Ethnic comparisons of the cross-sectional relationships between measures of body size with diabetes and hypertension

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Summary

Recent estimates indicate that two billion people are overweight or obese and hence are at increased risk of cardiovascular disease and its comorbidities. However, this may be an underestimate of the true extent of the problem, as the current method used to define overweight may lack sensitivity, particularly in some ethnic groups where there may be an underestimate of risk. Measures of central obesity may be more strongly associated with cardiovascular risk, but there has been no systematic attempt to compare the strength and nature of the associations between different measures of overweight with cardiovascular risk across ethnic groups. Data from the Obesity in Asia Collaboration, comprising 21 cross-sectional studies in the Asia-Pacific region with information on more than 263 000 individuals, indicate that measures of central obesity, in particular, waist circumference (WC), are better discriminators of prevalent diabetes and hypertension in Asians and Caucasians, and are more strongly associated with prevalent diabetes (but not hypertension), compared with body mass index (BMI).

For any given level of BMI, WC or waist : hip ratio, the absolute risk of diabetes or hypertension tended to be higher among Asians compared with Caucasians, supporting the use of lower anthropometric cut-points to indicate overweight among Asians.

Keywords: Diabetes, ethnicity, hypertension, obesity.

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Introduction

There are few countries that remain unaffected by the global epidemic of overweight and obesity, such that the number of overweight (1.6 billion) (1) or obese (400 million) (1) individuals now exceeds the number of those who are underweight. Excess weight is associated with an array of adverse health consequences that include cardiovascular, endocrine, inflammatory, mechanical diseases and psychosocial disease states; hence, the timely identification of high risk individuals is an important priority in primary health care (2–4).

Past methods to define excess weight using body mass index (BMI) have largely been based on data derived from predominantly Caucasian populations (5). However, whether this method can be generalized to non-Caucasian populations has been questioned, because of potential ethnic differences in the strength of the associations between obesity and cardiovascular risk factors (6). In turn, this has prompted the suggestion that there should be 'ethnic-specific' cut-points for overweight and obesity – although what values these should assume remains a matter of debate.

*Members listed in acknowledgements.

There have been a number of studies which have attempted to assess whether the associations between body size and cardiovascular risk factors are stronger in Asians compared with Caucasians (7–9) A series of World Health Organization (WHO) meetings have attempted to assess this and produce some rational proposals based on preliminary analyses (6,10,11). The guidelines issued by the WHO (10) have defined overweight as a BMI of ≥25 kg m^{-2} (2) and obesity as ≥30 kg m^{-2} (2). These cut-points are derived from morbidity and mortality data from predominantly US and European populations and reflect the risk associated with the development of type 2 diabetes and cardiovascular disease (CVD). There are few comparable data from countries of the Asia-Pacific region, where more than one-third of the world's population lives. It is currently unknown whether the WHO cut-points are applicable to Asian populations, but data are accruing to suggest that the use of these cut-points could substantially underestimate the true burden of disease related to excess weight in non-Caucasians populations (11). For example, in several countries or regions of Asia, such as China and Hong Kong, where the mean population level of BMI is lower than the WHO cut-point of 25 kg m^{-2} (2), the prevalence of type 2 diabetes and other cardiovascular risk factors is already relatively high and increasing (12).

Alternative measures, such as waist circumference (WC) and the waist : hip ratio (WHR), which reflect central adiposity, have been suggested to be superior to BMI in predicting CVD risk (13,14). Central adiposity has been highlighted as a growing problem, particularly among Asian populations where individuals may exhibit a 'normal' BMI but have a disproportionately large WC (3). Currently, the WHO recognizes that WC between 94.0 and 101.9 cm in men and 80.0–87.9 cm in women, and WHR greater than 0.8 and 0.9 in women and men, respectively, correspond with the BMI overweight range of 25–29.9 kg m^{-2} (2). But, again, these estimates are based on data from a Dutch population, and it is unclear whether these definitions are appropriate in non-Caucasian populations. Moreover, there is currently no consensus over which of these measures is the most strongly associated with CVD risk, either within or between different ethnic groups. Providing answers to these fundamental questions is a crucial requirement for the effective management of weight and for defining prevention strategies for the weight-related morbidity in populations of the Asia-Pacific region and underpins the rationale for the Obesity in Asia Collaboration.

