

Body fat measurements in children as predictors for the metabolic syndrome: focus on waist circumference

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The global epidemic of obesity in children will see a rise in the number of cases of metabolic syndrome, which is a clustering of CVD risk factors, including atherogenic levels of blood lipids, hyperinsulinaemia and raised blood pressure. Rather than excess general fatness (assessed by BMI), more specifically it is excess abdominal fatness, quantified by waist circumference measurement, which is a better measure of risk for these metabolic abnormalities in children of all ages. Insulin resistance, a consequence of excess visceral fat, is understood to be the driving force underpinning the metabolic syndrome. Consequently, assessment of abdominal fatness in children is proving to be more clinically useful. Waist circumference centile charts have now been developed for the UK and other paediatric populations to assist in this process. Furthermore, studies in the UK and elsewhere have shown that abdominal fatness has increased in infants, children and adolescents to a greater extent than overall fatness over the past 10–20 years, suggesting that obesity prevalence may be underestimated when based entirely on BMI. Additionally, ethnic differences in fat distribution have been demonstrated in children, with those from south Asian backgrounds having a greater abdominal distribution compared with Caucasian children and consequently having a much greater risk for type 2 diabetes. The information that can be provided by waist circumference measurement in children, as in adults, together with the recent changes in body fat distribution should provide the impetus for its measurement to be standardised and routinely taken in clinical and epidemiological settings.

Metabolic Syndrome: Abdominal obesity: Waist circumference: Children: Ethnicity

It is well established that there is an epidemic of overweight and obesity in both the adult and childhood populations within the UK and globally (Bundred *et al.* 2001; Chinn & Rona, 2001; Lobstein *et al.* 2003). These data are based on BMI as the measure for overweight and obesity. The exact data are continually being updated, but those for England from the Health Survey for England (Sproston & Primatesta, 2002) put the percentages for both overweight and obese categories at approximately 22 for boys and 28 for girls. The prevalence in the Republic of Ireland is not much different from that for the UK. Observers claim that this dramatic rise in obesity prevalence in children is fuelling a major public health crisis (Lobstein *et al.* 2004).

Obesity increases the risk for related morbidities, particularly the metabolic syndrome (MS; Must, 1996; Kopelman & Albon, 1997), which is defined as a clustering of CVD risk factors, including impaired glucose tolerance,

dyslipidaemia and hypertension. Obesity, especially abdominal obesity (in which lipid deposition in visceral adipose tissue is increased) is fundamental to the MS. Insulin resistance, a consequence of abdominal obesity, is understood to be the driving force of MS (Weiss & Caprio, 2005). Across increasing body-weight categories there is a rising and significant trend for the metabolic variables associated with the MS, including plasma glucose and insulin concentrations, increasing triacylglycerol levels, decreasing HDL levels, increased impaired glucose tolerance test and increased systolic blood pressure (P for trend <0.001 ; Weiss *et al.* 2004). Consequently, it has been reported that the MS is one of the most pressing diet-related public health issues to affect future generations, as risk for MS has been shown to originate early in life.

Most often in a clinical situation it will be the child's BMI that will initiate further examination for comorbidities. BMI represents the sum of fat-free mass and

Abbreviations: ALSPAC, Avon Longitudinal Study of Parents and Children; MS, metabolic syndrome; WC, waist circumference; WHtR, WC:height ratio.

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fat mass. BMI charts for clinical use in children have been available for some time (Cole *et al.* 1995, 2000; Dietz & Bellizzi, 1999; National Center for Health Statistics, 2000). In relation to the use of BMI in children, it may well be that this type of measurement does not fully capture all those children who may be at risk for the MS. This situation is in part a result of its sensitivity and specificity. Whilst BMI is able to correctly identify the fattest children in a sample (high specificity, low false positive rate), because of its low sensitivity (moderate–high false negative rate) it can misclassify large numbers of children with a high body fat content (Reilly *et al.* 2000). Furthermore, BMI is unable to distinguish between gains in fat-free mass and gains in fat mass. In an epidemiological context, as BMI is used to monitor trends in overweight and obesity in children, its known limitations can therefore be particularly problematic for public health applications such as surveillance of obesity (Ellis *et al.* 1999; Moreno *et al.* 2000).

