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The estimation of cardiovascular risk factors by body mass index and body fat percentage in Korean male adults

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Abstract

The aim of the study was to assess cardiovascular risk in men with high body fat percentage (BF%) and normal body mass index (BMI) and men with normal BF% and high BMI. This study was a cross-sectional study using data on 5534 Korean male adults. Body mass index, BF%, and waist circumference were measured as adiposity indices. Bioelectrical impedance analysis was used for measuring BF%. Blood pressure, fasting plasma glucose, total cholesterol, triglyceride, and high-density lipoprotein cholesterol were measured routinely. Information regarding alcohol consumption, smoking, exercise, and past/current medical history was obtained by structured questionnaires. Subjects were categorized into 4 groups by means of BMI and BF% (group 1, BMI <25 kg/m^2 and BF% <25%; group 2, BMI <25 kg/m^2 and BF% ≥25%; group 3, BMI ≥25 kg/m^2 and BF% <25%; group 4, BMI ≥25 kg/m^2 and BF% ≥25%). Cardiovascular risk factors (CVRFs) such as high blood pressure, hyperglycemia, and dyslipidemia were estimated in each group. As might be expected, the prevalences of high blood pressure, hyperglycemia, and dyslipidemia were lowest in group 1 and were highest in group 4. Multivariate analyses showed that subjects in group 2 or group 4 had a 1.8 times increased risk of clustering of 2 or more CVRFs compared with subjects in group 1 ($P < .001$). The adjusted odds ratio (1.15; 95% confidence interval, 0.94-1.40) of subjects in group 3 on clustering of 2 or CVRFs was not significantly increased ($P = .180$). High BF% was related to increase of cardiovascular risk regardless of the level of BMI in Korean men. However, cardiovascular risk of men with high BMI without high BF% was not significantly increased.

1. Introduction

Obesity is defined as an excess of body fat that results in increased risk of metabolic abnormalities. The World Health Organization [1] and the National Heart, Lung, and Blood Institute (NHLBI) [2] defined obesity based on the body mass index (BMI); and most epidemiologic studies on obesity have used BMI for measurement of body fatness. However, the BMI has several limitations in estimating obesity for some individuals [3,4]. The BMI could misclassify those with increased body fat and decreased lean body mass as normal. In addition, some muscular young men without excess body fat might be classified as obese. Therefore, an accurate and reliable method is needed for assessing body composition. The reference methods such as multicompartment model, underwater weighing, dual-energy x-ray absorptiometry (DXA), and stable isotope dilution methods are not widely available in the clinical setting because of requirements for trained technicians, expensive equipment, and dedicated facilities [5-7]. Recently, bioelectrical impedance analysis (BIA) has been reported to have good correlation with DXA and has become popular in clinical practice because of its validity, feasibility, safety, and cost [8,9].

Body mass index and body fat percentage (BF%) could indicate different health risks of patients in clinical practice. Some patients have a high BF% but a normal BMI, whereas

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other patients have a normal BF% but a high BMI. When clinicians meet such patients, there is some difficulty in assessing their cardiovascular risk. Ito et al [10] reported increased cardiovascular risk factors (CVRFs) in subjects with high BF% and normal weight. However, prior research results on the cardiovascular risk of those with normal BF% but a high BMI have been inconsistent [4,10-12]. This study was conducted to assess cardiovascular risk in men with a high BF% and a normal BMI and in those with a normal BF % and a high BMI. The cross-sectional data from 5534 Korean men were used for the analyses.

2. Methods

The subjects were 5534 Korean men aged 19 to 82 years who visited a university health care center for a general health checkup from January to December 2005.

Anthropometric measurements were obtained with light clothing and without shoes by trained technicians. Each anthropometric measurement was done by the same technician, by the same instrument, and with the same technique. Quality control for all measurements was monitored regularly. The height was measured to the nearest 0.1 cm and weight to the nearest 0.1 kg in the upright position using an automatic height and weight measurement system (FA-600; Fanics, Busan, Korea). The BMI was calculated as the body weight divided by the height squared (kilograms per square meter). The waist circumference measurements were obtained using an anthropometric tape (to the nearest 0.1 cm) at the end of normal expiration at the level of the midpoint between the lower end of the 12th rib and upper end of the iliac crest.

