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Original Communication
The development of waist circumference percentiles in British children aged 5.0–16.9 y

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Objective: To develop waist circumference percentile curves for British children and to compare these curves with those from other countries.
Design: Cross-sectional study.
Setting: School-aged population.
Subjects: A representative sample of school children from the geographical regions of Great Britain, approximately in proportion to their age distribution. The sample population consisted of 8355 children (3585 males, 4770 females) with ages ranging between 5.0 and 16.9 y.
Interventions: Waist circumferences were measured with a flexible non-elastic tape and waist circumference percentiles were constructed and smoothed using the LMS method.
Main outcome measures: Smoothed waist circumference percentile curves.
Results: Mean waist circumference increased with age in both boys and girls. For girls, curves began to plateau after the age of 13 y whereas, for boys, waist percentile curves continued to increase more sharply after this age. However, these curves mainly reflect the patterns of waist circumference in Caucasian children.
Conclusions: These curves represent the first waist circumference percentiles for British children and could be used provisionally for both clinical and possibly epidemiological use, although they should be validated against equivalent longitudinal data.
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Descriptors: waist circumference; percentile curves; morbidity; children; intra-abdominal adiposity
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Introduction

Overweight and obesity have been increasing within the UK population over the past 15 y among both adults (Jebb, 1999) and children (Reilly *et al*, 1999). This trend is also being observed in other countries (Troiano *et al*, 1995; Hanley *et al*, 2000; Lazarus *et al*, 2000; Moreno *et al*, 2000) and childhood obesity has also been linked with increased risk of obesity in adulthood (Parsons *et al*, 1999) and morbidity and mortality in adults (Power *et al*, 1997). Factors associated with obesity risk in childhood have recently been reviewed and include parental obesity, low socio-economic status and early maturation (Parsons *et al*, 1999). A study from the USA demonstrated that type 2 diabetes amongst adolescents increased 10-fold from 1982 to 1994, and virtually all diagnosed cases of type 2 diabetes occurred in obese individuals (Pinhas-Hamiel *et al*, 1996). In addition, obesity in children is commonly associated with fasting hyperinsulinaemia (Gower *et al*, 1998; Goran & Gower, 1999).

The increased prevalence of paediatric obesity and its associated morbidities demonstrates the need for a simple anthropometric tool which can be used to assess and identify children who are at risk of becoming obese and subsequently require appropriate intervention. Estimates of the prevalence of overweight and obesity in population groups are typically based on body mass index (BMI), and BMI centile curves have been developed for use in the paediatric population for clinical and possibly epidemiological purposes (Cole *et al*, 1995). It has been suggested, however, that BMI may be a less sensitive indicator of

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fatness amongst children (Reilly *et al*, 2000), and BMI gives no indication about fat distribution. Until more studies include ethnic groups other than whites however, BMI should be used cautiously in assessing fatness across populations (Dietz & Bellizzi, 1999).

In the adult population, waist circumference measurement has proved to be a useful tool for assessing risk for obesity-related diseases such as cardiovascular disease (Lemieux *et al*, 2000). Waist circumference has been shown to correlate well with intra-abdominal fat mass (Lean *et al*, 1995), which in turn has been shown to be related to an atherogenic lipoprotein profile (Han *et al*, 1995).

Until recently, waist circumference in children had not been regarded as being an important measure of adiposity. During growth in childhood, body fat is laid down both subcutaneously and intra-abdominally (Brambilla *et al*, 1994). The distribution of fat between the subcutaneous and intra-abdominal sites is likely to vary with both age and as a result of excessive body fat accumulation (Fox *et al*, 1993). The health risks associated with an excessive abdominal fat distribution in children in comparison to adults remain unclear at this stage, although there is mounting evidence to suggest that concern should be raised. For example the relationship between an increasing waist circumference in obese children aged 12–14 y with an adverse atherogenic lipoprotein profile has been observed (Flodmark *et al*, 1994). Secondly, data from the Bogalusa Heart Study showed that an abdominal fat distribution (indicated by waist circumference) in children aged between 5 and 17 y was associated with adverse concentrations of triacylglycerol, LDL cholesterol, HDL cholesterol and insulin (Freedman *et al*, 1999). Such evidence now suggests that obtaining information on waist circumference in children could be as useful as BMI as a means of identifying the overweight and obese in childhood population studies, and screening those children who could benefit from early dietary and exercise intervention. To these ends, waist circumference percentile curves have been generated for the Italian and Spanish childhood populations (Zannolli & Morgese, 1996; Moreno *et al*, 1999) but, as yet, no such data have been produced for the UK. We now present in this paper, the first set of working waist circumference percentiles obtained from data collected from British children.

