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Waist to Height Ratio Is a Simple and Effective Obesity Screening Tool for Cardiovascular Risk Factors: Analysis of Data from the British National Diet and Nutrition Survey of Adults Aged 19–64 Years

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Key Words

Central obesity · Central fat distribution · Waist to height ratio · Waist circumference, BMI · Cardiovascular CVD risk factors

Summary

Objective and Method: To analyse data from the nationally representative National Diet and Nutrition Survey (NDNS) collected in 2000/2001 and to investigate how the BMI and two proxy indicators of central fat distribution, namely the waist circumference and the waist to height ratio (WHtR), are associated with each other and with cardiovascular disease (CVD) risk factors. **Results:** Screening health risk by BMI alone would 'miss' 35% of men and 14% of women who are within the normal BMI range (18.5–25 kg/m^2) but have central fat distribution, defined by WHtR > 0.5. In the total population this equates to 17% of all men and 6% of all women who would be inadequately screened by BMI alone. Compared to BMI, WHtR was more closely associated with CVD risk factors among both men and women. Furthermore, in a combined analysis of men and women, central fat distribution with a normal BMI was associated with higher levels of CVD risk factors than being overweight without central fat distribution. **Conclusion:** WHtR is a simple and effective, non-invasive screening tool for CVD risk factors. Our proposed boundary value of 0.5 translates into a simple public health message: 'Keep your waist circumference to less than half your height'.

Introduction

Obesity, particularly excess visceral fat, is associated with an increased risk of cardiovascular disease and mortality [1]. BMI has become the most widely accepted index of obesity and a proxy for total body fatness, but it does not differentiate between the over-muscled and the over-fat or distinguish between individuals with different types of fat distribution [2, 3]. Jean Vague [4, 5] first pointed out in the mid 20th century that people with a 'central' type of fat distribution (android shape) were at greater health risk than those whose fat was deposited 'peripherally' (gynoid shape). Only in the last 2 decades has there been a consensus view that health risks (predominantly cardiovascular disease (CVD) and diabetes) can be determined as much by the relative distribution of the excess fat as by its total amount. The use of imaging techniques such as computed tomography (CT) [6] and magnetic resonance imaging (MRI) [7] has subsequently indicated that central obesity ('apple' shape) is associated with a preferential deposition of fat in the internal, visceral fat depots rather than the external, subcutaneous fat depots ('pear' shape).

Relative fat distribution, as measured by the ratio of waist circumference to hip circumference (WHR), was popular for many years and is a good predictor of health risk [8]. However, although very useful for risk assessment, WHR is not always helpful in a risk management because both waist and hip can decrease with weight reduction and so the ratio of WHR can sometimes change very little. Another problem is that WHR requires measurements of 2 circumferences. Although our dataset allowed calculation of WHR, this index was not considered further in our study, since we do not believe that WHR is useful in a public health context as its use does not always motivate risk reduction.

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Much attention has subsequently been given to the use of waist circumference for risk assessment and management [9, 10], as this is more strongly correlated with visceral fat than WHR. The widely used cut-points [11], namely 102 cm for men and 88 cm for women, were originally intended as a simpler alternative to BMI cut-offs indicating a need for weight reduction. Different thresholds may however be needed for men and women, for different ages, and for ethnic groups [12]. Furthermore, a report from Japan showed a difference in metabolic risks between people of similar waist circumference with different heights [13].

In 1995 and 1996, another anthropometric index, waist to height ratio (WHtR), was shown to be better associated with metabolic risk factors. Researchers in Japan [14, 15] and the UK [16, 17] suggested that the same boundary value for risk (WHtR 0.5) might be used for both men and women. A boundary value of WHtR 0.6 was also proposed to indicate central obesity or more severe risk [18]. Collaborative work between these authors has continued to promote the use of WHtR for adults of all ethnic groups and for children [19]. Further, a recent meta-analysis [20] comparing the area under the curve from receiver-operating characteristics (ROC) analyses of various anthropometric indices and CVD risk factors showed that WHtR was the best discriminator for hypertension, diabetes, and dyslipidaemia in both sexes (i.e. better than BMI, waist circumference, and WHR). These authors have supported the previously suggested boundary value of 0.5.

