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Optimal cut-off values and population means of waist circumference in different populations

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Abdominal obesity is a risk factor for cardiometabolic disease, and has become a major public health problem in the world. Waist circumference is generally used as a simple surrogate marker to define abdominal obesity for population screening. An increasing number of publications solely rely on the method that maximises sensitivity and specificity to define 'optimal' cut-off values. It is well documented that the optimal cut-off values of waist circumference vary across different ethnicities. However, it is not clear if the variation in cut-off values is a true biological phenomenon or an artifact of the method for identifying optimal cut-off points. The objective of the present review was to assess the relationship between optimal cut-offs and population waist circumference levels. Among sixty-one research papers, optimal cut-off values ranged from 65·5 to 101·2 cm for women and 72·5 to 103·0 cm for men. Reported optimal cut-off values were highly correlated with population means (correlation coefficient: 0·91 for men and 0·93 for women). Such a strong association was independent of waist circumference measurement techniques or the health outcomes (dyslipidaemia, hypertension or hyperglycaemia), and existed in some homogeneous populations such as the Chinese and Japanese. Our findings raised some concerns about applying the sensitivity and specificity approach to determine cut-off values. Further research is needed to understand whether the differences among populations in waist circumference were genetically or environmentally determined, and to understand whether using region-specific cut-off points can identify individuals with the same absolute risk levels of metabolic and cardiovascular outcomes among different populations.

Waist circumference: Optimal cut-off points: Abdominal obesity: Sensitivity: Specificity

Introduction

Excess abdominal fat is associated with an increased risk of cardiometabolic disease[(1)]. However, precise measurement of abdominal fat content requires the use of expensive radiological imaging techniques. Therefore, waist circumference is often used as a surrogate marker of abdominal fat mass, because waist circumference correlates with abdominal fat mass and is associated with cardiometabolic disease risk[(1)]. Although there is a continuous association between waist circumference and the risk of cardiometabolic disease, a cut-off point is often determined for defining abdominal (or central) obesity for population screening[(2,3)]. The identification of waist circumference cut-off points is critical for both clinical care and public health research. Recently, an increasing number of research papers have been published to define optimal waist circumference cut-off values in different populations[(2,3)]. Most of those papers solely rely on the receiver-operating characteristic (ROC) curve method to maximise sensitivity and specificity to define 'optimal' cut-off values. It is well documented that optimal cut-off values vary across different ethnicities. Such a variation in waist circumference cut-off values may be explained by ethnic differences in visceral adipose tissue and in the relationships between waist circumference and visceral adipose tissue[(4,5)]. The reported cut-off values also vary substantially within some relatively homogeneous populations such as the Chinese and Japanese. There has been a recommendation to use region-specific cut-off values[(3)]. However, the huge variation among different regions within one ethnic group raised a question whether such a variation in cut-off values is a true biological phenomenon or an artifact of the widely used approach of maximising both sensitivity and specificity for identifying optimal cut-off points.

In the present review, we focused on assessing the relationship between the reported optimal cut-off values and population means of waist circumference. This relationship is essential for understanding why different optimal cut-off values of waist circumference have been reported in different studies. It is also useful for comparing the

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prevalence of abdominal obesity among different regions and for monitoring changes in the prevalence of abdominal obesity over time in the same population. The techniques for measuring waist circumference vary in the literature; so are the outcome measurements for defining waist circumference cut-off values. We further examined if the relationship between the cut-off values and population means of waist circumference was independent of waist circumference measurement methods and the cardiometabolic outcomes.

Methods

Literature search strategy and inclusion criteria

Papers were included according to the following criteria. First, we searched the following strings on the PubMed Medline: 'waist circumference' AND 'cut-off OR cutoff OR cut point' AND language as English (eng). A total of 304 citations published from 1999 to 2009 were retrieved for possible inclusion. Second, we (Z. W. and D. S.) reviewed all abstracts and full papers if available to identify articles that defined waist circumference cut-off values in adults. Studies of children and adolescents and those that did not define waist circumference cut-off values were excluded. A total of seventy-five papers that defined waist circumference cut-off values in adults were included. Third, ten studies without obtainable population waist circumference means were excluded. Fourth, four more studies were excluded due to small sample size ($n < 100$). Therefore, sixty-one studies were included in the present review.

