MEASUREMENT OF OBESITY IN CHILDREN

Jean Cowie focuses on the tools and strategies available to identify obesity and overweight in young patients

Abstract

The prevalence of obesity in childhood has been increasing dramatically worldwide in recent years. It is associated with cardiovascular disease, hypertension, diabetes, osteoarthritis and cancer (Hannon et al 2005, Nathan and Moran 2008). Children who are obese also have an increased risk of obesity persisting into adult life; in addition, obesity in childhood has also been associated with mental health issues in young people (Gray and Leyland 2012). While the measurement of obesity in adults can be calculated easily using body mass index, determining overweight and obesity in children is more controversial (Griffiths et al 2012). This article explores the tools and strategies used to measure and assess overweight and obesity in children and determine what is currently considered to be the most reliable and effective.

Keywords

Body mass index, childhood obesity, measurement of obesity, overweight children, reference curves

Obesity is a major public health issue across the globe (Keenan et al 2012, Mandalia 2012). The World Health Organization (WHO) (2011) considers its increasing prevalence to have reached epidemic levels, more than doubling in the past 30 years and, as a result, putting more people worldwide at risk of death related to obesity than to being underweight.

While obesity has traditionally been a problem in adults, evidence suggests that there has been a marked increase in incidence among children in the past 30 years (de Onis et al 2010). Among developed countries, the UK has one of the highest levels of childhood obesity (Parkes et al 2012), with Scotland leading the trend – only countries such as the US and Mexico have higher levels (Scottish Government 2010).

Essentially, obesity is caused by an imbalance in equilibrium between energy intake and energy expenditure. Many factors can upset this fine balance. However, the main predisposing factors leading to the increased prevalence of obesity and overweight in children relate to lifestyle changes associated with family and neighbourhood constraints, and parental role-modelling (Parkes et al 2012).

Over the years, children have increasingly become more sedentary, spending more time watching television and playing computer games and less time taking part in physical activities such as walking or sports. This, coupled with the increase in consumption of high fat and energy-dense convenience foods and snacks (Dhir and Ryan 2010, Scottish Intercollegiate Guidelines Network (SIGN) 2010, Public Health England (PHE) 2013), means it is no surprise to find that energy intake exceeds energy expenditure, resulting in overweight and obese children.

As the prevalence of overweight and obesity has risen, perceptions about what is normal body shape, overweight and obesity have changed, with overweight now accepted and considered the norm (Scottish Government 2010). These changes in attitude serve only to perpetuate the problem and are detrimental to health.

Obesity is a precursor to developing cardiovascular disease (SIGN 2010) and obese children also have the risk of obesity persisting into adulthood. A link has also been made to mental health issues in the young (SIGN 2010, Gray and Leyland 2012). Consequently,
obesity is recognised as a significant public health problem and features prominently in many UK policies (Scottish Government 2008a, 2008b, 2012, Department of Health 2011). The scale of the problem is such that interventions early in a child’s life are needed (De Onis et al 2010).

Measurement
WHO (2006) defines obesity as an accumulation of adiposity, or body fatness, that presents a risk to health. While this definition appears straightforward, it poses many challenges. For example, Reilly et al (2000) highlight that it is extremely difficult to measure body fatness in clinical practice; as a result, a variety of tools and strategies based on weight, or weight for height, rather than on adiposity and/or the distribution of body fat, are used (Sweeting 2007, Reilly 2010).

Strategies to determine the extent of body fatness and a more appropriate assessment of obesity include laboratory methods such as densitometry and dual-energy X-ray absorptiometry (DXA), as well as portable methods, such as bioelectrical impedance (body-fat scales), skin-fold thickness, girths – such as waist, hip and neck – and various indices of these, such as stature and mass (Stewart and Sutton 2012). Densitometry – measurement of underwater weight and DXA – a type of scan that measures the amount of X-ray absorbed by fatty tissue and bone minerals – are direct measures of adiposity and are seen as the gold standard (Rudolf et al 2012). Although they provide a more accurate assessment of the extent of fatness, they are intrusive and better suited for research purposes than everyday clinical practice (Sweeting 2007, Kipping et al 2008). Reilly (2010) suggests that DXA and bioelectrical impedance should be used with caution because, when used with children, errors can occur.

