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■ Original Article

Correlation of Cardiovascular Risk Factors with Central Obesity and Multiple Body Mass Index in Korea

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Background: Body mass index (BMI) and waist circumference (WC) are associated with cardiovascular (CV) risk factors. The aim of this study was to investigate the correlation of CV risk factors by cross-tabulating central obesity with multiple BMI categories in Korea.
Methods: A total of 328,789 adults aged 30–84 years who completed health assessments for National Health Insurance in 2012–2013 in Korea were examined. The participants were divided into two WC and five BMI groups to investigate CV risk factors, including metabolic syndrome (MetS), hypertension, diabetes, and dyslipidemia.
Results: The proportions of central obesity and obesity were 24.2% and 39.5% in men and 19.4% and 28.1% in women, respectively, according to the Korean Society for the Study of Obesity and World Health Organization Asia-Pacific Guideline criteria. The odds ratios (ORs) of CV risk factors in all sexes increased with increases in BMI and WC. Compared to the group with a normal WC and BMI, the adjusted ORs (95% confidence intervals) for having MetS and diabetes in the centrally obese and highest BMI group (BMI ≥30.0 kg/m^2) were 35.95 (33.75–38.30) and 3.51 (3.26–3.77) in men and 29.22 (27.36–31.20) and 4.35 (4.02–4.70) in women, respectively. Participants who were centrally obese and obese (BMI ≥25.0 kg/m^2) had the strongest correlation with all CV risk factors compared with those who were not centrally obese or obese.
Conclusion: The presence of central obesity in multiple BMI categories may significantly identify individuals at increased risk of CV risk factors.

Keywords: Body Mass Index; Waist Circumference; Cardiovascular Diseases; Obesity; Diabetes Mellitus

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INTRODUCTION

The increase in the number of overweight and obese people is a growing public health concern worldwide. It is known that having a high body mass index (BMI) is an important risk factor for chronic diseases, including cardiovascular disease (CVD), type II diabetes, and hypertension.[1-4] Some studies have suggested that BMI is just as important as waist circumference (WC) in predicting and screening for metabolic syndrome (MetS) and its components.[5,6]

Although BMI has traditionally been used as an anthropometric index for CVD risk in many epidemiological studies, WC, which reflects central adiposity and body fat distribution, can be superior to BMI in predicting CVD risk factors.[7-11] On the other hand, some studies have reported a stronger positive association between cardiovascular risk factors, such as hypertension and lipid and glucose concentrations, and both BMI and WC together than BMI or WC alone.[12-14]

In Korea, some studies have shown that either BMI or WC is strongly associated with cardio-metabolic risk or CVD, respectively.[15] The correlation of cardiovascular risk factors measured by both BMI and WC simultaneously has not yet been reported in Korea.

As a part of the National Health Insurance Service National Sample Cohort (NHIS-NSC) in South Korea, the goal of this analysis was to investigate the correlation of cardiovascular risk factors by cross-tabulating central obesity with multiple BMI categories in this population.

METHODS

1. Study Design and Population

All Korean nationals are eligible to enroll in the Korean National Health Insurance Service (KNHIS). Thus, almost all of data in this health system are centralized in large databases, including diagnostic codes, prescription drugs, procedures, medical costs, and dental services. A unique identification number, called the Resident Registration Number, is assigned to all Korean residents at birth. Because this number is used by both the Korean government and the KNHIS, there are no duplicate or omitted health records.

This study was based on data from the NHIS-NSC 2002–2013 (NHIS-2014-2-008), which was provided by the KNHIS. The data comprises 1,025,340 nationally representative random participants, which amounted to approximately 2.2% of the entire population of the KNHIS in 2002. The data were produced by the KNHIS using a systematic sampling method to generate a representative sample from all 46,605,433 Korean residents in 2002. This database includes all medical claims and the data of health assessments that the NHIS has served every year or two, filed from January 2002 to December 2013.[16]

This study was cross-sectional in design and based on data from medical claims and health assessments from 2012–2013. We recruited 354,494 participants from 30–84 years of age who had NHIS health assessments during 2012–2013 out of the 1,025,340 NHIS-NSC respondents from 2002–2013. We excluded 23,838 participants who reported a history of cancer (all cancer types) and CVD at enrollment as well as 245 who died during the same year that they had the health assessments. In addition, 1,622 participants with a low BMI (less than 15 kg/m^2), short stature (1.3 m or less), or incomplete data for BMI, blood pressure, serum cholesterol, fasting serum glucose, alcohol consumption, and smoking were excluded. This resulted in a final analytical sample of 328,789 people, including 169,011 men and 159,778 women (Figure 1).