Methods

Study identification and eligibility

Members of the Asia–Oceania Association for the Study of Obesity, representing 16 nations within the region, who attended the 'WHO Expert Consultation on Appropriate BMI for Asian Populations' in Singapore, 2002, were invited to join the Obesity in Asia Collaboration (15). Studies were eligible if they contained information on each of the following variables: age, sex, weight, height, WC, hip circumference, fasting plasma glucose, systolic blood pressure, diastolic blood pressure and cigarette smoking status. For the purposes of these analyses, diabetes was defined as fasting blood glucose >7 mmol L^{-1} and hypertension as systolic blood pressure ≥140 mmHg and diastolic blood pressure ≥90 mmHg. Individuals with a history of diabetes or on diabetic medication were excluded. Sensitivity analyses were conducted for individuals on blood pressure lowering medication and the results were reported if there was evidence of a significant impact of treatment on the reported associations.

Statistical methods

A more detailed description of the statistical methods used is given elsewhere.[16,17] In brief, logistic regression models, stratified by sex and study, and adjusted for age (and subsequently by smoking and blood pressure), were used to estimate the odds ratio and 95% confidence intervals for prevalent diabetes and hypertension associated with a 0.5 standard deviation (SD) increment in each of the measures. To assess the ability of each anthropometric variable to discriminate between those with and without diabetes or hypertension, areas under the Receiver Operating Characteristic (ROC) curves were computed. The area under the curves (AUCs) was subsequently pooled to find region-specific AUCs using a random effects meta-analysis. The anthropometric threshold values for diabetes and hypertension were derived by identifying cut-points from the ROC that maximized the sum of sensitivity and specificity were identified for each sex and study.

Results

A comprehensive review of the results describing the relationships between current body size with blood pressure and diabetes are given elsewhere (16,17). Here, we attempt to summarize the principal findings from these analyses that included data on more than 263 000 individuals (73% Asian) from 21 study populations from 11 countries in the Asia-Pacific region (Fig. 1; Tables 1 and 2).

Is the strength of the relationship between body size and diabetes and hypertension the same in Asians and Caucasians?

For diabetes, there was no evidence to suggest that the strength of the associations between BMI, WC or WHR

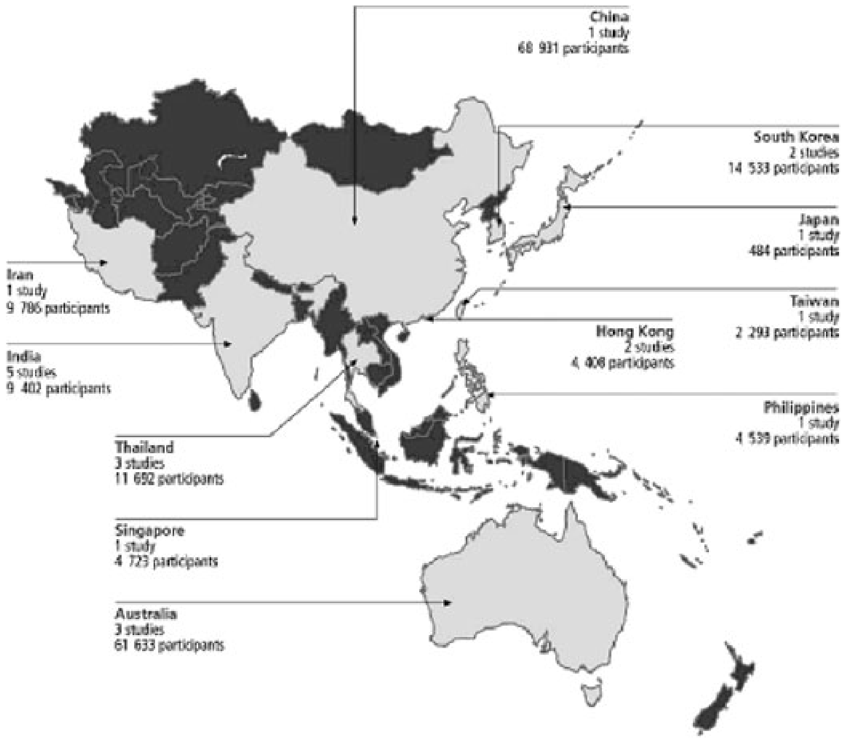

Figure 1 Map indicating location of participating studies in the Obesity in Asia Collaboration. An additional study from Canada including Asians and Caucasians was included.