Anthropometric measures such as height, weight, skin-fold thickness and waist circumference measure body fatness indirectly. These approaches are also less invasive and more acceptable to children (Kipping et al 2008). Height and weight measurements can be used to calculate body mass index (BMI); in the UK, for example, BMI is currently the recommended measure of obesity in children (National Institute for Health and Care Excellence (NICE) 2007, SIGN 2010). The formula to calculate BMI is:

\[ BMI = \frac{\text{body mass (kg)}}{\text{stature} \times \text{stature (m\(^2\)}} \]

This favoured measure is not without limitations, particularly for use with children (Cole et al 2000, McCarthy et al 2005, Reilly 2010, Rudolf et al 2012). A significant issue with BMI as a measure of obesity is that it cannot discern between fat, lean tissue and bone mass (McCarthy et al 2006, Must and Anderson 2006). This can lead to errors in diagnosis: for example, children who are fit, athletic and sporty will have a greater percentage of lean tissue, especially muscle mass that is heavier than fat, which may inadvertently lead to them being misdiagnosed as obese (Reilly 2010).

Cameron et al (2009) highlight that BMI cannot determine body fat distribution and, according to McCarthy et al (2005), this is significant, because central body fat distribution in children has been associated with an increased risk of diabetes, hypertension and cardiovascular disease.

It has been suggested that measurement of waist circumference, which provides a better indication of central or trunk adiposity, and therefore overweight and obesity in adults, may be useful for measuring obesity in children (McCarthy et al 2005, Ochiai et al 2010). However, a systematic review by Reilly (2010) did not find evidence to support this as a diagnostic tool to aid assessment of obesity in children, a view shared by SIGN (2010).

As BMI is calculated using stature (height) and body mass measurements, it is essential that these figures are accurate. According to Lipman et al (2004) and Foote et al (2011), linear and height measurement of children is often inaccurate. Foote et al (2011) attribute this to, for example, faulty or flawed measurement tools, poor posture or diurnal height variation (Table 1). Frequently, the wrong measurement tools are used for a child’s age, or they are not calibrated or installed properly, leading to error (Lipman et al 2004, Foote et al 2011).

Lipman et al (2004) highlight that in one study poor measurement technique was found in 70% of cases with, for example, height being measured with children wearing shoes or standing with feet apart.

Diurnal height variation, which depends on the fluid content and height of intervertebral discs and the effect of weight bearing on the discs (Foote et al 2011), is also significant when measuring children’s height. It fluctuates during the day and can affect measurement (Foote et al 2011). Voss et al (1997) found an average variation of 5mm in measurement of children’s height, with as much as 1cm in some cases.

While these variations may appear small, they are significant when considered in relation to children’s stature. Subsequently, unreliable height measurement can result in inaccurate BMI calculation and outcomes. For instance, reported diurnal change of 1.4 BMI units in a healthy five-year-old girl equates to 35 centiles on the growth chart (Stewart and Sutton 2012).

It is also likely that historic measurements have not been precise enough, as older versions of growth charts required stature to be measured to the nearest centimetre. This represents substantial scope for...
inaccuracy and the recommended practice now is to assess stature to 0.1cm or the nearest millimetre (Stewart and Sutton 2012). Other factors, such as age, maturity and reference charts, can also affect BMI calculation (Table 2) (Kipping et al 2008, Reilly 2010).

Age and sexual maturation
Daniels et al (1997) reported a stronger correlation between BMI and stage of maturation or sexual maturity rather than between BMI and chronological age. They concluded that sexual maturity is better at determining the extent of body fat in children and adolescents than age. Bini et al (2000) explained that this is due to changes in body composition during puberty - as a general rule, percentage of body fat increases in girls, while lean tissue or muscle increases in boys. Guo et al (1997) also found that gender has a strong influence on body composition, adiposity and therefore BMI, with Sweeting (2007) indicating that differences in levels of body fat in children become more apparent during puberty.

Nevertheless, because BMI does not take account of the changes in children’s body composition due to growth and development, it can make it difficult to ascertain whether a change in BMI over time is due to an increase in body fat or an increase in lean tissue or muscle. Consequently, when determining BMI in children and adolescents, gender and sexual maturity need to be considered alongside chronological age.

Assessing sexual maturity is considered intrusive in adolescents, who are generally more sensitive about their bodies. Assessment of sexual maturity is not as prevalent, nor undertaken as frequently as it was in the past (Hume and Stewart 2012).