Our study design was reviewed and approved by the Institutional Review Board of the National Health Insurance Service Ilsan Hospital in Gyeonggi-do, Korea (2015-5-012). The requirement for written informed consent was waived.

2. Data Collection

The health assessments followed a standard procedure and were conducted by medical staff at hospitals nationwide. Using a standardized questionnaire, the participants were asked to report their alcohol consumption, smoking habits (never, former, or current smoker), intensity

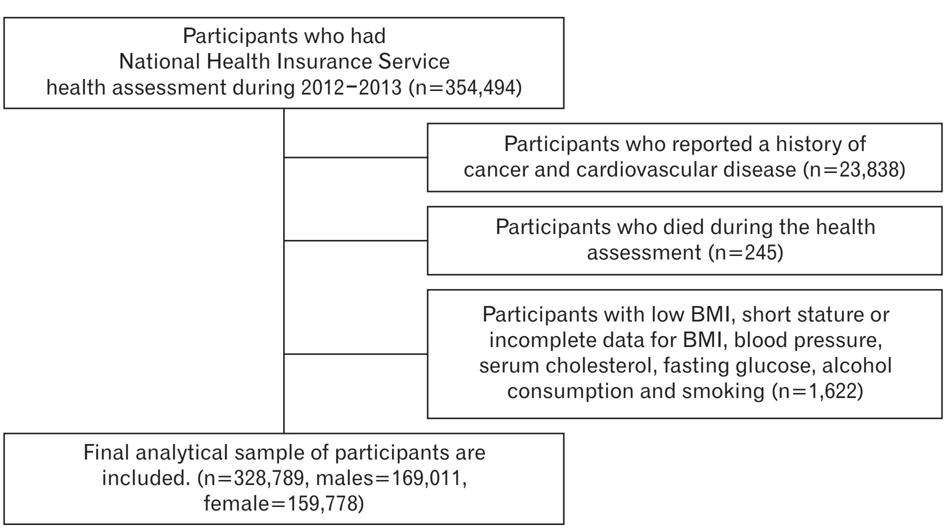

Figure 1. Selection scheme for study population. BMI, body mass index.

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of exercise, residential area, household income, current diseases, and family disease history. The completed questionnaires were reviewed by trained staff and subsequently entered into a database.

Measurements of fasting serum glucose and total cholesterol were obtained during a medical evaluation after the patient had fasted overnight. Each hospital had internal and external quality control procedures in place that were overseen by the Korean Association of Laboratory Quality Control. Data for weight and height were obtained with the participants in light clothing. Blood pressure was measured in the seated position with a mercury sphygmomanometer or an automatic manometer. BMI was calculated as weight over height squared (kg/m^2). WC was measured at the horizontal plane between the inferior costal margin and the iliac crest at the mid-axillary line (recorded in cm).

3. Definition of Main Exposure and Outcome Variables

Central obesity was defined as a WC ≥90 cm in men and ≥85 cm in women according to the Korean Society for the Study of Obesity.[17] Overweight and obesity were defined by the World Health Organization Asia-Pacific Guideline (overweight: 23.0≤ BMI <25.0 kg/m^2; obesity I: 25.0≤ BMI <30.0 kg/m^2; obesity II: BMI ≥30.0 kg/m^2).[18] We used the modified National Cholesterol Education Program-Adult Treatment Panel III (NCEP-ATP III) criteria to define MetS as the presence of three or more of the following components: (1) WC ≥90 cm in men and ≥85 cm in women, adopted from the Korean Society for the Study of Obesity criteria; (2) triglyceride (TG) level ≥150 mg/dL; (3) high-density lipoprotein cholesterol (HDLC) level <40 mg/dL in men and <50 mg/dL in women; (4) blood pressure ≥130/85 mm Hg or current treatment for hypertension; and (5) fasting glucose level 100 mg/dL or a previous diagnosis of diabetes mellitus (DM).[19]

Hypertension was diagnosed as a systolic blood pressure (SBP) ≥140 mm Hg or a diastolic blood pressure (DBP) ≥90 mm Hg as measured during the health assessments or the presence of treated hypertension with lower readings.[20] Treated hypertension was defined as having been previously diagnosed with hypertension (based on International Classification of Disease 10th Revision [ICD-10] I10 guidelines) and receiving antihypertensive therapy based upon medical claims during the year when the participants completed the health assessment.