Waist circumference measurements

Different measurement methods for waist circumference were used in the literature, and those methods were categorised into the following four groups: (1) midway between the bottom of the lower rib and the top of the iliac crest; (2) at the umbilicus; (3) at the narrowest point between the umbilicus and xiphoid process; (4) other methods or unspecified.

Health outcomes

Outcome measures included hyperglycaemia (impaired fasting glucose, impaired glucose tolerance and diabetes), hypertension, dyslipidaemia (high total cholesterol, high TAG, high LDL-cholesterol, and low HDL-cholesterol), the metabolic syndrome, CHD, CVD, elevated visceral fat and overall mortality.

The definitions for some outcomes varied among studies. Most outcomes were defined according to the International Diabetes Federation, the National Cholesterol Education Program Adult Treatment Panel III, the Chinese Diabetes Society, the Japanese Committee of the Criteria for Metabolic Syndrome and the American Diabetes Association. Specifically, the commonly used definitions for hypertension, dyslipidaemia and hyperglycaemia are as follows:

Hypertension – systolic blood pressure (SBP) ≥ 140 mmHg or diastolic blood pressure (DBP) ≥ 90 mmHg; or SBP ≥ 130 mmHg or DBP ≥ 85 mmHg.

Dyslipidaemia – total cholesterol $\geq 5{\cdot}2$ mmol/l or $\geq 6{\cdot}2$ mmol/l.

TAG – $\geq 1{\cdot}7$ mmol/l or $\geq 2{\cdot}3$ mmol/l.

HDL-cholesterol – $< 0{\cdot}9$ mmol/l, $< 1{\cdot}0$ mmol/l, or $< 1{\cdot}29$ mmol/l.

LDL – $\geq 3{\cdot}5$ mmol/l, or $\geq 4{\cdot}14$ mmol/l.

Hyperglycaemia and diabetes – fasting plasma glucose $\geq 5{\cdot}6$ mmol/l, $\geq 6{\cdot}1$ mmol/l, or $\geq 7{\cdot}0$ mmol/l; 2 h plasma glucose $\geq 7{\cdot}8$ mmol/l, or $\geq 11{\cdot}1$ mmol/l.

Most studies presented one waist circumference cut-off value for detecting a clustering of multiple outcomes, such as one or more metabolic risk factors, or two or more metabolic or CVD risk factors. If a study presented multiple cut-off values for individual outcomes instead of a summary cut-off value, a mean cut-off value was calculated. If the sex-specific waist circumference means of the study sample were not presented in the original article, we derived the mean waist circumference using the data provided if possible.

Methods of optimising sensitivity and specificity

Optimal cut-off points are commonly determined according to sensitivity and specificity values. Different methods were used to optimise sensitivity and specificity values. Those methods were categorised into four groups: (1) a waist circumference point with the maximum of the sum of sensitivity and specificity; (2) a point with the shortest distance on the receiver-operating characteristic (ROC) curve, where the distance is $\sqrt{((1-\text{sensitivity})^2 + (1-\text{specificity})^2)}$; (3) a point where sensitivity equals specificity; (4) the details were not specified although a sensitivity and specificity approach was mentioned in the paper.

Data analysis to explore the association between cut-off values and population means of waist circumference

Cut-off values were plotted against corresponding population means of waist circumference. Pearson correlation coefficients between cut-off values and population means were calculated for each sex. We also calculated subgroup correlation coefficients by: (1) the methods of optimising sensitivity and specificity; (2) the measuring methods of waist circumference; (3) health outcome measurements; (4) the representativeness of study samples. Correlation coefficients for two well-studied homogeneous populations, the Chinese and Japanese, were calculated separately. All analyses were conducted using Stata 10 (StataCorp LP, College Station, TX, USA)[6].