Table 1 Mean (SD) levels of characteristics of male study participants at study baseline

Country/region	Study size	Age (years)	BMI (kg m^{-2})	WC	WHR	Hypertension (%)	Diabetes (%)
China	32744	49 (11)	23.0 (3.2)	78.9 (9.3)	0.86 (0.06)	34.8	3.6
Hong Kong	909	37 (9)	23.4 (3.0)	80.8 (7.8)	0.87 (0.05)	28.4	1.5
Hong Kong	1412	46 (13)	24.3 (3.4)	83.0 (9.6)	0.88 (0.07)	25.2	5.5
India	125	38 (11)	24.8 (3.6)	85.3 (10.4)	0.88 (0.07)	9.4	0.0
India	127	51 (15)	21.0 (3.9)	80.4 (11.6)	0.88 (0.08)	26.8	13.5
India	2179	42 (7)	23.7 (3.4)	87.6 (10.3)	0.97 (0.06)	42.6	10.1
India	2511	47 (9)	22.1 (4.3)	82.3 (13.4)	0.97 (0.08)	22.7	8.8
India	1096	41 (14)	22.6 (3.8)	85.4 (11.3)	0.93 (0.08)	14.8	12.1
Iran	4069	42 (14)	25.8 (4.1)	88.3 (11.4)	0.91 (0.07)	28.7	
Japan	258	51 (8)	23.5 (2.9)	81.6 (8.2)	0.88 (0.06)	36.4	5.0
Korea	3597	44 (15)	23.1 (3.0)	82.8 (8.4)	0.89 (0.06)	38.6	10.3
Korea	2864	45 (15)	23.7 (3.1)	84.4 (8.4)	0.89 (0.06)	15.0	
Philippines	2240	49 (17)	21.9 (3.4)	78.2 (9.7)	0.90 (0.06)	40.0	4.1
Singapore	2368	39 (13)	23.7 (3.8)	84.7 (10.1)	0.88 (0.06)	29.7	7.7
Taiwan	34378	43 (14)	23.8 (3.2)	82.0 (9.0)	0.87 (0.06)	48.7	4.3
Thailand	2701	43 (5)	23.2 (3.1)	82.1 (8.7)	0.98 (0.03)	25.8	1.5
Thailand	2135	43 (5)	24.0 (3.5)	86.4 (9.2)	0.90 (0.05)	35.1	5.4
Thailand	2092	54 (12)	23.1 (3.9)	81.7 (11.5)	0.90 (0.08)	31.2	9.4
Australia	4550	44 (13)	25.9 (3.6)	90.4 (10.6)	0.89 (0.06)	42.3	6.7
Australia	5048	52 (14)	27.2 (4.1)	97.5 (11.3)	0.93 (0.06)	35.0	3.6
Australia	16939	55 (9)	27.2 (3.6)	93.5 (9.9)	0.92 (0.06)	58.7	

BMI, body mass index; WC, waist circumference; WHR, waist : hip ratio.

were stronger in Asians compared with Caucasians in both sexes (Fig. 2a,b). Rather, the reverse was true, particularly in women, where the odds of prevalent diabetes associated with a 0.5 SD increment in each of the three indices of body weight with prevalent diabetes were consistently stronger in Caucasians. By comparison, for the same standard increment in anthropometric indices the odds of hypertension were stronger (although not always statistically significantly so) in Asians compared with Caucasians for both men and women (Fig. 2a,b).