Dyslipidemia was diagnosed in patients with the presence of one of the following abnormal lipid profiles, according to the NCEP-ATP III: total cholesterol ≥240 mg/dL, TG ≥ 200 mg/dL, or HDLC <40 mg/dL in men (<50 mg/dL in women), a low-density lipoprotein cholesterol (LDLC) ≥160 mg/dL during their health assessments, or treated dyslipidemia. Treated dyslipidemia was defined as having been diagnosed with dyslipidemia (ICD-10 E78) and being prescribed cholesterol-lowering medications according to medical claims occurring in the same year when the participants received a health assessment.

DM was diagnosed as either a fasting blood glucose ≥126 mg/dL during the health assessments or treated diabetes.[21] Treated diabetes was defined as having been diagnosed with diabetes (ICD-10 E11) and using oral hypoglycemic agents or insulin.

4. Statistical Analysis

The participants were divided into two WC and five BMI groups as follows: WC group I (WC <90 cm in men and <85 cm in women), WC group II (≥90 cm in men and ≥85 cm in women), BMI group I (BMI <18.5 kg/m^2), BMI group II (≥18.5 to <23.0 kg/m^2), BMI group III (≥23.0 to <25.0 kg/m^2), BMI group IV (≥25.0 to <30.0 kg/m^2), and BMI group V (≥30.0 kg/m^2). These WC and BMI categories were cross-tabulated to form 10 combinations of WC and BMI (WC*BMI) groups.

These categories allowed us to evaluate the clinical utility of combined WC and BMI in determining cardiovascular risk factors. A multivariable logistic regression was conducted to assess cardiovascular risk for MetS, hypertension, DM, and dyslipidemia, according to the status of central obesity and obesity. The adjusted odds ratios (ORs)

Table 1. Characteristics of participants by sex (N=328,789)

Characteristic	Males (n=169,011)	Females (n=159,778)
Age group (y)		
30–39	38,507 (22.8)	20,092 (12.6)
40–49	49,403 (29.2)	46,623 (29.2)
50–59	43,242 (25.6)	46,351 (29.0)
60–69	23,979 (14.2)	28,254 (17.7)
≥70	13,880 (8.2)	18,458 (11.6)
Body mass index (kg/m^2)		
<18.5	3,216 (1.9)	6,415 (4.0)
18.5–23.0	52,501 (31.1)	71,180 (44.6)
23.0–25.0	46,628 (27.6)	37,254 (23.3)
25.0–30.0	59,440 (35.2)	38,786 (24.3)
≥30.0	7,226 (4.3)	6,143 (3.8)
Waist circumference (cm)		
<90 in men (<85 in women)	128,112 (75.8)	128,820 (80.6)
≥90 in men (≥85 in women)	40,899 (24.2)	30,958 (19.4)
Smoking		
Never	49,740 (29.4)	151,627 (94.9)
Former	48,910 (28.9)	2,650 (1.7)
Current	70,361 (41.6)	5,501 (3.4)
Alcohol (yes)	114,625 (67.8)	37,986 (23.8)
Exercise (yes)	100,316 (59.4)	76,490 (47.9)
Household income relative to the median (%)		
0–30	25,945 (15.4)	42,185 (26.4)
30–60	39,681 (23.5)	40,314 (25.2)
60–90	73,206 (43.3)	54,383 (34.0)
90–100	30,179 (17.9)	22,896 (14.3)
Residential area		
Seoul (metropolitan)	31,170 (18.5)	31,264 (19.6)
Large city	45,062 (26.7)	42,991 (26.9)
Small city	78,965 (46.8)	70,997 (44.5)
Rural	13,584 (8.1)	14,337 (9.0)
Systolic blood pressure (mm Hg)	124.8±14.0	120.2±15.4
Diastolic blood pressure (mm Hg)	78.1±9.7	74.4±9.9
Total cholesterol (mg/dL)	196.9±36.6	199.1±37.2
Low-density lipoprotein cholesterol (mg/dL)	115.2±34.1	117.9±34.0
High-density lipoprotein cholesterol (mg/dL)	51.8±15.3	58.6±17.8
Triglycerides (mg/dL)	154.8±104.7	113.7±71.6
Fasting glucose (mg/dL)	101.7±26.9	96.7±21.4

Values are presented as number (%) or mean±standard deviation.

and 95% confidence intervals (CIs) are given. We considered covariates to be age at enrollment, smoking status (never, former, or current smoker), exercise status (intensity of exercise response of "yes": ≥600 metabolic equivalents of task-minutes per week), alcohol consumption (a response of "yes": more than 1 day a week), residential area according to 4 regions (Seoul, a metropolitan area in Korea, responses included large city, small city, and rural area) and household income (≤30%, 30%–60%, 60%–90%, >90% of the median). Analyses were performed with SAS Windows ver. 9.2 (SAS Institute Inc., Cary, NC, USA).