Results

As described previously, sixty-one studies were included in the present review (see Appendix 1)[7–67]. Those articles reported optimal cut-off values of waist circumference for different populations including Australians[16,31], Brazilians[8,13,25,48], Canadians[20], Chinese[12,29,30,35–37,40,62,64–67], French[11], Guadeloupeans[24], Indians (Asia)[19,42,59], Iranians[18,22,26], Iraqis[41], Jamaicans[54], Japanese[21,28,32,33,38,43,46,52,55,57,58,61], Koreans[10,27,34,39,47], Mexicans[9,14,53], Mongolians[58], New Zealand Maoris[51], Singaporeans[49,50], Swedish[45],

Table 1. Some characteristics of the sixty-one cited papers

	Number	%
Methods for optimising sensitivity and specificity		
1. Maximum of sensitivity and specificity	38	62
2. Shortest distance on ROC curve	9	15
3. Sensitivity = specificity	9	15
4. Others or unspecified	5	8
Waist circumference measurements		
1. Midway between the bottom of the lower rib and top of the iliac crest	25	41
2. The narrowest point between the umbilicus and xiphoid process	14	16
3. At the umbilicus	10	23
4. Other methods and unspecified	12	20
Representative sample		
1. Yes	24	39
2. No	37	61
Range of waist circumference means (cm)		
1. Male	72·5 to 106·6	
2. Female	65·3 to 100·2	
Range of optimal waist circumference cut-offs (cm)		
1. Male	72·5 to 103·0	
2. Female	65·5 to 101·2	

ROC, receiver-operating characteristic.

Thais[7,44], Tongans[17], Tunisians[15], Turkish[63], and African-Americans and White Americans[23,60]. Among sixty-one studies, thirty-eight (62 %) used the maximum of the sum of sensitivity and specificity to identify an optimal cut-off point (Table 1). Most studies (fifty-five out of sixty-one; 90 %) were cross-sectional, and six studies were of cohort design. Of the studies, twenty-four (39 %) were based on representative samples. The most commonly used technique to measure waist circumference was to measure the midway between the bottom of the lower rib and the top of the iliac crest (twenty-five out of sixty-one; 41 %).

Of the studies, thirteen presented optimal waist circumference cut-off values based on a single outcome, and most studies (*n* 48) reported optimal cut-off values for a clustering of multiple outcomes. In addition to the overall optimal cut-off values, some studies reported optimal cut-off values for detecting individual components of the metabolic syndrome or CVD risk factors. Commonly reported cut-off values were for hyperglycaemia (*n* 29), hypertension (*n* 25) and dyslipidaemia (*n* 20).

Means and cut-off values of waist circumference

The mean values of waist circumference varied substantially among different studies and so did the optimal cut-off values, ranging from 72·5 to 103·0 cm for men and from 65·5 to 101·2 cm for women. The minimum and the maximum cut-off values differed by as much as 30·5 cm for men and 35·7 cm for women. The optimal cut-off values were highly correlated with the population mean values (Fig. 1). The cut-off values increased with the increasing population means. The correlation coefficient was 0·91 (95 % CI 0·86, 0·95) for men and 0·93 (95 % CI 0·89, 0·96) for women.

The Chinese and Japanese are considered two relative homogeneous groups genetically. Although their mean values and optimal cut-off values were generally smaller than those in non-Asian populations, the correlation coefficient remained high, particularly in Chinese women (*r* 0·96; 95 % CI 0·88, 0·99) and Japanese women (*r* 0·92; 95 % CI 0·72, 0·98). The optimal cut-off values among studies within each ethnic and sex group still differed by 9·1 to 18·5 cm (Fig. 2).

The method of measuring waist circumference had little impact on the association between waist circumference cut-off values and population means. Correlation coefficients were calculated separately according to the waist circumference measurement method. The correlation coefficients were 0·96 (95 % CI 0·91, 0·99), 0·88 (95 % CI 0·59, 0·97) and 0·92 (95 % CI 0·76, 0·97) for men whose waist circumferences were measured using (1) the midway between the bottom of the lower rib and the top of the iliac crest, (2) at the umbilicus and (3) at the narrowest point between the umbilicus and xiphoid process, respectively. The corresponding values for women were 0·96 (95 %