We investigated the strength of association between various proposed indices of obesity, central obesity, and CVD risk factors using original data from the National Diet and Nutrition Survey (NDNS) of adults aged 19–64 years [21]. The fact that this survey is nationally representative makes it acceptable to generalise the results to the total population.

Measurements of weight, height, and waist circumference allowed us to investigate two proxy indicators of central fat distribution and central obesity, namely waist circumference and WHtR, as well as BMI, and to relate these to CVD risk factors, namely systolic blood pressure (SBP) and diastolic blood pressure (DBP), total cholesterol (TC), plasma non-HDL cholesterol (non-HDL-C), and plasma HDL cholesterol (HDL-C).

Methods

Measurements of Anthropometric Characteristics

In the NDNS, anthropometric data (weight, height, and waist circumference) were collected on 1,776 individuals who were representative of British adults aged between 19 and 64 years.

Measurements of standing height, weight, waist, and hip circumferences were each taken twice by interviewers trained in accurate measurement techniques [21]. Subjects were asked to remove their shoes and socks and to wear only light clothing. Weight was taken using Soehnle Quantratronic scales, (100 gram units) calibrated prior to the start of field-work. Height was measured using the Leicester Height Measure. Waist circumference measurement was taken at the midway point between the iliac crest and the lower rib at the end of a normal expiration.

Definitions of Anthropometric Characteristics

In this paper, we have used the terms, definitions, and boundary values shown in table 1.

Measurements of Blood Pressure and CVD Risk Factors

Methods for blood pressure measurement and measurements of blood analytes (TC, non-HDL-C, HDL-C) are given in the published NDNS report [21].

Statistical Data Analysis

Data files were obtained from the Data Archive (*www.data-archive.ac.uk*) and relevant variables extracted. All analyses were conducted using SPSS version 16.0 and 17.0 (SPSS UK, Surrey, UK).

Normally distributed continuous variables have been summarised by means and standard deviations. Categorical variables are presented as percentages and compared with a chi-square test. Partial correlation coefficients were calculated between each anthropometric index and SBP, DBP, TC, HDL-C, and non-HDL-C after controlling for age and sex (for the whole sample) and age only (for each gender). Analysis of covariance (adjusted for age (years) and sex) was used to compare the 4 groups classified using dual criteria (BMI and WHtR). Pair-wise contrasts were performed with 'Bonferroni' correction for multiple comparisons. P-values of <0.05 (2-tailed test) were regarded as significant, although actual p-values are also quoted.

Results

Details of Subjects

Table 2 shows the mean values for anthropometric variables. All analyses are based on the sample of 1,776 adults who provided data for all 3 variables of relevance to this study (weight,

Table 1. Definitions and boundary value used

Measurements	Term	Definition
Weight and height	overweight	BMI > 25
Weight and height	total obesity	BMI > 30
Waist circumference	central fat distribution	waist circumference > action level 1*
Waist circumference	central obesity	waist circumference > action level 2*
Waist circumference and height	non-central fat distribution – 'pears'	WHtR ≤ 0.5
Waist circumference and height	central fat distribution – 'apples'	WHtR > 0.5
Waist circumference and height	central obesity	WHtR > 0.6

*NICE guidelines [63].
Waist circumference action level 1 = >80 cm (women) or >94 cm (men); waist circumference action level 2 = >88 cm (women) or >102 cm (men).

height, and waist circumference). Their mean age (42 years, SD = 12 years) was identical to that of the total sample (n = 2,251).

Relationship of Anthropometric Indices with Each Other

BMI, waist circumference, and WHtR were all strongly correlated with each other ($p < 0.0001$) (age- and sex-adjusted coefficients: 0.844 (BMI vs. waist), 0.86 (BMI vs. WHtR), 0.95 (waist vs. WHtR)). Correlations for men and women separately are shown in table 3.

Relationship of Anthropometric Indices with CVD Risk Factors

Table 3 shows that, for all CVD risk factors, correlation coefficients were higher for WHtR than for BMI in both men and women. Correlations were fair ($r > 0.25$) for HDL-C and SBP, weaker for non-HDL-C, and weakest for TC.