Table 2 Mean (SD) levels of characteristics of female study participants at study baseline

Country/region	Study size	Age (years)	BMI (kg m^{-2})	WC	WHR	Hypertension (%)	Diabetes (%)
China	36156	49 (11)	23.5 (3.6)	76.6 (9.5)	0.81 (0.06)	34.8	3.9
Hong Kong	600	39 (9)	23.3 (3.5)	74.9 (8.3)	0.80 (0.06)	10.3	1.4
Hong Kong	1487	45 (13)	23.9 (3.8)	75.3 (9.4)	0.81 (0.08)	19.6	5.7
India	167	40 (12)	25.1 (4.9)	78.4 (11.0)	0.78 (0.06)	9.4	1.2
India	154	49 (14)	21.2 (4.1)	72.9 (11.1)	0.81 (0.09)	14.9	3.4
India	252	38 (5)	25.8 (4.3)	81.5 (10.3)	0.86 (0.08)	12.3	10.7
India	2976	46 (9)	22.8 (5.2)	75.9 (11.9)	0.83 (0.08)	19.0	8.4
India	1254	38 (12)	23.1 (4.1)	81.7 (11.2)	0.85 (0.08)	17.3	6.3
Iran	5717	41 (13)	27.5 (5.0)	87.5 (12.9)	0.84 (0.08)	29.5	
Japan	226	50 (9)	23.4 (3.6)	74.6 (9.7)	0.80 (0.07)	24.3	0.5
Korea	4365	45 (16)	23.3 (3.4)	78.5 (9.7)	0.84 (0.08)	27.8	8.3
Korea	3707	45 (16)	23.4 (3.4)	78.4 (9.7)	0.84 (0.08)	12.7	
Philippines	2301	48 (16)	22.3 (4.1)	73.7 (9.9)	0.83 (0.05)	29.8	7.2
Singapore	2355	39 (13)	23.0 (4.3)	75.0 (9.8)	0.79 (0.06)	19.7	8.3
Taiwan	37658	43 (14)	22.4 (3.5)	72.0 (8.7)	0.77 (0.06)	27.0	3.5
Thailand	794	42 (5)	22.8 (3.3)	74.3 (8.1)	0.88 (0.04)	13.9	0.2
Thailand	767	43 (5)	23.4 (3.8)	78.7 (9.6)	0.82 (0.06)	15.4	2.4
Thailand	3211	53 (11)	24.9 (4.5)	82.4 (12.2)	0.86 (0.08)	25.9	10.6
Australia	4726	43 (13)	24.9 (4.7)	76.5 (11.3)	0.76 (0.06)	28.9	4.0
Australia	6199	51 (15)	26.7 (5.5)	85.4 (13.3)	0.81 (0.07)	22.8	1.5
Australia	24314	55 (9)	26.7 (4.9)	80.0 (11.7)	0.79 (0.07)	45.4	

BMI, body mass index; WC, waist circumference; WHR, waist : hip ratio.

Is there any appreciable difference in the strength of the association between measures of overweight with prevalent diabetes and hypertension?

With the exception of Caucasian men, measures of central obesity were more strongly associated with prevalent diabetes than BMI (Fig. 2a,b). The same was not true for hypertension; for a standard increment the odds of hypertension were comparable across the three anthropometric measures for both men and women (Fig. 2a,b).

Is one anthropometric measure a better discriminator of diabetes and hypertension?

The ability of each of the three measures to discriminate prevalent diabetes or hypertension ranged from 0.63 to 0.71 in men and from 0.66 to 0.80 in women. The AUCs tended to be slightly (but in most instances non-significantly) higher for WC compared with BMI or WHR, across the sex and ethnic groups.

Does the proportion of individuals with diabetes or hypertension at any given level of body size differ between Asians and Caucasians?

At any given level of BMI, WC or WHR, the absolute risk of diabetes was consistently higher in Asians compared with Caucasians among both men and women. For example, at a BMI of 24 kg m^{-2} (2) the proportion of men with diabetes was 5% in Asians compared with 2% in Caucasians, and in women the corresponding values were 5% and 1% respectively (Fig. 3a). Similarly, at a WC of 90 cm or a WHR of 0.9, the proportion of Asian men with diabetes was about 6% compared with 2% in Caucasian men and in women, for a WC of 80 cm and a WHR of 0.8, the estimates were approximately 5% and 1% respectively.