Another major drawback with BMI is that its measurement gives no indication of body fat distribution. It has been known for some time that a central distribution of body fat, particularly an excess accumulation of fat intra-abdominally rather than a more peripheral distribution, carries a higher risk for obesity-related ill health. Waist circumference (WC) measurement in adults can quantify abdominally-accumulated fat and is used as a clinical measure for CVD risk (Lean *et al.* 1995). Other measures such as the WC:height ratio (WHtR) and waist:hip ratio can also be used to indicate abdominal obesity and its related risk (Ashwell *et al.* 1996).

There has been an assumption that intra-abdominal (or visceral) fat accumulation is a phenomenon associated mainly with adulthood and hence adult risk for CVD. Thus, for a long time visceral fat remained unmeasured in the childhood population. Furthermore, the technology available at the time for quantifying visceral fat (computerised tomography) was thought to be prohibitive to its use in children because of the radiation risk. As a result, for some time the metabolic risk of intra-abdominal adipose tissue accumulation in children was overlooked and so the use of WC as a measure of body fat distribution in children was ignored. De Ridder *et al.* (1992) and Fox *et al.* (1993) were among the first investigators to examine intra-abdominal fat deposition in children. Both studies used nuclear magnetic resonance imaging in 11-year-old children and late pubertal girls. Essentially, in both studies it was found that whilst intra-abdominal or visceral fat is present in children, its amount is highly variable between individuals and the percentage of cross-sectional area taken up by visceral fat is less than that found in normal-weight adults. In addition, in these children subcutaneous abdominal adipose tissue was found to be predominant compared with intra-abdominal adipose tissue. However, a proportion of the children were found to have intra-abdominal:subcutaneous abdominal fat values that have been associated with higher health risks in obese adults. These findings would suggest that the partitioning of dietary energy (as triacylglycerol) between the intra-abdominal depot and subcutaneous depot in childhood is a regulated process that is incompletely understood. The process by which excess fat can accumulate intra-abdominally in children must

relate, in part, to the biology of adipose tissue growth and different physiological mechanisms must exist for the acquisition of subcutaneous and intra-abdominal adipose tissue mass (Huang *et al.* 2001). As a measure of intra-abdominal fat deposition in these children, waist to hip ratio was not found to be a useful marker, whereas WC alone was found to be a good predictor of abdominal fatness. It should be noted that these observations were conducted before the current obesity epidemic and, given the increases seen in WC in UK children (see p. 388), a repeat of those earlier magnetic resonance imaging studies may prove more illuminating. Later research using dual-energy X-ray absorptiometry has confirmed that the strongest correlate of fat distribution in children and adolescents is WC and it is also the correlate least affected by gender, ethnicity, age and overall fatness (Daniels *et al.* 2000; Taylor *et al.* 2000).

Given the association between excess abdominal fat in adults and morbidity, is the same true for children? It is indeed the case, as a number of studies have demonstrated. In a group of obese children aged 10–15 years intra-abdominal adipose tissue mass was shown to be positively and significantly ($P < 0.04$) related to both total cholesterol and LDL-cholesterol, and triacylglycerol levels (Brambilla *et al.* 1994). A separate study in obese adolescent girls has shown that cardiovascular risk factors including plasma triacylglycerol and HDL-cholesterol concentrations and systolic and diastolic blood pressure are directly related to the amount of intra-abdominal fat (Caprio *et al.* 1996). Similar findings have also been reported for obese children aged 7–11 years (Owens *et al.* 1998). In relation to insulin sensitivity and risk for type 2 diabetes mellitus, intra-abdominal adipose tissue (assessed by magnetic resonance imaging) has been shown to be highly correlated with basal insulin secretion, glucose-stimulated insulin secretion and insulin sensitivity in obese adolescent girls (Caprio *et al.* 1995). Studies reviewed by Goran & Gower (1999) have shown the clinical relevance of intra-abdominal adipose tissue in children and adolescents, including its effects on dyslipidaemia and glucose tolerance.