RESULTS

Clinical characteristics of the 328,789 participants by sex are presented in Table 1. Men had a higher mean value for SBP, DBP, total cholesterol, fasting glucose, and TG than women, whereas women had a higher value for LDLC and HDLC. The proportion of central obesity was 24.2% in men and 19.4% in women. The incidences of being overweight, obese I, and obese II were 27.6%, 35.2% and 4.3% in men and 23.3%, 24.3% and 3.8% in women, respectively.

Table 2 presents the proportions of cardiovascular risk factors with the combinations of WC and BMI in men and women. The total study population was divided into 10 groups. As expected, among men with a WC <90 cm, the proportion of MetS, hypertension, DM, treated dyslipidemia, and dyslipidemia increased with increases in BMI. Among women with a WC <85 cm, the proportion of MetS, hypertension, treated DM, DM, and dyslipidemia in women increased with increases in BMI. Centrally obese participants (WC ≥90 cm in men and 85 cm in women) had a higher mean proportion of all cardiovascular risk factors compared to non-centrally obese participants of both sexes. The mean proportion of DM was the lowest among the mean proportion of all cardiovascular risk factors in each group for both sexes.

Table 3 summarizes the association of combined BMI and WC with cardiovascular risk factors after participants were divided into 10 groups. Noticeably, the ORs were often higher in men with a WC ≥90 cm and women with a WC ≥85 cm than in men with a WC <90 cm and women with a WC <85 cm in each quintile of BMI. For instance, in

Table 2. Proportions of cardiovascular risk factors with the combined use of BMI and WC in Koreans

Variable	BMI (kg/m^2)	No. of participants (n=328,789)	No. (%) of cardiovascular risk factors						
			MetS (n=70,684)	Treated HTN (n=51,340)	HTN (n=83,093)	Treated DM (n=16,761)	DM (n=31,054)	Treated DL (n=13,658)	DL (n=113,004)
Men		169,011							
WC <90 cm									
	<18.5	3,209	120 (3.74)	229 (7.1)	467 (14.6)	123 (3.8)	230 (7.2)	53 (1.7)	517 (16.1)
	18.5–23.0	51,744	4,169 (8.06)	5,301 (10.2)	9,804 (18.9)	2,331 (4.5)	4,421 (8.5)	1,117 (2.2)	13,864 (26.8)
	23.0–25.0	41,902	5,988 (14.29)	5,691 (13.6)	9,980 (23.8)	2,101 (5.0)	4,193 (10.0)	1,234 (2.9)	16,535 (39.5)
	25.0–30.0	30,911	6,197 (20.05)	4,561 (14.8)	8,618 (27.9)	1,399 (4.5)	3,181 (10.3)	945 (3.1)	14,647 (47.4)
	≥30.0	346	112 (32.37)	51 (14.7)	129 (37.3)	10 (2.9)	45 (13.0)	12 (3.5)	200 (57.8)
	Overall	128,112	16,586 (12.9)	15,833 (12.4)	28,998 (22.6)	5,965 (4.7)	12,070 (9.4)	3,361 (2.6)	45,763 (35.7)
WC ≥90 cm									
	<18.5	7	4 (57.14)	2 (28.6)	4 (57.1)	-	-	-	2 (28.6)
	18.5–23.0	757	388 (51.25)	191 (25.2)	302 (39.9)	70 (9.2)	137 (18.1)	20 (2.6)	320 (42.3)
	23.0–25.0	4,726	2,537 (53.68)	1,115 (23.6)	1,747 (37.0)	488 (10.3)	847 (17.9)	210 (4.4)	2,213 (46.8)
	25.0–30.0	28,529	17,620 (61.76)	6,212 (21.8)	10,732 (37.6)	2,189 (7.7)	4,495 (15.8)	988 (3.5)	15,242 (53.4)
	≥30.0	6,880	4,971 (72.25)	1,499 (21.8)	3,068 (44.6)	485 (7.0)	1,246 (18.1)	199 (2.9)	4,226 (61.4)
	Overall	40,899	25,520 (62.4)	9,019 (22.1)	15,853 (38.8)	3,232 (7.9)	6,725 (16.4)	1,417 (3.5)	22,003 (53.8)
Women		159,778							
WC <85 cm									
	<18.5	6,389	142 (2.22)	355 (5.6)	559 (8.7)	103 (1.6)	181 (2.8)	142 (2.2)	768 (12.0)
	18.5–23.0	69,730	3,962 (5.68)	6,644 (9.5)	9,987 (14.3)	2,005 (2.9)	3,102 (4.4)	3,113 (4.5)	14,477 (20.8)
	23.0–25.0	32,405	3,847 (11.87)	5,573 (17.2)	7,948 (24.5)	1,398 (4.3)	2,239 (6.9)	2,049 (6.3)	10,004 (30.9)
	25.0–30.0	19,808	3,213 (16.22)	4,184 (21.1)	6,036 (30.5)	900 (4.5)	1,641 (8.3)	1,288 (6.5)	6,934 (35.0)
	≥30.0	488	107 (21.93)	101 (20.7)	164 (33.6)	25 (5.1)	45 (9.2)	19 (3.9)	183 (37.5)
	Overall	128,820	11,271 (8.7)	16,857 (13.1)	24,694 (19.2)	4,431 (3.4)	7,208 (5.6)	6,611 (5.1)	32,366 (25.1)
WC ≥85 cm									
	<18.5	26	13 (50.00)	9 (34.6)	11 (42.3)	5 (19.2)	8 (30.8)	-	11 (42.3)
	18.5–23.0	1,450	639 (44.07)	379 (26.1)	522 (36.0)	148 (10.2)	207 (14.3)	91 (6.3)	509 (35.1)
	23.0–25.0	4,849	2,374 (48.96)	1,368 (28.2)	1,876 (38.7)	494 (10.2)	697 (14.4)	379 (7.8)	1,945 (40.1)
	25.0–30.0	18,978	10,643 (56.08)	6,020 (31.7)	8,339 (43.9)	1,875 (9.9)	3,023 (15.9)	1,425 (7.5)	8,034 (42.3)
	≥30.0	5,655	3,638 (64.33)	1,855 (32.8)	2,800 (49.5)	611 (10.8)	1,116 (19.7)	374 (6.6)	2,373 (42.0)
	Overall	30,958	17,307 (55.9)	9,631 (31.1)	13,548 (43.8)	3,133 (10.1)	5,051 (16.3)	2,269 (7.3)	12,872 (41.6)

