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Comparison of Waist Circumference, Body Mass Index, Percent Body Fat and Other Measure of Adiposity in Identifying Cardiovascular Disease Risks among Thai Adults

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Abstract

Objective—To compare the abilities of body mass index (BMI), percent body fat (%BF), waist circumference (WC), waist-hip ratio (WHR) and waist-height ratio (WHtR) to identify cardiovascular disease risk factors.

Methods—This cross-sectional study is comprised of 1,391 Thai participants (451 men and 940 women) receiving annual health check-ups. Spearman's rank correlation was used to determine the association of the five anthropometric indices with metabolic parameters including fasting plasma glucose, triglyceride, high density lipoprotein and blood pressure. The prevalence of cardiovascular disease risk factors was determined according to tertile of each anthropometric measure. Receiver operating characteristic (ROC) curves were plotted to compare anthropometric measure as predictors of the prevalence of cardiovascular risk factors.

Results—Metabolic parameters were more strongly associated with %BF and WHR and least correlated with BMI in men. Among women, BMI was most strongly correlated with metabolic parameters. In both genders, the prevalence of cardiovascular disease risk factors increased across successive tertiles for each anthropometric measure. Review of ROC curves indicated that %BF and WHR performed slightly better than other measures in identifying differences in CVD risk factors among men. BMI performed at least as well or better than other measures of adiposity among women.

Conclusions—These findings confirm high correlations between anthropometric measures and metabolic parameters. BMI, WC and other measures were not materially different in identifying cardiovascular disease risk factors. Although small differences were observed, the magnitudes of those differences are not likely to be of public health or clinical significance.

Keywords

Epidemiology; Body Mass Index; Body Fat; Waist Circumference; Waist-Hip Ratio; Waist-Height Ratio; Cardiovascular Risk Factors

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Introduction

Obesity has reached epidemic levels with at least 400 million adults classified as being obese in 2005 (1). Cardiovascular diseases (CVD) have been the leading cause of death in Thailand since 1987. Between 1985 and 1997 the prevalence of heart disease in Thailand tripled to 168 per 100,000 population (2). Obesity has been proven to be a strong and consistent risk factor for CVD, though the best way to measure obesity in the context of clinical and population-based studies has become increasingly controversial (3–5). Current worldwide guidelines suggest that overweight be defined as a body mass index (BMI) of 25 kg/m^2 to 29.9 kg/m^2 and obesity as a BMI of 30 kg/m^2 or more (1). This classification has been recommended for people of all races, genders and ages. Waist circumference (WC), waist-hip ratio (WHR) and waist-height ratio (WHtR) are used as measures of central obesity, while BMI and %BF are generally used as measures of overall obesity.

Although BMI is the most commonly used anthropometric measure in epidemiologic studies, the specificity and predictive value of this measure has been questioned (3). BMI has proven in numerous studies not to be the most accurate indicator for predicting obesity-related diseases among all groups (6–8). Increasingly, investigators have identified limitations of employing measures and thresholds of obesity from studies of Caucasian population to studies of Asians (9–12). For instance, an WHO expert panel concluded that the BMI cut-off point for observed risk of CVD and type 2 diabetes in different Asian populations varies from 22 kg/m^2 to 25 kg/m^2 while for high risk it varies from 26 kg/m^2 to 31 kg/m^2 (4). Notably, Asians tend to have higher %BF for a given level of BMI (8, 12), in part, because of their smaller body frames (13, 14).

Elevations in measures of overall obesity and central fat distribution, including BMI, waist circumference (WC), percentage body fat (%BF), waist-hip ratio (WHR), and waist-height ratio (WHtR) are known to be positively associated with the prevalence (6, 7, 15) and incidence (16, 17) of CVD and type 2 diabetes. There has been considerable heterogeneity in results from studies that compare associations of CVD and CVD risk factors with measures of overall obesity and central obesity (3, 18–21). In their study of 1,010 African-American and Caucasian participants in the CARDIA study, Shen et al. reported that WC was more strongly associated with health risk indicators than BMI and %BF. Likewise Aekplakorn et al, in their study of 5,305 Thai adults, reported that measures of central obesity (i.e., WC, WHR and WHtR) were slightly more strongly associated with CVD risk factors than the overall adiposity measure, BMI (18). Conversely, Zhu et al reported that WC is a better indicator of CVD risk than BMI in their study of 10,969 participants from 3 different race-ethnicity groups (22).

