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Association between waist circumference at two measurement sites and indicators of metabolic syndrome and cardiovascular disease among Thai adults

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ABSTRACT

Introduction: Waist circumference (WC) is a measure of central obesity, which is an established indicator of the risk of chronic disease. The objective of this study was to investigate the applicability of WC and risk of metabolic abnormality at two frequently used measurement sites in Thailand namely, at the umbilicus level (WC-U) and midway between the lowest rib and iliac crest (WC-M). **Methods:** Healthy adults aged 35-60 years living in Sung Noen District, Nakhon Ratchasima Province, Thailand were recruited by convenience for the study (N=296). WC was measured at two locations (WC-U and WC-M). Socioeconomic, health-habits, and physical-activity data were collected. Six ml blood samples from each participant were taken for analysis of glucose, lipids and C-reactive protein concentrations. Association between WC-U and WC-M was determined statistically. **Results:** WC measurements taken at WC-U and WC-M correlated strongly with each other in men (r=0.978, p<0.001), and in women (r=0.873, p<0.001). Both WC-U and WC-M correlated significantly with BMI, blood pressure, triglyceride, and cholesterol levels in both men and women. Intraclass correlation analysis confirmed highly significant associations between these two WC-measurement sites in men (ICC=0.960, p<0.001) and women (ICC=0.808, p<0.001). **Conclusions:** The results confirmed that both WC-U and WC-M can be used to monitor health status in men and women; however, WC-U is a simpler procedure for community health-risk surveillance and for self-monitoring.

Keywords: Waist circumference, anthropometry, metabolic syndrome, cardiovascular disease, self-monitoring

INTRODUCTION

Classification of obesity typically relies on various measurements of body mass index (BMI) and waist circumference (WC), and both have been used as health risk indicators. Although relatively simple and straightforward for health professionals and the general population, BMI is a surrogate measurement of excess weight rather than excess fat.

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Thus, its use is limited especially among the elderly with diminished muscle mass, and trained athletes with high muscle mass. Changes in central obesity can also occur in the absence of BMI change.

Among these anthropometric markers, WC is a measurement of central obesity, a condition of excessive visceral fat accumulation in the abdominal area. Epidemiological data have shown an association between central obesity and hypertension, dyslipidaemia, cardiovascular diseases, and metabolic syndrome (Huxley *et al.*, 2010; Beydoun *et al.*, 2011; Nikolopoulou & Kadoglou, 2012). Visceral adiposity is also responsible for insulin resistance via induction of adipokines and pro-inflammatory cytokines disrupting the normal physiological insulin signalling (Coletta & Mandarino, 2011; Esser *et al.*, 2014). Owing to the strong associations of visceral fat (VF) with many non-communicable diseases, incorporating WC measurement as a part of health monitoring protocols and health promotion programmes is clearly necessary.

Presently, numerous organisations have established WC thresholds or cut-off values for different ethnic groups and specific countries (International Diabetes Federation, 2006; World Health Organization, 2008; He *et al.*, 2017). However, several abdomen measurement sites for WC exist and differ among the guidelines. The National Institute of Health (NIH) published a WC measurement site immediately above the iliac crest (National Institute of Health, 2000), whereas the World Health Organization (WHO) recommended taking the WC as the midpoint circumference between the lowest rib and the iliac crest (WHO, 2008). A study reported that WC according to the WHO guideline is not comparable between gender and geographical locations (Wang *et al.*, 2003).

In Thailand, the WHO method is generally preferred, but a simple measurement at the umbilicus level has also been suggested by Ministry of Health, Thailand. Owing to excess adipose tissue, locating the rib and the iliac crest can be difficult, thus it is unreliable in overweight and obese people. Without proper training, there will be individual differences in WC-M, measurements at midway between the lowest rib and the iliac crest, and therefore, it may not be suitable among rural populations with low literacy levels. To our knowledge, no studies have determined the differences between WC measurement sites in the Thai population, or whether both methods are comparable indicators of health risk.