The total study population was divided into 10 subgroups of combinations of BMI and WC. Treated HTN, DM and DL: participants who have already been diagnosed and are currently on medication. HTN, DM and DL: participants who had already been diagnosed and are on medication, or who met each diagnostic criterion.
BMI, body mass index; WC, waist circumference; MetS, metabolic syndrome; HTN, hypertension; DM, diabetes mellitus; DL, dyslipidemia.

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Table 3. ORs (95% confidence interval) of cardiovascular risk factors for the combined use of BMI and WC in Koreans

Variable	BMI (kg/m^2)	ORs of cardiovascular risk factors			
		Metabolic syndrome	Hypertension	Diabetes mellitus	Dyslipidemia
Men					
WC <90 cm					
	<18.5	0.41 (0.34–0.50)	0.63 (0.56–0.69)	0.73 (0.64–0.84)	0.50 (0.45–0.55)
	18.5–23.0	1.00	1.00	1.00	1.00
	23.0–25.0	1.97 (1.89–2.05)	1.44 (1.39–1.49)	1.25 (1.20–1.31)	1.83 (1.78–1.88)
	25.0–30.0	3.10 (2.97–3.24)	2.08 (2.01–2.16)	1.45 (1.38–1.53)	2.56 (2.49–2.64)
	≥30.0	6.32 (5.02–7.95)	4.21 (3.34–5.30)	2.34 (1.69–3.24)	3.90 (3.14–4.84)
WC ≥90 cm					
	<18.5	14.50 (3.22–65.28)	6.99 (1.45–33.55)	-	0.98 (0.19–5.07)
	18.5–23.0	10.79 (9.31–12.50)	1.82 (1.56–2.12)	1.66 (1.38–2.01)	2.03 (1.75–2.35)
	23.0–25.0	12.65 (11.84–13.51)	1.94 (1.82–2.08)	1.88 (1.73–2.04)	2.45 (2.31–2.61)
	25.0–30.0	19.45 (18.68–20.24)	2.76 (2.67–2.86)	2.04 (1.95–2.13)	3.23 (3.14–3.33)
	≥30.0	35.95 (33.75–38.30)	5.70 (5.38–6.03)	3.51 (3.26–3.77)	4.59 (4.36–4.84)
Women					
WC <85 cm					
	<18.5	0.43 (0.36–0.51)	0.67 (0.61–0.74)	0.75 (0.64–0.87)	0.62 (0.57–0.67)
	18.5–23.0	1.00	1.00	1.00	1.00
	23.0–25.0	1.94 (1.85–2.03)	1.61 (1.55–1.66)	1.32 (1.25–1.40)	1.48 (1.44–1.53)
	25.0–30.0	2.79 (2.65–2.93)	2.23 (2.15–2.32)	1.60 (1.50–1.71)	1.79 (1.73–1.86)
	≥30.0	5.22 (4.18–6.52)	4.17 (3.39–5.12)	2.43 (1.77–3.33)	2.47 (2.05–2.99)
WC ≥85 cm					
	<18.5	7.25 (3.31–15.88)	1.14 (0.51–2.55)	3.87 (1.66–9.01)	1.74 (0.79–3.80)
	18.5–23.0	8.99 (8.02–10.08)	1.67 (1.48-1.88)	2.10 (1.79–2.45)	1.55 (1.39–1.74)
	23.0–25.0	11.26 (10.52–12.04)	2.01 (1.88–2.15)	2.17 (1.98–2.38)	1.87 (1.76–1.99)
	25.0–30.0	16.24 (15.53–16.97)	2.91 (2.80–3.02)	2.64 (2.50–2.79)	2.11 (2.04–2.19)
	≥30.0	29.22 (27.36–31.20)	5.57 (5.23-5.93)	4.35 (4.02–4.70)	2.41 (2.28–2.55)