Heterogeneity in study findings may be attributable to differences in race/ethnicity, age and gender distributions of participants across study populations. A number of investigators have now reported differences in the predictive value of obesity indicators according to ethnicity (8, 11, 23). In a meta-analysis of 32 published reports, investigators noted that central obesity was a stronger predictor of incident type 2 diabetes than were measures of total body fat (3). However, measures of overall obesity were better predictor of type 2 diabetes in US and European Caucasian (24).

In light of the heterogeneity in previous study findings and potential contraindications of generalizing results across populations, we sought to examine the relationship of measures of overall obesity (BMI and %BF) and central obesity (WC, WHR and WHtR) with CVD risk factors among Thai adults.

Methods

Study Population

The study population comprised 1,608 people (536 men and 1072 women) who participated in annual health examinations at the Mobile Health Checkup Unit of King Chulalongkorn Memorial Hospital in Bangkok, Thailand during the period of December 2006 through February 2007. Each year, Chulalongkorn Memorial Hospital provides on-site annual health examinations for professional and office workers of approximately 45 private companies and governmental agencies in and around Bangkok. Given that blood chemistry evaluations are not routinely measured on all participants under the age of 35 years, this research was restricted to those participants who were ≥35 years of age at the time of annual health examination. Eligible participants were asked to provide information about their age, marital status, occupation, educational attainment, medical history, use of anti-hypertensive, anti-diabetic, or lipid lowering medications, smoking status, alcohol consumption habits, and physical activity. Participants underwent routine clinical physical examinations which included collection of venous blood samples after an overnight fast, and measurement of height, weight, waist circumference, hip circumference and resting blood pressures. Patients taking anti-hypertensive, anti-diabetic, or lipid lowering medications were excluded from further consideration. Hence a total of 1,391 participants (451 men and 940 women) remained for analysis. All participants provided informed consent and the research protocol was reviewed and approved by the Ethical Committee of Faculty of Medicine, Chulalongkorn University, and the Human Subjects Division, University of Washington.

Body Composition

Anthropometric measures were taken while participants were lightly clothed and wore no shoes. Body weight was measured to the nearest 0.1 kg using an automatic calibrated electronic scale (Seca Inc., Hamburg, Germany). Standing height was measured without shoes to the nearest 0.5 centimeter using the height rod attached to the scale. Body mass index (BMI) was calculated as weight (kg) divided by height squared (m^2). Circumferences were measured with a heavy-duty inelastic plastic fiber tape measure to the nearest 0.5 cm while the subject stood balanced on both feet, with the feet touching each other and both arms hanging freely. Waist circumference were taken midway between the inferior margin of the last rib and the iliac crest at the end of expiration (25). Hip circumference was measured around the largest portion of the buttocks (25). The waist to hip ratio (WHR) and waist to height ratio (WHtR) were then calculated. Percent body fat (%BF) estimates were determined using the Tanita bioelectrical impedance analysis (BIA) system (Tanita Model BC 532, Tokyo, Japan). The BIA system was routinely calibrated, and quality control measures were followed as recommended by the manufacturer. Systolic and diastolic blood pressures, measured using an automatic sphygmomanometer (UDEX-IIα, UEDA, Corp., Tokyo, Japan), were taken from the right arm in the seated position after participants rested for at least 5 minutes.

Laboratory Analyses

Fasting plasma glucose, serum lipids and lipoprotein concentrations were evaluated at clinical chemistry laboratories, King Chulalongkorn Memorial Hospital. Plasma glucose (FPG) concentrations were determined using the hexokinase method. Serum triglyceride (TG) concentrations were determined using standardized enzymatic glycerol phosphate oxidase assay procedures. High density lipoprotein-cholesterol (HDL-C) was measured by a chemical precipitation technique using dextran sulfate. All assays were completed without knowledge of participants' medical history. Lipid, lipoprotein and FPG concentrations were reported as mmol/L.

