Self-reported waist circumference compared with the 'Waist Watcher' tape-measure to identify individuals at increased health risk through intra-abdominal fat accumulation

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We evaluated the accuracy of self-reported home-assessed and self-measured waist circumference in 101 men and eighty-three women aged 28–67 years. The main outcome measures were subjects' self-reported and self-measured waist circumference, and self-classification according to the previously defined waist action level 1 (940 mm in men, 800 mm in women) and action level 2 (1020 mm in men, 880 mm in women), and waist circumference measured by the investigator using the 'Waist Watcher' tape-measure, as the reference method. The mean errors (95 % CI limits of agreement) for subjects' self-reported waist circumference (self-reported minus reference; mm) were –67 (95 % CI –210, 77) in men and –43 (95 % CI –211, 123) in women, and for self-measured waist circumference (mm) using the 'Waist Watcher' (self-measured minus reference) were –5 (95 % CI –62, 52) in men and –4 (95 % CI –50, 42) in women. The proportions of subjects classified into waist action level 1 or action level 2 by the investigator were used as the reference method. Self-reported waist circumference of men and women respectively would be classified correctly in different categories based on action level 1 with sensitivities of 58·3 and 78·7 %, and specificities of 92·5 and 91·7 %, and action level 2 with sensitivities of 35·3 and 44·9 %, and specificities of 98·5 and 90·7 %. Using the 'Waist Watcher' with different colour bands based on the action levels, male and female subjects respectively classified themselves into correct categories according to action level 1 with sensitivities of 100 and 95·7 %, and specificities of 95·1 and 97·2 %, and according to action level 2 with sensitivities of 97·1 and 100 %, and specificities of 100 % for both sexes. Only 2 % of the sample misclassified themselves into the wrong categories according to waist circumference action levels. In conclusion, people tend to underestimate their waist circumference, but the 'Waist Watcher' tape-measure offers advantages over self-reported home-assessed measurement, and may be used as a screening tool for self-classifying the risk of ill health through intra-abdominal fat accumulation.

Abdominal fat distribution: Health promotion: Waist circumference

Obesity is increasing by 2–5 % per decade and has now reached an epidemic proportion, affecting more than 15 % in most Western countries (Kuczmarski, 1992; Seidell, 1995). On the basis of current epidemiology and trends, targets set by health authorities to reduce the rising prevalence by the year 2000 will inevitably fail. People in the UK and other urban societies are increasingly suffering from a catalogue of symptoms of obesity and secondary diseases, including tiredness, sweating, breathlessness, back pain, arthritis, menstrual and fertility disorders, cardiovascular disease, non-insulin-dependent diabetes mellitus and several major cancers. These lead to impaired quality of life, depression and premature death. Recent estimates

of annual costs for treating obesity are £195 million in Britain (Office of Health Economics, 1994) and $70 billion in the USA (Institute of Medicine, 1995). These estimates, coupled with the lack of public awareness in self-assessment of obesity and a sense of medical impotence in management, urge the development of new strategies. Clinical guidelines for improved medical management are available in several countries (German Society of Obesity Research, 1995; Institute of Medicine, 1995; Scottish Intercollegiate Guidelines Network, 1996).

Health promotion and bathroom scales have hitherto made no impact on the upward trend in overweight and obesity. Given the complex interactions between cosmetic

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Fig. 1. The 'Waist Watcher' tape-measure. (Further information on the pamphlet containing photographic instructions for measuring waist circumference can be obtained from the authors.)

and health impact of body shape and size, a waist circumference reduction is a rewarding consequence of slimming and has been suggested as a better motivator than weight change (Egger *et al.* 1995). We have recently proposed the use of waist circumference as a simple method for detecting overweight (BMI) and central fat distribution (waist:hip ratio; Lean *et al.* 1995), and for identifying people with cardiovascular risk factors (Han *et al.* 1995, 1996). The values for waist circumference action level 1 (940 mm in men, 800 mm in women) and action level 2 (1020 mm in men, 880 mm in women) were identified for health promotion to alert people to increasing health risks (Lean *et al.* 1995). A 'Waist Watcher' tape-measure (patent pending) was manufactured specifically for the present study based on these action levels (Fig. 1). The present study was designed to evaluate the 'Waist Watcher' tape-measure in self-measurement and self-classification of waist circumference categories according to the action levels.