In this study, we reported the differences between WC measurements taken at the midpoint between the lowest rib and iliac crest (WC-M) according to the WHO guidelines, and at the umbilicus level (WC-U). In addition, we investigated the association between the WC measurement at two different sites, and factors associated with metabolic syndrome (MetS) and cardiovascular disease (CVD), including lipid profiles, blood sugar, oral glucose tolerance test (OGTT) and blood pressure.

MATERIALS AND METHODS

Study population

A total of 218 participants, aged 35–60 years, from Sung Noen District, Nakhon Ratchasima Province, Thailand were recruited by convenience sampling. Sample size was calculated based on $[Z_{1-\alpha/2}{}^2\ p(1-p)]/d^2$. Exclusion criteria were BMI <18.5 kg/m^2, presence of severe chronic conditions requiring medication such as diabetes, cancer, chronic kidney disease, and coronary heart disease, as well as ongoing pregnancy or lactation.

Anthropometric assessment and questionnaire

A trained staff member measured the anthropometric measurements of height and weight of the participants in light clothing and without shoes. Weight (kg) was divided by height squared (m^2) to calculate BMI. Percentage body fat and VF were estimated with a bioimpedance analyser (HBF-375, Omron Healthcare, Kyoto, Japan). Individual average blood pressure was obtained from automatic sphygmomanometers after 5 min of rest in a sitting position. In order to measure WC, participants stood straight with arms and legs slightly apart. The staff member stood on the side and placed a measuring tape on unclothed skin at two horizontal planes, the WC-U and the WC-M. Measurements of each type of WC were taken twice and the average of the two measurements was used. Socioeconomic, health habits, and physical activity data were collected using a questionnaire composed of general information and food, with physical activity calculated in Metabolic Equivalent of Task (MET).

Blood analysis

Following overnight fasting, a 6 mL blood sample was taken from each participant, who was then administered orally 75 g glucose for an OGTT. Blood glucose at baseline (fasting blood glucose, FBG), at 2-h after glucose loading (2hBG), and glycated haemoglobin (HbA_{1C}) levels were measured by a Cobas® 6000 analyser (Roche Diagnostics Ltd., Basel, Switzerland). Fasting insulin levels were determined using a human insulin enzyme linked immunosorbent assay (ELISA) kit (EMD Millipore, Billerica, MA, USA). Homeostatic model assessment of insulin resistance (HOMA-IR) and of beta cell function (HOMA-β) were calculated by the following equations: HOMA-IR = fasting glucose (mmol/L) × fasting insulin (μIU/mL)/405; HOMA-β = [20 × fasting insulin (μIU/mL)]/[fasting glucose (mmol/L) – 3.5].

Levels of triglyceride (TG), serum total cholesterol (TC), and low-density lipoprotein cholesterol (LDL-c) were analysed using the Cobas® 6000 analyser (Roche Diagnostics Ltd) while high-density lipoprotein cholesterol (HDL-c) was calculated from the following Friedwald equation: LDL-c = TC – (HDL-c + TG/5). A nephelometer (Siemens Healthcare GmbH, Erlangen, Germany), was used to determine the concentration of C-reactive protein (CRP).

The presence of MetS was determined using the National Cholesterol Education Program Adult Treatment Panel (NCEP ATP) III criteria. In brief, MetS was defined as the presence of at least three of the following conditions: central obesity (>102 cm male and >88 cm female), hypertriglyceridemia (>150 mg/dl), low HDL-c (<40 mg/dl male and <50 mg/dl female), hypertension (≥130/85 mmHg) and FBG (>110 mg/dl).

Statistical analysis

SPSS version 18 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. Continuous data were reported as mean and standard deviation, while categorical data were presented as frequency and percentage. Pearson's correlation coefficients were used to investigate the association between the two WC measurement locations, WC-U and WC-M, and the risk indicators for MetS and CVD. The differences in correlation coefficients between the two WC sites and the risk indicators for MetS and CVD were then determined by a test for equal correlation (http://vassarstats.net/rdiff.html). Intraclass correlation (ICC) was computed to demonstrate the strength of the relationship between the two WC location measurements and indicators of risk for MetS and CVD.