Whilst these measurements of intra-abdominal adipose tissue in children by imaging techniques correlate with risk for CVD and MS, it must be remembered that the intra-abdominal adipose mass is only one component of the WC, and WC measurement in children relates to both subcutaneous abdominal fat and intra-abdominal fat. Thus, it is also important to determine whether WC rather than intra-abdominal fat relates to CVD risk in children. A study of a group of 12–14-year-old obese children (Flodmark *et al.* 1994) has shown that after adjusting for puberty and gender WC is significantly correlated with HDL-cholesterol ($P < 0.05$) and plasma triacylglycerol ($P < 0.01$) levels, indicating that for this group of obese children, abdominal obesity is related to an adverse blood lipid profile and that WC measurement is a convenient and informative indicator of obesity-related metabolic alterations. Further to these observations, the Bogalusa Heart Study (Freedman *et al.* 1999) has examined the relationship between WC and measures of lipid and insulin concentrations in 5–17-year-olds. Again, it was found that, independently of age, height, weight, gender and ethnicity,

increasing WC is associated with increasing fasting insulin concentration (indicative of insulin resistance) together with adverse concentrations of plasma triacylglycerols and LDL- and HDL-cholesterol. From the latter study it was further concluded that information on body fat distribution, particularly WC measurement, may help to identify those children who are likely to have adverse blood concentrations of insulin and lipids. More recently, an important finding from the Avon Longitudinal Study of Parents and Children (ALSPAC) project (see p. 389) has demonstrated raised plasma cholesterol and triacylglycerol concentrations in preschool children with the highest WC (Cowan *et al.* 2000).

Evidence for a relationship between WC and blood pressure in children is not as abundant, although using data from ALSPAC an increase has been observed in systolic blood pressure in 4- and 5-year-olds with increasing WC (HD McCarthy, KV Jarrett, PM Emmett, I Rogers and the ALSPAC Study Team, unpublished results). In prepubertal children systolic and diastolic blood pressure, as well as apoA1:apoB, total cholesterol and HDL-cholesterol have been shown to be significantly associated with WC, independently of age, gender and BMI ($P < 0.01$; Maffeis *et al.* 2001). Furthermore, children identified with a WC in the top 10% of the age- and gender-related distribution are more likely to have multiple risk factors than children with a WC in the remaining 90% of the WC distribution. In pubertal children positive relationships between systolic and diastolic blood pressure and trunk fat (determined by both WC measurement and dual-energy X-ray absorptiometry and adjusted for total fat) have been found in boys but not in girls (He *et al.* 2002a). Thus, a broad range of evidence in children of all ages suggests that WC is strongly associated with obesity-related morbidity and is a useful measurement to identify those children most at risk, and one which is easy to undertake with an acceptable extent of reproducibility (see p. 390).

Waist circumference percentile charts

Given the findings of the research into intra-abdominal fat accumulation in children, its association with metabolic risk factors and the ability of WC to predict abdominal fatness, WC centile charts should prove to be a useful addition or alternative to BMI centile charts in the clinical assessment of childhood obesity. Compared with BMI, WC would better identify children with high abdominal fatness and hence risk for MS. This premise is especially true given the known limitations of BMI and BMI centile charts in children for identifying those who may be at risk for the MS. Up until 2001, there had been no obesity-related reference data for WC in UK children, but WC centile charts had been developed for the Italian (aged 6–14 years; Zannolli & Morgese, 1996) and Spanish (aged 6–15 years; Moreno *et al.* 1999) paediatric populations. Waist:hip ratio centiles had also been developed for Cuban children and adolescents (Martinez *et al.* 1994). For equivalent UK charts it was essential that historical data were utilised and collected before the emergence of the current obesity epidemic. If contemporary data had been used, then

comparison with the UK references for height, weight and BMI would be difficult (Cole *et al.* 1995). One key issue in the development of the WC centile chart and the use of WC measurement in paediatric obesity research is that there is no universal agreement on the definition of the WC landmark. Most research groups have taken the WC as being mid-way between the 10th rib and the top of the iliac crest (for example, see Freedman *et al.* 1999; Moreno *et al.* 1999). Others, such as those who developed the Italian charts, have measured WC at the level of the umbilicus (Zannolli & Morgese, 1996). This disparity makes comparisons between populations difficult.

