Validity of self-reported abdominal obesity in Thai adults: A comparison of waist circumference, waist-to-hip ratio and waist-to-stature ratio

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Abstract Background and aims: Waist circumference (WC), waist-to-hip ratio (WHR) and waist-to-stature ratio (WSR), being common proxy measures of abdominal obesity, are useful tools in epidemiologic studies, but little is known about their validity when the indices are derived from self-reported measurements. We determine and compare the validity of self-reported WC, WHR and WSR in order to identify the optimal index for use in epidemiologic surveys.

Methods and Results: Technician- and self-reported measurements of height, waist and hip circumference were obtained from 613 Thai adults (mean age 35 years). Regarding technician-reported measurements as reference, diagnostic test properties were derived and performances of the indices compared using receiver-operator-characteristic curves and the area-under-the-curve (AUC) analyses. There was good agreement between technician- and self-reported measurements for WC and WSR (concordance correlation coefficients ranged from 0.84 to 0.90) but not for WHR (0.50 in men, 0.45 in women). The sensitivity and specificity of self-reported WC and self-reported WSR as measures of abdominal obesity were superior to those of self-reported WHR in both sexes. AUCs for WC and WSR were comparable (0.93 and 0.92, respectively, in men; 0.88 and 0.87 in women) and significantly higher than for WHR (0.80 in men; 0.76 in women; p < 0.0001).

Conclusion: WC and WSR derived from self-reported waist and height measurements are valid methods for determining abdominal obesity. Self-reported measurements should not be used to derive the WHR. In Asian populations, WSR may be the optimal index of abdominal obesity when measurements are derived from self-reports in epidemiologic surveys.

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Abbreviations: AUC, area-under-the-curve; BMI, body mass index; PPV, positive predictive value; ROC, receiver-operator characteristic; STOU, Sukhothai Thammathirat Open University; TCS, Thai Cohort Study; WC, waist circumference; WHR, waist-to-hip ratio; WSR, waist-to-stature ratio.

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With the alarming rise in obesity worldwide, practical and economic means of measuring excess body fat have become increasingly important in routine clinical practice and in epidemiologic studies [1]. Body mass index (BMI), which reflects overall body fat, is the most commonly used measure of obesity as it has strong links to risks of adverse health outcomes [1]. Mounting evidence suggests that excess deposition of fat in the abdominal region is more strongly associated with subsequent adverse cardio-metabolic outcomes than overall body fat [2]. But the optimal approach for routine measurement of abdominal obesity remains controversial [3,4].

Waist circumference (WC) and the ratio of waist to hip circumference (waist-hip ratio, WHR) are two popular proxy measures of abdominal obesity [5]. More recently, the ratio of waist to height (waist-stature ratio, WSR) has been proposed as an alternative measure of abdominal obesity [6]. All three indices, WC, WHR and WSR, are strongly associated with cardio-metabolic risks and subsequent adverse outcomes [7–9], but no one index is clearly superior as studies comparing the performances of these indices have conflicting findings. WHR outperformed WC and WSR as a measure of risk of myocardial infarction in the INTERHEART study across 52 countries [10], but a meta-regression of 15 prospective studies involving 258,114 participants found little difference between WHR and WC [11], while WC and WSR predicted cardiovascular risk better than did WHR in the European DETECT study of over 5500 adults [12]. In one Chinese study of 15,236 adults, WC and WHR were equally able to identify diabetes mellitus [13], but in another of 75,788 Chinese adults WC outperformed WHR [14]. Several recent studies have reported some superiority of the WSR in Asian populations [8,14–20].

The rise in recent decades of mortality from cardiovascular disease in Thailand has been attributed to the increased prevalence of obesity among Thai adults [21]. This study was motivated by the desire to assess abdominal obesity in the Thai Cohort Study (TCS), a large prospective study of health risk transitions in over 80,000 men and women from the Sukhothai Thammathirat Open University (STOU) in Thailand [22]. We needed to determine which of WC, WHR or WSR would be optimal for use in a self-administered questionnaire as information in the TCS is sought through mail-out surveys. However there is a dearth of information about the validity of WC, WHR and WSR when the underlying anthropometric measurements are self-reported. We found just ten studies examining the accuracy of self-reported WC or self-reported WHR [23–32], and none of self-reported WSR. Further these studies were all conducted in the US and Europe and may not be applicable to an Asian population.