Analytical Variable Specification

Cardiovascular risk factors were defined using the ATP III guideline (26). Elevated blood pressure is defined as systolic blood pressure (SBP) ≥130 mmHg or diastolic blood pressure ≥85 mmHg. High triglyceride (TG) is defined as TG ≥1.7 mmol/L (≥150 mg/dl). Low high-density lipoprotein-cholesterol (HDL-C) is defined as HDL-C <1.0 mmol/L (<40 mg/dl) in men or <1.3 mmol/L (<50 mg/dl) in women. Elevated fasting plasma glucose (FPG) is defined as FPG ≥5.6 mmol/L (≥100 mg/dl).

Statistical Analyses

All statistical analysis was performed separately for men and women. Frequency distributions of socio-demographic, behavioral and clinical characteristics were examined. Continuous variables were expressed as means ± standard deviation (SD). Spearman's rank correlation coefficients were calculated to quantify associations between anthropometric measures (BMI, %BF, WC, WHR and WHtR) and cardiovascular disease risk factors (FPG, TG, HDL-C, systolic and diastolic blood pressure). Anthropometric variables were categorized into tertiles and frequencies of cardiovascular risk factors were evaluated for each measure. Receiver operating characteristic (ROC) curves were plotted to compare anthropometric measure as predictors of the prevalence of cardiovascular risk factors. We calculated the area under the curve as a summary estimate of discrimination. All statistical analyses were performed using SPSS (version 14.0, SPSS Inc. Chicago, IL, USA) software. All reported p-values are two tailed, and confidence intervals were calculated at the 95% level.

Results

The socio-demographics and clinical characteristics of the study population are presented in Table 1. Results are summarized separately for men and women. The correlations among the individual anthropometric variables and metabolic parameters (fasting plasma glucose, triglyceride, high density lipoprotein-cholesterol and blood pressure) are presented in Table 2. Overall, among men, three of the metabolic parameters (i.e., triglyceride (r=0.374), high density lipoprotein-cholesterol (r=−0.377) and systolic blood pressure (r=0.318)) were most strongly correlated with %BF. Fasting plasma glucose (r=0.291) and diastolic blood pressure (r=0.272) were most strongly correlated with waist-hip ratio. Body mass index among men was least correlated with fasting plasma glucose (r=0.178), systolic (r=0.287) and diastolic (r=0.222) blood pressure. In contrast to men, BMI, a measure of overall adiposity, was most strongly associated with 3 metabolic parameters (high density lipoprotein (r=−0.380), systolic (r=0.371) and diastolic blood pressure (r=0.325)) in women. Conversely, among the remaining four measures of adiposity, waist-hip ratio was least correlated with metabolic parameters.

The prevalence of CVD risk factors according to tertile for each measure of adiposity are summarized in Table 3. As expected, the prevalence of elevated fasting plasma glucose, elevated triglyceride concentrations, low high density lipoprotein-cholesterol concentrations, and elevated blood pressure were increased across successive tertiles for each measures of obesity. These patterns were evident for both men and women.

In addition, the frequencies of CVD risk factors were similar across the tertiles of each measure (for both men and women). For example, the prevalence of elevated fasting plasma glucose among men in the upper tertiles of the distribution of each measure of adiposity were as follows: BMI ≥ 25.7 kg/m^2 (19.7%); %BF ≥ 24.2% (21.7%); WC ≥ 88 cm (20.0%); WHR ≥ 0.89 (22.8%); WHtR ≥ 0.52 (22.1%). The corresponding prevalence estimates among women in the upper tertile of each measure of adiposity were: BMI ≥ 24.7 kg/m^2

(16.0%); %BF ≥35.1% (16.1%); WC ≥ 78cm (16.7%); WHR ≥ 0.80 (14.2%); WHtR ≥ 0.50 (16.7%).

Review of ROC curves (Figure 1) indicated that BMI performed at least as well as the other measures of adiposity in identifying risk of dyslipidemia and elevated blood pressure among men. BMI was slightly less predictive of elevated fasting plasma glucose (AUC = 62%, 95% CI 54–69%) than were %BF (AUC = 66%, 95% CI 59–73%) and WHR (AUC = 69%, 95% CI 63–75%). In women, BMI performed at least as well as, or better than, other criteria in predicting all CVD risk factors investigated in this study. The AUC for WHR were consistently lower than that for the other measures of adiposity (Figure 2).