Methods

Subjects

A subsample of subjects who had participated in the fourth Glasgow MONICA coronary risk factor survey 1 year previously were recalled by letter and telephone. Their selection was based on the predetermined values, according to their previous measured waist circumference and age, available from the fourth Glasgow MONICA database. From these subjects, quota sampling was used in order to assign an approximately equal number to each of the twelve subgroups defined by sex, waist-circumference action levels (below action level 1, between action level 1 and action level 2, and above action level 2), and age (below and above 50 years). Subjects were randomized within each subgroup. One group received general advice about weight management and were given the 'Waist Watcher' tape-measure and guidance in its use (101 men and eighty-three women) to monitor their waist circumference. The other group, serving as controls, did not receive advice or the tape-measure (100 men and seventy-eight women). In the present study, the 101 men and eighty-three women who received the 'Waist

Watcher' were analysed, comparing their baseline self-reported home-assessed, self-measured and self-classified waist circumference according to the action levels with those made by the investigator.

Anthropometry

Subjects' self-reported home-assessed measurements. Subjects were asked to complete a postal questionnaire about current body weight, height, waist and hip circumferences measured at home by themselves and to bring it with them for a visit to the Department of Human Nutrition, Glasgow Royal Infirmary.

Subjects' self-measured waist circumference using the 'Waist Watcher' tape-measure. Of the 362 subjects recruited, 184 subjects were randomly assigned to receive the 'Waist Watcher' tape-measure to monitor their waist circumference. This group was asked to use the 'Waist Watcher' to measure their waist circumference themselves at the Royal Infirmary. This tape-measure (Fig. 1) was made to help subjects measure their waist circumference easily. The tape is made into a complete loop and fitted firmly around the waist by a spring mechanism, controlled by a push-button. This allows subjects to have their hands free for adjusting the tape. The measurement could be conveniently read by removing the tape from the waist, which was particularly helpful to overweight subjects who found it hard to read bending down. The tape had the conventional numbers in centimetres and inches on each side, and three colour bands separated by action levels: green band to indicate waist circumference below action level 1 (<940 mm in men, <800 mm in women); amber band between action level 1 and action level 2 (940–1020 mm in men, 800–880 mm in women); and red band above action level 2 (≥1020 mm in men, ≥880 mm in women). The meaning of the band colours was explained in the handout *Recommendations for Weight Management*, which included a set of step-by-step photographic instructions to guide subjects as to how to measure their waist circumference without any assistance from the investigator.

Subjects' waist circumference measured by investigator using 'Waist Watcher' tape-measure. After the subjects had finished measuring their waist circumference using the 'Waist Watcher' tape-measure, they were asked to have their waist circumference measured by the investigator, thus subjects did not know beforehand that their measurement of the waist would be checked. Also, the investigator did not see the subjects' measurement values. Weight, height and hip circumference were also measured according to the World Health Organization (1995) recommendations. The 'Waist Watcher' tape-measure was used by the investigator to measure subjects' circumferences. A 'standard' steel tape (Holtain, Crymych, Dyfed, UK) was also used and gave identical readings.