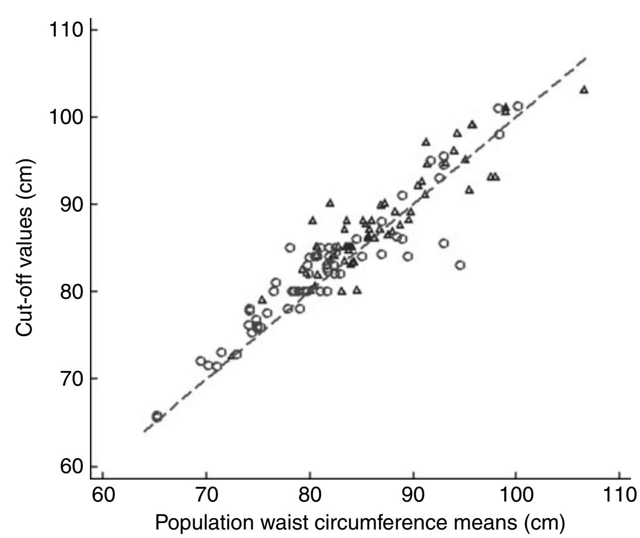

Fig. 1. Optimal waist circumference cut-off values and population means by sex: ○, female (*r* 0·93); △, male (*r* 0·91). (- - -), Line of identity.

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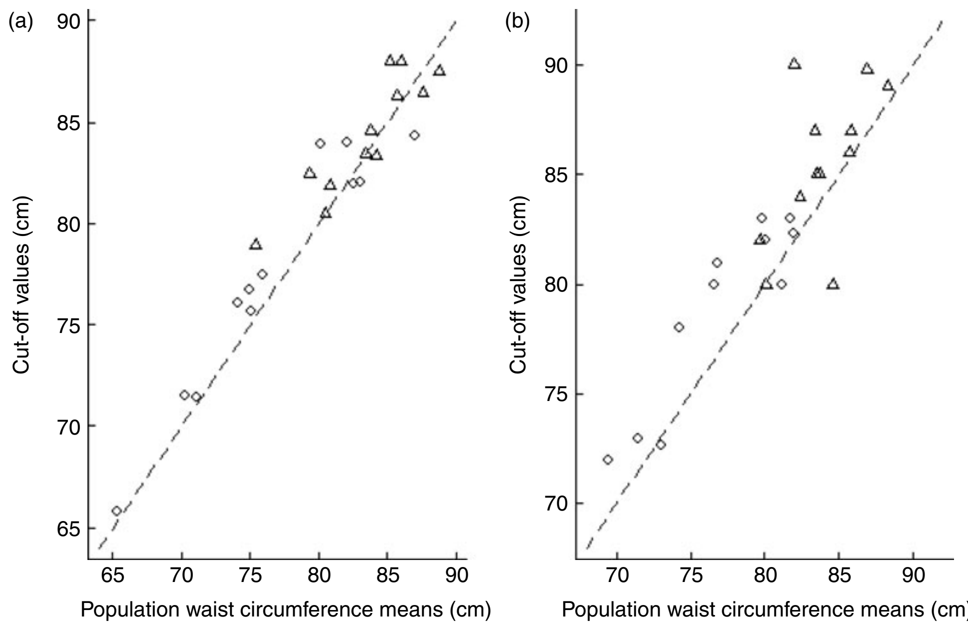

Fig. 2. Optimal waist circumference cut-off values and population means of (a) Chinese by sex: ◇, female (*r* 0·96); △, male (*r* 0·84). Optimal waist circumference cut-off values and population means of (b) Japanese by sex: ◇, female (*r* 0·92); △, male (*r* 0·58). (- - -), Line of identity.

CI 0·92, 0·98), 0·91 (95 % CI 0·65, 0·98) and 0·86 (95 % CI 0·64, 0·95). In addition, the relationship between cut-off values and population means existed in both cross-sectional (*r* 0·91, 95 % CI 0·85, 0·95 for men; *r* 0·92, 95 % CI 0·87, 0·96 for women) and cohort (*r* 0·93, 95 % CI 0·57, 0·99 for men; *r* 0·98, 95 % CI 0·88, 0·99 for women) studies.