Materials and methods

The data used were collected cross-sectionally and consisted of 8355 subjects (3585 males and 4770 females) aged 5.0–16.9 y. The data was a collection from four measurement surveys by the HUMAG Research Group, Department of Human Sciences, University of Loughborough (BSI, 1990). The specific locations selected from various regions in Great Britain were chosen to provide a good balance between cost and sampling requirements. These included a broad geographical coverage, an urban/rural mix, and a mix of socio-economic status families.

As far as was possible, the sample was representative of the population of girls and boys in Great Britain in 1988. All racial groups were measured but it did not prove possible to measure a truly representative sample of the non-Caucasian population.

Subjects measured in this survey were aged between birth and 17.0 y, although in this paper, subjects were selected between the ages of 5.0 and 16.9 y. Decimal age was recorded to two decimal places. Stature and weight were measured using standard procedures (WHO, 1995). The waist circumference measurement was taken midway between the tenth rib and the iliac crest and was recorded to the nearest millimetre.

A non-elastic flexible tape measure was employed with the subject in a standing position (BSI, 1990; WHO, 1995).

Figures 1 and 2 show the two common sites for waist circumference measurement—the natural waist (as in this study), and umbilicus level (Norris & Wilson, 1994).

Smoothed percentiles for waist circumference were constructed from the raw data and were entered onto a spreadsheet separately for boys and girls and imported into the software package LMS (Cole, 1990).

The LMS method enables normalised growth centile standards to be developed, and deals generally with skewness which might be present in the distribution of the circumference measurements. This method assumes that the data can be normalised by using a power transformation, which removes skewness from the data set by extending one tail of the distribution and reducing the other (Cole, 1990). The maximum power required to obtain normality is calculated for each age group series and the trend is then summarised by a smooth (L) curve. The trends observed for the mean (M), and coefficient of variation (S), are similarly smoothed. These LMS curves contain information to draw any centile curve, and to convert measurements into exact s.d. scores (Cole 1990).

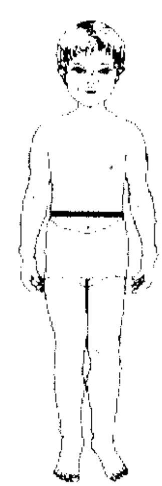

Figure 1 Waist circumference measurement site–natural waist.

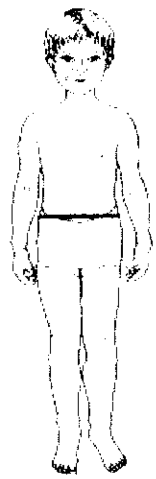

Figure 2 Waist circumference measurement site—umbilicus level.

Results

Tables 1 and 2 show the descriptive statistics for weight, height, BMI and waist circumference for boys and girls respectively by age.

Mean weight, height, BMI and waist circumference increased with age for both boys and girls. Table 3 shows the sample size and selected waist circumference percentile values at each age interval for boys and girls separately.

Figures 3 and 4 show the smoothed computed waist circumference percentile curves for the 5th, 10th, 25th, 50th, 75th, 90th and 95th percentile for boys and girls. Mean waist circumference increased with age in both sexes, although the absolute increase was greater for boys. At the upper end of the age range, the curves tended to plateau in girls, whereas in boys they continued to increase, and this probably reflected the different timings of the onset of puberty and gender-specific influences on waist circumference.