Data used for the development of the UK WC centile charts were collected in 1977 for boys and 1987 for girls and the measurement site was the midpoint between the 10th rib and the top of the iliac crest (British Standards Institute, 1990). Using the LMS curve-fitting software developed by Cole and colleagues (Cole, 1990), gender-specific and age-related smoothed centile charts have been constructed (McCarthy *et al.* 2001). In this dataset there is an age-related increase in mean WC up to age 17 years. Gender differences are evident from age 9 years onwards, with boys having the greater mean WC at each age; the difference in mean WC between boys and girls at age 17 years is 6.3 cm. At present, the published WC centile charts cover the age-range between 3 and 17 years, and include the standard nine centile lines, with a channel width of 0.66 sd score. The 91st and 98th centiles are used to define overweight and obese, in line with the UK BMI charts.

Since the development of WC centile charts for UK children, other nations have produced similar charts, including Cyprus (ages 6–17 years; Savva *et al.* 2001), USA (ages 2–18 years; Fernandez *et al.* 2004), Canada (ages 11–18 years; Katzmarzyk, 2004), Australia (ages 7–15 years, Eisenmann, 2005), The Netherlands (ages birth to 21 years; Fredriks *et al.* 2005) and Mexico (ages 6–10 years; Gomez-Diaz *et al.* 2005). However, there is variation between these studies in the landmark used to define the waist, again leading to potential difficulties when attempting to make cross-cultural comparisons. Furthermore, most of the WC data were collected from contemporary children and in countries with known increased prevalences of overweight and obesity.

When BMI–WC relationships in children and adolescents are examined, a strong positive relationship between these two variables exists. However WC can vary greatly for a given BMI at a particular age. As a result, this relationship can give an insight into how combining age-related BMI and WC measurements could improve the identification of those children most at risk of MS, and conversely how it could assist in avoiding the incorrect classification of some children. Table 1 illustrates this issue in four boys of approximately similar age, and the BMI–WC relationships highlighted can be demonstrated across all ages and in both genders.

As two separate measures of fatness BMI and WC interact in a complex fashion, especially in childhood, and are both influenced by age, gender and pubertal stage. In a recent cross-sectional study in 474 healthy adolescents aged 17 years (Neovius *et al.* 2005) both BMI and WC

Table 1. Combining age-related BMI and waist circumference (WC) measurements could assist in avoiding the incorrect classification of some children, as illustrated for four boys of similar age*

Subject	Age (years)	BMI (kg/m ²)	WC (cm)	BMI percentile	WC percentile
A	7.7	15.2	48	Approx 50th	<9th
B	7.5	15.3	65	Approx 50th	>98th
C	7.1	19.1	53	>91st	Approx 50th
D	7.1	20.0	67	>98th	>99.6th

Approx, approximately.

*Child A can be considered a reference child with an average BMI for age and gender. Child B, based on BMI would also be considered average for age. However, when WC is taken into account, this child would be classified as obese. The latter is an example of where there is not excess body mass, but excess central body fat accumulation (furthermore, it is likely that this child would be shorter than child A). Child C would be considered overweight based on his BMI, but his WC is average. This example could be a case where the child is more muscular (and possibly taller, leading to a greater fat-free mass) for his age. Finally, child D is considered obese based on his BMI and obese based on his WC.

have been shown to perform well as diagnostic tests for fatness (air-displacement plethysmography was used as the reference method and diagnostic accuracy was evaluated through receiver operating characteristics). However, as measures of risk for obesity-related morbidity, age- and gender-related BMI and WC can lead to different interpretations. As a result, it may be more useful in clinical practice (and possibly in epidemiological studies) to perform both measurements and to make an evaluation on the child based on the combined observations. Indeed, such a recommendation has been supported by findings in children for whom outcome measures of HDL-cholesterol level, triacylglycerol level, high glucose level, high insulin level and high blood pressure were predicted from age-specific BMI and WC values (Katzmarzyk *et al.* 2004; Janssen *et al.* 2005). From these studies the authors have concluded that a combination of BMI and WC should be recommended for use clinically to predict risk factor clustering and elevated health risk among children and adolescents.