Identification of the Most 'at Risk' Subjects by Combining Anthropometric Indices

For this part of the study, we focussed on two anthropometric indices: BMI and WHtR. To increase the power to detect differences, we combined data for men and women and adjusted for sex and age as covariates. The adults were subdivided into 4 groups according to BMI (boundary value > 25 kg/m^2) and WHtR (boundary value for 'apples' > 0.5). The groups were defined as follows (% study population in brackets):

i) non-overweight 'pears' (BMI ≤ 25 and WHtR ≤ 0.5) (32%),
ii) overweight 'pears' (BMI > 25 and WHtR ≤ 0.5) (6%),
iii) non-overweight 'apples' (BMI ≤ 25 and WHtR > 0.5) (9%),
iv) overweight 'apples' (BMI > 25 and WHtR > 0.5) (53%).

The mean values for CVD risk factors in these 4 groups, adjusted for age and sex, are shown in table 4.

Contrast tests indicated greater differences according to shape than relative weight. Thus, 'apples' (groups 3 and 4) had higher levels of all risk factors (higher TC, non-HDL-C, SBP, DBP, but lower HDL-C) than 'pears' (groups 1 and 2). By contrast, the differences attributable to weight (group 1 vs. 3; group 2 vs. 4) were smaller; 'pears' (groups 1 and 2) had similar levels of risk factors irrespective of whether they were overweight or not (i.e. BMI status).

Most interesting of all, non-overweight 'apples' (group 3) appeared to be at higher risk than overweight 'pears' (group 2). Thus, non-HDL-C was 0.3 mmol/l (7%) higher, while SBP and DBP were 4 mm Hg and 3 mm Hg higher in group 3 compared with group 2. These differences are clinically significant.

How Many People with Central Fat Distribution Are Not Screened as 'at Risk' by Measuring BMI Alone?

It has been traditional to screen individuals for health risk based solely on their weight and height, rather than their fat distribution. Because health risk is correlated better with central fat distribution, we wanted to compare screening efficiency based on central fat distribution as well as BMI. In this instance we used WHtR as our proxy for central fat distribution. Since it is appropriate to use the lower boundary values of anthropometric indices rather than those indicating overt risk, cross tabulations of NDNS data were performed using boundary values of BMI > 25 kg/m^2 (overweight) and WHtR > 0.5 (central fat distribution).

Table 5 shows that, of those men who are not classed as overweight (BMI ≤ 25 kg/m^2), 35% have WHtR of >0.5 and therefore have central fat distribution without being overweight. Similarly, of those women who are not classed as over-

Table 2. Subject characteristics – anthropometry means and standard deviations (SD)

	Male, n = 806		Female, n = 970	
	mean	SD	mean	SD
Age	42	12	42	12
Height, cm	176	7	162	6
Weight, kg	84	15	69	15
BMI, kg/m^2	27.2	4.5	26.5	5.6
Waist circumference, cm	96	12	83	12
WHtR	0.55	0.07	0.51	0.08

Table 3. Partial correlation of anthropometric indices with each other and with individual CVD risk factors (adjusted for age)

	Men, n = 566			Women, n = 670		
	BMI	waist	WHtR	BMI	waist	WHtR
BMI	–	0.875	0.890	–	0.830	0.848
Waist	0.875	–	0.935	0.830	–	0.962
WHtR	0.890	0.935	–	0.848	0.962	–
Plasma TC, mmol/l	0.098*	0.076	0.119**	0.053	0.076*	0.088*
Plasma non-HDL-C, mmol/l	0.157	0.148	0.185	0.143	0.180	0.194
Plasma HDL-C, mmol/l	–0.218	–0.261	–0.247	–0.258	–0.297	–0.303
SBP	0.214	0.230	0.223	0.250	0.267	0.289
DBP	0.168	0.171	0.179	0.170	0.177	0.201

All correlations significant at $p < 0.0001$; except for plasma TC where p is indicated as follows: *$p < 0.05$; **$p < 0.01$.

