Does Waist Indicate Dyslipidemia better than BMI in Korean Adult Population?

Obesity is an independent and modifiable risk factor for cardiovascular disease, and known as a core of the metabolic syndrome. Obesity has been largely diagnosed based upon anthrompometric measurements like waist circumference (WC) and body mass index (BMI). We sought to determine associations between anthropometric measurements and dyslipidemia in a community adult sample composed of 1,032 community residents (356 men, 676 women) aged 50 yr and over in Namwon, Korea. Blood tests for lipid profiles, including total cholesterol (TC) and HDL cholesterol (HDL) were performed, and dyslipidemia was defined as TC/HDL greater than 4. Anthropometric measurements included WC, waist-to-height ratio (WHtR), waist-to-hip ratio, and BMI. All anthropometric measures were categorized into quartiles and evaluated for associations with dyslipidemia. TC/HDL showed the significant associations with the anthropometric measures, independently of potential confounders. In women, increases of obesity indexes by quartile analyses showed linear increases of odds ratios for dyslipidemia (p values <0.01 by trend test). In men, except BMI, same patterns of association were noted. WC and WHtR were significantly associated with dyslipidemia in Korean adult population. As a simple and non-invasive method for a detection of obesity and dyslipidemia, anthropometric measurements could be efficiently used in clinical and epidemiologic fields.

Key Words : *Anthropometry; Waist Circumference; Body Mass Index; Hyperlipidemia; Population*

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INTRODUCTION

Prevention of risk factors for cardiovascular diseases (CVD) such as obesity and dyslipidemia has been an important challenge in developing countries due to the westernization of diet and lifestyle changes (1). One approach to preventing the condition was the identification of individuals at risk by screening with simple anthropometric measurements, followed by individualized counseling or treatment (2). The anthropometric measurements of interest include waist circumference (WC) (3), waist-to-hip ratio (WHR) (4), waist-to-height ratio (WHtR) (5), skin fold thickness (6), and body mass index (BMI) (7). These indexes were considered measurements of obesity and diagnostic components of the metabolic syndrome (8, 9).

Interpretation of WC and other anthropometric parameters depended on ethnicity and cultural background, because adult anthropometry has been recognized as a biomarker of 'early life' (10). Careful analysis and interpretation lead to a comprehension of obesity as a risk factor for cardiovascular disease (CVD) (11, 12) and dementia or cognitive impairment (13). In the Korean peninsula, there have been several periods of impoverishment in recent history, including colonial dominion under the rule of Japanese imperialism from 1910 to 1945 and the Korean War from 1950 to 1953 (14). Now, about 50 yr after the Korean War, CVD including stroke has become the leading cause of mortality and morbidity in Korea, as it is in many developed and developing countries (15). Rapid economic improvements and modernization have led to an increasing epidemic of obesity and dyslipidemia (16).

Studies of anthropometric measurements can present important strategies for the control of dyslipidemia and obesity, and, ultimately, CVD (17). We therefore sought to assess the usefulness of the four anthropometric measures, WC, WHtR, WHR, and BMI, in identifying individuals with dyslipidemia, in a population-based sample of Korean adults, as well as to determine any sex-based differences in these associations.

MATERIALS AND METHODS

Subjects

Potential participants for this study were recruited in 1999 from all inhabitants aged 50 yr and over recorded in national residents registration lists within three rural areas (Ayoung,

Ibaek, and Jucheon) of Namwon city, Jeonbuk province, Korea. These three rural areas are comprised of 31 local districts, of which 21 were selected by multi-stage cluster sampling (68%). These 21 districts cover a land area of 90 km² and have a population of 3,984, of whom 1,787 (44.9%), 704 men and 1,083 women, were aged 50 yr and over. Among the 1,787 eligible individuals, 1,032 (57.8%) responded to the survey. The 1,032 participants were slightly older (65.9± 8.2 yr) than the 755 non-participants (64.9±8.9 yr) and consisted of more women (62.4% vs. 37.6%). Subjects who had severe unilateral weakness due to previous strokes or known CVD were excluded from our cohort. All participants gave written informed consent, and the study was approved by the institutional research ethics committee.

