

# Relationship between heavy drinking, binge drinking, and metabolic syndrome in obese and non-obese Korean male adults

Jung Eun Oh<sup>§</sup>

Department of Family Medicine, Soonchunhyang University Cheonan Hospital, Soonchunhyang University College of Medicine, 31, Soonchunhyang 6-gil, Dongnam-gu, Cheonan 31151, Korea

**BACKGROUND/OBJECTIVES:** Obesity and alcohol drinking are associated with metabolic syndrome. However, few studies show the relationship between alcohol drinking and metabolic syndrome according to varying degrees of obesity. This study aimed to determine the association between alcohol drinking and metabolic syndrome in obese and non-obese Korean male adults.

**SUBJECTS/METHODS:** This cross-sectional study included 5,867 males aged  $\geq 20$  years who were examined at the Soonchunhyang University health promotion center during June 2008-December 2010. The subjects were divided into non-obese (body mass index [BMI]  $< 25$  kg/m<sup>2</sup>) and obese (BMI  $\geq 25$  kg/m<sup>2</sup>) groups and further divided according to weekly alcohol consumption into nondrinking (0 drinks/week), moderate drinking ( $\leq 14$  drinks/week), and heavy drinking ( $> 14$  drinks/week) groups. The subjects were also categorized into binge drinking and non-binge drinking groups. To obtain odds ratios (ORs) for metabolic syndrome, binary logistic regression analysis was performed.

**RESULTS:** The overall metabolic syndrome prevalence was 27.3% (12.8%, non-obese group; 50.4%, obese group). After adjusting for age, physical activity, and smoking, in the non-obese group, the OR for heavy drinking with binge drinking (reference: nondrinking) was 1.56 (95% confidence interval [CI] = 1.12-2.18), with a significant increase in metabolic syndrome prevalence. In the obese group, the OR for heavy drinking with binge drinking was 1.42 (95% CI = 1.07-1.88), showing a significant increase in metabolic syndrome prevalence ( $P < 0.05$ ).

**CONCLUSIONS:** In both non-obese and obese Korean males, heavy drinking with binge drinking was associated with increased risk of metabolic syndrome. Thus, both non-obese and obese males should restrict their alcohol intake and not indulge in binge drinking.

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## INTRODUCTION

Excessive alcohol consumption includes heavy drinking ( $\geq 15$  drinks/week for men;  $\geq 8$  drinks/week for women), binge drinking ( $\geq 5$  drinks on an occasion for men;  $\geq 4$  drinks on an occasion for women), and any drinking by pregnant women or people below 21 years old [1]. Excessive drinking increases the risk of death, injury, violence, and various diseases such as high blood pressure, heart disease, stroke, liver disease, mental health problems, and cancers of the breast, throat, esophagus, liver, and colon [1,2]. Particularly, the South Korean society has a prevalent drinking culture and a generous view toward drinking. According to the World Health Organization report, South Korea had an alcohol consumption per capita of 12.3 L in 2010, the highest among Asian countries [2]. This is twice as high as the average alcohol consumption of the world. Therefore, people from South Korea have a high probability of developing various health problems due to drinking.

Previous studies have reported an association between drinking and metabolic syndrome [3,4]. Metabolic syndrome is a cluster of conditions including abdominal obesity, elevated blood pressure, hyperglycemia, elevated serum triglycerides (TGs), and low serum high-density lipoprotein (HDL) cholesterol, and it is known to increase the risk of cardiovascular disease and type 2 diabetes [5,6]. The mechanism of metabolic syndrome is not completely understood, but abdominal obesity [7,8] and insulin resistance [9] are major factors. Other known factors include genetics [10], aging [11], and various lifestyle habits [12] such as smoking, physical inactivity and alcohol consumption. The prevalence of metabolic syndrome is high worldwide; according to the 2013-2016 Korea National Health Examination, the prevalence in Korea was very high at 25.0% (men, 28.4%; women, 21.1%) [13]. This has led to increasing interest in metabolic syndrome as a major health problem that requires focused attention.

Metabolic syndrome occurs in both obese and non-obese

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<sup>§</sup> Corresponding Author: Tel. 82-41-570-2238, Fax. 82-41-574-7792, Email. [jeoh2238@naver.com](mailto:jeoh2238@naver.com)

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people. However, the effects of alcohol drinking on metabolic syndrome may differ between in the non-obese people and in the obese people. This is because blood alcohol concentration is inversely correlated with body weight [14], which translates to higher blood alcohol concentration among non-obese people compared with obese people when consuming the same amount of alcohol. Several studies have investigated the relationship between alcohol drinking and metabolic syndrome [3,4,15,16], but the results were based on drinking status without obesity categories. Thus, it is necessary to determine the effects of drinking on metabolic syndrome in obese and non-obese groups.