The total study population was divided into 10 subgroups of combinations of BMI and WC. Using the combination group with a WC <90 cm in men (WC <85 cm in women) and a BMI 18.5 to 23.0 kg/m^2 (n=51,744 in men, n=3,962 in women) as the referent (OR=1), the ORs are shown. Adjusted for age, smoking status, exercise status, alcohol consumption, residential area, and household income.
OR, odds ratio; BMI, body mass index; WC, waist circumference.

women, the ORs (95% CIs) for DM in the group with a WC <85 cm versus those with a WC ≥85 cm were 1.00 versus 2.10 (range, 1.79–2.45), 1.32 (range, 1.25–1.40) versus 2.17 (range, 1.98–2.38), 1.60 (range, 1.50–1.71) versus 2.64 (range, 2.50–2.79), and 2.43 (range, 1.77–3.33) versus 4.35 (range, 4.02–4.70) for BMI groups I, II, III, IV, and V, respectively. Compared to the group with a normal WC and a normal BMI, the centrally obese and highest BMI group (BMI ≥30.0 kg/m^2) were associated with a nearly 36-fold greater risk of MetS in men and a 29-fold greater risk in women. In contrast, for women, the presence of central obesity had less influence on hypertension and dyslipidemia than it did on MetS and DM, because the increase of ORs in hypertension and dyslipidemia was less remarkable than the increase of ORs in MetS and DM in the group with a WC ≥85 cm compared with those with a WC <85 cm.

Figure 2 shows the correlation of cardiovascular risk factors with the status of central obesity and obesity. The total study population was divided into four subgroups with different combinations of BMI and WC according to the status of central obesity and obesity.

Compared to men and women with a WC <90 cm and <85 cm, respectively, and a BMI <25.0 kg/m^2, the participants who were obese (BMI ≥25.0 kg/m^2) or centrally obese (WC ≥90 cm in men and ≥85 cm in women) had a slightly increased correlation with all cardiovascular risk factors; at the same time, participants who were centrally obese (WC ≥90 in men and >85 cm in women) and obese (BMI ≥25.0 kg/m^2) had the strongest correlation of all cardiovascular risk factors. For example, in men, the adjusted ORs (95% CIs) for MetS were 2.26 (range, 2.18–2.34) in the group with a WC <90 cm and a BMI ≥25.0 kg/m^2, 9.11 (range, 8.60–9.65) in the group with a WC ≥90 cm and a BMI <25.0 kg/m^2, and 15.73 (range, 15.26–16.21) in the centrally obese and obese group (BMI ≥25.0 kg/m^2).

In addition, those that were centrally obese had a significantly increased risk for MetS and DM compared to hypertension and dyslipidemia among both sexes, because the difference in ORs between the group with a WC <90 cm in men (<85 cm in women) and a BMI ≥25.0 kg/m^2 and the group with a WC ≥90 cm in men (≥85 cm in women) and a BMI <25.0 kg/m^2 was positively more remarkable for the risk factors MetS and DM.