We collected technician- and self-reported measurements of height, waist and hip circumference on a representative sample of 613 adult Thai subjects. Our purpose is to determine the validity of WC, WHR and WSR when these indices are derived from self-reported measurements and, by comparing their performances, to determine the optimal abdominal obesity index for routine use in epidemiologic studies.

**Methods**

**Study population and data collection**

Study subjects were a convenience sample of 613 STOU students who attended the main campus in Bangkok during May 2008 for special courses on professional ethics before graduation. Participation was voluntary. Participants were given written Ministry of Public Health instructions for measuring waist and hip circumference along with a diagram and photo illustration. They were asked to self-report their weight and height and then use a graduated tape to measure their waist and hip circumferences. The waist was measured at the level of the umbilicus and hip measurement defined as the widest part of the hip. The participants wore light clothing and these were not removed. After reporting their results on a form they were invited to allow the same measurements to be made by a trained technician and all agreed. Weight and height measurements were made by one technician and waist and hip measurements by two technicians working together. Height was measured without shoes with a SECA stadiometer. Height, waist and hip were measured to the nearest centimetre.

**Wrist, hip, height and the derived WHR and WSR variables**

WHR was calculated as WC divided by hip circumference; WSR as WC divided by height. Technician-reported indices are calculated from technician-reported measurements; and self-reported indices from self-reported measurements. Discrepancies were calculated as self-reported minus technician-reported measurements. Discrepancies in WC or hip circumference of over 5 cm, height discrepancies of over 10 cm, and percentage discrepancies in WHR or WSR over 5% were checked for data entry errors.

**Statistical methods**

Agreement between self- and technician-reported measurements was assessed using the concordance correlation coefficient [33]. The coefficient evaluates the degree to which pairs of measurements fall on the 45° line through the origin and is an appropriate measure of agreement between two continuous variables. The Pearson correlation coefficient is reported here for comparison with existing studies because it is frequently, although inappropriately, used as a measure of agreement [34].

By regarding the self-reported indices as diagnostic tests and the technician-derived indices as reference (gold standard), validity of the self-reported indices was assessed.
by the standard diagnostic test criteria of sensitivity, specificity, positive and negative predictive values [35]. 

Sensitivity is the proportion of obese individuals who are correctly identified as obese from the self-reported obesity index; specificity the proportion of non-obese individuals who are correctly identified as non-obese from the self-reported index. Positive predictive value (PPV) is the probability of truly being obese when the result from the self-reported obesity index is positive; negative predictive value the probability that the self-reported index will correctly identify a non-obese person. Youden’s Index, defined as (sensitivity + specificity – 1), combines sensitivity and specificity into a single number and gives a simple measure of the overall performance of a test which is particularly useful for comparing test performance in situations where sensitivity and specificity are equally important [35]. Values are close to 1 when both sensitivity and specificity are high.

These methods rely on a (binary) gold standard to dichotomise subjects into normal or abnormal, where abnormal in our context is excess abdominal obesity. The technician-reported WC, WHR and WSR are gold standards on a continuous-scale which can be converted to binary gold standards using cut-off points. We use cut-off points for WC, WHR and WSR derived from a study of 5305 Thai adults [36]. The seven cardiovascular risk factors examined in the study reported optimal cut-off points for WC ranging from 80 to 85 cm in men and 81 to 85 cm in women, for WHR from 0.89 to 0.91 in men and 0.85 to 0.88 in women and for WSR from 0.49 to 0.52 for men and 0.53 to 0.56 in women [36]. The smallest and the largest cut-off points are used here. The largest cut-off points were associated with Type II diabetes and the smallest with dyslipidemia in both sexes for all three indices.