The BF% was quantified with bioelectrical impedance (InBody 3.0; Biospace, Seoul, Korea). The resistance of arms, trunk, and legs was measured at frequencies of 5, 50, 250, and 500 kHz with an 8-polar tactile-electrode impedance meter: 4 are in contact with the palm and thumb of both hands; and 4, with the anterior and posterior aspects of the sole of both feet. A set of externally derived BIA prediction equations was used to calculate the BF% using age, sex, weight, and resistance [13]. The correlation coefficient of BF% between the InBody 3.0 and DXA was 0.93 in Korean men, and the mean error was 1.2% (95% confidence interval [CI], −4.6~7.1) [14]. Participants were asked to comply with the following instructions before the impedance analysis. They were asked to fast overnight, have no exercise for at least 12 hours, and have no alcohol for at least 24 hours.

In our study, *obesity by BMI* was defined as a BMI of at least 25 kg/m^2, which has been recommended for Asians by the World Health Organization [15]; and *obesity by BF%* was defined as BF% of at least 25%, which was used for diagnosis of obesity, although still debatable, in clinical setting and several epidemiologic studies [16,17]. Subjects were categorized into 4 groups: group 1, BMI less than 25 kg/m^2 and BF% less than 25%; group 2, BMI less than 25 kg/m^2 and BF% of at least 25%; group 3, BMI of at least 25 kg/m^2 and BF% less than 25%; and group 4, BMI of at least 25 kg/m^2 and BF% of at least 25%.

Systolic and diastolic blood pressures were measured in the right arm using an automatic manometer (FT-200S; Jawon medical, Kyungsan, Korea) in the sitting position after a 10-minute rest period. During the 30 minutes preceding the measurement, the subjects were required to refrain from smoking or consuming caffeine. Blood samples were drawn from an antecubital vein into Vacutainer tubes containing EDTA the morning after an overnight fast. The samples were subsequently analyzed at the laboratory of the Hallym University Hallym Sacred Heart Hospital. Fasting plasma glucose (FPG), total cholesterol (T-Chol), triglyceride (TG), and high-density lipoprotein cholesterol (HDL-C) were measured using an auto-analyzer (Hitachi 7600; Hitachi, Tokyo, Japan). Low-density lipoprotein cholesterol (LDL-C) was calculated by the Friedewald equation (LDL-C = T-Chol − [HDL-C + TG/5]) [18].

Information regarding alcohol consumption, smoking, exercise, and past/current medical history was obtained by structured questionnaires. Alcohol consumption status was classified into 3 groups: nondrinker, moderate drinker, or heavy drinker. We calculated manually the average amount of alcohol consumption with reported average frequency and amount of alcohol beverage drinking and the alcohol concentration of the alcohol beverage. *Moderate drinking* was defined as an average alcohol consumption not exceeding 24 g/d, and *heavy drinking* was defined as an average alcohol consumption greater than 24 g/d [19]. Smoking status was classified into 3 groups: nonsmoker, ex-smoker, or current smoker. The exercise status was estimated from the weekly frequency of moderate-intensity exercise for more than 30 minutes and was classified into 3 groups: no exercise, irregular exercise (1-2 times a week), or regular exercise (≥3 times a week).

The definitions of CVRFs used in this study are given below. Each cutoff value of CVRF was based on the criteria of borderline abnormality for each CVRF suggested by the American Diabetes Association; American Heart Association; and National Heart, Lung, and Blood Institute [20-22].

1. High blood pressure: a systolic blood pressure of at least 130 mm Hg and/or a diastolic blood pressure of at least 85 mm Hg and/or treatment for previously diagnosed hypertension.
2. Hyperglycemia: an FPG of at least 100 mg/dL (≥5.6 mmol/L) and/or treatment for previously diagnosed type 2 diabetes mellitus.
3. Dyslipidemia: a TG of at least 150 mg/dL (≥1.7 mmol/L) and/or an HDL-C less than 40 mg/dL (<1.03 mmol/L) and/or an LDL-C of at least 160 mg/dL (≥4.1 mmol/L) and/or treatment for previously diagnosed dyslipidemia.

