A study of central fatness using waist-to-height ratios in UK children and adolescents over two decades supports the simple message – 'keep your waist circumference to half your height'

H. David McCarthy and Margaret Ashwell[1]

Institute of Health Research & Policy, London Metropolitan University, Holloway Road, London, N7 8DB; [1]Ashwell Associates, Ashwell Street, Ashwell, Herts, SG7 5PZ

Correspondence: Dr McCarthy

Tel. 020-7133-2547

Fax. 020-7133-2184

Email. d.mccarthy@londonmet.ac.uk

Running title: waist: height ratio in children

Abstract

Objective: To examine the influence of age and gender on the waist:height ratio (WHTR) in children and to compare changes over time in WHTR, a measure of central fatness in British children.

Design: Representative cross-sectional surveys in 1977, 1987 and 1997.

Setting: Great Britain and Northern Ireland.

Participants: Survey 1: Children aged 5-16 years measured in 1977 (boys) and 1987 (girls) (BSI, *n*=8135) and Survey 2: children aged 11-16 measured in 1997 (NDNS, *n*=773).

Outcome measures: From Survey 1, waist: height ratio related to age and sex and the proportion of children with a WHTR greater than 0.500 (a boundary value used for adults). From Survey 2, comparison of WHTR in children with that from Survey 1 and the actual proportion of children with a WHTR greater than 0.500 compared with the expected proportion using the survey 1 as reference.

Results: WHTR decreased with age (P<0.01 for trend), with the mean WHTR being significantly lower in girls (P<0.01). WHTR was significantly greater in children in Survey 2 compared with those measured 10 and 20 years earlier in Survey 1 (P<0.0001). The proportion of children where WHTR exceeded the 0.500 boundary value in Survey 2 was 17% of boys and 11.7% of girls (against 5.0% and 1.5% respectively in Survey 1, P<0.0001). The increase in WHTR in boys exceeded that in girls.

Conclusions: Values of WHTR during the past 10-20 years have increased greatly showing that central fatness in children has risen dramatically. WHTR is more closely linked to childhood morbidity than body mass index (BMI) and we suggest it should be used as an additional or alternative measure to BMI in children as well as adults. A simple public health message that is the same for adults and children of both sexes and all ages could be stated as 'keep your waist circumference to less than half your height'.

Key words: waist circumference, waist: height ratio, central fatness, obesity, child

Introduction

Several recent studies have highlighted an increase in the prevalence of overweight and obesity in British children of all ages (Bundred *et al.* 2001, Chinn & Rona, 2001, Reilly *et al.* 1999). Studies of this nature have used the Body Mass Index (BMI) as the measure of overweight and obesity (Cole *et al* 1995). However, this index has some important drawbacks when used in children. For example, BMI correlates not only with fat mass but also with fat-free mass (Maynard *et al.* 2001, Reilly *et al.* 2000). Secondly, BMI gives no indication of body fat distribution, and it is now clear that in children, as in adults, an upper body or centralised deposition of excess body fat carries an increased risk for obesity-associated metabolic complications. These include adverse lipoprotein and fasting insulin concentrations (Caprio *et al.* 1996, Kahn *et al.* 2005).

Waist circumference has been shown to be a highly sensitive and specific marker of upper body fat accumulation in children (Daniels *et al.* 2000, Taylor *et al.* 2000). The associated lipid abnormalities and insulin concentrations also correlate with waist circumference (Flodmark *et al.*1994, Freedman *et al.* 1999). However, stature influences the magnitude of waist circumference throughout growth in childhood and ultimately into adulthood, although its precise effect upon waist circumference is quantitatively unknown. Thus waist circumference measurement, either alone or in combination with stature might offer a more sensitive means than BMI for identifying overweight and obese children who might be at an increased risk for developing the metabolic complications highlighted above. In this context, the first set of age-related waist circumference percentile curves for British children have recently been developed (McCarthy *et al.* 2001).

A second index - the ratio of the waist circumference to height (WHTR) is increasingly being used to assess risk for diseases related to central fatness in adults (Ashwell *et al.* 1996, Hsieh *et al.* 2003, Sargeant *et al.* 2002, Bertsias *et al.* 2003). The rationale underlying this index is that for a given height, there is an acceptable degree of fat stored on the upper body. A WHTR boundary value of 0.500 has been proposed as a simple means of indicating whether in adults, the amount of upper body fat accumulation is excessive and a risk to health (Ashwell *et al*. 1996). WHTR has been shown to be a simple, non-invasive and practical tool that correlates well with visceral fat, and it has been developed into a consumer-friendly tool known as the Ashwell © Shape Chart (Ashwell, 1998).