Assessments and measurements

The study was conducted by medical personnel in the health care center of Namwon city, all of whom were trained and supervised by preventive medicine physicians. A blood sample was taken from each participant, and an interview was conducted, according to standard protocols. The administered questionnaire was designed to determine prior history of CVD, stroke, diabetes, hypertension, and medication usage. Lifestyle questions included alcohol drinking status, as estimated by frequency, duration, amounts and kinds of liquor, and standard drinks (9.5 g of alcohol) per day were calculated. Smoking status was categorized into current smokers, ex-smokers and non-smokers. Blood pressure was measured on the right arm, with the subject in the sitting position, using a standard mercury manometer after at least 5 min of rest. First appearance (phase I) and disappearance (phase V) of Korotkoff's sounds were used to define systolic and diastolic pressure. Readings were recorded to the nearest even number, and two readings at 5 min intervals were taken from each participant. The lower of the two readings was recorded as the individual's blood pressure (18).

Anthropometric measurements

WC was measured, with the subject standing and wearing only underwear, at the level midway between the lower rib margin and the iliac crest. Hip circumference (HC) was measured at the fullest point around the buttocks. A digital scale, with an accuracy of ±100 g, was used to measure body weight (BW). Subjects were weighed without shoes, in their underwear. Standing body height (BH) was measured to the nearest 0.5 cm with a commercial stadiometer without shoes and with the shoulders in a relaxed position and the arms hanging freely. WC (cm) was divided by HC (cm) and BH (m) to calculate WHR and WHtR, respectively. BMI was calculated by a computer as weight divided by height squared (kg/m²).

Biochemical analyses

Laboratory procedures have previously been documented in detail (9). Blood samples were taken after an overnight fast and before breakfast. Blood lipids were analyzed at Seonam University Research Laboratory on the day of collection using a 550 Express Chemistry Analyzer (Ciba-Corning 550 Express, GMI Inc, Minnesota, U.S.A.). Total cholesterol (TC) was assayed by an enzymatic colorimetric test with cholesterol esterase and cholesterol oxidase, and HDL cholesterol (HDL) was quantitatively determined based on immunoinhibition by antihuman β-lipoprotein antibody kits (Wako Pure Chemical Industries, Ltd, Osaka, Japan). The ratio of TC to HDL (TC/HDL) was calculated. Fasting blood glucose was measured using an enzymatic colorimetric assay with hexokinase.

Definitions

Obesity was defined as BMI greater than 25 kg/m² (19). High WC was defined as greater than 90 cm in men and 80 cm in women (19). Lipid profiles were evaluated for correlations with anthropometric measurements, and individuals with TC/HDL ≥4 and those taking lipid-lowering agents were defined as having dyslipidemia (20). TC/HDL has been found to better predict the occurrence of CVD events than measurements of various cholesterol levels (21). Subjects with persistent elevation of blood pressure (≥140/90 mmHg) or taking antihypertensive medications were classified as hypertensive (22). Type 2 diabetes mellitus (DM) was defined as a self-reported history of being told by a physician that diabetes was present or having a fasting blood glucose of 126 mg/dL or greater, according to the criteria defined by the American Diabetic Association (23).

Statistical analysis

Age, lipid profile, and anthropometric measures were reported as mean±SD. The proportion of subjects having CVD risk factors was recorded. The differences in various anthropometric parameters and cardiovascular risk factors in men and women were compared by Student's t-test or χ^2 test, as appropriate. Independent associations between TC/HDL and anthropometric measurements were evaluated with linear regression models, adjusting for the potential confounders. Subjects were categorized separately by gender according to their WC, WHR, WHtR, and BMI quartiles. Multiple logistic regression analysis was used to compute odds ratios (OR) and 95% confidence intervals (CI). Four categories were considered as explanatory variables, with the first quartile each of WC, WHR, WHtR, and BMI as reference categories and dyslipidemia as a dichotomous outcome variable, and a likelihood ratio test for trend was performed. All statistical calculations were performed using Stata 8.2 for Windows package (Stata Corporation, College Station, TX, U.S.A.). *P* values <0.05

were considered statistically significant.