Continuous variables that did not have a normal distribution were analyzed after log transformation. The differences in the CVRFs among the 4 groups were examined with 1-way analysis of variance and post hoc Tukey tests for continuous variables and with the χ^2 tests for categorical variables. The odds ratios on clustering of 2 or more CVRFs were calculated in each group using the multiple logistic regression analysis with adjustments for age, smoking, alcohol, exercise, and waist circumference. Because medications could affect some variables including body composition, we repeated the same analysis after excluding subjects in treatment for hypertension, type 2 diabetes mellitus, and/or dyslipidemia. All statistical analyses were performed with SPSS 13.0 for Windows (SPSS, Chicago, IL), and values with P less than .05 (2-tailed tests) were considered statistically significant.

3. Results

The geometric means of age, BMI, %BF, and waist circumference of the subjects were 43.8±1.2 years, 24.5 ± 1.1 kg/m^2, 21.4% ± 1.3%, and 84.2 ± 1.1 cm, respectively. The number of subjects with a BMI of at least 25 kg/m^2 was 2305 (41.7%), and the number of subjects with a BF% of at least 25% was 1381 (25.0%). The number of subjects in groups 1, 2, 3, and 4 were 2994 (54.1%), 235 (4.2%), 1159 (20.9%), and 1146 (20.7%), respectively.

The general characteristics of the study population are presented in Table 1. Subjects in group 2 were older ($P <$ .001) and had lower exercise frequency compared with subjects in the other groups. Subjects in group 3 were less likely to be nonsmokers and reported more alcohol consumption and exercise compared with subjects in the other groups. Frequencies of treatment for hypertension and type 2 diabetes mellitus were higher in subjects in group 2 and group 4 than the other 2 groups, and the frequency of treatment for dyslipidemia was higher in subjects in group 3 and group 4 than the other 2 groups.

The mean levels of anthropometric variables and CVRFs in each of the 4 groups are presented in Table 2. The geometric mean of waist circumference was lowest in subjects in group 1 and highest in subjects in group 4. Subjects in the other groups had higher blood pressure, FPG, T-Chol, TG, LDL-C, and lower HDL-C compared with subjects in group 1. All CVRFs were highest in subjects in group 4. Diastolic blood pressure, FBS, and HDL-C were significantly higher in subjects in group 2 than in group 3; but there were no differences in the other risk factors between groups 2 and 3.

In the subjects in this study, high blood pressure, hyperglycemia, and dyslipidemia were found in 2135 (38.6%), 732 (13.2%), and 2443 (44.1%), respectively. The number of subjects with 2 or more CVRFs was 1433 (25.9%). The prevalence of high blood pressure, hyperglycemia, dyslipidemia, and clustering of 2 or more

Table 1
General characteristics of study subjects

	Group 1 (n = 2994)	Group 2 (n = 235)	Group 3 (n = 1159)	Group 4 (n = 1146)	P value[a]
Age (y)					<.001
≤34.9	339 (11.3)	12 (5.1)	103 (8.9)	102 (8.9)	
35.0-39.9	590 (19.7)	40 (17.0)	250 (21.6)	252 (22.0)	
40.0-44.9	762 (25.5)	54 (23.0)	332 (28.6)	265 (23.1)	
45.0-49.9	593 (19.8)	42 (17.9)	259 (22.3)	198 (17.3)	
≥50	710 (23.7)	87 (37.0)	215(18.6)	329 (28.7)	
Smoking					.001
Nonsmoker	787 (26.4)	70 (29.8)	258 (22.5)	308 (27.1)	
Ex-smoker	776 (26.1)	61 (26.0)	348 (30.3)	346 (30.5)	
Current smoker	1413 (47.5)	104 (44.3)	543 (47.3)	482 (42.4)	
Alcohol[b]					<.001
Nondrinker	700 (23.4)	52 (22.1)	209 (18.0)	234 (20.5)	
Moderate	1333 (44.6)	108 (46.0)	497 (42.9)	495 (43.3)	
Heavy	957 (32.0)	75 (31.9)	452 (39.0)	414 (36.2)	
Exercise[c]					<.001
No	1209 (40.8)	110 (47.6)	389 (34.0)	453 (40.0)	
Irregular	1051 (35.5)	87 (37.7)	422 (36.9)	411 (36.3)	
Regular	703 (23.7)	34 (14.7)	334 (29.2)	268 (23.7)	
Tx for HTN	166 (5.5)	35 (14.9)	90 (7.8)	170 (14.8)	<.001
Tx for type 2 diabetes mellitus	76 (2.5)	11 (4.7)	30 (2.6)	45 (3.9)	.035
Tx for dyslipidemia	27 (0.9)	2 (0.9)	24 (2.1)	19 (1.7)	.014