Secular changes in abdominal fatness in children

Reference data for WC and hence abdominal fatness in UK children exists. Thus, in view of the escalation in childhood overweight and obesity, it was important to determine whether abdominal fatness has increased in British children, thus increasing the numbers at risk for the metabolic consequences of abdominal obesity and the MS. This issue was resolved by comparing the WC reference data (McCarthy *et al.* 2001) with that collected 10 and 20 years later for 11–16-year-old children participating in the National Diet and Nutrition Survey (Gregory & Lowe, 2000). This survey was the first contemporary nationally-representative children's survey in which WC measurements had been collected. Fortunately, the landmark used for WC measurement was the same as that for the earlier survey. In the analysis (McCarthy *et al.* 2003) WC was expressed as a standard deviation score, using the first survey (British Standards Institute, 1990) as the reference.

Changes in BMI were analysed in the same way but using the UK data as the reference (Cole *et al.* 1995). Overweight and obesity were defined as measurements >91st and 98th centile respectively. The key finding from this study is the sharp increase in WC over the 10-year period in girls (6.2 cm, 1.02 SD score; $P < 0.0001$) and over the 20-year period in boys (6.9 cm, 0.84 SD score; $P < 0.0001$). In centile terms, the increase was found to be greater for girls than for boys. For BMI, the extent of the increase was smaller and was similar for boys and girls (mean 1.5 and 1.6 BMI units respectively, or 0.47 and 0.53 SD score; $P < 0.0001$). In the National Diet and Nutrition Survey (Gregory & Lowe, 2000) sample WC was found to exceed the 91st centile in 28% of boys and 38% of girls, with 14% and 17% of boys and girls respectively exceeding the 98th centile ($P < 0.0001$). By comparison, for BMI 17% of boys and 21% of girls were found to exceed the 91st centile in the National Diet and Nutrition Survey (Gregory & Lowe, 2000) sample, with the corresponding rates for the 98th centile being 10% for boys and 8% for girls. These findings clearly demonstrate that increases in central fatness over the past 10–20 years (measured by WC) have exceeded increases in overall fatness (measured by the BMI) and that BMI is a poor proxy for central fatness. These findings also indicate that obesity prevalence has been systematically underestimated by measurements based on height and weight. As indicated earlier, BMI measures the sum of fat mass and fat-free mass (Maynard *et al.* 2001; Wells *et al.* 2002), and it is impossible to know the contribution of each compartment to these increases in BMI in this study. The increase in WC is unlikely to be entirely a result of increases in visceral adipose tissue, and probably reflects subcutaneous and hence total fatness. Taken together, these findings suggest that body composition (and hence body shape) has changed over this period of time, with the increase in (central) fat mass being obscured by decreases in fat-free (and hence probably skeletal muscle) mass. Whether this possible skeletal muscle issue is related to decreases in physical activity levels is unclear at this time. It is known that in obese adolescents excess fat accumulates predominantly in the upper body region rather than in the peripheral region (Brambilla *et al.* 1994; Moreno *et al.* 1998). These findings have important implications for risk of MS, given the fact that children in the upper distribution of the WC values have a more atherogenic blood lipid profile and raised fasting insulin concentrations. These secular increases in WC and abdominal fatness in adolescents have also been demonstrated outside the UK, but over a shorter period of time, indicating the reproducibility of this phenomenon in other populations (Moreno *et al.* 2005). Also, an earlier study of Spanish children (Moreno *et al.* 2001b) has shown that between 1980 and 1995 there was a shift towards a central distribution of fat patterning in children as young as 6 years of age. These observations were based on ratios of skinfold thicknesses at the periphery and trunk and were independent of trends in BMI. Furthermore, conversion of these children's skinfold thickness measurements into predicted percentage body fatness indicates a secular increase in total percentage body fat of between 2.5 and 6.0% that is greater than the increase in BMI, again suggesting a

change in body composition over the 15-year period (Moreno *et al.* 2001a).