DISCUSSION

As the Korean population is rapidly aging, it is expected that the prevalence of CVD will continue to increase.[22,23] A system should be estab-

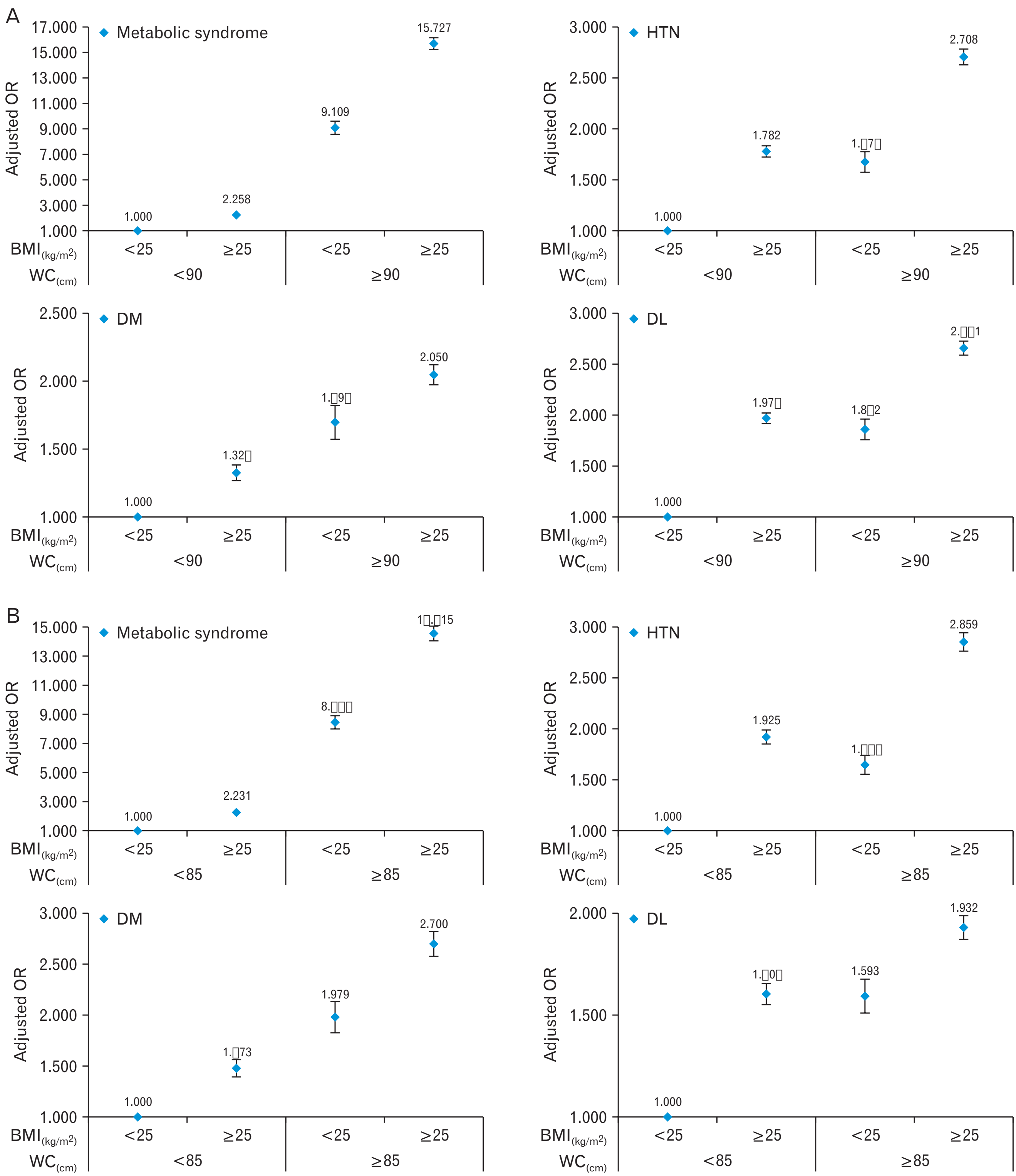

Figure 2. ORs (95% confidence interval) of cardiovascular risk factors using combined BMI and WC in males (A) and females (B). The total study population was divided into four subgroups according to the participants' status of central obesity and obesity. Using the combination group with a WC <90 in males (WC <85 in females) and a BMI <25 (n=96,855 in males, n=108,524 in females) as the referent (OR=1), the ORs are shown. The P-values of all ORs were P<0.05 and were adjusted for age, smoking status, exercise status, and alcohol consumption. OR, odds ratio; WC, waist circumference; BMI, body mass index; MetS, metabolic syndrome; HTN, hypertension; DM, diabetes mellitus; DL, dyslipidemia.

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lished to prevent CVD and warn the aging population of the dangers of CVD. This study investigated the prevalence of central obesity and obesity as well as the correlation of cardiovascular risk factors by cross-tabulating central obesity with multiple BMI categories.