Table 1 Mean and standard deviations (s.d.) for weight, height, BMI and waist circumference for boys aged 5.0–16.9 y

Age (y)	*Sample size (n)*	*Weight (kg) Mean (s.d.)*	*Height (m) Mean (s.d.)*	*BMI (kg/m²) Mean (s.d.)*	*Waist circumference (cm) Mean (s.d.)*
5.00–5.99	254	19.92 (2.52)	1.11 (0.0510)	15.89 (1.24)	52.27 (3.23)
6.00–6.99	349	21.72 (2.89)	1.17 (0.0508)	15.77 (1.31)	52.76 (3.67)
7.00–7.99	334	24.72 (3.78)	1.23 (0.0598)	16.08 (1.68)	54.60 (4.01)
8.00–8.99	333	26.91 (4.45)	1.28 (0.0573)	16.13 (1.79)	55.67 (4.83)
9.00–9.99	337	30.23 (5.56)	1.34 (0.0650)	16.65 (2.06)	58.10 (5.62)
10.00–10.99	357	32.99 (5.85)	1.39 (0.0660)	16.88 (2.06)	59.57 (5.69)
11.00–11.99	298	36.54 (7.04)	1.44 (0.0775)	17.42 (2.53)	61.49 (6.33)
12.00–12.99	347	40.31 (7.26)	1.49 (0.0753)	17.85 (2.42)	63.84 (6.15)
13.00–13.99	319	46.21 (9.18)	1.57 (0.0876)	18.61 (2.72)	66.36 (7.41)
14.00–14.99	279	52.30 (9.75)	1.64 (0.0927)	19.28 (2.45)	68.65 (6.60)
15.00–15.99	288	57.62 (10.55)	1.69 (0.0912)	19.85 (2.47)	70.81 (7.13)
16.00–16.99	90	61.90 (9.56)	1.71 (0.0706)	20.89 (2.75)	71.84 (6.69)

Table 2 Mean and standard deviations (s.d.) for weight, height, BMI and waist circumference for girls aged 5.0–16.9 y

Age (y)	*Sample size (n)*	*Weight (kg) Mean (s.d.)*	*Height (m) Mean (s.d.)*	*BMI (kg/m²) Mean (s.d.)*	*Waist circumference (cm) Mean (s.d.)*
5.00–5.99	401	19.36 (2.89)	1.11 (0.0494)	15.47 (1.59)	51.32 (3.69)
6.00–6.99	400	21.29 (3.08)	1.17 (0.0525)	15.39 (1.52)	52.16 (3.75)
7.00–7.99	376	24.70 (4.80)	1.24 (0.0577)	15.93 (2.12)	54.43 (4.68)
8.00–8.99	413	27.01 (4.62)	1.29 (0.0586)	16.06 (2.06)	55.34 (4.59)
9.00–9.99	395	30.33 (5.65)	1.35 (0.0614)	16.53 (2.26)	56.81 (4.90)
10.00–10.99	364	33.71 (6.40)	1.40 (0.0689)	16.90 (2.36)	57.99 (5.53)
11.00–11.99	357	37.68 (7.49)	1.46 (0.0765)	17.55 (2.62)	59.95 (5.79)
12.00–12.99	375	41.90 (7.89)	1.51 (0.0757)	18.11 (2.47)	61.58 (5.05)
13.00–13.99	390	47.79 (8.42)	1.57 (0.0687)	19.30 (2.76)	63.55 (5.45)
14.00–14.99	404	51.41 (7.58)	1.60 (0.0630)	19.92 (2.53)	64.71 (4.81)
15.00–15.99	433	52.40 (7.44)	1.61 (0.0601)	19.96 (2.46)	64.90 (4.93)
16.00–16.99	462	55.55 (7.76)	1.62 (0.0588)	20.92 (2.47)	66.19 (5.48)

Table 3 Sample size and percentage values of percentiles of waist circumference by age and sex