This study aimed to determine the association between metabolic syndrome and alcohol drinking in obese and non-obese Korean male adults. Only men were studied as the prevalence of heavy drinking in women (1.8%) was much lower than in men (12.4%).

## SUBJECTS AND METHODS

### *Design, subjects, and study period*

This study has a cross-sectional design. The sample was taken from 9,465 patients aged  $\geq 20$  years who visited the health promotion center of Soonchunhyang University Cheonan Hospital between June 2008 and December 2010 for health examination, of which 6,293 were male. Among them, 410 patients on medical treatment for hypertension, diabetes mellitus, and/or dyslipidemia and 16 patients with missing values for baseline characteristics were excluded. Therefore, 5,867 males were included as study subjects. Written informed consent was obtained from the participants, and the study was approved by the Institutional Review Board of Soonchunhyang University Cheonan Hospital (SCHCA 2015-11-001).

### *Body measurement and blood tests*

An automatic body measuring device (model FA-96H; Fanics Co., Busan, South Korea) was used for measuring height and weight. Body mass index (BMI) was calculated as weight (kg)/height squared ( $m^2$ ). Based on BMI, the subjects were categorized into non-obese ( $BMI < 25 \text{ kg}/m^2$ ) and obese ( $BMI \geq 25 \text{ kg}/m^2$ ) groups. Using a tape measure, waist circumference was measured at the midpoint between the lowermost rib and uppermost iliac crest with the subject in the upright position. Blood pressure was measured in both upper arms using an automatic blood pressure measuring device after 5 min or longer of a stable state, and the higher blood pressure measured was selected. A blood sample was drawn from the antecubital vein after a 12-h fast. Serum was separated on-site and analyzed. The serum levels of glucose, TG, and HDL cholesterol were measured enzymatically using an automated analyzer (Cobas 8000 modular analyzer; Roche, Indianapolis, USA).

### *Survey of disease history and lifestyle habits*

Using self-administered questionnaires, data on physical activities, drinking, smoking habits, and history of hypertension, diabetes mellitus, dyslipidemia, and medication use were obtained. Alcohol consumption was assessed by asking for the drinking frequency (drinking days per week) in the past 30 days,

as well as the type of alcoholic beverage the subject drank and the amount consumed in one day, excluding days where no alcohol was consumed. The amount of alcohol consumption per week was converted to grams according to the each type of alcoholic beverage, i.e., one 360 mL (one bottle) of *sochu* (traditional Korean liquor) was converted to 56 g, 355 mL (one can) of beer to 14 g, 750 mL (one bottle) of wine to 72 g, and 750 mL (one bottle) of *makgeolli* (traditional Korean liquor) to 36 g. Due to the lack of consensus criteria for measuring drinking level and determining the standard amount of drinking worldwide, a lifestyle guideline from the 2015 US Ministry of Agriculture and Forestry [17] was used for this study. An alcoholic drink containing 14 g of alcohol was set as the standard amount of 1 drink; a standard drink is roughly equivalent to one can of beer (355 mL), a 1/4 bottle of *shochu* (90 mL) and a glass of wine (150 mL). The subjects were divided into three categories according to the drinking level: nondrinking (0 drinks/week), moderate drinking ( $\leq 14$  drinks/week), and heavy drinking ( $> 14$  drinks/week). Having  $\geq 5$  drinks on the same occasion more than once in the past month was defined as binge drinking. For physical activity habits, the subjects were classified into four categories: exercise for  $\geq 30$  min/day for  $\geq 5$  days/week, 3-4 days/week, 1-2 days/week, and less than 1-3 days/month. For smoking habits, the subjects were classified into smoking (currently smoking) and nonsmoking (not smoking or had quit smoking) groups.