Receiver-operator-characteristic (ROC) curves and area-under-the-curve (AUC) analyses were used to compare the overall performances of the self-reported indices. This approach was necessary because of the absence of universally accepted cut-off points for the three indices since comparing performances of the indices using arbitrary choices of cut-off points could be misleading. For example, with proposed cut-off points for WC in women ranging from 80 cm to 90 cm [37], the sensitivity (or specificity) of self-reported WC could be artifically varied with choice of cut-off point. Consequently comparison of the performances of the self-reported indices could be manipulated through judicious choices of cut-off points for each index. The ROC-AUC method used here overcomes this potential bias by giving equal consideration to all possible cut-off points for each index when computing its AUC.

Derivation of the ROC curves was based on a method by Obuchowski [38] for continuous-scale gold standards. An ROC curve is a trace of sensitivity against “1-specificity”. Instead of relying on a single cut-off point, the ROC-AUC method here creates the ROC trace over the entire range of potential cut-off points. For each of WC, WHR and WSR, 50 values between the minimum and maximum of the observed values of the index were defined, and sensitivity and “1-specificity” computed using these values as cut-off points. For all three indices, sensitivity and “1-specificity” increase with increasing magnitude of the cut-off point. For example, for WC in men, 50 values between 71.6 cm (minimum) and 101 cm (maximum) were defined, and sensitivity and “1-specificity” computed using the 50 values in turn as cut-off point. For clarity in graphing the ROC curves, the x-axis (“1-specificity”) was partitioned into seven sectors (0−0.01, 0.01−0.05, 0.05−0.1, 0.1−0.2, 0.2−0.3, 0.3−0.4, 0.4−1), and the sensitivities and “1-specificities” averaged within each sector for plotting. Non-parametric AUC estimates were derived using the trapezoidal method [39] and variances estimated by bootstrapping [40]. All analyses and computations were performed using Stata Version 9.

Results
The sample of 613 Thai adults ranged in age from 21 to 62 years, with a mean of 35 years. Mean BMI was 24.6 kg/m² (SD 3.8) in men and 22.3 kg/m² (SD 3.7) in women.

Agreement between technician- and self-reported measurements
Except for hip circumference in women, all other self-reported values were statistically significantly different from technician-reported values (Table 1). Both men and women over-estimated their height and under-estimated their hip circumference (WC), while men also under-estimated their hip circumference. Correlations between technician- and self-reported values were lower for WHR than for WC and WSR, for both men and women (Table 1).

Self-reported values of the three abdominal obesity indices were under-estimated by both men and women, except for WHR which was over-estimated by men (Table 2). When examined within BMI tertiles, the percentage differences between technician- and self-reported values increased with increasing body size (Table 2). The correlations between technician and self-reported values were also higher as body size increased, indicating greater systematic bias in self-reported values with increasing body size.

Validity
Tables 3 and 4 show, for men and women respectively, diagnostic test values for the three abdominal obesity indices using two sets of cut-off points to define excess body fat. In men, cut-off points used were 80 cm and 85 cm for WC, 0.89 and 0.91 for WHR and 0.49 and 0.52 for WSR (Table 3). Sensitivity was similar for the three indices and specificity was similar for WC and WSR but lower for WHR than for WC and WSR (Table 3). In women, cut-off points used were 81 cm and 85 cm for WC, 0.85 and 0.88 for WHR and 0.53 and 0.56 for WSR (Table 4). Both sensitivity and specificity were similar for WC and WSR, and higher than for WHR (Table 4). Youden’s Index was consistently lowest for WHR (Tables 3 and 4).

2 Hypertension, Type II diabetes, high total cholesterol, low high-density lipoprotein cholesterol, high low-density lipoprotein cholesterol, high triglyceride and dyslipidemia.
PPV was also lower for WHR. The PPVs corresponding to the smallest and largest cut-off points for WHR were 56.8% to 63.3%, respectively, in men and 34.5% to 52.5%, respectively, in women (Tables 3 and 4). PPVs for WC and WSR were similar, and higher in men than in women.