We assessed the relationships between population means and cut-off values of waist circumference separately for three commonly reported single outcomes (Fig. 3). Correlation coefficients were 0·93 (95 % CI 0·86, 0·97), 0·94 (95 % CI 0·85, 0·98) and 0·94 (95 % CI 0·85, 0·98) in men, and 0·96 (95 % CI 0·91, 0·98), 0·92 (95 % CI 0·80, 0·97) and 0·97 (95 % CI 0·94, 0·99) in women, for hyperglycaemia, dyslipidaemia and hypertension, respectively.

The representativeness of the study samples had little impact on the relationship between population means and cut-off values. The correlation coefficients were 0·97 (95 %

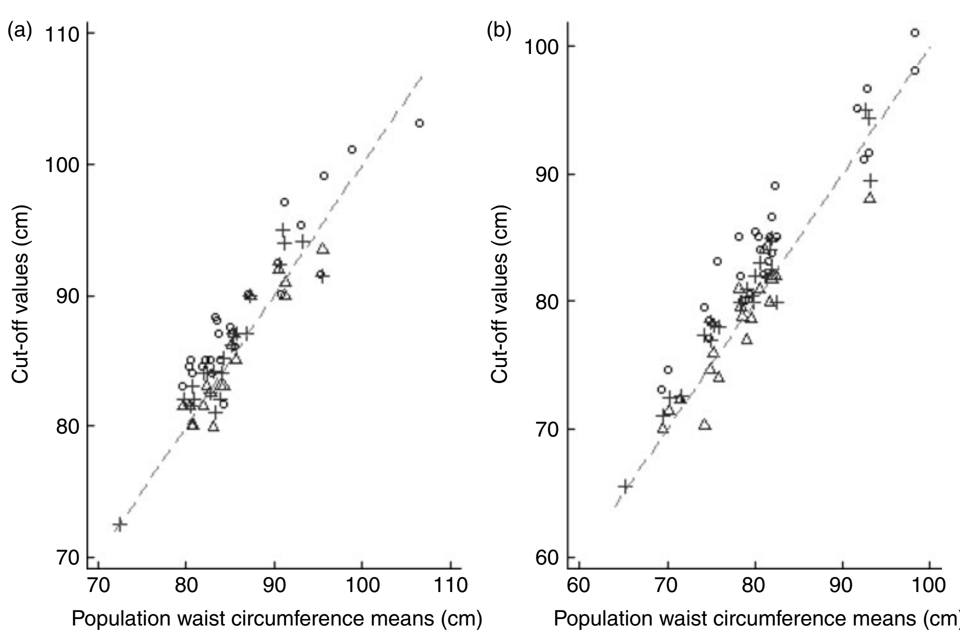

Fig. 3. Optimal waist circumference cut-off values and population means of (a) males by outcome: ○, hyperglycaemia (*r* 0·93); △, dyslipidaemia (*r* 0·94); +, hypertension (*r* 0·94). Optimal waist circumference cut-off values and population means of (b) females by outcome: ○, hyperglycaemia (*r* 0·96); △, dyslipidaemia (*r* 0·92); +, hypertension (*r* 0·97). (- - -), Line of identity.

CI 0·93, 0·99) for men and 0·94 (95 % CI 0·86, 0·97) for women in studies with representative samples and 0·89 (95 % CI 0·79, 0·94) for men and 0·91 (95 % CI 0·83, 0·95) for women in those with convenience samples.

Discussion

The optimal cut-off values of waist circumference vary substantially across different populations. Importantly, the optimal cut-off values determined using sensitivity and specificity values also vary considerably among studies within relatively homogeneous ethnic groups such as the Chinese and Japanese. We found that such a variation was mainly driven by the population waist circumference levels. The cut-off values linearly increase with increasing population means. The strong relationship is independent of waist circumference measurement techniques regardless of whether the health outcome is hypertension, dyslipidaemia, hyperglycaemia or a cluster of multiple outcomes.