			Percentiles						
Sex	*Age*	n	*5th*	*10th*	*25th*	*50th*	*75th*	*90th*	*95th*
Boys	5+	254	46.8	47.7	49.3	51.3	53.5	55.6	57.0
	6+	349	47.2	48.2	50.7	52.2	54.6	57.1	58.7
	7+	334	47.9	48.9	50.9	53.3	56.1	58.8	60.7
	8+	333	48.7	49.9	52.1	54.7	57.8	60.9	62.9
	9+	337	49.7	51.0	53.4	56.4	59.7	63.2	65.4
	10+	357	50.8	52.3	55.0	58.2	61.9	65.6	67.9
	11+	298	51.9	53.6	56.6	60.2	64.1	67.9	70.4
	12+	347	53.1	55.0	58.4	62.3	66.4	70.4	72.9
	13+	319	54.8	56.9	60.4	64.6	69.0	73.1	75.7
	14+	279	56.9	59.2	62.6	67.0	71.6	76.1	78.9
	15+	288	59.0	61.1	64.8	69.3	74.2	79.0	82.0
	16+	90	61.2	63.3	67.0	71.6	76.7	81.8	85.2
Girls	5+	401	45.4	46.3	48.1	50.3	52.8	55.4	57.2
	6+	400	46.3	47.3	49.2	51.5	54.2	57.0	58.9
	7+	376	47.4	48.4	50.3	52.7	55.6	58.7	60.8
	8+	413	48.5	49.6	51.5	54.1	57.1	60.4	62.7
	9+	395	49.5	50.6	52.7	55.3	58.5	62.0	64.5
	10+	364	50.7	51.8	53.9	56.7	60.0	63.6	66.2
	11+	357	52.0	53.2	55.4	58.2	61.6	65.4	68.1
	12+	375	53.6	54.8	57.1	60.0	63.5	67.3	70.5
	13+	390	55.2	56.4	58.7	61.7	65.3	69.1	71.8
	14+	404	56.5	57.8	60.2	63.2	66.8	70.6	73.2
	15+	433	57.6	58.9	61.3	64.4	67.9	71.7	74.3
	16+	462	58.4	59.8	62.2	65.3	68.8	72.6	75.1

5+ means: group of children aged 5.00–5.99 y.

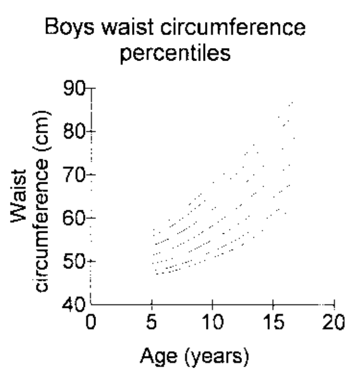

Figure 3 Smoothed computed waist percentile curves for the 5th, 10th, 25th, 50th, 75th, 90th and 95th percentile for boys.

Figures 5 and 6 show comparisons of the 50th percentile for waist circumference obtained from children from four countries, these being the UK (this study) USA, Cuba and Spain for boys and girls, respectively, aged 5.00–17.00 y. These figures comprised smoothed and unsmoothed data. Differences were clearly observed, particularly in the older children, with those from the USA having the highest values for waist circumference.

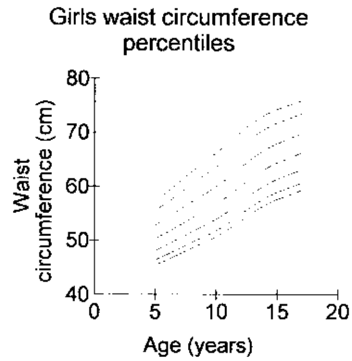

Figure 4 Smoothed computed waist circumference percentile curves for the 5th, 10th, 25th, 50th, 75th, 90th and 95th percentile for girls.

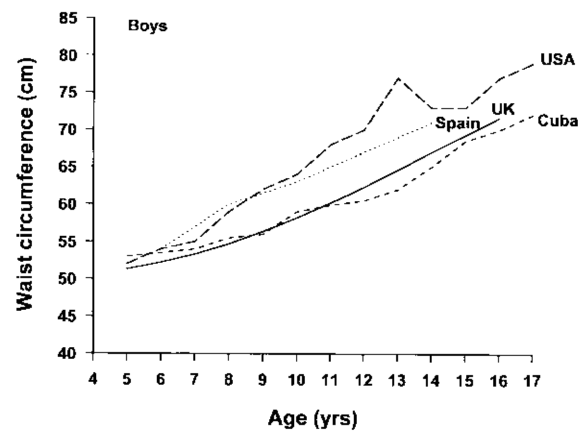

Figure 5 Comparisons of the 50th percentile for waist circumference obtained from the USA, Cuba, Spain (unsmoothed) and the UK (smoothed) for boys aged 5.0–17.0 y.