The relationship between age, height and waist circumference has not been closely studied in children, particularly in the British child and adolescent population. In the small number of studies that have examined this index in children, WHTR has been shown to be superior in its ability to predict cardiovascular disease (CVD) risk factors in children compared with either BMI or percentage body fat (Savva *et al.* 2000, Hara *et al.* 2002). The objective of this study was to utilise large-scale anthropometric data from surveys of British children to examine the influence of age and gender upon WHTR and to identify any secular trends in this ratio.

Subjects and Methods

This study involved a secondary analysis of previously collected data. Data were obtained for anthropometric variables, from British children in two large cross-sectional surveys. Survey 1 was conducted for the British clothing industry by the Human Measurements, Anthropometry and Growth Research Group, Loughborough University. Data on boys aged 5-16 years were collected in 1977 and on girls aged 5-17 years collected in 1987 (*n* 8135; 3528 boys, 4607 girls). Subjects represented socio-economic, ethnic and urban/rural groups as they occurred in the British population (British Standards Institute). Survey 2 was the National Diet and Nutrition Survey (NDNS) of young people aged 4-18 years carried out in 1997, where waist circumference was measured in those aged 11+ years. For this study, data for 8135 children aged 5.0-16.99 years from the BSI survey and 773 (390 boys and 383 girls) from the NDNS were selected for analysis.

Anthropometric Measurements

In both surveys stature was measured without shoes. Weight was measured in minimal clothing in the British Standards Institute survey, while in the National Diet and Nutrition Survey heavy clothing, jewellery and small change were removed before weighing. Weight was recorded to the nearest 0.1 kg and corrected for clothing effects in the National Diet and Nutrition Survey. In both surveys, waist circumference (cm) was measured midway between the 10^{th} rib and the top of the iliac crest. In the British Standards Institute survey clothing did not significantly influence the measurement, while the data from the National Diet and Nutrition Survey was corrected for clothing effects as previously described (McCarthy *et al.* 2003).

Study design and statistical methods

The data from surveys 1 and 2 were used to examine the influence of gender and age on waist:height ratio (WHTR) in children aged between 5.0 and 16.9 years. WHTR was calculated by dividing waist circumference (in cm) by height (in cm). Means and standard deviations were calculated at yearly intervals by sex. Correlation coefficients were computed to examine the influence of age on WHTR. WHTR in boys and girls were compared statistically using an unpaired t test. The proportion of children with a WHTR greater than 0.500 was calculated for each age group.

WHTR was compared between children in the two surveys, ten years apart for girls and 20 years apart for boys. Mean WHTR were calculated and compared between surveys using an unpaired t test. Boys and girls were analysed separately. Using the children from the BSI survey as the baseline, observed and expected numbers of children in the NDNS with a WHTR greater then 0.500 were compared in each age category using χ^2 goodness of fit test. All statistical analyses were performed using Statistical Package for Social Sciences version 10.0.

Results

Effect of age and gender on WHTR

Survey 1

Mean (SD) height and waist circumferences were 140.3 (19.3) cm and 60.4 (8.3) cm for the boys and 140.9 (18.4) cm and 58.9 (6.9) cm for the girls. Pearson's correlation coefficient between height and waist circumference were 0.790 ($P<0.01$) in boys and 0.749 ($P<0.01$) in girls. Individual values for WHTR ranged between 0.34 and 0.66 in boys and between 0.32 and 0.63 in girls. Mean values for WHTR at yearly intervals are shown in Table. 1. Mean WHTR ranged from 0.468 in the 5.0 y age group, to 0.418 in the 16.0 y age group in boys and from 0.460 and 0.407 in girls between the same ages. This decrease in WHTR with age was statistically significant in both boys and girls (boys r^2 = -.331, $P<0.01$, girls r^2 = -.459, $P<0.01$). Within the cohort, gender differences were consistent, with mean WHTR being lower in girls at all ages, reaching statistical significance except at ages 7y, 8y and 16y (P ranging between 0.01 and 0.001).

Table 2 shows the proportion of the whole cohort at yearly intervals that had a WHTR at 0.500 or above. A disproportionate number of 5 year-olds fell into this category compared with the rest of the cohort. With the exception of the 5 year-olds, slight variation in the proportion of children with a WHTR greater than or equal to 0.50 was observed between ages (range 3.5-6% in boys and 1-5% in girls). Gender differences were observed in the proportion of the cohort with a WHTR greater than or equal to 0.500, particularly from age12 years and upward.