RESULTS

Mean ages were comparable among men and women as in Table 1. The prevalence of smoking and alcohol drinking was each significantly higher in men ($p<0.001$ for each). The amount of alcohol ingested (standard drinks per day) was also significantly higher in men ($p<0.001$). The proportion of individuals with no formal education was significantly higher in women ($p<0.001$). Prevalence of type 2 DM and hypertension was similar in men and women. And the prevalence of obesity (defined by BMI ≥ 25 kg/m²), abdominal obesity, and dyslipidemia were all significantly higher in women than in men.

TC/HDL showed independent associations with WC, WHtR, WHR, and BMI, adjusting for age, sex, educational years, smoking, alcohol, manual occupation, hypertension, and type 2 DM as in Table 2. Correlation analyses showed that the coefficients between TC/HDL and WC, WHtR, WHR, and BMI were 0.17, 0.25, 0.13, and 0.22, respectively (all $p<0.001$).

Quartile analyses represented that the first quartiles (reference values) were WC <77 cm, WHR 0.85, WHtR 48.0, and BMI 20.4 in men and WC <77 cm, WHR 0.83, WHtR 51.5, and BMI 21.5 in women as in Table 3. BMI obesity criteria were present in the fourth quartile in men and the third quartile in women. The cut-offs for high WC were included in the fourth quartile in men and the second quartile in women.

The associations between dyslipidemia and quartiles for all anthropometric measurements were calculated, independent of age, education, smoking, alcohol, occupation, hypertension, and type 2 DM as in Table 3, 4. As for dyslipidemia, WC and WHtR showed significant linear increases of OR in men as in Table 3. Compared to the reference quartile, the highest quartile represents OR and 95% CI of 2.82 (1.21-6.55) in WC and 2.89 (1.29-6.46) in WHtR. For men, we observed linear increases in the ORs with increases in WC ($p=0.015$) and WHtR ($p=0.004$). Even the trend was significant, WHR did not show linearly increased ORs compared to WC and WHtR. The trend test was not significant for BMI.

For women, all four anthropometric measurements showed

Table 1. Descriptive data by gender

	Men (n=356)	Women (n=676)
Demographics and risk factors		
Age (yr)	66.2±7.7	65.8±8.4
No formal education (%)	34.6	77.5*
Smoking (current & ex-smoker) (%)	63.2	11.2*
Alcohol drinking (%)	59.6	19.8*
Standard drinks (alcohol 9.5 g per day)	3.0±5.5	0.1±0.5*
Manual occupation (%)	82.6	61.6*
Hypertension (reported & measured) (%)	48.9	43.6
Type 2 Diabetes (reported & measured) (%)	13.5	12.3
General obesity (BMI >25 kg/m²) (%)	17.3	33.0*
Abdominal obesity (%)	25.3	63.9*
Lipid profiles		
Total cholesterol, mg/dL	173.9±33.0	195.0±36.1*
HDL cholesterol, mg/dL	52.5±10.5	52.3±8.9
Ratio of TC to HDL	3.5±1.1	3.8±0.9*
Dyslipidemia (TC/HDL $\geq$4) (%)	21.6	38.0*

Values are mean±SD or proportion as appropriate. BMI, body mass index; TC, total cholesterol; HDL, high density lipoprotein cholesterol. *$p<0.001$, compared with men.