### *Diagnostic criteria for metabolic syndrome*

According to newly presented diagnostic criteria from the modified Adult Treatment Panel III by the American Heart Association and National Heart, Lung, and Blood Institute in 2005, which was based on the 2001 National Cholesterol Education Program Adult Treatment Panel III [18], satisfying more than three of the following five items constitutes a diagnosis of metabolic syndrome:

- 1) Waist circumference:  $\geq 90$  cm for men
- 2) Systolic blood pressure (SBP):  $\geq 130$  mmHg or diastolic blood pressure (DBP):  $\geq 85$  mmHg
- 3) Fasting blood sugar (FBS):  $\geq 100$  mg/dL
- 4) TG:  $\geq 150$  mg/dL
- 5) HDL cholesterol:  $< 40$  mg/dL for men

Considering racial differences, a waist circumference of  $\geq 90$  cm was adopted as the Korean male standard diagnostic criterion for abdominal obesity [19].

### *Statistical analysis*

After categorizing the subjects into groups based on obesity and alcohol consumption, the health risk factors and components of metabolic syndrome were compared using one-way analysis of variance and the chi-square test. After adjusting for confounding variables (age, physical activity, and smoking) in both obese and non-obese groups, the odds ratios (ORs) for metabolic syndrome and its individual components according to weekly drinking level or binge drinking, as well as the ORs for metabolic syndrome according to weekly drinking level and binge drinking (moderate drinking without binge drinking,

moderate drinking with binge drinking, heavy drinking without binge drinking, and heavy drinking with binge drinking), were obtained using binary logistic regression analysis. All statistical analyses were performed using Statistical Package for the Social Sciences 14.0 KO for Windows (IBM Corp., Armonk, NY, USA). *P*-values < 0.05 at 95% confidence intervals (CI) were considered statistically significant.

## RESULTS

### Characteristics of subjects

Among the 5,867 subjects, 3,613 (61.6%) and 2,254 (38.4%) were categorized to the non-obese and obese groups, respectively. The mean age  $\pm$  standard deviation (SD) was  $41.7 \pm 8.8$  years. The overall average alcohol consumption was  $114.8 \pm 137.8$  g/week; the average in the non-obese group was  $107.5 \pm 135.2$  g/week, and that in the obese group was  $126.6 \pm 141.1$  g/week ( $P < 0.001$ ). The percentage of heavy drinking and binge drinking was also higher in the obese group ( $P < 0.001$ ). The average frequency of binge drinking was  $2.2 \pm 1.3$  days/week in the non-obese group and  $2.1 \pm 1.1$  days/week in the obese group, showing no significant difference (data not shown). Among male subjects with binge drinking, 96.6% reported binge drinking more than once a week (data not shown). Moreover, the percentage of binge drinking in heavy drinking male subjects was 77.4% in the non-obese group (Table 2) and 85.9% in the obese group (Table 3), showing that most of the heavy drinking Korean male subjects were also engaged in binge drinking.

The overall prevalence of metabolic syndrome was 27.3%; the prevalence in the non-obese group was 12.8%, and that in the obese group was 50.4% ( $P < 0.001$ ). The mean waist circumference, SBP, DBP, FBS, and TG were higher in the obese group

( $P < 0.001$ ), while the mean HDL cholesterol was higher in the non-obese group ( $P < 0.001$ ) (Table 1).

### Metabolic syndrome components and other characteristics according to BMI and weekly alcohol drinking level

In the non-obese group, moderate drinking male subjects had the lowest mean age ( $40.9 \pm 8.5$  years), while heavy drinking male subjects had the highest mean waist circumference, SBP, DBP, FBS, TG, and HDL cholesterol ( $P < 0.001$ ) (Table 2).

In the obese group, moderate drinking male subjects had the lowest mean age ( $40.8 \pm 7.9$  years) and mean waist circumference ( $P < 0.05$ ), while heavy drinking male subjects had the highest mean SBP, DBP, FBS, TG, and HDL cholesterol ( $P < 0.05$ ) (Table 3).

### ORs for metabolic syndrome and its individual abnormalities according to BMI and weekly alcohol drinking level

In the non-obese group (with nondrinking as reference), after adjusting for age, physical activity, and smoking, binary logistic regression analysis showed an OR of 1.40 (95% CI = 1.03-1.92) in heavy drinking male subjects, indicating a significantly increased risk of metabolic syndrome ( $P < 0.05$ ) (Table 4), whereas no significant association with metabolic syndrome (OR = 1.04, 95% CI = 0.81-1.35) was shown in moderate drinking males. Among heavy drinking male subjects, higher ORs were reported for increased blood pressure, FBS, and TG, which were statistically significant ( $P < 0.001$ ), while a decreased OR was reported for low HDL cholesterol ( $P < 0.001$ ) (Table 4).