Ethics approval and consents to participate

Written informed consent was obtained from all subjects. The study was approved by the Ethics Committee of the Faculty of Tropical Medicine, Mahidol University (TMEC 13-073).

RESULTS

Socioeconomic and health habit characteristics of study groups

Table 1 shows socioeconomic and health habit data of participants, comprising 98 men and 120 women aged 35-61 years. Four-fifths of both men and women completed primary school. Most were farmers or worked in the industrial sector. More than half of the men smoked (58.2%) and consumed alcohol (61.9%), while only a few women smoked (3.3%) or drank alcohol (39.2%). Almost half of the participants failed to maintain the WHO (2011) recommended level of physical activity, i.e. at least 30 minutes' activity five times per week. One-third never exercised (35.7% of men and 35.8% of women), and 12.2% of men and 11.7% of women exercised less than three times per week.

Biometric and biochemical data of study groups

The MetS and CVD risk factors of the participants are shown in Table 2. Significant differences were found between the sexes in most of the study parameters, including higher levels of BMI, WC-U, WC-M, and body fat (BF) in women compared with men. The blood parameters of TC, LDL-c, 2hBG, HbA_{1c}, fasting insulin, HOMA-IR, and HOMA-β of women were significantly greater than in men, with the exception of TG and HDL-c levels.

Table 1. Demographic and health habits of participants

Variables	*Men (n=98)*		*Women (n=120)*	
	n	*%*	*n*	*%*
Education				
Illiterate	6	6.1	4	3.3
Primary school	80	81.6	98	81.7
High school	10	10.2	17	14.2
Other	2	2.0	1	0.8
Occupation				
Farmer	39	39.8	49	40.8
Factory worker	45	45.9	52	43.3
Grocer	5	5.1	8	6.7
Other	9	9.1	11	9.1
Smoking status				
Never smoked	25	25.5	112	93.3
Smoke	57	58.2	4	3.3
Used to smoke	16	16.3	4	3.3
Alcohol status				
Never drink	20	20.6	66	55.0
Drink	60	61.9	47	39.2
Used to drink	17	17.5	7	5.8
Frequency of physical activity				
Never	35	35.7	43	35.8
1-2 times/week	12	12.2	14	11.7
3-4 times/week	14	14.3	12	10.0
>4 times/week	37	37.8	51	42.5

Correlations between waist circumference measurements and risk factors of MetS and CVD

Table 3 shows the results of correlation analysis between the two WC locations: WC-U and WC-M, and the risk factors of MetS and CVD of the participants. In men, both WC-U and WC-M were significantly correlated with BMI, systolic blood pressure (SBP), diastolic blood pressure (DBP), BF, VF, TG, HbA_{1c}, fasting insulin, HOMA-IR, and HOMA-β. In women, WC-U and WC-M were significantly correlated with BMI, BF, VF, TC, LDL-c, HbA_{1c}, and HOMA-IR.

The intraclass correlation (ICC) analysis confirmed the degree of agreement between these two measurement sites (Table 4). The relatively high value of ICC (ICC = 0.960, $p<0.001$ in men and 0.808, $p<0.001$ in women) indicate no statistical differences between men and women for the MetS and CVD parameters.

Figure 1 shows the differences between the two waist circumferences measurements. A Bland-Altman plot described the mean differences and

Table 2. Metabolic syndrome (MetS) and cardiovascular disease (CVD) risk factors among male and female participants