Analysis

The accuracy of the subjects' self-reported home-assessed waist circumference, self-measured and self-classification of waist circumference into categories according to the action levels using the 'Waist Watcher' tape-measure,

Table 1. Characteristics of 101 men and eighty-three women participating in the study*

(Mean values and standard deviations, with ranges)

	Men				Women			
	n	Mean	SD	Range	n	Mean	SD	Range
Self-reported, home-assessed measurements†								
Age (years)	101	51·7	10·1	27·9–66·6	83	49·7	10·5	28·6–67·2
Weight (kg)	101	83·7	15·1	57·2–120·8	83	70·3	13·4	50·8–108·1
Height (m)	101	1·72	0·07	1·58–1·90	83	1·58	0·06	1·48–1·72
BMI (kg/m^2)	101	28·1	4·5	19·8–39·7	83	28·1	5·7	18·9–45·2
Waist circumference (mm)	100	922	102	711–1270	83	806	122	584–1118
Hip circumference (mm)	34	987	130	813–1372	80	1012	96	762–1270
Waist:hip ratio	34	0·94	0·11	0·75–1·19	80	0·80	0·09	0·65–1·10
Waist circumference by subjects using 'Waist Watcher' tape-measure								
Waist circumference (mm)	101	981	119	730–1300	83	844	130	650–1160
Measurements by investigator								
Weight (kg)	101	84·2	15·8	53·9–126·6	83	70·9	13·2	51·5–108·1
Height (m)	101	1·74	0·07	1·58–1·91	83	1·61	0·06	1·47–1·72
BMI (kg/m^2)	101	27·9	4·7	18·4–40·9	83	27·6	5·6	19·5–44·9
Waist circumference (mm)	101	986	128	712–1293	83	849	128	657–1165
Hip circumference (mm)	101	1048	78	890–1300	83	1054	99	870–1372
Waist:hip ratio	101	0·94	0·07	0·75–1·13	83	0·80	0·07	0·68–0·97

* For details of subjects and procedures, see p. 82.
† Self-reported home-assessed values by subjects were in empirical units and converted to metric units for analysis.

were compared with those made by the investigator using the 'Waist Watcher' tape-measure, which were considered as the reference method. Statistical and graphical presentation based on Bland & Altman's (1986) methods were used to characterize the biases, errors and 95 % CI limits of agreement of measurements in relation to waist size in each sex group. The proportions of subjects classified into categories of waist-circumference action levels based on their waist circumference measured by the investigator were used as reference group: large waist groups were considered as above action level 1 (≥940 mm men, ≥800 mm in women) or above action level 2 (≥1020 mm in men and ≥880 mm in women). Sensitivities and specificities (Armitage, 1971) were calculated to assess subjects' ability to classify themselves correctly into categories according to waist-circumference action level 1 or action level 2. The errors of self-reported hip circumference, weight,

height and derived indices, including waist:hip ratio and BMI were also analysed.

Results

Characteristics of subjects

Table 1 shows that the mean values for self-reported measurements and those made by the trained investigator were similar. Nearly all subjects reported all the measurements, although only 34 % of the men were able to provide their hip measurement. This suggests that some of the reported values were based on clothes sizes, not measurements.

Table 2 shows that according to the reference measurement made by the investigator, the percentage of subjects with waist circumference below action level 1 was about

Table 2. Proportions of subjects in different categories of waist-circumference action levels identified from measurements made by investigator (reference), from self-reported and from subjects' self-measurements using the 'Waist Watcher' tape-measure*

Waist circumference, based on action levels†	By investigator (reference)		Self-reported		Self-measured	
	n	%	n	%	n	%
Men (n 101)						
<940 mm	41	40·6	62	62·0	39	38·6
940–1020 mm	26	25·7	25	25·0	29	28·7
≥1020 mm	34	33·7	13	13·0	33	32·7
Women (n 83)						
<800 mm	36	43·4	43	51·8	37	44·6
800–880 mm	18	21·7	22	26·5	17	20·5
≥880 mm	29	34·9	18	21·7	29	34·9

* For details of subjects and procedures, see pp. 82–83.
† Action level 1 940 mm in men, 800 mm in women; action level 2 1020 mm in men, 880 mm in women (Lean et al. 1995).