Following on from the novel findings in adolescents (McCarthy *et al.* 2003), the next question to be asked was whether these body fatness findings were present in younger children. This question was answered using data from the ALSPAC study. ALSPAC is a longitudinal cohort study being conducted in the West of England, which was initiated in the early 1990s and comprises approximately 14 000 children (Golding *et al.* 2001). A subset of these children, comprising approximately 1000 children, has been studied in more detail (known as Children in Focus). WC and BMI between the ages of 2 and 5 years were compared with values for similar-aged children measured in 1987. The essential finding of this study is a significantly greater mean WC in the ALSPAC children at equivalent ages compared with those measured in the earlier study ($P < 0.05$; McCarthy *et al.* 2005). Whilst mean BMI was also found to be higher in the contemporary ALSPAC cohort, the proportional increase in WC was again greater than that for BMI. These findings mirror those in the older children, suggesting a greater rate of increase in abdominal fatness than in general fatness, and the occurrence of excess central fat deposition at a very young age. Again, this study demonstrates the shortcomings of BMI measurement, indicating that it can mask the true obesity-related risk in young children.

Longitudinal studies of both total fatness and abdominal fatness in children are scarce. The Nepean study (Garnett *et al.* 2005), which has examined both factors in detail between 7–8 years of age and 12–13 years of age, has found an increase of 0.74 for the mean WC *SD* score, but an increase 0.18 for BMI *SD* score. These findings suggest a greater rate of increase in abdominal fatness than in overall fatness in this contemporary cohort of children.

Abdominal fatness, ethnicity and health risk

The findings discussed so far have related almost exclusively to Caucasian children. However, the prevalence of overweight and obesity and its health consequences can be greater for children from other ethnic groups, especially those from south Asian and African and Caribbean backgrounds. A recent UK study (Saxena *et al.* 2004) has demonstrated that British Afro-Caribbean and Pakistani girls have an increased risk of being obese, while Indian and Pakistani boys have an increased risk of being overweight. These findings suggest that these individuals may be at a greater risk of obesity-related morbidity. Studies in the USA (Goran *et al.* 1997; He *et al.* 2002b) have demonstrated ethnic differences in fat distribution among Asian, African-American and Caucasian prepubertal children. Generally, the relative distribution of adipose tissue in the intra-abdominal region compared with the subcutaneous abdominal region is significantly lower in children from African-American backgrounds compared with Caucasian children. The relationship between intra-abdominal fat and insulin response in African-American children appears to be highly complex (Gower *et al.* 1998), although more recent findings in this ethnic group (Lee *et al.* 2006) have shown that WC is able to predict insulin

resistance independently of BMI. The authors further suggest that the prediction of health risks associated with obesity is improved by including WC measurement alongside BMI measurement. They also emphasise the importance of including WC measurement routinely in the assessment of childhood obesity in order to identify those children at increased metabolic risk because of excess abdominal fat. Although data is less abundant than that for Caucasian children, nevertheless the findings generally concur, in that a more central distribution of fat profoundly affects CVD risk factor levels, including HDL, LDL, triacylglycerol levels and systolic and diastolic blood pressure in black boys (Morrison *et al.* 1999a) and black girls (Morrison *et al.* 1999b).

In relation to insulin resistance and risk for type 2 diabetes in children of south Asian background, recent findings from the UK (Ehtisham *et al.* 2005) have demonstrated that south Asian children are less insulin sensitive than white Europeans and have significantly more body fat, with a greater central fat distribution ($P < 0.005$). It was concluded that children from south Asian backgrounds are fourteen times more likely than white European children to develop type 2 diabetes. Further work is required to examine the development of central body fat accumulation in UK children from other ethnic groups, especially those from a south Asian background and African and Caribbean backgrounds. However, British south Asian children as young as 8 years of age have been shown to have higher fasting and glucose-stimulated insulin concentrations and higher triacylglycerol levels, which may reflect an increased sensitivity to adiposity (Whincup *et al.* 2002). Although not observed in the latter study, recent findings have shown that a more truncal distribution of fat is present at birth and in early childhood in south Indian children (Krishnaveni *et al.* 2005) and that this pattern of fatness may be the forerunner of a diabetogenic adult phenotype.