**Relative performance of the indices**

The ROC curves of WC and WSR were similar for both sexes and consistently above the ROC curve of WHR (Fig. 1). The AUCs for WC and WSR were, respectively, 0.93 (95% confidence interval 0.91–0.95) and 0.92 (0.90–0.95) in men, and 0.88 (0.86–0.91) and 0.87 (0.84–0.90) in women. The AUCs for WHR were 0.80 (0.76–0.84) in men and 0.76 (0.71–0.80) in women, which were significantly lower ($p < 0.0001$) than the AUCs of the other two indices.

**Discussion**

We sought to determine and compare the validity of WC, WHR and WSR when these indices are derived from self-reported measurements to identify the best index for use in

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### Table 1

<table>
<thead>
<tr>
<th></th>
<th>Technician-reported</th>
<th>Self-reported</th>
<th>Discrepancy</th>
<th>Correlation coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (95%CI)</td>
<td></td>
</tr>
<tr>
<td>Waist circumference (WC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>84.3 (10.0)</td>
<td>83.2 (8.8)</td>
<td>−1.09 (−1.54, −0.64)</td>
<td>0.90 0.92</td>
</tr>
<tr>
<td>Women</td>
<td>74.4 (8.8)</td>
<td>73.2 (8.3)</td>
<td>−1.17 (−1.69, −0.65)</td>
<td>0.85 0.86</td>
</tr>
<tr>
<td>Hip circumference, cm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>96.2 (7.0)</td>
<td>93.7 (7.8)</td>
<td>−2.45 (−2.90, −2.01)</td>
<td>0.81 0.86</td>
</tr>
<tr>
<td>Women</td>
<td>91.4 (7.5)</td>
<td>91.6 (8.8)</td>
<td>0.19 (−0.62, 1.01)</td>
<td>0.62 0.62</td>
</tr>
<tr>
<td>Height, cm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>167.0 (6.0)</td>
<td>168.7 (6.4)</td>
<td>1.71 (1.46, 1.95)</td>
<td>0.87 0.94</td>
</tr>
<tr>
<td>Women</td>
<td>156.3 (5.2)</td>
<td>157.6 (5.3)</td>
<td>1.32 (1.1, 1.53)</td>
<td>0.91 0.94</td>
</tr>
<tr>
<td>Waist-Hip Ratio (WHR)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>0.87 (0.06)</td>
<td>0.89 (0.06)</td>
<td>0.013 (0.007, 0.019)</td>
<td>0.50 0.51</td>
</tr>
<tr>
<td>Women</td>
<td>0.81 (0.05)</td>
<td>0.80 (0.06)</td>
<td>−0.013 (−0.019, −0.006)</td>
<td>0.45 0.47</td>
</tr>
<tr>
<td>Waist-Stature Ratio (WSR)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>0.50 (0.06)</td>
<td>0.49 (0.05)</td>
<td>−0.012 (−0.014, −0.009)</td>
<td>0.88 0.91</td>
</tr>
<tr>
<td>Women</td>
<td>0.48 (0.06)</td>
<td>0.46 (0.05)</td>
<td>−0.011 (−0.015, −0.008)</td>
<td>0.84 0.85</td>
</tr>
</tbody>
</table>

A Discrepancy = Self-reported values − Technician-reported values.

b Concor dence correlation coefficient = Bias correction factor × Pearson correlation coefficient (Lin 1986).