Discussion

A number of cross-sectional studies have investigated the relationship between CVD risk factors according to multiple measures of adiposity (22, 27–29). However, there has yet to be consensus as to which anthropometric measure best predicts obesity-related disorders, particularly among Asians. In our study we observed that BMI was slightly more strongly associated with CVD risk factors in women, and that %BF and WHR were slightly more strongly associated with CVD risk factors in men. Collectively, observed small differences are not likely to be of public health or clinical significance.

Other investigators have reported that WHtR is the best predictor of CVD risk than other anthropometric measurements (18, 30, 31). Yet, others have reported that WC and BMI are equally predictive of CVD risk (27), or that WC is a better indicator of CVD risk than is BMI (22). Results from a recent meta-analysis (3), however, suggest that measures of overall obesity (BMI) and measures of central obesity (waist-hip ratio and waist circumference) performed equally well in predicting incident type 2 diabetes. Our study findings are largely similar to those reported by Vazquez et al (3).

Results from our study should be interpreted in light of several potential limitations. First, our study was conducted among a largely well educated population of employed office and professional workers, and so may not be generalizable to the broader Thai population. Second, the cross-sectional design of our study with only single measures of adiposity (taken at one point in time) may not accurately reflect participants' long-term adiposity status. Lastly, some error in reporting of smoking history, physical activity and other covariates may have occurred. The concordance of our findings with other studies, however, serves to attenuate some concerns about these potential study limitations.

Mortality from cardiovascular disease in Thailand has increased over the last two decades. The increased mortality appears to exceed those expected from aging of the population alone (32), and many cases may be attributable to the increased prevalence of obesity among Thai adults. In light of these important trends, more studies designed to systematically and rigorously evaluate the predictive performance of different measures of overall and central adiposity are warranted. In the meantime, however, a simple measure of overall obesity, such as BMI, appears to be a reasonable measure for epidemiological studies of CVD and CVD risk factors.

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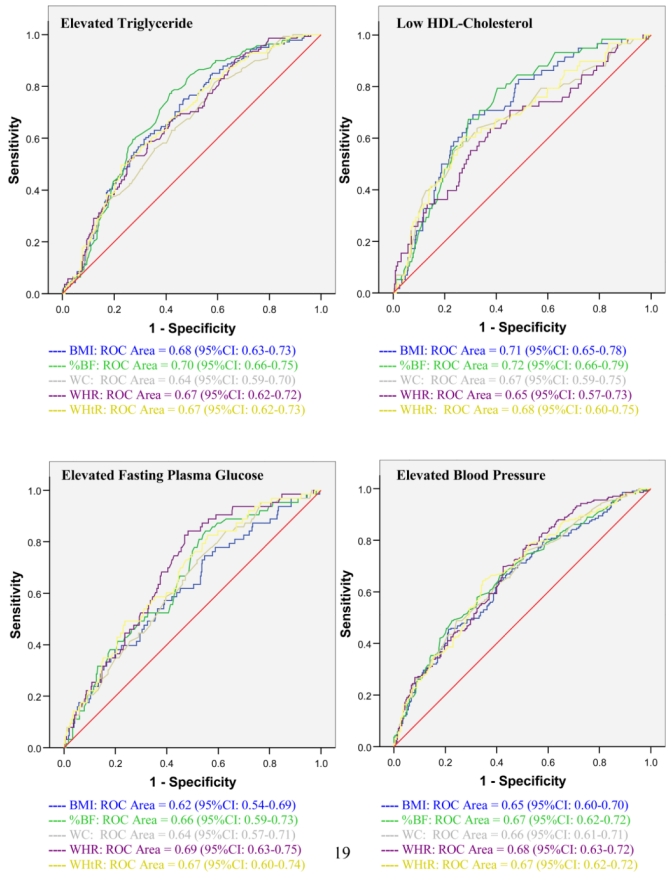

Figure I.

Receiver Operating Characteristic (ROC) curves with area under curve (AUC) and 95% confidence intervals of body mass index (BMI), percent body fat (%BF), waist circumference (WC), waist to hip ratio (WHR) and waist to height ratio (WHtR) for predicting cardiovascular disease risk factors among Thai men.