Variables	*Men (n=98)*		*Women (n=120)*		*p*
	Mean	*SD*	*Mean*	*SD*	
Age (years)	47.04	6.07	46.17	5.68	0.137
BMI (kg/m^2)	23.66	4.00	25.93	4.47	<0.001***
WC-U (cm)	83.19	11.18	87.33	9.39	0.001***
WC-M (cm)	81.13	10.78	83.53	9.45	0.041*
BF (%)	21.68	6.00	33.15	5.39	<0.001***
VF (%)	9.74	5.18	8.84	4.85	0.094
SBP (mmHg)	123.00	15.31	122.98	20.24	0.499
DBP (mmHg)	75.87	12.11	74.16	11.75	0.149
TG (mg/dl)	168.50	102.08	145.28	95.97	0.043*
TC (mg/dl)	193.93	49.73	210.62	61.92	0.016*
LDL-c (mg/dl)	92.94	62.86	160.10	63.74	<0.001***
HDL-c (mg/dl)	82.43	48.31	50.52	15.12	<0.001***
FBG (mg/dl)	95.82	11.20	94.06	19.34	0.213
2hBG (mg/dl)	116.80	60.06	134.30	58.94	0.017*
HbA_{1c} (%)	5.24	0.52	5.52	0.88	0.003*
Fasting insulin (μU/ml)	5.48	4.42	7.16	6.67	0.017*
HOMA-IR	1.29	1.07	1.65	1.52	0.027*
HOMA-β	65.39	50.88	99.40	100.69	<0.001***
CRP (mg/dl)	3.21	7.68	3.75	9.00	0.319

Abbreviations: BMI, body mass index; WC-U, waist circumference at umbilicus level; WC-M, waist circumference at the midpoint between the lowest rib and iliac crest; BF, body fat; VF, visceral fat; SBP, systolic blood pressure; DBP, diastolic blood pressure; TG, triglyceride; TC, total cholesterol; LDL-c, low-density lipoprotein cholesterol; HDL-c, high-density lipoprotein cholesterol; FBG, fasting blood glucose; 2hBG, 2-hour blood glucose; HbA_{1c}, glycated haemoglobin; HOMA-IR, homeostatic model assessment of insulin resistance; HOMA-β, homeostatic model assessment of β-cell function; CRP, C-reactive protein

$^{*}p<0.05$

$^{**}p<0.01$

$^{***}p<0.001$

Table 3. Correlation between metabolic syndrome and cardiovascular disease risk factors and the two waist circumference locations; umbilicus and the midpoint level in men and women

Variables	WC-U				WC-M				Correlation comparison between WC-U and WC-M	
	Men		Women		Men		Women		Men	Women
	r	p	r	p	r	p	r	p	p	p
BMI	0.937	<0.001***	0.825	<0.001***	0.929	<0.001***	0.852	<0.001***	0.330	0.203
BF	0.835	<0.001***	0.781	<0.001***	0.818	<0.001***	0.799	<0.001***	0.355	0.356
VF	0.943	<0.001***	0.757	<0.001***	0.933	<0.001***	0.779	<0.001***	0.284	0.341
SBP	0.395	<0.001***	0.106	0.250	0.399	<0.001***	0.182	0.046*	0.488	0.278
DBP	0.424	<0.001***	0.073	0.427	0.418	<0.001***	0.105	0.253	0.480	0.401
TG	0.345	<0.001***	-0.081	0.376	0.399	<0.001***	-0.106	0.251	0.333	0.425
TC	0.193	0.057	0.245	0.007**	0.188	0.064	0.230	0.012*	0.484	0.452
LDL-c	0.156	0.126	0.270	0.003**	0.164	0.106	0.238	0.009**	0.476	0.397
HDL-c	-0.020	0.842	-0.134	0.144	-0.045	0.661	-0.062	0.500	0.432	0.288
FBG	0.054	0.598	0.027	0.766	0.056	0.582	0.039	0.673	0.496	0.461
2hBG	0.107	0.295	0.123	0.182	0.129	0.207	0.124	0.176	0.440	0.496
HbA_{1c}	0.399	<0.001***	0.246	0.007**	0.348	<0.001***	0.271	0.003**	0.341	0.421
Fasting insulin	0.444	<0.001***	0.170	0.063	0.422	<0.001***	0.147	0.109	0.425	0.429
HOMA-IR	0.426	<0.001***	0.200	0.028*	0.411	<0.001***	0.186	0.042*	0.448	0.456
HOMA-β	0.435	<0.001***	0.143	0.120	0.410	<0.001***	0.117	0.204	0.417	0.421
CRP	0.117	0.251	-0.070	0.444	0.115	0.255	-0.204	0.798	0.496	0.363