Table 3. Mean errors and 95 % CI limits of agreement, and bias in self-reported and self-measured anthropometry in relation to reference values measured by investigator*

	n	Mean error†	SD	95 % CI limit of agreement (mean error and 2 SD)	Bias (r)‡	Statistical significance P
Men						
Waist circumference by 'Waist Watcher' (mm)§	101	−5	29	−62, 52	−0·40	<0·001
Waist circumference (mm)‖	100	−67	73	−210, 77	−0·58	<0·001
Hip circumference (mm)‖	34	−59	103	261, 143	0·01	0·953
Weight (kg)‖	101	−0·6	3·1	−6·7, 5·5	−0·33	0·001
Height (m)‖	101	−0·01	0·02	−0·05, 0·03	−0·17	0·081
Body mass index (kg/m²)¶	101	0·2	1·2	−2·2, 2·6	−0·24	0·014
Waist:hip ratio¶	34	0·00	0·11	−0·22, 0·22	−0·44	0·010
Women						
Waist circumference by 'Waist Watcher' (mm)§	83	−4	23	−50, 42	−0·04	0·721
Waist circumference (mm)‖	83	−43	85	211, 123	−0·41	<0·001
Hip circumference (mm)‖	80	−38	64	163, 87	−0·31	0·005
Weight (kg)‖	83	−0·6	2·7	−5·9, 4·7	−0·01	0·919
Height (m)‖	83	−0·02	0·03	−0·07, 0·03	−0·21	0·055
Body mass index (kg/m²)¶	83	0·5	1·6	−2·6, 4·7	−0·06	0·567
Waist:hip ratio¶	80	−0·01	0·09	−0·19, 0·17	−0·37	0·001

* For details of subjects and procedures, see p. 83.
† Self-measured minus reference or self-reported minus reference values (measured by investigator).
‡ Correlations between errors of self-reported or self-measured anthropometry with reference values.
§ Errors and bias in self-measured waist circumference by subjects using 'Waist Watcher' tape-measure.
‖ Errors and bias in self-reported home-assessed measurements.
¶ Errors and bias in indices derived from self-reported values.

40 and that above action level 2 was about 35. Subjects tended to under-report their waist circumference, such that there were fewer numbers in the highest (above action level 2) waist circumference category based on self-reported waist measurement. The distribution of subjects in each category based on waist circumference measured by subjects themselves using the 'Waist Watcher' was almost identical to the reference measurement.

Errors and biases in self-reported home-assessed waist circumference in relation to waist size

Table 3 and Fig. 2(a and b) show that the errors of self-reported home-assessed waist circumference from subjects (self-reported minus reference) were −67 mm (95 % CI −210, 77) in men and −43 mm (95 % CI −211, 123) in women. There was a systematic bias in errors of self-reported waist circumference in men (r −0·58, P <0·001) and in women (r −0·41, P < 0·001) of different waist size, i.e. subjects with a smaller waist tended to overestimate and those with a larger waist to underestimate their waist size, compared with the reference values.

Errors and biases in self-measured waist circumference in relation to waist size

Table 3 and Fig. 3(a and b) show that the errors of waist circumference measured by subjects using 'Waist Watcher' tape-measure (self-measured minus reference) were −5 mm (95 % CI −62, 52) in men and −4 mm (95 % CI −50, 42) in women. There was a systematic bias in errors of self-measured waist circumference (r −0·40, P = 0·01) in men of different waist size (Table 3, Fig. 3(a)), i.e. men with a smaller waist tended to obtain higher waist measurements and those with a larger waist tended to obtain lower waist

measurements, compared with the reference values. No bias in the errors of self-measured waist circumference was observed (r 0·04, P = 0·72) in women of different waist size (Table 3, Fig. 3(b)). The variability (spread) in the errors of self-measured waist circumference was similar throughout the range of waist circumference, i.e. subjects with a larger waist gave the same limits of errors as those with a smaller waist (Fig. 3(a and b)).