Table 4. CVD risk factors for groups defined by BMI and WHtR

	BMI and WHtR groups (adjusted* means for CVD risk factors, n = 1,776)			
	non-overweight 'pears' group 1	overweight 'pears' group 2	non-overweight 'apples' group 3	overweight 'apples' group 4
Number of subjects in groups	*562*	*114*	*154*	*946*
Mean age (years) prior to adjustment	38	38	45	45
Men/women, %	30/70	22/78	60/40	55/45
TC, mmol/l (n = 1,249)	5.08[a]	5.13[a]	5.41[b]	5.40[b]
Non-HDL-C, mmol/l (n = 1,249)	3.8[a]	3.9[a]	4.2[b]	4.3[b]
HDL-C, mmol/l (n = 1,248)	1.32[a]	1.24[a,b]	1.20[b]	1.11[c]
SBP (n = 1,707)	121[a]	121[a]	125[b]	128[c]
DBP (n = 1,707)	68[a]	68[a]	71[b]	72[b]

*Estimated means were adjusted for age (mean age = 42 years) and sex.
[a,b,c]For each risk factor, values sharing the same superscript are not significantly different (p > 0.05). See text for definitions of groups 1–4.

Table 5. Adults in NDNS classified by BMI and WHtR to show those with central fat distribution who would be 'missed' by BMI screening

	WHtR ≤ 0.5	WHtR > 0.5	Total
Men			
Not overweight			
Number	170	92	262
%	64.9	35.1	100.0
Overweight, BMI > 25 kg/m^2			
Number	25	519	544
%	4.6	95.4	100.0
Total			
Number	195	611	806
%	24.2	75.8	100.0
Women			
Not overweight			
Number	392	62	454
%	86.3	13.7	100.0
Overweight, BMI > 25 kg/m^2			
Number	89	427	516
%	17.2	82.8	100.0
Total			
Number	481	489	970
%	49.6	50.4	100.0

weight, 14% have central fat distribution. In the total population this equates to 17% of all men and 6% of all women who would be 'missed' if screening was based on BMI alone.

Discussion

Importance of Using WHtR for Prediction of CVD Risk Factors

From our analysis, it is clear from the correlation coefficients that the proxy indicators of central fat distribution, namely waist circumference and especially WHtR, are better at predicting metabolic risk factors than BMI.

In the last few years, there has been an exponential increase in evidence from investigators around the world showing the superiority of WHtR over other anthropometric indices in their association with metabolic risks, hypertension, and stroke and chronic kidney disease.

Supporting evidence has come from cross-sectional studies in adults from, among others, Taiwan [22–24], Greece [25], Jamaica [26], Hong Kong [27], Korea [28], Bangladesh [29], Singapore [30], China [31], Iran [32], Japan [33], Germany [34, 35], Thailand [36, 37], Pakistan [38], Australia [39], USA [40], Iraq [41], Korea [42], Brazil [43], and India [44].

A recent meta-analysis [20] comparing pooled data from 10 studies using the area under the curve from ROC analyses of various anthropometric indices and CVD risk in adults has shown that WHtR is better than BMI, waist circumference, and WHR. These authors have lent support to the previously proposed boundary value of WHtR 0.5 [15, 45, 46].

Some authors [e.g. 47] have argued that waist circumference is a more convenient measure than WHtR because of its simplicity. To an extent this is true, but concerns have been expressed that one set of boundary values for waist circumference (developed on Caucasian subjects) does not suit all ethnic groups [48] and that risk can differ for people with the same waist circumference, but different heights [13].

The most compelling argument for further consideration of WHtR has come from several studies which have confirmed its usefulness in children. In growing children, both height and waist circumference are continually changing, and it would be impossible to devise a set of boundary values for waist circumference. A boundary value of WHtR 0.5 for children is gaining support, too [46, 49–55]. To quote from a recent paper [55]: 'The WHtR has several advantages; it is easy to calculate, does not require sex- and age-specific centiles, and, as has been previously suggested, it is a simple message, easily understood by clinicians and families, to 'keep your waist circumference to less than half your height".'

Prospective Studies

It is intriguing that the very first mention of WHtR came from the prospective Framingham study [56]. Prospective data from the UK Health and Lifestyle Survey [57, 58] were originally used to support the use of WHtR to predict hypertension when the index was first proposed, and data from Sweden confirmed its use in the prediction of stroke. [59]. However, very recent analysis of 1,505 CVD cases from 16,332 men in the Physicians' Health Study (mean age 61 years in 1991) and 414 cases from the 32,700 women in the Women's Health Study (mean age 61 years in 1999) have shown that WHtR demonstrated statistically the best model fit and strongest associations with CVD [60]. Prospective evidence such as these add particular support to our suggestion that WHtR is considered seriously.