Similarly, in the obese group (with nondrinking as reference), after adjusting for age, physical activity, and smoking, binary logistic regression analysis showed an OR of 1.42 (95% CI = 1.08-1.87) in heavy drinking males, indicating a significantly increased risk of metabolic syndrome ( $P < 0.05$ ) (Table 4),

**Table 1.** Components of metabolic syndrome and lifestyle characteristics according to BMI

Characteristics	BMI < 25 kg/m <sup>2</sup> (n = 3,613)	BMI $\geq$ 25 kg/m <sup>2</sup> (n = 2,254)	Total (n = 5,867)	<i>P</i> -value <sup>1)</sup>
Age (yrs)	41.8 $\pm$ 9.1	41.5 $\pm$ 8.3	41.7 $\pm$ 8.8	0.200
Current smoker, n (%)	1,776 (49.2)	1,147 (50.9)	2,923 (49.8)	0.198
Alcohol drinking (g/week)	107.5 $\pm$ 135.2	126.6 $\pm$ 141.1	114.8 $\pm$ 137.8	< 0.001
Heavy drinking, n (%)	606 (16.8)	489 (21.7)	1,095 (18.7)	< 0.001
Binge drinking, n (%)	819 (22.7)	711 (31.5)	1,530 (26.1)	< 0.001
Physical activity				0.316
< 1-3 days/month, n (%)	2,169 (60.0)	1,302 (57.8)	1,347 (59.2)	
1-2 days/week, n (%)	458 (12.7)	316 (14.0)	774 (13.2)	
3-4 days/week, n (%)	649 (18.0)	418 (18.5)	1,067 (18.2)	
$\geq$ 5 days/week, n (%)	337 (9.3)	218 (9.7)	555 (9.5)	
BMI (kg/m <sup>2</sup> )	22.5 $\pm$ 1.8	27.1 $\pm$ 1.9	24.3 $\pm$ 2.9	< 0.001
Waist circumference (cm)	83.3 $\pm$ 6.0	94.1 $\pm$ 6.2	87.5 $\pm$ 8.0	< 0.001
Systolic BP (mmHg)	128.5 $\pm$ 14.1	136.3 $\pm$ 14.0	131.5 $\pm$ 14.6	< 0.001
Diastolic BP (mmHg)	75.6 $\pm$ 10.1	81.1 $\pm$ 10.5	77.8 $\pm$ 10.5	< 0.001
Fasting blood sugar (mg/dL)	93.2 $\pm$ 17.3	97.1 $\pm$ 18.8	94.7 $\pm$ 18.0	< 0.001
Triglycerides (mg/dL)	129.8 $\pm$ 83.7	180.0 $\pm$ 117.1	149.1 $\pm$ 100.9	< 0.001
HDL cholesterol (mg/dL)	52.8 $\pm$ 11.9	47.3 $\pm$ 9.7	50.7 $\pm$ 11.4	< 0.001
Metabolic syndrome, n (%)	462 (12.8)	1,137 (50.4)	1,599 (27.3)	< 0.001

BMI, body mass index; BP, blood pressure; HDL, high-density lipoprotein. Data are presented as means  $\pm$  SD or n (%).

<sup>1)</sup> *P*-values were obtained using analysis of variance or the chi-square test.

**Table 2.** Metabolic syndrome components and lifestyle characteristics according to weekly alcohol drinking level in subjects with BMI < 25 kg/m<sup>2</sup>