Biases in self-reported and self-measured waist circumference in relation to age

There were no significant systematic biases in the errors of self-reported waist circumference with age in men (r 0·08, P = 0·43) and in women (r −0·06, P = 0·61), or in the errors of self-measured waist circumference with age in men (r 0·06, P = 0·53) and in women (r −0·09, P = 0·43). In younger men and younger women below 40 years, the variability of errors of self-measured waist circumference was less than that in the older groups.

Sensitivities and specificities in the identification of subjects with a large waist circumference based on self-reported home-assessed and self-measured waist circumference

In Table 4, subjects in categories of waist-circumference action level 1 or action level 2 identified by the investigator were used as reference. Self-reported waist circumference of men and women respectively would be classified correctly in different categories based on action level 1 with sensitivities of 58·3 and 78·7 %, and specificities of 92·5 and 91·7 %, and action level 2 with sensitivities of 35·3 and 44·9 %, and specificities of 98·5 and 90·7 %. With the aid of the 'Waist Watcher' tape-measure and photographic instructions, men and women respectively self-classified
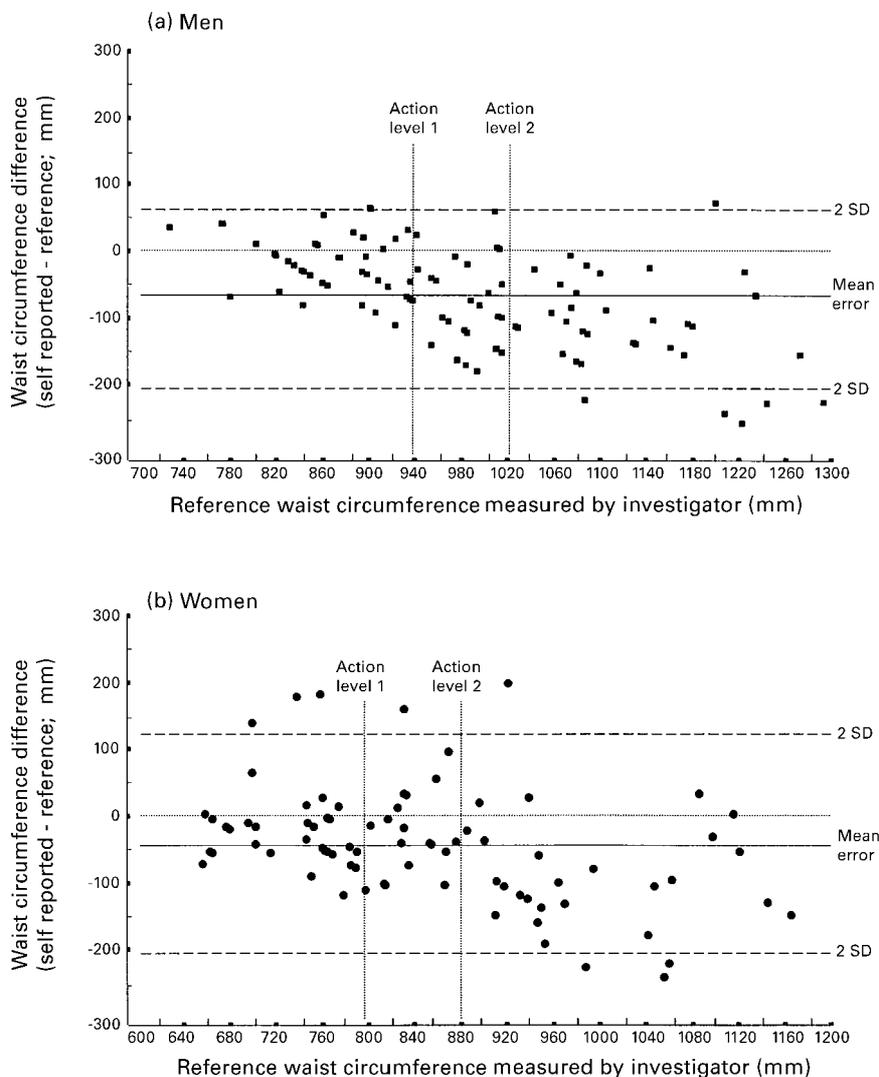
Fig. 2. Plots of errors of self-reported waist circumference (subjects' self-reported values minus reference values measured by investigator) *v.* reference values, in 101 men (a) and eighty-three women (b). (—), Mean error; (− − −), 95 % CI limits of agreement (2 SD of the mean error). For details of subjects and procedures, see p. 82. (a) $r -0.58$, $P < 0.001$; (b) $r -0.41$, $P < 0.001$.