Group 1, BMI less than 25 kg/m^2 and BF% less than 25%; group 2, BMI less than 25 kg/m^2 and BF% at least 25%; group 3, BMI at least 25 kg/m^2 and BF% less than 25%; and group 4, BMI at least 25 kg/m^2 and BF% at least 25%. Values are expressed as number (percentage). Tx indicates treatment; HTN, hypertension.

[a] P value by χ^2 test.

[b] Nondrinker, 0 g/d; moderate, not exceeding 24 g/d; heavy, greater than 24 g/d.

[c] No, 0 time a week; irregular, 1 to 2 times a week; regular: at least 3 times a week.

Table 2
The mean levels of anthropometric variables and CVRFs in each of the 4 groups

	Group 1 (n = 2994)	Group 2 (n = 235)	Group 3 (n = 1159)	Group 4 (n = 1146)	*P* value[a]
Height (cm)	170.4 (1.0)[c]	167.0 (1.0)[a]	171.3 (1.0)[d]	169.1 (1.0)[b]	<.001
Weight (kg)	65.3 (1.1)[a]	66.7 (1.1)[b]	77.2 (1.1)[c]	79.3 (1.1)[d]	<.001
BMI (kg/m^2)	22.5 (1.1)[a]	23.9 (1.0)[b]	26.3 (1.1)[c]	27.8 (1.1)[d]	<.001
Body fat (%)	19.6 (1.1)[a]	27.5 (1.0)[b]	19.7 (1.1)[a]	27.9 (1.1)[b]	<.001
WC (cm)	80.0 (1.2)[a]	84.5 (1.1)[b]	88.0 (1.2)[c]	91.8 (1.1)[d]	<.001
SBP (mm Hg)	120.6 (1.1)[a]	125.7 (1.1)[b]	123.7 (1.1)[b]	128.2 (1.1)[c]	<.001
DBP (mm Hg)	71.7 (1.2)[a]	75.7 (1.2)[c]	73.9 (1.2)[b]	77.4 (1.2)[d]	<.001
FPG (mg/dL)	85.7 (1.2)[a]	90.7 (1.3)[b,c]	88.8 (1.2)[b]	92.0 (1.2)[c]	<.001
T-Chol (mg/dL)	181.0 (1.2)[a]	192.9 (1.2)[b]	190.2 (1.2)[b]	198.2 (1.2)[c]	<.001
TG (mg/dL)	110.9 (1.7)[a]	143.5 (1.6)[b]	142.1 (1.7)[b]	161.1 (1.6)[c]	<.001
HDL-C (mg/dL)	53.4 (1.3)[c]	51.1 (1.3)[b]	48.5 (1.2)[a]	47.1 (1.2)[a]	<.001
LDL-C (mg/dL)	103.5 (29.4)[a]	110.4 (37.0)[b]	110.9 (30.8)[b]	116.4 (31.5)[c]	<.001

Group 1, BMI less than 25 kg/m^2 and BF% less than 25%; group 2, BMI less than 25 kg/m^2 and BF% at least 25%; group 3, BMI at least 25 kg/m^2 and BF% less than 25%; group 4, BMI at least 25 kg/m^2 and BF% at least 25%. Values except LDL-C are expressed as geometric means (GSD), and values of LDL-C are expressed as arithmetic means (SD). Variables except LDL-C were analyzed after log transformation. Values marked with a different letter are significantly different ($P < .05$) by post hoc Tukey test. WC indicates waist circumference; SBP, systolic blood pressure; DBP, diastolic blood pressure.

[a] *P* value by 1-way analysis of variance.