The 2014 Korea National Health and Nutrition Examination Survey (KNHANES) reported that the prevalence of central obesity was 23.1% (26.0% in men and 20.2% in women), while the incidence of obesity was 31.5% (37.7% in men and 25.3% in women).[24] Similar to the 2014 KNHANES, our results showed that central obesity and obesity were more prevalent in men than in women (Table 1); the proportion of central obesity and obesity were 24.2% and 39.5% in men and 19.4% and 28.1% in women, respectively.

Previous studies on cross-sectional associations were conducted to investigate variables to determine which was better among anthropometric indexes, including BMI, WC, and waist-to-height ratio, to predict a patient's cardiometabolic risk.[6,11,25,26] In this study, we used both BMI and WC as important anthropometric indexes for predicting cardiovascular risk factors on the premise that a stronger positive association exists between cardiovascular risk factors, such as hypertension and lipid and glucose concentrations, when both BMI and WC are considered than with BMI or WC alone. Hou et al.[14] reported the clinical advantage of using combined WC and BMI categories in identifying the risks for CMD and CVD. Their study found that a combination of WC and BMI categories significantly increased the power of identifying CMD risk compared to separate WC or BMI categories; these authors suggested that WC can be a helpful indicator for DM, and that BMI is closely related with hypertension in China. Our study is consistent with the previous study in that the combination of BMI and WC significantly increased the correlation of cardiovascular risk factors. According to Table 3, both BMI and WC likely had a positive relationship with each cardiovascular risk factor in both sexes; the ORs increased with increases in BMI and WC, except for the group with a BMI <18.5 kg/m^2 and a WC ≥90 cm in men (≥85 cm in women) because the group size was so small that the results were not statistically significant. The highest combination WC and BMI group (WC ≥90 cm in men and ≥85 cm in women and BMI ≥30.0 kg/m^2) was the one most strongly associated with all cardiovascular risk factors.

In addition, the presence of central obesity positively influenced each type of cardiovascular risk, as the ORs were mostly higher in the group with a WC ≥90 cm in men (≥85 cm in women) than in the group with a WC <90 cm in men (<85 cm in women) in each quintile of BMI. Similar to the previous study, WC was closely related with DM as well as MetS in this study.[9,14,27] In particular, it could be suggested that the presence of central obesity had a lesser effect on the risk of hypertension and dyslipidemia in women than the risk for MetS and DM.

The correlation of cardiovascular risk factors was the most remarkable in participants who were both centrally obese and obese at the same time (Figure 2). Participants who were either obese or centrally obese were more likely to have an increased risk of CVD than participants who were not centrally obese or obese. The Centrally obese groups had a significantly greater risk of MetS and DM than those with hypertension and dyslipidemia in all sexes (Figure 2). Based upon these findings, it is necessary to alert participants who are obese, centrally obese, or both that they have an increased risk for CVD, especially participants who are both centrally obese and obese. As mentioned above, centrally obese participants should be made aware of the risk for MetS and DM; these findings would be very appropriate for practical health education.

Our study had some limitations. First, this study only combined BMI and WC without comparing separate BMI and WC groups. Second, as the magnitude of interaction between BMI and WC was not examined in this study, the correlation of a combined WC and BMI on each cardiovascular risk factor cannot be quantified through a comparison of the ORs of these cardiovascular risk factors. Third, outcome variables in this study would be significantly influenced by age, so further study would be required to determine age-adjusted prevalence of disease. Fourth, the OR might be exaggerated because MetS as an outcome variable has a high prevalence. Fifth, this study was a cross-sectional survey, and it may preclude the identification of any causal relationship in each group. Finally, we depended on a subjective survey using questionnaires, so we cannot rule out recall bias.

The strength of this study was that it used nationally representative data from the KNHIS, and the findings are therefore generalizable to all Koreans. This was the first attempt to investigate the correlation of cardiovascular risk factors by considering the interaction of both BMI and WC simultaneously. These findings lead to significant speculation that the clinical utilization of combining both WC and BMI may provide a useful index for preventing CVD in Korea. Our study also provides evidence that cardiovascular risk determined by using a combined WC and BMI divided into 10 groups or 4 groups, respectively, would be worthwhile to design effective strategies for predicting and preventing CVD.

In conclusion, the purpose of this study was to investigate the clinical advantage of using WC and BMI categories simultaneously in identifying cardiovascular risk in Koreans. This study emphasized that the combination of both BMI and WC can help identify individuals at increased risk for developing CVD.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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