their waist circumference correctly according to action level 1 with sensitivities of 100 and 95·7 %, and specificities of 95·1 and 97·2 %, and according to action level 2 with sensitivities of 97·1 and 100 %, and specificities of 100 % (both sexes). There were less than 2 % of subjects who misclassified themselves into the wrong categories of waist circumference based on the action levels.

Errors and biases in self-reported measurements of other anthropometric measurements

Table 3 shows that hip circumference was under-reported by 60 mm in men and 40 mm in women. There was no bias in self-reported values in men of different hip sizes (r 0·01, $P = 0.953$), and a systematic bias in women ($r -0.32$, $P = 0.005$), i.e. women with larger hips tended to under-report more than those with smaller hips. The mean errors

of waist:hip ratio derived from self-reported waist and hip circumferences were close to zero in both sexes, but there was a significant bias of the errors both in men ($r -0.44$, $P = 0.010$) and in women ($r -0.37$, $P = 0.001$), thus subjects with a high waist:hip ratio tended to underestimate their waist:hip ratio more than those with a lower waist:hip ratio. Both sexes underestimated their weight by about 0·5 kg, and height by 10 mm in men and 20 mm in women. There was a significant bias in errors of weight in men ($r -0.33$, $P = 0.001$) but not in women ($r -0.01$, $P = 0.919$), and no systematic bias in the errors of self-reported height for both sexes. The BMI derived from self-reported weight and height was overestimated by 0·2 kg/m^2 by men and 0·5 kg/m^2 by women. Men with a high BMI tended to underestimate their BMI compared with men with a lower BMI ($r -0.24$, $P = 0.014$). There was no significant bias in the errors of BMI in women.
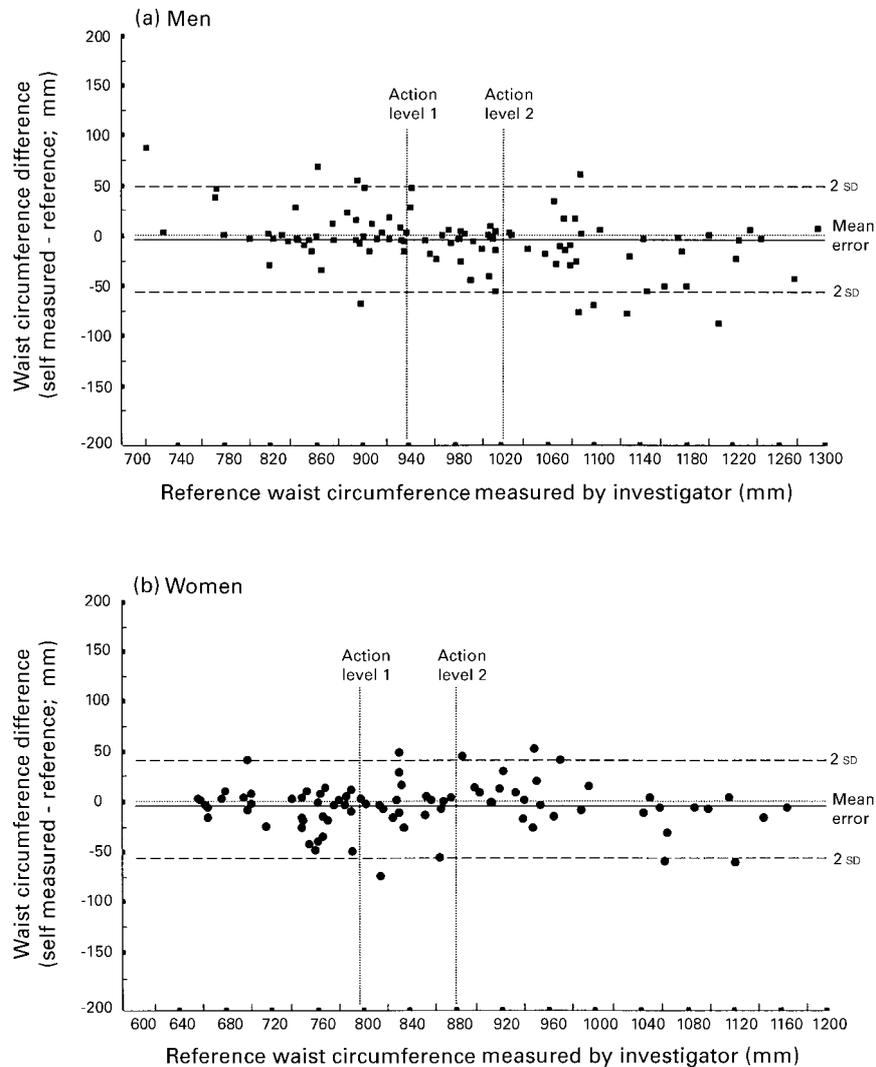
Fig. 3. Plots of errors of self-measured waist circumference using 'Waist Watcher' tape-measure (subjects' self-measured values minus reference values measured by investigator) *v.* reference values, in 101 men (a) and eighty-three women (b). (—), Mean error; (– – –), 95 % CI limits of agreement (2 SD of the mean error). For details of subjects and procedures, see p. 82. (a) r −0·40, $P < 0·01$, (b) r 0·04, $P = 0·72$.