Comparison of mean WHTR in children between Survey 1 and Survey 2

Figure 1 shows mean WHTR for boys and girls in the two surveys. This variable was considerably greater in the children from Survey 2 compared with those in Survey 1 with the differences being similar at all ages and between genders. The differences were statistically significant at all ages (P<0.0001).

Comparison of WHTR above boundary value of WHTR=0.500 in children between Survey 1 and Survey 2

Table 3 shows the proportion of children by sex with a WHTR ≥0.500 in Survey 2 using the levels of children in the survey 1 as the expected. At all ages, the proportion increased over time, with an average increase for all ages between 11 and 16 years from 5.0% to 17% in boys and from 1.5% to 11.7% in girls (P<0.01 for both).

Discussion

. When measured in conjunction with height, WC gives an index of proportionality, i.e. whether or not the amount of upper body fat accumulation in relation to height is appropriate. The WHTR in an index of this relationship and this is the first study to examine waist-height relationships in British children. Using cross-sectional data from a large national cohort, this study demonstrated that WHTR during childhood is influenced by age (and hence growth) and by gender. The significant decrease in mean WHTR between the ages of 5 and 16.9 years reflected the divergence in the velocities of growth in height and WC with age. That height and WC correlated suggested that the increase in WC in childhood is due in part to linear growth. Exactly how growth in height affects growth in WC is unclear at this stage, but this should be considered when variations in age-related WC are examined. It is expected that WHTR would plateau at around age 18 years when growth in height ceases and the mean values for WHTR for the later age groups suggested this was the case, particularly in boys. WHTR would start to increase when extra fat would start to accumulate on the upper body. WHTR in girls at all ages compared with boys reflects the differences in both body shape and body proportions between genders. Specifically, girls had lower WC values than did boys at any given height. These differences were most prominent from the age of 9 years.

The important observation in this study was the dramatic increase in WHTR in children aged between 11 and 16 years over a 20-year time span in boys and 10-year period in girls. The fact that this increase has occurred over a much shorter period of time in girls is even further cause for concern, and most likely reflects gender differences in diet and physical activity during this period. This finding agrees with other studies that have demonstrated that overweight and obesity in British children have increased recently. However, it shows that specifically central or upper body fatness has increased, perhaps to a greater extent than overall fatness, such as would be indicated through changes in BMI. This agrees with other recent findings in this area (McCarthy *et al.* 2003). However, it could be argued that secular changes in height could account for the increases in WC over time. The WHTR however takes height into account, so clearly this is not the case. Also there has been an alarming shift in the proportion of children with a WHTR greater than 0.500, which should be cause for concern, and attention should be paid to these children, as obesity-related morbidity is most likely to be present at this extreme in WHTR. A WHTR cut-off of 0.500 has been proposed as a simple means of indicating whether in adults, the amount of upper body fat accumulation is excessive and a risk to health (Ashwell *et al*. 1996). From the findings in this study, it appears on first examination, that a WHTR cut-off of 0.500 might also be an appropriate cut-off for children as well as for adults. However, in very young children, it might over-estimate the number considered at risk as well as the number of at risk boys compared with girls. In terms of percentiles and using the 1977/87 data as baselines, the 0.500 reference point corresponds to a value close the 95th centile for boys and the 97.5th centile for girls aged between 6 and 16.9 years. Although this reference point of WHTR of 0.500 has no true validity yet in children, it is not subject to the same drawbacks as the statistically based and age-and gender-related centile cut-offs. Indeed, it is probable that the 0.500 reference point would not be ideal for all ages – this is evident when examining the proportion of children aged 5.0 years who fall above this reference point compared with those children at older ages. Future research would enable us to identify more precise cut-off points that could equate to different levels of risk. In the meantime, we suggest that the simple cut-off of WHTR = 0.500 could be used in a public health context for assessing increased health risk in children relating to an excessive accumulation of body fat on the upper body or even internally. Much benefit could be gained from a simple public health message that is the same for adults and children of both sexes and all ages. It could be stated simply as ‘keep your waist circumference to less than half your height’ (McCarthy & Ashwell, 2002).

References

Ashwell, MA. The Ashwell Shape Chart- a public health approach to the metabolic risks of obesity. *Int J Obesity* 1998;**22:**(Suppl. 3):S213.

Ashwell MA, LeJeune SRE, McPherson B. Ratio of waist circumference to height may be better indicator of need for weight management. *Brit Med J* 1996;**312:**377.

Bertsias G, Mammas I, Linardakis M, Kafatos A. Overweight and obesity in relation to cardiovascular disease risk factors among medical students in Crete, Greece. *BMC Public Health* 2003;**3:**3.