CVRFs was lowest in group 1 and highest in group 4 ($P < .001$) (Table 3).

The adjusted odds ratios on clustering of 2 or more CVRFs were calculated by multiple logistic regression analysis (Table 4). Age, smoking, alcohol, exercise, and waist circumference with 4 groups classified by BMI and BF% were included as independent variables in this regression model. All other variables except exercise had significant relationship with clustering of 2 or more CVRFs. Subjects in group 2 (normal BMI and high BF%) or group 4 (high BMI and high BF%) had a 1.8 times increased risk of clustering of 2 or more CVRFs compared with subjects in group 1 (normal BMI and normal BF%) ($P < .001$). The adjusted odds ratio (1.15; 95% CI, 0.94-1.40) of subjects in group 3 (high BMI and normal BF%) on clustering of 2 or CVRFs was not significantly increased ($P = .180$). We also repeated the same analysis after excluding subjects in treatment for hypertension, type 2 diabetes mellitus, and/or dyslipidemia. Excluding them did not affect the results of this analysis (Table 4). In addition, the results of multivariate analyses wherein diagnosis of single CVRF such as high blood pressure, hyperglycemia, and dyslipidemia was chosen as dependent variable were also consistent (data not shown).

4. Discussion

Body mass index and BF% have been used as diagnostic indicators of obesity in clinical practice. The finding of a normal BMI and a high BF% in some individuals and vice versa in others has been frequently encountered. This study was designed to determine the cardiovascular risk of individuals whose BMI and BF% were conflicting. We categorized study subjects by means of BMI and BF% (group 1, BMI <25 kg/m^2 and BF% <25%; group 2, BMI <25 kg/m^2 and BF% ≥25%; group 3, BMI ≥25 kg/m^2 and BF% <25%; and group 4, BMI ≥25 kg/m^2 and BF% ≥25%). A quarter (25.1%) of the subjects of this study was categorized into the conflicting groups (group 2 or group 3) where one of BMI or BF% was normal. In previous studies, subjects with normal BMI and high BF% were consistently reported to have increased cardiovascular risk

Table 3
Frequency of CVRFs for the 4 groups

Variables	Group 1 (n = 2994)	Group 2 (n = 235)	Group 3 (n = 1159)	Group 4 (n = 1146)	*P* value[a]
High blood pressure[b]	934 (31.2)	109 (46.4)	445 (38.4)	647 (56.5)	<.001
Hyperglycemia[c]	284 (9.5)	44 (18.7)	165 (14.2)	239 (20.9)	<.001
Dyslipidemia[d]	962 (32.1)	131 (55.7)	615 (53.1)	735 (64.1)	<.001
No risk factor	1376 (46.0)	50 (21.3)	334 (28.8)	178 (15.5)	
≥1 Risk factor	1130 (37.7)	102 (43.4)	483 (41.7)	448 (39.1)	<.001
≥2 Risk factors	414 (13.8)	67 (28.5)	284 (24.5)	387 (33.8)	<.001
≥3 Risk factors	74 (2.5)	16 (6.8)	58 (5.0)	133 (11.6)	<.001

Group 1, BMI less than 25 kg/m^2 and BF% less than 25%; group 2, BMI less than 25 kg/m^2 and BF% at least 25%; group 3, BMI at least 25 kg/m^2 and BF% less than 25%; group 4, BMI at least 25 kg/m^2 and BF% at least 25%. Values are expressed as number (percentage).

[a] *P* value by χ^2 test.

[b] Systolic blood pressure at least 130 mm Hg and/or diastolic blood pressure at least 85 mm Hg and/or treatment for previously diagnosed hypertension.

[c] Fasting plasma glucose at least 100 mg/dL and/or treatment for previously diagnosed type 2 diabetes mellitus.

[d] Triglyceride at least 150 mg/dL and/or HDL-C less than 40 mg/dL and/or LDL-C at least 160 mg/dL and/or treatment for previously diagnosed dyslipidemia.