Discussion

We have addressed the public health needs, using a single measurement of waist circumference to alert the general public to their risks of ill health, and their need to seek professional help based on the action levels of waist circumference (Lean *et al.* 1995). Both men and women under-reported their waist circumference, thus the specificities for classification of subjects into the lower categories of waist-circumference action levels were high (>90 %), but the sensitivities for identifying those with a larger waist in higher categories of waist-circumference action levels were relatively low (58–79 % based on action level 1 and 35–45 % based on action level 2). With the aid of the 'Waist Watcher' tape-measure (Fig. 1) and photographic instructions which were designed specifically for the present study to help subjects measure their waist easily, most subjects could identify themselves correctly in different categories of waist circumference according to the action levels with sensitivities and specificities above 95 %. Thus, the 'Waist Watcher' tape-measure provides a useful screening tool in health promotion for self-classification of increased health risk through intra-abdominal fat accumulation, which otherwise would be missed from self-reported waist circumference.

Our previous findings indicate clearly that large waist circumference is associated with symptoms of obesity and secondary diseases (Han *et al.* 1995, 1997*a*, *b*; Seidell *et al.* 1997; Lean *et al.* 1998) imposing enormous burdens of ill health on health services and society. Waist circumference as an index of adiposity is minimally influenced by height (Han *et al.* 1997*c*), although height does have an influence on health which is independent of adiposity. Thus, a single measurement of waist circumference is a valid and simple indicator of ill health. If waist circumference is to be used for health promotion programmes for weight management

Table 4. Sensitivities and specificities of the identification of subjects into different waist circumference action level categories based on their reported and self-measured waist circumference, using groups classified from measurements made by the investigator as reference*

	Self-reported† waist circumference		Self-measured‡ waist circumference	
	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)
Men (*n* 101)				
Action level 1 (940 mm)	58·3	92·5	100	95·1
Action level 2 (1020 mm)	35·3	98·5	97·1	100
Women (*n* 83)				
Action level 1 (800 mm)	78·7	91·7	95·7	97·2
Action level 2 (880 mm)	44·9	90·7	100	100