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### Table 2

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Waist Circumference (WC)</th>
<th>Waist-Hip Ratio (WHR)</th>
<th>Waist-Stature Ratio (WSR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men % difference, a (95% CI)</td>
<td>313</td>
<td>−1.1 (−1.6, −0.5)</td>
<td>1.7 (1.0, 2.4)</td>
<td>−2.0 (−2.6, −1.5)</td>
</tr>
<tr>
<td>By BMI tertilesb</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bottom third</td>
<td>105</td>
<td>1.0 (0.1, 1.9)</td>
<td>4.4 (3.0, 5.8)</td>
<td>0.2 (−0.6, 1.1)</td>
</tr>
<tr>
<td>Middle third</td>
<td>104</td>
<td>−1.5 (−2.4, −0.6)</td>
<td>1.5 (0.4, 2.6)</td>
<td>−2.7 (−3.6, −1.7)</td>
</tr>
<tr>
<td>Top third (Highest BMI)</td>
<td>104</td>
<td>−2.6 (−3.4, −1.8)</td>
<td>−0.8 (1.8, 0.1)</td>
<td>−3.7 (−4.6, −2.9)</td>
</tr>
<tr>
<td>Women % difference, a (95% CI)</td>
<td>300</td>
<td>−1.3 (−2.0, −0.6)</td>
<td>−1.4 (2.2, −0.6)</td>
<td>−2.1 (−2.8, −1.4)</td>
</tr>
<tr>
<td>By BMI tertilesb</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bottom third</td>
<td>100</td>
<td>0.0 (−1.2, 1.3)</td>
<td>−1.0 (−2.7, 0.6)</td>
<td>−0.8 (−2.1, 0.5)</td>
</tr>
<tr>
<td>Middle third</td>
<td>100</td>
<td>−1.5 (−2.6, −0.3)</td>
<td>−1.3 (−2.4, −0.2)</td>
<td>−2.2 (−3.3, −1.1)</td>
</tr>
<tr>
<td>Top third (Highest BMI)</td>
<td>100</td>
<td>−2.5 (−3.7, −1.4)</td>
<td>−1.8 (−3.2, −0.5)</td>
<td>−3.4 (−4.6, −2.2)</td>
</tr>
</tbody>
</table>

a Percentage difference = (Self-reported value − Technician-reported value)/Technician-reported value × 100.

b Tertiles calculated from BMI values derived from technician measurements of weight and height.
large epidemiologic surveys. Self-reported WHR performed significantly worse than the other two indices. Self-reported WC and self-reported WSR both demonstrated good validity and were comparable on all diagnostic testing performance criteria.

We therefore considered two other criteria to choose between WC and WSR.

(1) Predictive ability. For the Thai population of the TCS, WSR may be preferable to WC as several studies on Asian populations have demonstrated superiority of WSR over other abdominal obesity indices [8,14–20]. In Western populations, although a few studies have shown superiority of WSR [9,12,41], the conflicting findings over an optimal abdominal obesity index have led some authors to conclude that the differences in predictive ability between the indices are clinically irrelevant [7,9].

(2) Simplicity of cut-off points. With WSR, a universal cut-off point of 0.5 has been recommended for all subgroups – men and women, children and adults, as well as Asians and Caucasians [6]. This is an advantage over WC for which universally applicable cut-off points cannot be developed because populations differ in the level of risk associated with a particular waist circumference [1,42]. For example, at least seven pairs of cut-off points have been suggested for WC for men and women in different ethnic populations [37].

With these considerations, we believe WSR is the most appropriate index of abdominal obesity for use in epidemiologic surveys, particularly in Asian populations.

**Previous work on self-reported abdominal obesity indices**

We are not aware of any other study of self-reported WSR, but have identified a few of self-reported WC or self-reported WHR. These studies focused primarily on agreement between self- and technician-reported measurements rather than on validity of the self-reported indices. Nevertheless there were some interesting observations between our findings and results from these studies.

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**Table 3** Test values for self-reported waist circumference (WC), self-reported waist-hip ratio (WHR) and self-reported waist-stature ratio (WSR) using two sets of cut-off points to define excess body fat in men (n = 313).