Our findings raised some concerns about applying the sensitivity and specificity approach to determine an optimal cut-off value. The so-called optimal cut-off is a point that maximises both sensitivity and specificity. To achieve this, there will always be some 'optimised' numbers of participants above and below the cut-off point. This will make the cross-population comparison of the prevalence of abdominal obesity difficult. For example, the optimal cut-off values for Chinese women in two studies are 74·7 cm(29) and 82·05 cm(64), respectively. Although the difference in waist circumference means between two study populations is as high as 7·7 cm (75·3 *v.* 83·0 cm), the two populations have a similar prevalence of 'abdominal obesity' (53 %) if applying each cut-off value to its own population. Therefore, the true problem of abdominal obesity in the population with a higher waist circumference is masked by a higher cut-off value, unless such a difference is mainly determined by genetic background.

There are an increasing number of studies using the sensitivity and specificity approach to determine optimal cut-off values in recent years. We should be cautious about interpreting and applying those optimal cut-off values. Because the sensitivity and specificity approach produces different optimal cut-off values for the regions with different levels of waist circumference within one population, it has been suggested that a region-specific cut-off value should be considered(3). Our question is: Should a population with higher waist circumference levels have higher cut-off values? To answer this question, further investigation is needed. First, efforts should be made to understand the causes of regional variations in population waist circumference levels. If the regional variation in waist circumference levels is mainly genetically determined, the use of region-specific cut-off values can be justified. A recent study by the DECODE group (Diabetes Epidemiology: Collaborative analysis of Diagnostic criteria in Europe) has shown that given the same waist circumference cut-off value, the prevalence of diabetes varies among ethnic groups, and the Europeans need a higher cut-off than Asians to obtain the same prevalence of diabetes(68). This indicates that genetic differences play a major role among those populations. However, if such a variation is mainly due to the differences in diet and physical activity among regions, a uniform cut-off value across regions within a population is preferred. Generally, Asians with lower mean waist circumference have lower cut-off values. However, the huge variation in the waist circumference mean values among different regions in China accompanied by the rapid increase in population means in recent years(69) suggests that the nutrition, physical activity and lifestyle factors may have contributed to regional variation. Calculating absolute risk corresponding to different waist circumference cut-off values in different regions will provide some evidence on this issue. Regardless of population waist circumference levels, if the absolute risks corresponding to a specific waist circumference point are the same in different regions, a uniform cut-off value is warranted.

Since most studies are cross-sectional, more cohort studies in this area have been encouraged(2,70). However, if the approach of maximising sensitivity and specificity is applied to cohort data, the strong relationship between estimated cut-off values and population means remains, as indicated by the high correlation coefficient among cohort studies in the present review.

The current trend of mainly relying on maximising sensitivity and specificity to determine cut-off points may over-simplify the complexity for defining waist circumference cut-off values. Future research should focus on searching and applying methods alternative to the widely used method that maximises sensitivity and specificity. Perhaps, multiple approaches should be applied. One alternative is to calculate an absolute risk for the health outcome of interest. Although further research is needed on how to identify a cut-off value according to absolute risks, cut-off values based on multiple outcomes should be identified when the absolute risks reach a certain level that is considered to be high enough to take action. Further understanding of genetic and lifestyle factors contributing to the regional variation in waist circumference will also be useful. Most studies cited in the present review investigate cut-off values in a single population in isolation. Further research is needed to study different populations using the same sample selection criteria, measurements and analytical techniques.

In conclusion, the cut-off values determined using the sensitivity and specificity approach are highly correlated with population waist circumference levels. This can be problematic for comparing the prevalence of abdominal obesity across different populations as well as for monitoring the time trend in the same population, particularly when the population variation in waist circumference is due to differences in diet and lifestyle factors. Further research is required to examine alternatives including methods that use absolute risk levels to define waist circumference cut-off values in different populations.

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Z. W. proposed the project, performed data analysis and drafted the manuscript. D. S, J. M. and Z. W. contributed to

the study design and data collection, and revised the article critically and approved the final version.

The authors declare that there are no conflicts of interest.