A similar pattern was observed for the absolute risk of hypertension, which tended to be higher among Asians compared with Caucasians for any given measure of body size. At a BMI of 24 kg m^{-2} (2) the proportion of men with hypertension was 32% in Asians compared with 17% in Caucasians, and in women the corresponding values were 20% and 10% respectively (Fig. 3b). For measures of central obesity, however, the proportions of individuals with hypertension at a given level of WC or WHR were broadly similar in both Asians and Caucasians: at a WC of 90 cm, the proportion of Asian men with hypertension was 39% compared with 32% in Caucasian men and in women, at a WC of 80 cm, the values were 21% and 18% respectively. For a WHR of 0.9, the estimates were approximately 35% and 32% in Asian and Caucasian men, respectively, and for a WHR of 0.8, the prevalence of hypertension was the same (5%) in both Asian and Caucasian women.

What are the optimal anthropometric cut-points that offer the best discrimination for diabetes and hypertension?

As might be expected, the BMI, WC and WHR cut-points for the optimal discrimination of diabetes and hypertension

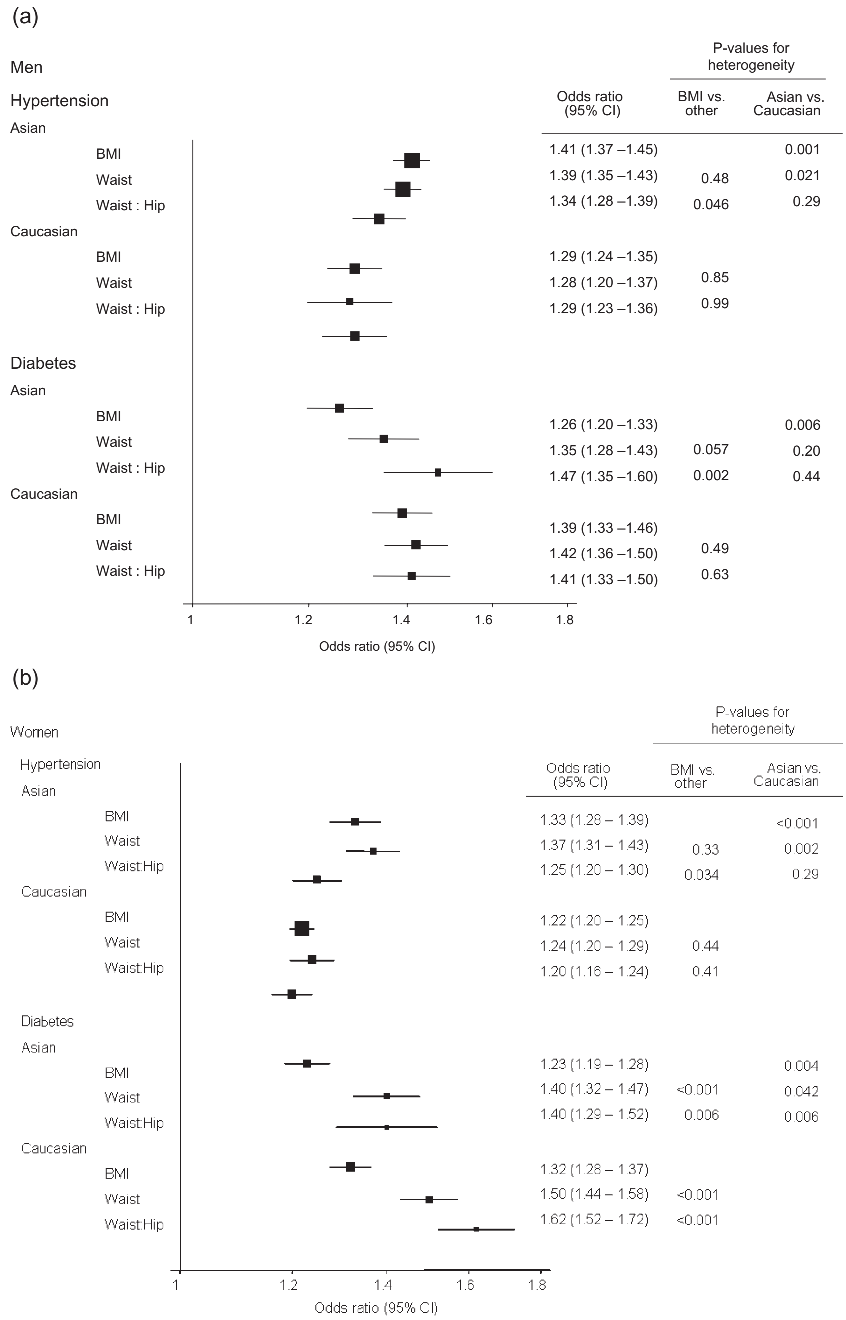

Figure 2 Age-adjusted odds ratios and 95% confidence intervals for prevalent type 2 diabetes and hypertension associated with 0.5 SD increment in each anthropometric measure: body mass index (BMI), waist circumference (WC) and waist : hip ratio (WHR). Results are shown separately by sex (a for men; b for women) and ethnic group (Asian, Caucasian). The strength of the association between WC and diabetes or hypertension and between WHR and diabetes or hypertension are compared against the strength of the association between BMI and diabetes or hypertension. For each variable the strength of the association with diabetes or hypertension is compared between Asian and Caucasian individuals. *P*-values for the differences are shown.

were lower in Asians compared with Caucasians (Table 3). These cut-points, which optimized sensitivity and specificity such that both values nearly always exceeded 60% in all groups, varied however, particularly for BMI and WC, according to the outcome under investigation, and were higher for the discrimination of diabetes compared with hypertension. By comparison, WHR cut-points of approximately 0.9 and 0.8 in men and women, respectively, were common to both Asians and Caucasians.

Discussion

Irrespective of which measure of excess weight is used, for a given level the absolute risk of diabetes and hypertension tended to be higher among Asians compared with Caucasians. For hypertension, this might be explained, in part, by a stronger association with body size (particularly BMI) in Asians compared with Caucasians. The mechanisms that might mediate the apparent greater susceptibility in Asians