Bundred P, Kitchiner D, Buchan I. Prevalence of overweight and obese children between 1989 and 1998: population based series of cross sectional studies. *Brit Med J* 2001;**322:**1-4.

British Standards Institute. Body Measurements of Boys and Girls from Birth up to 16.9 years, BS7321. London British Standards Institute. 1990.

Caprio S, Hyman LD, McCarthy S, Lange R, Bronson M, Tamborlane WV. Fat distribution and cardiovascular risk factors in obese adolescent girls: importance of the intraabdominal fat depot. *Amer J Clin Nutr* 1996;**64:**12-17.

Chinn S, Rona R. Prevalence and trends in overweight and obesity in three cross-sectional studies of British children, 1974-94. *Brit Med J* 2001;**322:**24-25.

Cole TJ, Bellizzi C, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. *Brit Med J* 2000;**320:**1240-1253.

Flodmark CE, Sveger Y, Nilsson-Ehle P. Waist measurement correlates to a potentially atherogenic lipoprotein profile in obese 12-14 year old children. *Acta Paediat* 1994;**83:**941-945.

Freedman DS, Serdula MK, Srinivasan SR, Berensson GS. Relation of circumferences and skinfold thicknesses to lipid and insulin concentrations in children and adolescents: the Bogalusa Heart Study.*Amer J Clin Nutr* 1999;**69:**308-317.

Gregory J, Lowe S *National Diet and Nutrition Survey, Young People Aged 4 to 18 Years.* London: Stationary Office, 2000.

Hara M, Saito E, Iwata F, Okada T Harada K . Waist-to-height ratio is the best predictor of cardiovascular disease risk factors in Japanese schoolchildren. *J Atheroscler Thromb* 2002;**9:**127-132.

Hsieh SD, Yoshinaga H, Muto T. Waist-to-height ratio, a simple and practical index for assessing central fat distribution and metabolic risk in Japanese men and women. *Int J Obes* 2003;**27:**610-616.

Kahn HS, Imperatore G, Cheng YJ. A population-based comparison of BMI percentiles and waist-to-height ratio for identifying cardiovascular risk in youth. *J Pedatr* 2005;**146**:482-8.

Maynard LM, Wisemandle W, Roche AF, Chumlea WC, Guo SS, Siervogel RM. Childhood body composition in relation to body mass index. *Pediatrics* 2001;**107**:344-350.

McCarthy HD, Ashwell M. Waist:height ratios in British children aged 5-16 years : a suggestion for a simple public health message – 'keep your waist circumference to less than half your height'. *Proc Nutr Soc* 2002;**61**:116A.

McCarthy HD, Jarrett KV, Crawley HF. Development of waist circumference percentiles in British children aged 5.0-16.9 years. *Eur J Clin Nutr* 2001;**55:**902-907.

McCarthy HD, Ellis SM, Cole, TJ. Dramatic increases in central overweight and obesity in British children aged 11-16 year: cross-sectional surveys of waist circumference. *Brit Med J* 2003;326:624-627.

Moreno LA, Fleta J, Mur L, Sarria A, Bueno M. Fat distribution in obese and non-obese children and adolescents. *J Paed Gastr Nutr* 1998;**27:**176-180.

Reilly JJ, Dorosty AR, Emmett PM. Prevalence of overweight and obesity in British children: cohort study. *Brit Med J* 1999;**319:**1039.

Reilly JJ, Dorosty AR, Emmett PM & the ALSPAC Study Team. Identification of the obese child: adequacy of the body mass index for clinical practice and epidemiology. *Int J Obes* 2000;**24:**1623-1627.

Sargeant LA, Bennett FI, Forrester TE, Cooper RS, Wilks RJ. Predicting incident diabetes in Jamaica: the role of anthropometry. *Obes Res* 2002;**10:**792-798.

Savva, SC, Tornaritis, M *et al*. Waist circumference and waist-to-height ratio are better predictors of cardiovascular disease risk factors in children than body mass index. *Int J Obes* 2000;**24:**1453-458.

Taylor RW, Jones IE, Williams SM, Goulding A. Evaluation of waist circumference, waist-to-hip ratio and the conicity index as screening tools for high trunk fat mass, as measured by dual-energy X-ray absorptiometry, in children aged 3-19 years. *Amer J Clin Nutr* 2000;**72:**490-495.

Ulijaszek SJ, Kerr DA. Anthropometric error and the assessment of nutritional status. *Brit J Nutr* 1999;**82:**165-177.

WHO. Physical Status: The use and interpretation of anthropometry. Geneva: Technical Report Series 854. 1995.

Figure 1.

Waist:height ratios in British boys and girls aged 11-16 years.
Values = mean ± SE; BSI survey (circles), NDNS (triangles); boys (dotted line), girls (solid line). * $P<0.0001$ vs BSI.