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Appendix 1. Studies defining waist circumference cut-off values in adult populations

	Male			Female							
First author and year	Cut-off (cm)	Mean (cm)	*n*	Cut-off (cm)	Mean (cm)	*n*	Population	Method*	Outcome measurement†	Age range (years)	Waist measurement‡
Aekplakorn (2006)[7]	84·0	80·7	2093	84	80·6	3212	Thailand	M3	MF	35 +	W4
Almeida (2009)[8]				86	84·65	270	Brazil	M3	CHD risk	30–69	W2
Alonso (2008)[9]	98·0	94·3	727	84	89·6	309	Mexico	M4	MF	35–65	W3
Baik (2009)[10]	85	84·1	1995	78	77·9	2682	Korea	M2	MF	20–80	W4
Balkau (2006)[11]	94	91·3	1746	83	78·2	1823	France	M1	MF	40–64	W2
Bao (2008)[12]	87·5	88·77	525	84·3	86·98	615	China	M1	VFA, MF	35–75	W1
Barbosa (2006)[13]	88	83·6	718	84	80·8	718	Brazil	M3	MF	20 +	W2
Berber (2001)[14]	90	87·26	2426	85	81·92	5939	Mexico	M3	MF	20 +	W2
Bouguerra (2007)[15]	85	83·9	1144	85	81·1	2191	Tunisian	M3	MF	20 +	W1
Chen (2007)[16]	95	95·1	3165	80	81·8	4026	Australia	M1	CVD risk	30–74	W4
Craig (2007)[17]	100·5	99	314	101·2	100·2	453	Tonga	M2	MF	15 +	W1
Delavari (2009)[18]	89	89·8	1431	91	89	1535	Iran	M1	MF	25–64	W1
Deshmukh (2006)[19]	72·5	72·5	1059	65·5	65·3	1641	India	M1	Hypertension	18 +	W1
Dobbelsteyn (2001)[20]	91	91·2	4951	78	79·1	4962	Canada	M1	MF	18–74	W2
Doi (2009)[21]	90	82	1050	80	81·1	1402	Japan	M1	CVD incidence	40 +	W3
Esteghamati (2008)[22]	91·5	95·47	1046	85·5	93·1	1706	Iran	M1	MF	18–80	W1
Flegal (2007)[23]	93	98	4668	86	89	4830	USA	M1	Health level	40–59	W4
Foucan (2002)[24]				83	82·4	5149	Guadeloupe	M1	MF	18–74	W1
Gus (2009)[25]	87	86·8	255	80	79·8	334	Brazil	M2	Hypertension	Adults	W1
Hadaegh (2009)[26]	94·5	91·4	1614	94·5	93·1	2006	Iran	M1	CVD incidence	40 +	W2
Han (2008)[27]	88·1	89·6	276	84	85·1	540	Korea	M2	VFA	17–69	W1
Hara (2006)[28]	85	83·5	408	78	74·3	284	Japan	M1	MF	30–80	W1
Ho (2003)[29]	79·9	83·1	1412	75·9	75·3	1483	China	M1	MF	25–74	W1
Huang (2005)[30]	88	85·2	1243	84	82	1189	China	M1	MF	65 +	W1
Huxley (2007)[31]	99	95·7	9000	85	82·6	12 265	Australia	M1	DM	25 +	W4
Ito (2003)[32]	84	82·4	768	72	69·5	1960	Japan	M3	MF	20–79	W4
Kashihara (2009)[33]	89	88·3	5080	83	81·7	1656	Japan	M2	MF	30–74	W4
Kim (2009)[34]	83	84	18 551	76	75	12 525	Korea	M1	MF	20–89	W1
Ko (1999)[35]	81·85	80·8	910	76·75	74·9	603	China	M1	MF	Adults	W2
Ko (2009)[36]	84·6	83·8	129	75·7	75	153	China	M1	High MFT	20–68	W2
Ko (2007)[37]	83·3	84·2	4837	76·1	74·1	10 082	China	M1	CVD risk	18–93	W1
Lee (2007)[38]	80	84·6	1146	82	80	1330	Japan	M1	MF	30–80	W3
Lee (2007)[39]	85	82·8	2930	80	78·6	3631	Korea	M1	MF	20–80	W2
Lin (2002)[40]	80·5	80·5	26 359	71·5	70·2	29 204	China	M1	MF	Adults	W1
Mansour (2007)[41]	92·5	90·9	6693	93	92·6	6293	Iraq	M1	MF	18 +	W3
Mohan (2007)[42]	87·6	85·4	1175	82·6	81·7	1175	India	M2	MF	20 +	W2
Narisawa (2008)[43]	87	85·8	7762	83	79·8	4963	Japan	M1	MF	21–88	W3
Narksawat (2007)[44]	83·5	82·02	396	80·05	79·57	602	Thailand	M1	MF	45–59	W1
Nilsson (2008)[45]	96	94	181	88	87	190	Sweden	M1	MF	75–	W1
Oka (2008)[46]	89·8	86·9	1061	82·3	81·9	809	Japan	M1	MF	Adults	W3
Park (2009)[47]	83·3	84·3	2327	79·95	78·4	3102	Korea	M4	MF	20 +	W1
Peixoto (2006)[48]	86	86·3	431	80	78·6	806	Brazil	M3	Hypertension	20–64	W1
Pua (2006)[49]				75·3	74·5	358	Singapore	M3	Low CRF	17–65	W1
Pua (2005)[50]				77·8	74·3	566	Singapore	M1	MF	18–68	W1
Rush (2009)[51]	103	106·6	1344	98	98·4	2742	New Zealand	M2	MF	28 +	W1
Sakurai (2009)[52]	80	80·1	2935	72·7	73	1622	Japan	M1	MF	35–59	W4
Sanchez-Castillo (2003)[53]	94·7	93·2	11 730	95·5	93	26 647	Mexico	M3	MF	20–69	W1
Sargeant (2002)[54]	88	80·3	290	84·5	82·6	438	Jamaica	M1	DM	25–74	W4