Table 4
Results of multiple logistic regression analysis on clustering of 2 or more CVRFs

	Total subjects		Subjects without treatment for HTN, type 2 diabetes mellitus, and/or dyslipidemia	
	Odds ratio (95% CI)	*P* value	Odds ratio (95% CI)	*P* value
Age (y)				
≤34.9	1.00 (reference)		1.00 (reference)	
35.0-39.9	1.45 (1.09-1.92)	.011	1.38 (1.03-1.85)	.030
40.0-44.9	1.50 (1.13-1.98)	.005	1.24 (0.93-1.66)	.145
45.0-49.9	1.78 (1.33-2.36)	<.001	1.48 (1.10-2.00)	.010
≥50	2.83 (2.14-3.73)	<.001	1.97 (1.47-2.65)	<.001
Smoking				
Nonsmoker	1.00 (reference)		1.00 (reference)	
Ex-smoker	1.15 (0.96-1.37)	.139	1.23 (1.00-1.51)	.052
Current smoker	1.22 (1.03-1.44)	.020	1.21 (1.00-1.47)	.048
Alcohol				
Nondrinker	1.00 (reference)		1.00 (reference)	
Moderate	1.07 (0.90-1.29)	.442	1.25 (1.01-1.55)	.038
Heavy	1.37 (1.14-1.65)	.001	1.66 (1.34-2.07)	<.001
Exercise				
No	1.00 (reference)		1.00 (reference)	
Irregular	1.04 (0.89-1.20)	.658	1.07 (0.90-1.26)	.453
Regular	0.98 (0.82-1.16)	.811	0.92 (0.75-1.12)	.378
WC (cm)				
≤79	1.00 (reference)		1.00 (reference)	
80-84	2.19 (1.72-2.78)	<.001	2.14 (1.63-2.80)	<.001
85-89	3.38 (2.62-4.37)	<.001	3.23 (2.42-4.30)	<.001
≥90	5.21 (3.90-6.95)	<.001	4.86 (3.52-6.70)	<.001
BMI and BF%[a]				
Group 1	1.00 (reference)		1.00 (reference)	
Group 2	1.77 (1.31-2.39)	<.001	1.52 (1.06-2.18)	.021
Group 3	1.15 (0.94-1.40)	.180	1.17 (0.94-1.46)	.160
Group 4	1.82 (1.47-2.26)	<.001	1.76 (1.39-2.24)	<.001

[a] Group 1, BMI less than 25 kg/m^2 and BF% less than 25%; group 2, BMI less than 25 kg/m^2 and BF% at least 25%; group 3, BMI at least 25 kg/m^2 and BF % less than 25%; group 4, BMI at least 25 kg/m^2 and BF% at least 25%.

[11,23,24]; but results of the studies on the cardiovascular risk of the subjects with high BMI and normal BF% have not been consistent [4,12,25]. In our study, the cardiovascular risk of subjects whose BF% only was high was similar to that of subjects in whom both BMI and BF% were high. However, the cardiovascular risk in the subjects whose BMI only was high was not increased over that in subjects whose BMI and BF% were normal.

Over the past 20 years, some individuals have been identified with metabolic abnormalities despite a normal weight. Such individuals have been referred to as *metabolically obese with a normal weight*. These individuals are not obese based on height and weight but are hyperinsulinemic, insulin resistant, and predisposed to type 2 diabetes mellitus and premature coronary heart disease [23]. The possible causes of being metabolically obese with a normal weight are the amount and the distribution of fat mass, insulin resistance, and abnormal fat metabolism. Dvorak et al [24] reported that body fat was significantly increased in normal-weight women with insulin resistance. Tanaka et al [26] reported that male subjects with normal weight and elevated adiposity had higher cardiovascular risk than male subjects with normal weight and less adiposity (from the Quebec Family Study and the Heritage Family Study). Han and Kim [11] reported that an increased BF% was related to CVRFs in Korean men with normal weight. Our study showed that subjects in group 2 (normal BMI and high BF%) had increased CVRFs: high blood pressure, hyperglycemia, and dyslipidemia. The increased cardiovascular risk of subjects in group 2 was maintained after adjustment for age, smoking, alcohol, exercise, and waist circumference (Table 4). In groups 1 and 2, categorized by only the difference of BF%, a slight difference in the BMI was observed between the 2 groups (Table 2). However, there was no change of odds ratio on clustering of CVRFs in subjects in group 2 after additional adjustment for the BMI (data not shown). Subjects in group 2 were the oldest and had the lowest exercise frequency among subjects of the 4 groups. These characteristics correspond with those of sarcopenic obesity in which physical activity decreases with aging [27], although we cannot clearly diagnose sarcopenia in the subjects of this study. Decreased physical activity with aging might cause a progressive loss of muscle mass and strength through reducing trophic effect on muscle mass and, at the same time, might result in an increase of body fat through positive energy balance. The muscle is one of the target tissues controlling glucose metabolism. The loss of muscle mass might aggravate insulin resistance, the metabolic syndrome,