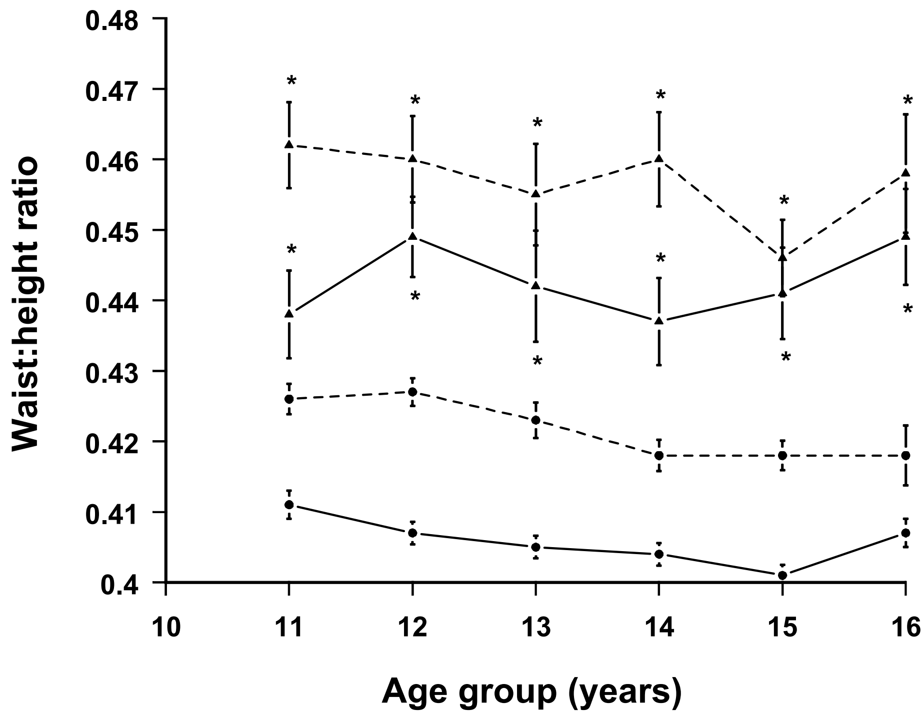
0.48
0.47
0.46
0.45
0.44
0.43
0.42
0.41
0.4
Waist:height ratio
10
11
12
13
14
15
16
Age group (years)

Table 1. Mean (SD) WHTR at yearly intervals in British boys and girls (BSI survey)

Age (y)	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Boys	.468	.451	.442	.432	.433	.427	.426	.427	.423	.418	.418	.418
	.029	.029	.031	.032	.035	.035	.038	.036	.044	.036	.035	.039
Girls	.460*	.445*	.439	.428	.421*	.412*	.411*	.407*	.405*	.404*	.401*	.407
	.030	.030	.033	.033	.033	.036	.037	.031	.033	.031	.030	.033
Difference	.008	.006	.003	.004	.012	.015	.015	.020	.018	.014	.017	.011

**P*<0.0001 vs boys

Table 2. Percentage of children with a WHTR at 0.500 or above (Survey 1)

Age (y)	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Boys												
(n)	251	349	331	332	329	355	310	337	298	270	278	88
(%)	14	5.0	4.5	3.5	5.5	4.0	5.5	5.5	6.0	4.0	3.5	5.5
Girls												
(n)	406	398	384	416	396	373	361	393	395	407	413	265
(%)	8.0	4.0	3.0	2.5	2.5	5.0	3.0	1.0	1.0	1.0	1.0	2.0

Table 3. Children (Survey 2) with a WHTR at 0.500 or above compared with expected (Survey 1). Values are numbers with percentages.

Boys

Age (y)	**11**	**12**	**13**	**14**	**15**	**16**	**Total**
n	82	61	59	66	65	57	390
0.500 cut-off	15**	10*	10*	13**	7*	11**	66*
Actual %	18.3	16.4	17	19.7	10.8	19.3	17
Expected %	5.5	5.5	6.0	4.0	3.5	5.5	5.0

Frequencies significantly different from expected values (%).
*$P<0.01$

Girls

Age (y)	**11**	**12**	**13**	**14**	**15**	**16**	**Total**
n	65	75	55	63	61	64	383
0.500 cut-off	7*	12**	8**	5**	7**	6*	45**
Actual %	10.8	16	14.5	7.9	11.5	9.4	11.7
Expected %	3.0	1.0	1.0	1.0	1.0	2.0	1.5

Frequencies significantly different from expected values (%).
*$P<0.001$