Sato (2008)[55]	87	83·4	118	80	76·6	277	Japan	M4	MF	35 +	W4
Seo (2009)[56]	86·8	88	308	86·2	88·5	381	Korea	M2	MF	63 +	W3
Shimajiri (2008)[57]	86	85·7	3148	81	76·8	2423	Japan	M4	MF	Adults	W3
Shiwaku (2005)[58]	82	79·7	121	73	71·5	240	Japan	M1	MF	30–60	W2
	92	90·5	100	84	82	152	Mongolia	M1	MF	30–60	W2
Snehalatha (2003)[59]	85	80·7	4711	80	79	5314	India	M4	DM	20 +	W4
Stevens (2001)[60]	101	99	4602	95	91·8	5293	USA (White)	M2	DM incidence	45–64	W3
	99	95·8	1102	101	98·3	1817	USA (African)	M2	DM incidence	45–64	W3
Tabata (2009)[61]	85	83·7	4800				Japan	M1	Elevated HOMA-IR	39–60	W3
Tseng (2010)[62]	86·25	85·7	2280	77·5	75·9	2403	China	M1	MF	25–74	W4
Uzunlulu (2009)[63]	93	97·58	447	83	94·65	592	Turkey	M1	Elevated HOMA-IR	18 +	W2
Wang (2009)[64]	86·45	87·6	59 874	82·05	83	15 914	China	M1	MF	18–85	W1
Woo (2002)[65]	83·4	83·4	999	83·9	80·1	1033	China	M1	Mortality (CVD risk)	70 +	W2
Yang (2006)[66]	78·9	75·4	887	65·8	65·3	694	China	M1	PBF	20–30	W2
	82·4	79·3	222	71·4	71·1	185	China	M1	PBF	31–40	W2
Ye (2009)[67]	88	86	114	82	82·5	176	China	M1	MF	35–75	W1

* Methods for optimising sensitivity and specificity: M1, maximum of sensitivity and specificity; M2, shortest distance on receiver-operating characteristic (ROC) curve; M3, sensitivity = specificity; M4, other methods or unspecified.

† Outcome measurements: MF, multiple factors for CVD or the metabolic syndrome; VFA, visceral fat area; DM, diabetes mellitus; MFT, mesenteric fat thickness; CRF, cardiorespiratory fitness; HOMA-IR, homeostatic model assessment of insulin resistance; PBF, elevated percentage body fat.

‡ Waist circumference measurements: W1, midway between the bottom of the lower rib and top of the iliac crest; W2, the narrowest point between the umbilicus and xiphoid process; W3, at the umbilicus; W4, other methods and unspecified.