Abbreviations: WC-U, waist circumference at umbilicus level; WC-M, waist circumference at the midpoint between the lowest rib and iliac crest; BMI, body mass index; BF, body fat; VF, visceral fat; SBP, systolic blood pressure; DBP, diastolic blood pressure; TG, triglyceride; TC, total cholesterol; LDL-c, low-density lipoprotein cholesterol; HDL-c, high-density lipoprotein cholesterol; FBG, fasting blood glucose; 2hBG, 2-hour blood glucose; HbA_{1c}, glycated haemoglobin; HOMA-IR, homeostatic model assessment of insulin resistance; HOMA-β, homeostatic model assessment of β-cell function; CRP, C-reactive protein.

*$p<0.05$

**$p<0.01$

***$p<0.001$

Table 4. Absolute agreement (ICC) and correlation coefficient (*r*) between WC-U and WC-M

Variables	*Absolute agreement (ICC)*		*Coefficient (r)*
	ICC	*95% CI*	
Men	0.960	0.800-0.985	0.978 (<0.001)
Women	0.808	0.445-0.912	0.873 (<0.001)

mean waist circumferences per subject. The overall mean difference in waist circumference between WC-U and WC-M was 3.018 cm (SD: 2.86, 95%; limits of agreement: -2.59 and 8.62 cm). The scatter of differences around the zero line was not constant, but the differences tended to be positive.

DISCUSSION

Studies have linked the increasing prevalence of obesity to the rise in MetS and CVD (Zalesin *et al.*, 2008; Song, Wang & Zhang, 2013; Global Burden of Metabolic Risk Factors for Chronic Diseases Collaboration *et al.*, 2014; Jung, Ha & Kim, 2016). Central obesity in particular, is a major predictor of these diseases, irrespective of changes in BMI. WC is a key anthropometric measurement of nutritional status as well as a predictor of health risks commonly reported in many studies (Janssen, Katzmarzyk & Ross, 2004; Klein *et al.*, 2007; Mbanya *et al.*, 2015; Tsukiyama *et al.*, 2016).

However, studies have not reported consistent results for WC measurements taken at different sites. Studies from Germany and China compared WC at the lowest rib, 1 or 4 cm above the umbilicus, midpoint, top of the iliac crest, and the narrowest waist and found all WC measurements correlated with BMI and body fat mass (Hitze *et al.*, 2008; Yang & Wang, 2017). However,

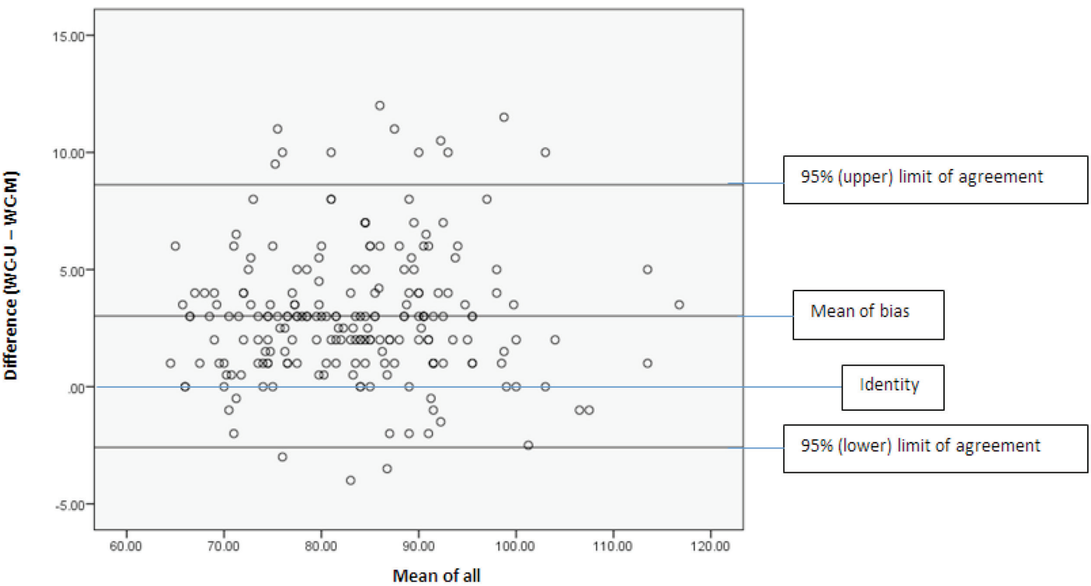

Figure 1. Bland-Altman plot of the mean difference in waist circumferences by WC-U and WC-M for each subject. The overall mean difference and 95% limits of agreement are shown.

