ADP). A combination of one measure from the second or third group with measures from the first group might provide the highest utility of measuring obesity for decision making process before arthroplasty. Further studies are required to evaluate the statistical reliability and validity of the combination of these methods. Future research is also required to compare the utility of these instruments for each of knee and hip replacement.

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