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Positive predictive value (PPV)</th>
<th>Negative predictive value (NPV)</th>
<th>Youden’s Index</th>
<th>Prevalence, %</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Waist circumference, WC</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smallest cut-off (80 cm)</td>
<td>0.86</td>
<td>0.86</td>
<td>0.89</td>
<td>0.82</td>
<td>0.72</td>
<td>57</td>
</tr>
<tr>
<td>Largest cut-off (85 cm)</td>
<td>0.70</td>
<td>0.95</td>
<td>0.90</td>
<td>0.82</td>
<td>0.64</td>
<td>40</td>
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<tr>
<td><strong>Waist-hip ratio, WHR</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smallest cut-off (0.89)</td>
<td>0.82</td>
<td>0.73</td>
<td>0.63</td>
<td>0.87</td>
<td>0.55</td>
<td>36</td>
</tr>
<tr>
<td>Largest cut-off (0.91)</td>
<td>0.63</td>
<td>0.82</td>
<td>0.57</td>
<td>0.85</td>
<td>0.45</td>
<td>27</td>
</tr>
<tr>
<td><strong>Waist-stature ratio, WSR</strong></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Smallest cut-off (0.49)</td>
<td>0.80</td>
<td>0.89</td>
<td>0.90</td>
<td>0.80</td>
<td>0.69</td>
<td>54</td>
</tr>
<tr>
<td>Largest cut-off (0.52)</td>
<td>0.68</td>
<td>0.98</td>
<td>0.95</td>
<td>0.84</td>
<td>0.66</td>
<td>36</td>
</tr>
</tbody>
</table>

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**Table 4** Test values for self-reported waist circumference (WC), self-reported waist-hip ratio (WHR) and self-reported waist-stature ratio (WSR) using two sets of cut-off points to define excess body fat in women (n = 300).

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Positive predictive value (PPV)</th>
<th>Negative predictive value (NPV)</th>
<th>Youden’s Index</th>
<th>Prevalence, %</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Waist circumference, WC</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Smallest cut-off (81 cm)</td>
<td>0.63</td>
<td>0.96</td>
<td>0.81</td>
<td>0.91</td>
<td>0.59</td>
<td>21</td>
</tr>
<tr>
<td>Largest cut-off (85 cm)</td>
<td>0.60</td>
<td>0.99</td>
<td>0.88</td>
<td>0.95</td>
<td>0.59</td>
<td>12</td>
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<tr>
<td><strong>Waist-hip ratio, WHR</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Smallest cut-off (0.85)</td>
<td>0.44</td>
<td>0.88</td>
<td>0.53</td>
<td>0.84</td>
<td>0.32</td>
<td>23</td>
</tr>
<tr>
<td>Largest cut-off (0.88)</td>
<td>0.40</td>
<td>0.93</td>
<td>0.35</td>
<td>0.95</td>
<td>0.33</td>
<td>8</td>
</tr>
<tr>
<td><strong>Waist-stature ratio, WSR</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Smallest cut-off (0.53)</td>
<td>0.67</td>
<td>0.97</td>
<td>0.84</td>
<td>0.93</td>
<td>0.57</td>
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<tr>
<td>Largest cut-off (0.56)</td>
<td>0.60</td>
<td>0.99</td>
<td>0.79</td>
<td>0.97</td>
<td>0.66</td>
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</table>

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(a) The smallest and the largest of seven cut-off points reported in Aekplakorn (2006).

(b) Youden’s Index = (Sensitivity + Specificity − 1).
First, the majority of studies had cautioned against the use of self-reported WHR as we have. Four were relatively small studies, with less than 200 subjects each [25,26,28,29]. The British study of 4492 participants found unacceptably high misclassification rates for self-reported WHR (66.9% and 69.8% of men and women, respectively) leading the authors to conclude that “using WHR derived from self-reported measurements may be more likely to obscure true associations than using either waist or hip measurement alone” [32].

One study [30] concluded WHR would be a useful tool in epidemiologic studies. This study, comprising 111 employees from a medical institution, found high sensitivity (77% in men; 81% in women) and specificity (93% in both) for self-reported WHR. The high levels of accuracy may be because participants and technicians were instructed to take each measurement twice, plus a third if there was excessive difference between the first two, and to report the average measurement.

Second, as in our study, all previous studies found the correlations between self- and technician-reported measurements for WHR to be lower than the correlations for WC [25,29–32]. In men, WHR correlations ranged from 0.44 to 0.78 compared with 0.80 to 0.95 for WC; in women WHR correlations ranged from 0.62 to 0.83 compared with 0.83 to 0.99 for WC. Although high correlations do not imply that the self-reported measurements are valid, low correlations do indicate that the self-reported measurements are not acceptable substitutes for technician-reported measurements.