Table 2. Associations between lipid levels* and anthropometric measurements

	$\beta^\dagger$	SE	p	95% CI	
				Lower	Higher
WC	0.014	0.003	0.000	0.01	0.02
WHtR	0.023	0.005	0.000	0.01	0.03
WHR	1.440	0.431	0.001	0.59	2.29
BMI	0.047	0.009	0.000	0.03	0.06

WC, waist circumference; WHtR, waist-to-height ratio; WHR, waist-to-hip ratio; BMI, body mass index. *Lipid levels denote ratio of total cholesterol to HDL cholesterol (TC/HDL ratio). †Adjusted for age, sex, educational years, smoking, alcohol, manual occupation, hypertension, and type 2 DM.

Table 3. Adjusted* odds ratios for dyslipidemia by quartiles of anthropometric measurements in men

Quartiles	Dyslipidemia (TC/HDL ratio $\geq$4)							
	WC		WHtR		WHR		BMI	
	Ranges	OR (95% CI)	Ranges	OR (95% CI)	Ranges	OR (95% CI)	Ranges	OR (95% CI)
First	62-76	1.00	38.1-47.9	1.00	0.70-0.85	1.00	15.3-20.4	1.00
Second	77-82	1.99 (0.85-4.70)	48.0-51.7	1.59 (0.68-3.70)	0.86-0.89	1.46 (0.62-3.45)	20.5-22.1	1.17 (0.53-2.57)
Third	83-89	2.61 (1.13-6.02)‡	51.8-54.9	2.71 (1.20-6.16)‡	0.90-0.93	3.58 (1.57-8.15)§	22.2-24.2	2.00 (0.94-4.23)
Fourth	90-116	2.82 (1.21-6.55)‡	55.0-71.3	2.89 (1.29-6.46)‡	0.94-1.20	2.13 (0.93-4.92)	24.3-35.1	1.74 (0.81-3.77)
$p^\dagger$		0.015		0.004		0.025		0.080

OR, odds ratio; CI, confidence intervals; WC, waist circumference; WHtR, waist-to-height ratio; WHR, waist-to-hip ratio; BMI, body mass index. *Adjusted for age, education, smoking, alcohol drinking, occupation, hypertension, and type 2 DM. †p values of trend test. ‡$p<0.05$, §$p<0.01$, ‖$p<0.001$ compared to the reference quartiles.

Table 4. Adjusted* odds ratios for dyslipidemia by quartiles of anthropometric measurements in women

Quartiles	Dyslipidemia (TC/HDL ratio ≥4)							
	WC		WHtR		WHR		BMI	
	Ranges	OR (95% CI)	Ranges	OR (95% CI)	Ranges	OR (95% CI)	Ranges	OR (95% CI)
First	60-76	1.00	38.7-51.4	1.00	0.44-0.82	1.00	15.7-21.4	1.00
Second	77-83	1.99 (1.25-3.16)[§]	51.5-55.6	1.92 (1.19-3.08)[‡]	0.83-0.88	1.64 (1.01-2.66)[§]	21.5-23.8	1.33 (0.83-2.13)
Third	84-89	2.27 (1.40-3.69)[§]	55.7-60.4	1.73 (1.07-2.79)[‖]	0.89-0.92	2.60 (1.62-4.17)[‡]	23.9-26.0	1.79 (1.12-2.88)[‡]
Fourth	90-145	2.29 (1.45-3.63)[‖]	60.5-94.5	2.67 (1.66-4.28)[‖]	0.93-1.13	2.33 (1.45-3.74)[‖]	26.1-43.7	2.29 (1.42-3.69)[§]
$p^{†}$		0.001		<0.001		<0.001		<0.001

All the abbreviations are same as table 3. *Adjusted for age, education, smoking, alcohol drinking, occupation, hypertension, and type 2 DM. [†]p values of trend test. [‡]$p<0.05$, [§]$p<0.01$, [‖]$p<0.001$ compared to the reference quartiles.

strongly significant results from the likelihood ratio test for trend (Table 4). The adjusted ORs (95% CI) in the highest quartiles of WC and BMI were 2.29 (1.45-3.63) and 2.29 (1.42-3.69), respectively. WHR showed slightly decreased OR in the highest quartile compared to the third, which was the same pattern observed in men.