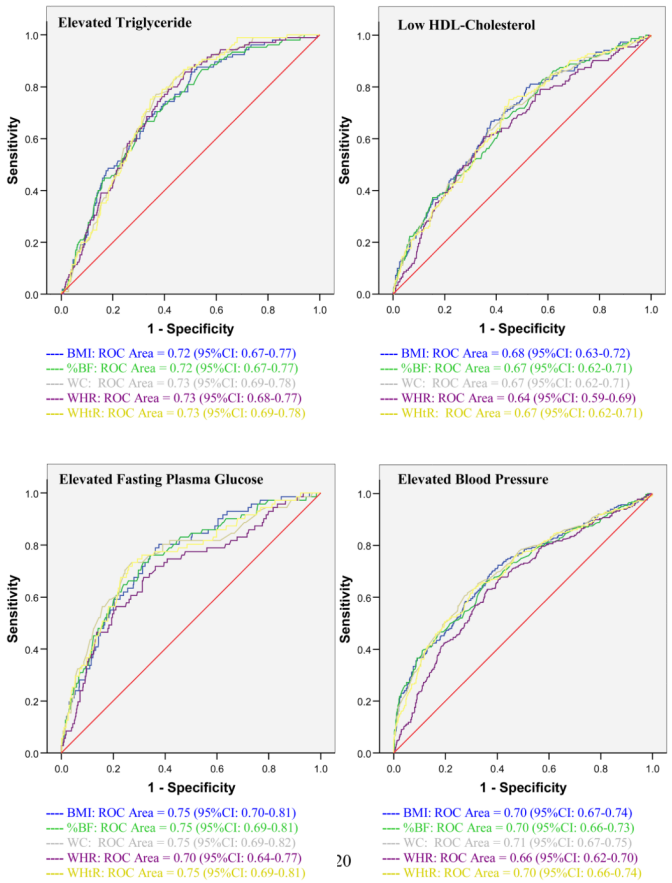

Figure II.

Receiver Operating Characteristic (ROC) curves with area under curve (AUC) and 95% confidence intervals of body mass index (BMI), percent body fat (%BF), waist circumference (WC), waist to hip ratio (WHR) and waist to height ratio (WHtR) for predicting cardiovascular disease risk factors among Thai women.

Table I

Socio-demographic and clinical characteristics of study participants

Characteristics	Men (N=451)		Women (N=940)	
	n*	%	n*	%
Age (Years)				
<40	116	25.7	169	18.0
40–49	193	42.8	454	48.3
50–59	127	28.2	305	32.4
≥60	15	3.3	12	1.3
Mean ± SD	46.5 ± 7.6		47.2 ± 6.8	
Education				
< Bachelor degree	129	29.1	170	18.3
Bachelor degree	90	20.3	388	41.7
Master degree	88	19.8	217	23.3
PhD degree	137	30.9	156	16.8
Smoking Status				
Never smoker	280	62.5	882	94.7
Previous smoker	81	18.1	34	3.7
Current smoker	87	19.4	15	1.6
Alcohol Consumption Status				
Non Drinker	227	50.7	794	85.4
Current Drinker	221	49.3	136	14.6
	Median (IQR)**		Median (IQR)**	
Waist circumference (cm)	84.4 (78.5, 91.0)		73.0 (68.0, 80.5)	
Body mass index (kg/m^2)	24.4 (22.7, 26.9)		23.1 (20.8, 25.9)	
Body fat percentage (%)	22.4 (19.4, 25.4)		32.5 (28.8, 36.8)	
Fasting plasma glucose (mmol/L)	4.9 (4.7, 5.3)		4.7 (4.5, 5.0)	
Triglyceride (mmol/L)	1.4 (0.9, 2.0)		0.9 (0.7, 1.3)	
HDL-cholesterol (mmol/L)	1.3 (1.1, 1.6)		1.6 (1.4, 1.9)	
Systolic blood pressure (mmHg)	121.0 (113.5, 136.0)		119.0 (110.0, 130.0)	
Diastolic blood pressure (mmHg)	80.0 (70.0, 84.0)		70.0 (65.0, 80.0)	

*Number may not be added up to the total number due to missing data

**IQR = Interquartile range

Table II

Spearman's rank correlation coefficients for anthropometric measurements and cardiovascular disease risk factors.