Third, the trend of decreasing accuracy with increasing body size in self-reported WC and self-reported WHR were reported in three studies [26,28,30–32]. This trend, also observed in the present study, has been consistently documented in validation studies of self-reported BMI, for example [43–45], and in our parallel validation study of self-reported BMI [46].

In summary, key findings from this study are consistent with conclusions of earlier studies, that (1) WHR derived from self-reported measurements is not valid, (2) self-reported WC performs better than self-reported WHR, and (3) the validity of self-reported obesity indices decreases with increasing body size.

Comparing validity of self-reported WSR to validity of self-reported BMI

BMI derived from self-reported weight and height is widely used in epidemiologic studies as a measure of obesity. In non-Asian populations, the sensitivity and specificity of self-reported BMI range from 68% to 86% and 96% to 99%, respectively, in men and from 69% to 89% and 97% to 99% in women [43–45,47]. Our parallel validation study of self-reported BMI in Thailand using the Thai BMI cut-off point of 25 kg/m² for obesity found sensitivity and specificity of 74.2% and 97.3%, respectively, in men and 71.9% and 100% in women [46].

The sensitivity and specificity of self-reported BMI are similar to the sensitivity and specificity of self-reported WSR using a cut-off point of 0.5 (76% and 97.6%, respectively, in men; 69% and 97.3% in women). The comparability in validity of self-reported WSR with validity of the widely used self-reported BMI supports the case for use of WSR derived from self-reported measurements in epidemiologic studies.

Positive predictive values (PPVs)

PPV is arguably the most important test property for the purpose of determining obesity from self-reported data.
because it reflects the probability that a positive test result correctly identifies obesity. In this study, PPVs for WC and WSR were generally high, close to 80% or greater, but PPVs for WHR were low, ranging from 35% and 63%. The low PPVs for WHR mean that, in our study population, individuals whose self-reported WHR indicate excess abdominal fat have low probabilities of truly being obese.

**Generalisability**

Our sample was designed to represent Thais who were educated enough to self-report measurements. They were drawn from the STOU student population who were all Thai citizens (72% have Chinese ethnic links), enrolled for distance-learning university degrees and almost all had completed high school and the central 90% of the age distribution was between 25 and 46 years. The median income of the TCS sample was the equivalent of US$2550 and the income distribution was quite similar to that of the Thai population in general [22]. Overall they were sufficiently homogeneous in relation to factors that could affect self-reporting and sufficiently representative to allow generalisation to educated adult Thais.

**Limitations**

Care should be taken when generalising to non-Asian populations because of different body frames and possibly different culturally desirable body images which may influence the bias in self-reported body size measurements. Confirmation of our findings in other settings is needed. Another limitation was waist measurement only at the level of the umbilicus which may restrict the clinical utility of our findings. This restriction may not however be significant as authors of the Oxford study had concluded that acceptable results were obtained in their study despite no instructions being given to participants on how to make waist and hip measurements [32].

We did not examine or control for variability in the technician-reported measurements. As Panoulos [48] found significant inter-technician variability in waist measurement, more reliable technician measurements using, for example, replications could affect our findings. However, we expect minimal differences from replicated measurements in the present study because in every instance of more than 50 cases where participants had requested the technicians repeat their measurements, the repeated results were the same. Accuracy of self-reported waist measurements could be improved by requesting respondents to have another person measure them [28] or by instructing respondents to take at least two separate measurements and to report the average [30,31].

**Conclusions**

WC and WSR derived from self-reported waist and height measurements are valid methods for measuring abdominal obesity in epidemiologic studies. Use of WHR should be restricted to measurement by trained technicians because of poor validity when derived from self-reported measurements. In Asian populations, WSR may be the optimal measure of abdominal obesity when measurements are derived from self-reports in epidemiologic surveys.

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**Appendix. Supplementary data**

Supplementary data associated with this article can be found in the online version, at doi:10.1016/j.numecd.2010.04.003.

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Validity of self-reported abdominal obesity in Thai adults


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