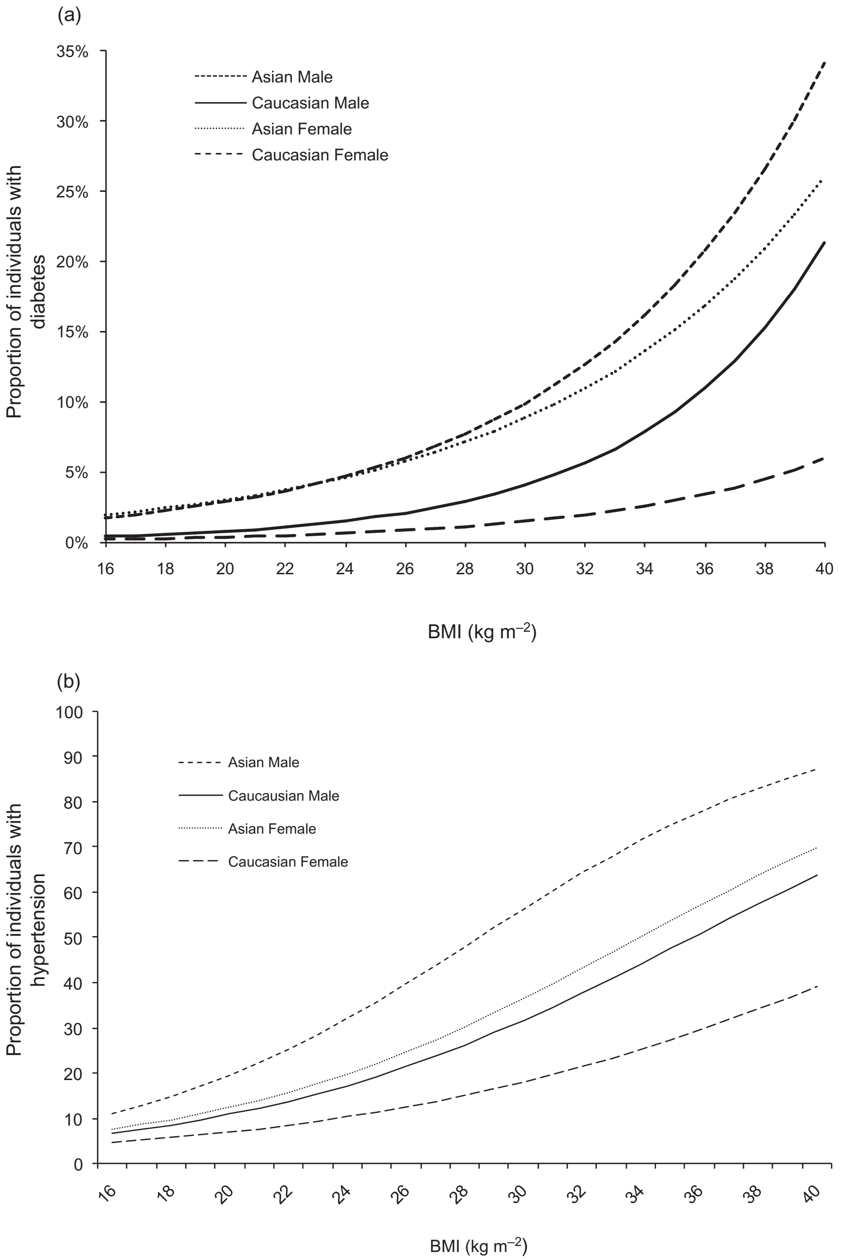

Figure 3 Age-adjusted proportion of individuals in the Obesity in Asia Collaboration with type 2 diabetes (a) and hypertension (b) by level of each anthropometric variable: body mass index (BMI), waist circumference and waist : hip ratio. Results are shown separately by sex and ethnic group. CI, confidence intervals.

Table 3 Optimal anthropometric cut-points for the discrimination of diabetes and hypertension in Asians and Caucasians

	BMI		WC		WHR	
	Asians	Caucasians	Asians	Caucasians	Asians	Caucasians
Men						
Diabetes	24	28	85	99	0.90	0.94
Hypertension	24	27	85	94	0.92	0.92
Women						
Diabetes	25	28	80	85	0.82	0.85
Hypertension	24	26	80	80	0.84	0.80

BMI, body mass index; WC, waist circumference; WHR, waist : hip ratio.

at any given level (or measure) of body size for diabetes are unknown, but the data indicate that it is not caused by a stronger association with body size among Asians compared with Caucasians, as there was no indication of a difference between the two ethnic groups. Rather, it may be that for any given value of BMI or WC, Asians may have lower lean muscle mass and higher visceral fat mass compared with Whites. (18–21) An alternative explanation is that of epigenetic modification of gene expression induced in pregnancy or 'programming effects'. There is some evidence to suggest, for example, that in Asian populations, exposure to under-nutrition in pregnancy followed by relative postnatal over-nutrition (as a result of better economic development, increasing Westernization and adoption of diets high in fat and calories) might be associated with an increase in the subsequent risk of diabetes (22,23).

Although the relationships between excess weight and major cardiovascular risk factors, such as diabetes and hypertension, are monotonic continuous down to low levels, measures such as BMI and WC are frequently categorized into 'normal' and 'overweight'. Specifying a single value of 'overweight' along the continuum of risk provides clinicians and public health specialists with an opportunity to identify those individuals most at risk of developing diabetes (and other weight-related illness) and who, consequently, would be expected to derive the greatest health benefits from interventions aimed at preventing further weight gain. Despite years of work, there is still much uncertainty regarding what value, or values these cut-points should take and, which measure, or combination of measures, of excess weight has the greatest discriminatory capability for cardiovascular risk factors as reflected by the different cut-points used by various guidelines for the detection of diabetes or definition of the metabolic syndrome.