	BMI (kg/m^2)	%BF (%)	WC (cm)	WHR	WHtR
Men					
Fasting Plasma Glucose (mmol/L)	0.178	0.215	0.202	0.291	0.224
Triglyceride (mmol/L)	0.312	0.374	0.282	0.330	0.329
HDL-C (mmol/L)	−0.370	−0.377	−0.350	−0.299	−0.358
Systolic Blood Pressure (mmHg)	0.287	0.318	0.315	0.306	0.312
Diastolic Blood Pressure (mmHg)	0.222	0.271	0.229	0.272	0.249
Women					
Fasting Plasma Glucose (mmol/L)	0.320	0.329	0.339	0.300	0.327
Triglyceride (mmol/L)	0.389	0.404	0.419	0.382	0.420
HDL-C (mmol/L)	−0.380	−0.362	−0.357	−0.289	−0.351
Systolic Blood Pressure (mmHg)	0.371	0.358	0.368	0.286	0.358
Diastolic Blood Pressure (mmHg)	0.325	0.324	0.314	0.224	0.300

All correlation coefficients are significant at the 0.001 level.

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Table III

Prevalence of cardiovascular disease risk factors in relation to varying degree of adiposity as assessed using different anthropometric measures.

Measurement of Obesity	Cardiovascular Disease Risk Factors			
	Elevated FPG	High TG	Low HDL-C	Elevated BP
	%	%	%	%
Among Men				
Body mass index (kg/m^2)				
Tertile$_1$ (<23.3)	8.8	14.3	4.8	32.0
Tertile$_2$ (23.3–25.7)	14.2	34.5	9.5	44.6
Tertile$_3$ (>25.7)	19.7	46.9	25.2	64.4
Body fat percentage (%)				
Tertile$_1$ (<20.8)	4.7	12.2	2.7	33.3
Tertile$_2$ (20.8–24.2)	17.1	33.6	11.0	41.5
Tertile$_3$ (>24.2)	21.7	50.0	25.7	66.0
Waist circumference (cm)				
Tertile$_1$ (<81.0)	7.0	16.9	7.7	31.9
Tertile$_2$ (81.0–87.9)	16.0	34.7	7.6	43.1
Tertile$_3$ (≥88)	20.0	43.1	23.1	64.2
Waist to hip ratio				
Tertile$_1$ (<0.85)	4.1	18.4	9.5	29.3
Tertile$_2$ (0.85–0.89)	16.7	29.3	8.0	49.7
Tertile$_3$ (>0.89)	22.8	48.3	22.1	62.2
Waist to height ratio				
Tertile$_1$ (<0.48)	6.8	16.3	7.5	29.1
Tertile$_2$ (0.48–0.51)	14.0	30.7	8.0	51.7
Tertile$_3$ (≥0.52)	22.1	49.0	24.1	60.5
Among Women				

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Measurement of Obesity	Cardiovascular Disease Risk Factors			
	Elevated FPG	High TG	Low HDL-C	Elevated BP
	%	%	%	%
Body mass index (kg/m^2)				
Tertile$_1$ (<21.5)	1.6	3.2	7.8	16.2
Tertile$_2$ (21.5–24.7)	5.5	10.3	16.2	27.1
Tertile$_3$ (>24.7)	16.0	20.6	25.7	47.4
Body fat percentage (%)				
Tertile$_1$ (<30.1)	2.3	2.9	6.6	17.4
Tertile$_2$ (30.1–35.1)	4.4	10.4	18.6	26.5
Tertile$_3$ (>35.1)	16.1	21.2	24.4	46.6
Waist circumference (cm)				
Tertile$_1$ (<70.0)	3.6	2.3	7.2	16.1
Tertile$_2$ (70.0–77.9)	2.6	10.5	17.0	25.7
Tertile$_3$ (≥78)	16.7	21.8	25.6	48.9
Waist to hip ratio				
Tertile$_1$ (<0.75)	4.2	2.3	10.0	17.5
Tertile$_2$ (0.75–0.80)	4.5	11.0	14.9	29.6
Tertile$_3$ (>0.80)	14.2	21.7	25.2	43.7
Waist to height ratio				
Tertile$_1$ (<0.44)	2.9	2.6	7.5	16.6
Tertile$_2$ (0.44–0.49)	3.0	9.7	17.4	26.4
Tertile$_3$ (≥0.50)	16.7	21.5	24.6	47.2

FPG = Fasting Plasma Glucose; TG = Triglyceride; HDL-C = High Density Lipoprotein-Cholesterol; BP = Blood Pressure