Race and ethnicity
The complexity of determining adiposity, overweight and obesity in children and adolescents is further compounded by the issue of race and ethnicity. For example, black children, especially African black children, carry less body fat than Caucasian children; Hispanic, Asian and Chinese children generally have a higher percentage of body fat (Sweeting 2007, Ogden et al 2012). Cognisance needs to be taken of race, ethnicity and the associated differences in the level and distribution of body fat when using BMI as a measure of overweight and obesity in children.

Reference curves
According to McCarthy et al (2006), anthropometric reference curves are drawn from a representative sample of the wider population and reflect potential geographical, socioeconomic, nutritional, and ethnic and racial influences. Given the variances in the level and distribution of body fat between children of different ethnic and racial groups, different reference data and benchmarks for defining overweight and obesity have been established in various countries.

As a consequence, numerous reference curves and percentile charts have been developed, such as the Tanner Whitehouse Standards, the Cole-International Obesity Task Force (Cole-IOTF) thresholds, the UK 1990 reference data for BMI in childhood, the Centers for Disease Control (CDC) (2010) growth charts, the WHO 2007 growth curves and, more recently, the Royal College of Paediatrics and Child Health growth charts (Freeman et al 1995, McCarthy et al 2006, SIGN 2010, Kakinami et al 2012, Scottish Government 2012). All these measures have their strengths and weaknesses.

**US Centers for Disease Control**
These reference curves (CDC 2010) are based on a reference sample of boys and girls aged 2-20 years in the period 1963-80 (Must and Anderson 2006). It could be argued that these data are outdated,

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<th>Table 1</th>
<th>Inaccurate body mass index measurement</th>
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<td>This can occur because of:</td>
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<tr>
<td>Flawed or faulty tools</td>
<td>Incorrectly installed and calibrated measurement tools.</td>
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<tr>
<td>Poor technique</td>
<td>Measuring children with shoes on, allowing them to stand with feet apart and so on.</td>
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<tr>
<td>Movement of the child</td>
<td>Children moving and wriggling.</td>
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<tr>
<td>Poor posture of the child</td>
<td>Children not standing tall against the measure/wall and with chin up.</td>
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<tr>
<td>Diurnal height variation</td>
<td>Time of day should be recorded when taking linear or height measurements.</td>
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<th>Table 2</th>
<th>Measurement of body mass index in children</th>
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<td>Considerations:</td>
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<tr>
<td>Gender</td>
<td>Girls generally have a greater percentage of adiposity than boys.</td>
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<td>Age</td>
<td>Body mass index (BMI) changes with age.</td>
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<td>Sexual maturity</td>
<td>BMI does not take account of changes in body composition due to growth and development.</td>
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<td>Race/ethnic origin</td>
<td>Black children have less body fat than Caucasian children. Hispanic, Asian and Chinese children generally have a higher percentage of body fat.</td>
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<td>Physical fitness (sporty/athletic)</td>
<td>BMI cannot discern between fat, lean tissue and bone mass. Therefore, very fit and sporty children, who have a greater percentage of muscle mass that is heavier, can be misdiagnosed as obese.</td>
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<td>Measurement technique</td>
<td>BMI depends on accurate measurement of height and weight.</td>
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because there is strong evidence that over the past 20-30 years there has been a global increase in the prevalence of overweight and obesity among children (De Onis et al 2010, Ogden et al 2012, Reilly 2010).

As a result, Ogden et al (2012) argue that the exaggerated rate of childhood obesity in the US compared with other countries can, in part, be attributed to the poor representation of the reference population group used, as well as the fact that children in the US are now bigger and heavier.

### Cole-International Obesity Task Force

Due to the difficulty in comparing the prevalence of overweight and obesity in children between countries, the Cole-IOTF established thresholds for doing so (Cole et al 2000, Reilly 2010). They were derived from reference data across six countries: Brazil, Hong Kong, Netherlands, Singapore, the UK and US (Cole et al 2000). A limitation of the thresholds is that they have been derived from BMI standards for adults and can be used only to categorise children as having a healthy weight, being overweight or being obese for their height (Royal College of Paediatrics and Child Health (RCPCH) 2012).