a standardised anatomic point for WC measurement has yet to be defined. Therefore it is crucial to identify a simple and valid approach for health monitoring and promotion that is applicable to the general population.

In this study, we investigated the correlations of WC-U and WC-M between the study indicators that included the anthropometric parameters BMI, SBP, DBP, BF, VF, and the biochemical parameters TG, TC, LDL-c, HDL-c, FBG, 2hBG, fasting insulin, HOMA-IR, HOMA-β, and CRP. For all participants, both WC-U and WC-M were significantly correlated with BMI, BF, VF, HbA_{1c}, and HOMA-IR. Additionally, each of the two WC sites were significantly correlated with SBP, DBP, TG, fasting insulin, and HOMA-β in men ($p<0.001$), and with TC and LDL-c ($p<0.05$) in women. In other studies, Guan *et al* (2016) investigated the correlation between WC-U and MetS risk factors and found that all analysed correlations reached statistical significance ($p<0.001$). Similarly, a magnitude of association between WC-M and cardiometabolic risk factors was also reported (Sardinha *et al.*, 2016).

Based on the test of intraclass correlation and Bland and Altman plot test, our study found WC-U and WC-M significantly consistent for both men and women. Similarly, Harrington *et al.* found that WC-M did not differ significantly from WC-U among African-American males (Harrington *et al.*, 2013). Likewise, Ross *et al.* reported lack of significance in association between sex, age, and ethnicity, and morbidity of CVD and diabetes for different WC protocols (Rose *et al.*, 2008). This study further demonstrated that either WC-U or WC-M measurements can be used. The WC measurement position recommended by the International Society for the Advancement of Kinanthropometry (ISAK) is taken at the narrowest waist point between the lower costal (10th rib) bordering the iliac crest, or if it is not apparent, at the mid-point between the lowest rib and the top of the hip bone (iliac crest); however, these two measurement points have been found to be difficult with obese adults. Alternatively, WC-U is easy and simple to perform, and thus appropriate for regular self-monitoring (ISAK, 2001).

CONCLUSION

This study found significant associations between MetS and CVD risk factors and WC-M and WC-U measurements in a sample of Thai population. WC-U measurement is suitable for routine self-monitoring as the umbilicus is simpler to locate than the midpoint criteria of WHO. Furthermore, the umbilicus is readily identifiable in obese subjects and the method is reproducible by the general population with minimal training.

List of abbreviations

WC: Waist circumference; WC-U: Waist circumference at the umbilicus level; WC-M: Waist circumference at midway between the lowest rib and iliac crest; BMI: Body mass index; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; VF: Visceral fat; MetS: Metabolic syndrome; CVD: Cardiovascular disease; FBG: Fasting blood glucose; 2hBG: 2-h after glucose loading; HbA_{1c}: Glycated hemoglobin; ELISA: enzyme linked immunosorbent assay; HOMA-IR: Homeostatic model assessment of insulin resistance; HOMA-β: Homeostatic model assessment of beta cell function; TG: Triglyceride; TC: Total cholesterol; LDL-c: Low-density lipoprotein cholesterol; HDL-c: High-density lipoprotein cholesterol; CRP: C-reactive protein.

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Authors' contributions

NC obtained data, analysed and interpreted data, read and approved the final manuscript; CP designed the study, obtained data, read and approved the final manuscript; CU obtained data, read and approved the final manuscript; PP designed the study, obtained data, read and approved the final manuscript; KK provided the research question, designed the study, obtained data, wrote the first draft, read and approved the final manuscript.

Conflict of interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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