Waist circumference alone or in combination with height?

The evidence thus far indicates that WC can provide vital information in children in relation to measurement of abdominal fatness and risk for obesity-related ill health. One matter of concern, however, is the influence of stature on WC in both children and adults. There is a strong positive correlation between height and WC throughout growth, throughout childhood and into adulthood, although the precise influence of height on WC remains quantitatively unclear. It has been suggested that a measure of WC in combination with height may partly correct for the effect of height on WC. Thus, WHtR has been proposed as a simple indicator of excess abdominal fat accumulation, with a cut-off or boundary value of WHtR ≥ 0.50 defining those with excess abdominal fatness (Ashwell *et al.* 1996). This measure has been proposed to be equally appropriate for use in adults and children, in both boys and girls and at all ages >5 years. Indeed, several studies have demonstrated the WHtR to be superior in its ability to predict CVD risk factors compared with BMI or percentage body fat (Savva *et al.* 2000; Hara *et al.* 2002; Kahn *et al.* 2005). A recent examination of WHtR in British children

(McCarthy & Ashwell, 2006) has shown that the percentage of children with a WHtR above the boundary value of 0.50 has increased in recent years (boys 17 and girls 12 v. 5 and 1.5 respectively 10–20 years earlier).

Too many measures of central obesity in children could be confusing, but the concept of WHtR may be one that is easily grasped by the public, with a simple public health message to 'keep your waist circumference to less than half your height'. Additional work in this area should help to clarify the 0.50 boundary value and the usefulness of this ratio.

Waist circumference and the metabolic syndrome in children

As stated earlier, the MS is one of the most important public health issues affecting future generations around the world. In order to be able to readily identify those children who are most at risk of developing this disorder a simple and effective screening tool is required, and the WC appears to best fit the requirements of such a tool. While it is generally agreed that obesity is the predominant correlate of risk for MS among the young (Goodman *et al.* 2005), an increasing number of studies are showing that WC is the best measure for identifying children with insulin resistance and hypertriglycerolaemia, and hence those most at risk for MS (Moreno *et al.* 2002; Hirschler *et al.* 2005; Esmailzadeh *et al.* 2006). WC has been found to perform better than BMI in this context, and these studies have recommended that WC should be used in paediatric clinical settings. Furthermore, when determining the prevalence of MS in prepubertal children, the classification of MS in children depends strongly on whether hyperinsulinaemia is central to the MS classification (Golley *et al.* 2006). The authors have concluded that there is a need for the establishment of normal insulin ranges in childhood and adolescence and a consistent definition of MS.

Standardisation of waist circumference

WC now appears to be fundamental in determining risk of MS and related disorders in both childhood and adulthood. There is, therefore, an important need for WC to be measured routinely in the clinical setting, and in epidemiological research in which obesity is a component of predictive or outcome measures. At the same time, there is an urgent need for a consensus on the definition of the WC measurement site (Wang, 2006). In adults WC measurement certainly differs, depending on the chosen landmark and gender, and there is likely to be a similar difference in children (Wang *et al.* 2003; Bigaard *et al.* 2005). Furthermore, whilst WC can be considered a simple measurement technique, this very characteristic can result in erroneous measurements. There is a need for health professionals to become proficient in WC measurement through appropriate training, practice and experience. With increasing experience, measurement error can be reduced (Ulijaszek & Kerr, 1999) to an acceptable extent, thus allowing comparison between centres to be more reliable and valid, and

for individual children to be confidently assessed in the clinical situation.

Conclusions

Research has shown that abdominal fatness is as important in children as it is in adults. Excess abdominal fatness in children results in metabolic alterations associated with features of the MS and hence risk for CVD in later life. Its measurement can add more information to that provided by BMI measurement in the paediatric clinical setting, and WC centile charts are available for clinical use in the UK. It is now time that all health professionals working in the field of childhood obesity should routinely perform WC measurement as part of a clinical assessment. Further research should demonstrate whether a WC measurement alone will be sufficient to identify those children at greatest risk for obesity-related ill health and the need for weight management.

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