Unlike other growth references, the Cole-IOTF cannot calculate BMI centiles for age across a dataset of children. Nevertheless, its ability to compare population groups has made it one of the most widely used tools to determine overweight and obesity in the UK and internationally (RCPCH 2012). Reilly (2010) highlights that another criticism of the Cole-IOTF threshold is its low sensitivity, meaning that it has a tendency to miss or underdiagnose obesity in children, who may be fat despite being relatively light.

### UK reference data

Since their construction, the BMI centiles of the UK 1990 chart have been considered the reference standard for the UK population (SIGN 2010, PHE 2013) and remain the recommended tool (SIGN 2010, PHE 2013, 2014), despite data being acquired a quarter of a century ago and the likelihood of demographic changes and secular trends since then.

The 1990 chart identifies two demarcation values for overweight and obesity in children. One is for clinical use and has greater sensitivity to detect overweight and obesity, in that it classifies overweight children by a BMI on the 91st centile or above, and obesity by a BMI on the 98th centile or above. This differs from the international definitions, which are BMI on the 85th centile for overweight and the 95th centile for obesity. According to SIGN (2010), the difference is due to practical reasons and the recording charts used in the UK.

Therefore for public health and epidemiological purposes only, the lower criteria of BMI on the 85th centile for overweight and the 96th centile for obesity have generally been used to determine prevalence (RCPCH 2012). For individual and clinical purposes, the demarcation offering greater sensitivity is used: this means that in clinical practice a BMI on 91st centile or above is classed as overweight, and a BMI on the 98th centile or above is classed as obese. These variations can cause confusion if practitioners are not aware of the rationales for these different cut-off points and criteria.

Interestingly, due to the greater sensitivity of the UK 1990 reference curves in detecting overweight and obesity, Reilly (2010), SIGN (2010) and PHE (2013)...

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**References**

advise the use of national reference data and percentiles – that is, overweight BMI 91st centile and obesity 98th centile – rather than international reference data, such as the Cole-IOTF cut-offs – overweight BMI 85th centile and obesity 95th centile.

**WHO growth reference curves**

With the problem of childhood overweight and obesity increasing worldwide, the WHO developed the 2007 growth reference curves for BMI for age (de Onis et al 2007). This tool is based on the population reference data used by the CDC, modified to reflect better an international population of children, enabling global comparisons of the prevalence of overweight and obesity (de Onis et al 2007, RCPCH 2012).

Using standard deviations of +1SD and +2SD, and the threshold centiles of BMI on the 84.1st centile for overweight, and the 97.7th centile for obesity, the cut-off points determining overweight and obesity in children are comparable with those used in the UK (de Onis et al 2007, RCPCH 2013).

**RCPCH growth charts**

More recently, the RCPCH (2012) has developed growth charts for school-age children, which amalgamate data from the WHO growth standards up to age four years and the UK 1990 growth reference for 4-18 years. These charts are recommended for use in the UK (Scottish Government 2012, PHE 2014). According to the Scottish Government (2012), this has not required a change to current routines and practices, but instead has simplified the process of calculating and recording BMI for age and stage of maturation.

**Conclusion**

It is clear that BMI is the accepted tool to assess overweight and obesity in children (WHO 2006, NICE 2007, SIGN 2010). However, it needs to be used with caution, as BMI is not a measure of fat mass or of the distribution of adipose tissue in the body (McCarthy et al 2006, Must and Anderson 2006, Cameron et al 2009).

When assessing overweight, obesity and BMI in children, cognisance needs to be taken of factors such as the accuracy and reliability of height and weight measures, a child’s age, gender, maturity, race and ethnicity (Maynard et al 2001, Sweeting 2007, SIGN 2010).

While efforts are being made to establish common reference data and tools to record and compare BMI and the prevalence of overweight and obesity internationally, current evidence recommends the use of national reference data, such as the UK 1990 reference data or the RCPCH growth charts, in preference to international reference data and centile curves (Reilly 2010, SIGN 2010).

Nevertheless, because of the limitations of the tools and strategies to determine overweight and obesity, and the uniqueness of each and every child, practitioners would benefit from training in anthropometric measurements and quality assurance measures necessary to ensure accuracy. They also need to be aware of all the factors at play and use their knowledge and professional judgement when deciding whether or not a child has an excessive accumulation of body fat that presents a health risk (WHO 2014) and, therefore, fits the criteria to be diagnosed as overweight or obese.