Greater Risk Attached to Having Central Fat Distribution even at Normal Weight

The practical significance of this becomes apparent when the subjects are split into 4 groups according to their BMI and WHtR. The most 'at risk' group overall (highest SBP and DBP, TC, and non-HDL-C, and lowest HDL-C) is group 4 (overweight apples) which shows high BMI and high WHtR.

However, the most interesting comparison is between groups 2 and 3, which shows that people with high WHtR and normal BMI exhibit higher CVD risk factor levels than those who have low WHtR. This demonstrates that greater risk is attached to having central fat distribution even at normal weight and confirms previous observations in Japanese people [33].

Concern about Use of BMI Giving False Re-Assurance of Low Health Risk

This new analysis of nationally representative data from Great Britain shows that more than 1 in 3 normal weight men and 1 in 7 normal weight women may be at increased health risk on account of their central fat distribution. In the total population this equates to 17% of all men and 6% of all women who would be inadequately screened by BMI alone.

Limitations of This Study

As a preliminary investigation of the validity of using WHtR instead of BMI, we acknowledge that this study has some limitations in scope and depth of analysis. The modest sample size in the NDNS limits the power to demonstrate statistical significance when the data are stratified by sex or age group. However, when performed separately for men and women, the four-group contrast tests (ANCOVA, with adjustment for age) showed the same trends (data not shown).

No adjustment could be made for the impact of concurrent drug use, on which limited information was available. Approximately 7% of respondents were taking antihypertensives, but as their blood pressure was not significantly different from the remainder, their exclusion would not have materially affected the results. Furthermore, given that CVD medication is more likely in older people, those who are more overweight and/or have metabolic syndrome, the net effect of including all subjects is likely to be in the direction of underestimation of the true differences attributable to body weight or shape.

Further analysis is planned to explore the sensitivity and specificity of WHtR, compared with BMI in identifying subjects 'at risk' of CVD, but larger surveys may be better powered for this purpose. In addition, the absence of data on fasting triglycerides and glucose in the NDNS precludes an assessment of overall risk based on combined indicators.

It should be stated that no anthropometric measurement or index is a good predictor of abnormal blood lipids and blood pressure, and certainly not a surrogate for investigation of risk factors. However, WHtR may be more representative of body fat distribution than BMI and appears to be at least as efficient in identifying adults who may require follow-up.

Screening for Health Risk Should Use WHtR rather than BMI

It is vitally important that any screening scheme to help the public to minimise health risks encompasses an assessment of fat distribution (preferably using the WHtR) instead of the BMI.

These results support the suggestion from previous English [16] and Japanese [15, 45, 61, 62] studies that an action point based on WHtR 0.5 could be a simpler and more effective tool for health promotion [45] than any tools based on BMI or waist circumference (e.g. the WHO public health 'action point' based on BMI [1] or the National Institute For Clinical Excellence (NICE) guidelines [63] which promote action levels based on waist circumference). Indeed, several investigators are now using a WHtR of 0.5 as a boundary value to analyse their results.

Standardisation of Terminology and Measurement

As the importance of WHtR for health screening becomes more popular, we believe it would be useful to standardise terminology. Thus, waist to stature ratio (WSR), waist/height (W/Ht), waist:height ratio, waist circumference to height ratio (WC/Ht), and waist-to-height ratio (WHTR) could all be rephrased as waist to height ratio and abbreviated to WHtR.

Standardisation of the measurement of waist circumference will become even more important, and several studies have already addressed this issue [64, 65]. It is particularly important that this standardisation includes population groups such as the elderly and very obese.

Conclusion

In 2006, in a Lancet editorial [66], Franzosi asked the question: 'Should we continue to use BMI as a CVD risk factor?'

Our answer is a firm 'no'. WHtR is a much better, simple, non-invasive tool for screening for CVD risk. The boundary value of 0.5 translates into a simple public health message: 'Keep your waist circumference to less than half your height'. Considering the acknowledged health costs of central fat distribution and obesity [67], this simple message has the potential for significant cost savings.

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Disclosure

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