and obesity. The increased body fat might promote production of tumor necrosis factor–α, interleukin-6, and other adipokines that potentially have a direct catabolic effect on muscle and aggravate insulin resistance. Therefore, an increase of body fat and a loss of muscle mass could initiate a vicious cycle of continuing deterioration [28].

Research on the cardiovascular risks in muscular individuals with elevated weight and normal adiposity has been ongoing over the past 20 years. Van Italie [25] reported that individuals with elevated weight and normal adiposity had a higher prevalence of hypertension and dyslipidemia. However, adiposity was measured by skin fold thickness of the triceps and subscapular area in his study. Therefore, there was a possibility that body fat was present in the visceral cavity or unmeasured subcutaneous region, which could lead to a bias by misclassification. Segal et al [4] reported that individuals with an increased BMI and normal BF% did not have increased CVRFs compared with individuals with a normal BMI and BF%. However, Cho et al [12] reported different results; that is, when either the BMI or the BF% was elevated, although the other was within reference range, the CVRFs such as hypertension, diabetes, and dyslipidemia were increased. The discrepancy of prior study results could be explained by differences of the instruments for body fat measure or sampling of study subjects among previous studies. In the study of Segal et al, the number of subjects was only 32; but the groups were matched with respect to lean body mass, BMI, and total body weight, and body fat was quantified by hydrostatic weighing. The number of subjects in the study reported by Cho et al [12] was 22 704. However, the groups were not matched; and the body fat was measured by BIA. Our study was methodologically similar to the study of Cho et al. The univariate analysis in our study showed that the cardiovascular risk of subjects with elevated BMI was increased, although their BF% was normal, a finding consistent with that of Cho et al. However, the difference in the cardiovascular risk between group 1 (normal BMI and normal BF%) and group 3 (high BMI and normal BF%) was no longer present after adjustment for the waist circumference (Table 4). In the study of Cho et al, waist circumference was not included as covariate. Many studies have demonstrated that not only the amount of body fat mass but body fat distribution determines the cardiovascular risk associated with obesity and that abdominal fat is associated with the CVRFs [29-31]. Therefore, a marker of body fat distribution such as waist circumference should be considered in estimating cardiovascular risk by anthropometric variables [32,33].

Several limitations of our study should be recognized. We measured the body fat not by the more accurate DXA or underwater weighing, but by BIA. However, in clinical practice, DXA and underwater weighing are generally not used because of cost and feasibility issues. Differences in some of the variables such as age, smoking, alcohol drinking, exercise, and waist circumference were found among the 4 groups. However, those variables were adjusted in the multivariate analyses. Because the cardiovascular risk according to 4 groups categorized by the BMI and BF% was compared, independent relationships of body fat and lean body mass with the cardiovascular risk could not be analyzed. The results of our study cannot be generalized to the general population because the subjects were only adult men who visited a university health care center for a general health checkup. Despite these several limitations, our study has an advantage in measuring BF% through BIA in a relatively large number of subjects (5534 men). A further strength is that this study was performed in an Asian population, whereas most other studies on this issue have been from white populations. The relationship between body fat mass and disease risk may differ according to race and ethnicity [15,17].

High BF% was related to increased cardiovascular risk regardless of the level of BMI in Korean men. However, cardiovascular risk of men with high BMI without high BF% was not significantly increased. Both the amount and distribution of body fat should be considered in estimating cardiovascular risk by anthropometric measures. If BF% and waist circumference of individuals are known, BMI adds little additional information on the cardiovascular risk of individuals.

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