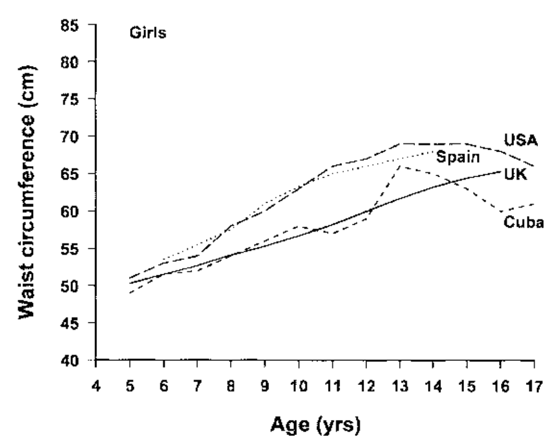

Figure 6 Comparisons of the 50th percentile for waist circumference obtained from the USA, Cuba, Spain (unsmoothed) and the UK (smoothed) for girls aged 5.0–17.0 y.

Discussion

To date waist percentile curves have been developed for Italian, Cuban and Spanish children (Zannolli & Morgese, 1996; Martinez *et al*, 1994; Moreno *et al*, 1999). In this report we have presented the first working waist percentile curves for British children aged 5.0–16.9 y, where we have been able to define the mean and distribution of waist circumference at each age. Although the data were collected in 1988, to the best of our knowledge they are the most up to date large collection of data available on waist circumference in British children. In view of recent findings that the incidence of overweight and obesity has increased in British children (Reilly *et al*, 1999), a further survey of waist circumference and other body dimensions would be advisable. Furthermore, in order for cross-cultural comparisons to be made, a commonly agreed site of measurement should be used, particularly if universally applicable standards are adopted. For instance comparisons with the Italian data are made difficult due to measurement site differences (Zannolli & Morgese, 1996; Norris & Wilson, 1994; Figure 1). Conversely, comparisons with the Cuban data can be made directly and showed waist circumference values that were in closer agreement with those in British children (Martinez *et al*, 1994). For those populations where comparisons could be made (Figures 5 and 6), it can be seen that important differences do exist and that waist circumference was highest for the USA boys compared with those from the UK, Spain and Cuba. This is likely to reflect the overall higher incidence of overweight and obesity in children in that country. This reinforces the importance of developing population-specific standards. One potential difficulty with the waist circumference measurement will be its use across ethnic groups. Children from different populations vary in their rate of proportional growth and in fat patterning (Goran *et al*, 1997). Visceral adiposity is highly variable in children and is related to ethnicity. Goran *et al*, (1997) have shown that the relative distribution of intra-abdominal tissue compared with the subcutaneous abdominal region is significantly lower in African-American children than in whites. The effect of visceral adiposity on the metabolic complications and risk of cardiovascular disease and non-insulin dependent diabetes in adults may also vary amongst ethnic groups (Albu *et al*, 1997). This could have implications for children in the UK from different ethnic groups, and on the use of waist circumference percentiles in general. It then seems prudent to develop standards which are truly representative of children from all ethnic backgrounds.

In view of the observed relationships between waist circumference, intra-abdominal fat deposition and cardiovascular disease risk factors in children, waist circumference could be adopted as an alternative or additional measurement to BMI in children. Furthermore, waist circumference is a straightforward measurement requiring inexpensive simple equipment and the recording of a single value (or a mean of two or three measurements). BMI on the other hand requires more complex equipment and mathematical calculations. Ultimately the value of waist circumference in children will be dependent upon the measurement error (both within- and between-observer error), and will be a function of observer training. This issue has been discussed elsewhere (Ulijaszek & Kerr, 1999).

In the future, it could be envisaged that cut-off points similar to those used with BMI centile curves could be implemented, but it is premature at this stage to define these values. It may not necessarily be the case that the 85th and 95th centiles would be used to classify the overweight and obese groups, respectively. Validation of these percentile curves against equivalent longitudinal data would be necessary since the data has been collected cross-sectionally. In the short term, however, we propose that these centiles could be used provisionally for both clinical practice and possibly epidemiological studies.

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