A major consideration of cut-points is striking the right balance between the proportions of individuals correctly identified with having the condition (sensitivity) vs. those who are incorrectly identified (specificity). If, for example, we choose to use the BMI cut-point of 20 kg m^{-2} (2) to screen for diabetes, we would almost certainly identify most individuals at risk but this would be offset by the large number of people incorrectly identified with the condition, which in essence would be little better than giving everyone a glucose tolerance test. An alternative, more pragmatic approach is to examine both the sensitivity and specificity to balance the percentage of individuals correctly identified as having diabetes and the percentage correctly diagnosed as free from the condition. Overall, examination of the AUCs for BMI, WC and WHR revealed marginal differences in each measure's capability for discriminating diabetes or hypertension, although measures of central obesity (in particular, WC) tended to perform slightly better compared with BMI.

Given that there is no significant material advantage to using any one of the three anthropometric measures over the others, and that different sex and ethnic cut-points are required for all three measures to optimally discriminate different cardiovascular risk factors, weighing up the benefits and disadvantages of each of the measures in turn may help to shed some light on which measure of excess weight should be used in routine clinical practice for screening purposes.

Traditionally, BMI has been the most widely used measure in both epidemiological and clinical studies, although the concept of a ratio is often difficult for individuals to grasp (24). It also requires the use of both a weighing scale and a stadiometer, which may not be standard equipment in remote rural areas and in developing countries. WHR shares the problem of being a ratio with BMI, although it only requires a tape measure. In a recent report from the 'Workshop on Use of Anthropometry for Public Health and Primary Health Care', the use of ratio measurements was discouraged, because of difficulty in the interpretation of these measurements (24). WHR is also the most difficult of the three methods to measure, requiring the individual to accurately locate the waist and hips (which is a particular problem in very overweight individuals). Furthermore, measuring an individual's girth around the hips may not be acceptable in some societies (particularly if an individual is being measured by a member of the opposite sex). That leaves us with WC; a more readily understood measure compared with BMI and WHR, and which is easily determined with the aid of a tape measure. Furthermore, by marking on the tape where sex and ethnic cut-points are, the necessity of having to remember these values (which are likely to change over time as the prevalence of obesity continues to increase) is removed. However, without adequate training, even the apparently simple measurement of waist circumference can be problematical.

There are several limitations of this current study. First, although we recognize that the ethnic groupings we use in the current study are crude, not taking into account the potential significant variation in genetic differences between different Asian populations, we did not have sufficient data to produce reliable country-specific estimates for most Asian countries. Second, these analyses are cross-sectional, which precludes examination of the temporal nature of the association between measures of excess weight and diabetes, a non-trivial consideration given that the development of diabetes may influence body size.

Screening for cardiovascular risk factors in countries of the Asia-Pacific region, which is expected to shoulder the greatest burden of diabetes in the future, needs to be simple if it is to be effective at identifying individuals most at risk. Unlike diabetes, hypertension is relatively easy to screen for, requiring the measurement of blood pressure as opposed to a time-consuming and more invasive glucose-tolerance test. So, of the two, it is more important that the chosen cut-points reflect the ability to discriminate diabetes. The benefits of measuring WC rather than BMI or WHR include the requirement only for a tape-measure rather than a weighing scale, stadiometer and a calculator.

Our findings suggest that current recommended WC cut-points should be modified to 80 cm in Asian women, 85 cm in White women, 85 cm in Asian men and 99 cm in White men to optimize the discrimination of diabetes in these populations. The Caucasian values proposed here of 85 cm for women and 99 cm for men are not much different from the upper WHO values for Caucasian waists of 88 cm for women and 102 cm for men and our values are derived from associations with specific morbidities rather than simply being a correlation with BMI measures in a Caucasian population. The Asian values of 80 cm for women and 85 cm for men also correspond fairly closely with those previously proposed at the Hong Kong meeting of WHO/IASO/IOTF. It is recognized, however, that they differ from the Japanese values which, because they use an absolute cardiovascular risk approach, result in WC cut-points being higher in women (90 cm) than in men (85 cm) (25) whereas here, the cut-points were made on a relative and not an absolute risk basis.

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