DISCUSSION

This study showed that anthropometric measurements like WC and WHtR could be used as an indicator of risk factor for CVD, like dyslipidemia in Korean adult population. We also found sex differences in the associations between dylipidemic status and BMI. Even BMI was independently associated with TC/HDL, BMI showed inconsistent results in men and women. This finding should be carefully considered when using BMI, as for a marker of vascular risk factor.

In the subsequent context, details of the anthropometric measurements would be discussed. Three concepts related to anthropometric measurements should be considered. First, all the anthropometric parameters measured here were influenced by lipidemic status, so they could be used as markers of vascular risk factors (2). Second, these anthropometric measurements in late adulthood were closely associated with early childhood growth patterns and birth weights (24, 25). Finally, anthropometric parameters may differ, depending on sex, ethnicity, and socio-economic conditions (26, 27).

Higher WC and WHtR were significantly associated with dyslipidemia in men and women. This might be due to male type (android) adiposity in men (26) and changes in body composition after menopause (28) in late adult women. The combination of WC and height, that is WHtR, could manifest better the morphology of an enlarged abdomen with disproportionately short stature. This finding was in part consistent with the previous report, which showed the superiority of WHtR to WC (5). But, as in the Table 3 and 4, the cut point for metabolic indexes could be different in Korean population. In Japanese population, WHtR of 50.0 was suggested as cut-point. But, in Korean adult population, WHtR of 50.0 was included in second quartile in men and first in women. The cut-points for the last quartiles were 55 and 60 in men and women, respectively, even these values should be re-evaluated for their usefulness.

And WHR did not show linear associations, suggesting that WHR could be lower in predicting dyslipidemia compared to WC and WHtR in both sexes, BMI in women. This finding differed from those in Asian Indians, in which WHR had a higher discriminant ability than WC (29).

We found that, in women but not in men, BMI showed a statistically significant association by the trend test for dyslipidemia. This might be largely due to a difference in fat distribution between sexes, in that women were known to have more subcutaneous fat than men (26). This difference was manifested as early as 5-7 yr old (30) and affected energy homeostasis (31). The differences in sex might also be related to socio-economic factors. Drinking intensity was known to affect the distribution of body fat and was positively associated with central adiposity (32). Larger amounts and higher percentage of alcohol drinking, as in the present study, could affect fat distribution more viscerally in men than in women. Education also affects obesity (27). The population studied here was largely deprived of educational attainment, especially for women. Considering the effects of early life environment upon the late vascular risk factors (33), this low educational attainment should be dealt with special attention. Finally both WC and BMI could be associated with dyslipidemia in women, and that was differed from those in Guadeloupean women, in which WC had a higher discriminant ability than BMI (34).

There were some limitations to this analysis. We could not determine individual levels of nutrition, even the participants born before the Korean War were supposed to be suffered from severe malnutrition when they were young. At that time, the Korean peninsula had no systematized social structures, including those for public health. Second, we did not acquire any information about the hormonal status of our women subjects. Thus, we do not know whether these women went through earlier menopause and whether this was related to redistribution of fat. Finally, participation rates in our survey were somewhat low. On average, nonparticipants were younger than participants, and there was a higher percentage of men

in the former. Even if all the nonparticipants had participated in the study, however, our results would not change, although additional statistical power would be added to our analysis.

Obesity has been extensively studied as a main cause of metabolic disturbances, including metabolic syndrome (8), nonalcoholic fatty liver disease (9), and type 2 DM (23). As a simple and non-invasive method for a detection of obesity and dyslipidemia, anthropometric measurements could be efficiently used in clinical and epidemiologic fields.

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