* For details of subjects and procedures, see p. 82.
† Waist circumference was reported by subjects from home assessment.
‡ Self classification into waist circumference categories by subjects was aided by 'Waist Watcher' tape-measure (Fig. 1) and photographic instructions.

among the general public, it is essential that the subjects should be able to measure their waist correctly. Some previous studies have found waist circumference measured by trained observers to be reliable (Hall & Young, 1989; Rimm *et al*. 1990; Ferrerio *et al*. 1995). In these studies, conventional tape-measures were used, and these may be problematic for the very obese who cannot see their waist. The 'Waist Watcher' allows a more reliable 'blind' measurement. The present study found that the variability of errors (spread of errors about the mean error) of self-measured waist circumference was similar in subjects of different waist size (Fig. 3(a and b)), and younger people were able to measure their waist more accurately than older groups. In the present study, while nearly all subjects were able to report all home-assessed measurements, only 34 % men offered a hip measurement. These results provide further support for the use of a single measurement waist circumference in health promotion directed at the general public.

A recent study on self-reported weight and height in British teenagers (16–17 years) found that shorter and fatter individuals overestimated their height and underestimated their weight, while conversely taller and thinner subjects underestimated their height (Crawley & Portides, 1995). The agreement between self-reported and measured values for height and weight were within 10 mm and 1 kg respectively, but they varied (95 % CI) by 70 mm and 7 kg respectively (Nakatsuka *et al*. 1995). In the present study, subjects with a large waist size or high waist:hip ratio tended to underestimate their waist circumference and waist:hip ratio. There was no evidence for women with a high body weight or BMI to under-report weight or BMI respectively. These results suggest that subjects were more concerned about their body shape than body mass, such that there was a bias towards reporting a body shape that is less related to abdominal fat accumulation. Including the 100 men and seventy-eight women from the control group for analysis showed an almost identical result in errors and bias of self-reported anthropometric measurements (data not presented).

The present study is part of a larger prospective study.

At baseline, waist size self-reported and self-measured by the subjects using the 'Waist Watcher' tape-measure were compared with that measured by the investigator. Subjects will be recalled to assess the effectiveness of the 'Waist Watcher' tape-measure, used as a motivational tool to prevent weight gain in those with a waist circumference below action level 1, and to encourage weight loss in those with a waist circumference above action level 1. In addition, comparisons between weight and height measured by the investigator and those reported by the subjects, and the influences of body image perception on the differences between self-reported or self-measured anthropometry and assessment by an investigator will be evaluated.

The practical value of this research is that a single measurement of waist circumference can be adopted confidently both by health professionals and the general public as a tool for alerting individuals who need weight management. Health promotion can contribute to weight management by alerting individuals to their level of risk and the need to take action. This implies the need to establish specialized obesity clinics to serve these needs. Individuals with a waist circumference below action level 1 do not need to lose weight but should be aware of potential health risks if their waist exceeds this level. In the range between action level 1 and action level 2, individuals should not further gain weight, but implement lifestyle modification such as increasing physical activity level and some self-weight management. Individuals above action level 2 should be urged to take action and to seek professional help to achieve sustained weight loss. These waist-circumference action levels have already been recognized by epidemiologists in the field of public health (Björntorp, 1997; Carey *et al*. 1997), and adopted for national health promotion by British Diabetic Association (Walker, 1997), Health Education Board for Scotland (1997), Scottish Intercollegiate Guidelines Network (1996), and the recent National Health and Medical Research Council Working Party on the Prevention of Overweight and Obesity (1997) in Australia. A loss of 50–100 mm in individuals with waist circumferences above the action levels is likely to lead to improved cardiovascular risk factors (Han *et al*. 1997*a*).

Conclusions

A 'Waist Watcher' tape-measure with photographic instructions offers advantages over self-reported measurement of waist circumference in self-classifying waist size, and provides a useful tool for screening people at increased health risk through intra-abdominal fat accumulation.

Acknowledgements

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