	Alcohol drinking level (drinks/week)			P-value <sup>1)</sup>
	None (0)	Moderate (≤ 14)	Heavy (> 14)	
n (%)	770 (21.3)	2,237 (61.9)	606 (16.8)	
Age (yrs)	43.3 ± 10.1 <sup>a</sup>	40.9 ± 8.5 <sup>b</sup>	43.3 ± 9.3 <sup>a</sup>	< 0.001
Alcohol drinking (g/week)	0 <sup>a</sup>	80.8 ± 49.2 <sup>b</sup>	342.5 ± 165.8 <sup>c</sup>	< 0.001
Binge drinking, n (%)	0 (0.0)	350 (15.6)	469 (77.4)	< 0.001
Current smoker, n (%)	260 (33.8)	1,119 (50.0)	397 (65.5)	< 0.001
Physical activity				0.001
< 1-3 days/month, n (%)	484 (62.9)	1,307 (58.4)	378 (62.4)	
1-2 days/week, n (%)	72 (9.4)	313 (14.0)	73 (12.0)	
3-4 days/week, n (%)	125 (16.2)	426 (19.0)	98 (16.2)	
≥ 5 days/week, n (%)	89 (11.6)	191 (8.5)	57 (9.4)	
BMI (kg/m <sup>2</sup> )	22.2 ± 1.9 <sup>a</sup>	22.5 ± 1.7 <sup>b</sup>	22.7 ± 1.8 <sup>b</sup>	< 0.001
Waist circumference (cm)	82.5 ± 6.5 <sup>a</sup>	83.4 ± 5.8 <sup>b</sup>	84.2 ± 5.7 <sup>c</sup>	< 0.001
Systolic BP (mmHg)	127.0 ± 13.7 <sup>a</sup>	128.1 ± 13.9 <sup>a</sup>	142.0 ± 14.5 <sup>b</sup>	< 0.001
Diastolic BP (mmHg)	74.5 ± 9.7 <sup>a</sup>	75.6 ± 10.0 <sup>b</sup>	78.0 ± 10.4 <sup>c</sup>	< 0.001
Fasting blood sugar (mg/dL)	93.1 ± 20.9 <sup>a</sup>	92.3 ± 14.4 <sup>a</sup>	96.7 ± 21.3 <sup>b</sup>	< 0.001
Triglycerides (mg/dL)	120.3 ± 71.3 <sup>a</sup>	126.5 ± 76.8 <sup>a</sup>	153.7 ± 112.3 <sup>b</sup>	< 0.001
HDL cholesterol (mg/dL)	49.7 ± 10.9 <sup>a</sup>	53.3 ± 11.9 <sup>b</sup>	54.8 ± 12.1 <sup>c</sup>	< 0.001

BMI, body mass index; BP, blood pressure; HDL, high-density lipoprotein.

Data are presented as means ± SD or n (%).

Superscript <sup>a,b,c</sup> indicate that values with same letters are not significantly different between groups using Turkey's multiple comparison test.

<sup>1)</sup> P-values were obtained using analysis of variance or the chi-square test.

**Table 3.** Metabolic syndrome components and lifestyle characteristics according to weekly alcohol drinking level in subjects with BMI ≥ 25 kg/m<sup>2</sup>

	Alcohol drinking level (drinks/week)			P-value <sup>1)</sup>
	None (0)	Moderate (≤ 14)	Heavy (> 14)	
n (%)	411 (18.2)	1,354 (60.1)	489 (21.7)	
Age (yrs)	43.2 ± 9.3 <sup>a</sup>	40.8 ± 7.9 <sup>b</sup>	42.2 ± 7.9 <sup>a</sup>	0.001
Alcohol drinking (g/week)	0 <sup>a</sup>	87.1 ± 48.3 <sup>b</sup>	342.3 ± 144.9 <sup>c</sup>	0.001
Binge drinking, n (%)	0 (0.0)	291 (21.5)	420 (85.9)	0.001
Current smoker, n (%)	139 (33.8)	707 (52.2)	301 (61.6)	< 0.001
Physical activity				0.015
< 1-3 days/month, n (%)	265 (64.5)	781 (57.7)	256 (52.4)	
1-2 days/week, n (%)	43 (10.5)	194 (14.3)	79 (16.2)	
3-4 days/week, n (%)	64 (15.6)	256 (18.9)	98 (20.0)	
5 days/week, n (%)	39 (9.5)	123 (9.1)	56 (11.5)	
BMI (kg/m <sup>2</sup> )	27.4 ± 2.0 <sup>a</sup>	27.0 ± 1.8 <sup>b</sup>	27.2 ± 1.9 <sup>a,b</sup>	0.002
Waist circumference (cm)	94.6 ± 6.3 <sup>a</sup>	93.7 ± 5.8 <sup>b</sup>	94.7 ± 7.1 <sup>a</sup>	0.001
Systolic BP (mmHg)	134.3 ± 13.0 <sup>a</sup>	136.4 ± 14.3 <sup>b</sup>	137.6 ± 14.0 <sup>b</sup>	0.002
Diastolic BP (mmHg)	79.2 ± 10.2 <sup>a</sup>	81.3 ± 10.5 <sup>b</sup>	82.1 ± 10.3 <sup>b</sup>	0.001
Fasting blood sugar (mg/dL)	96.0 ± 19.3 <sup>a</sup>	96.3 ± 17.7 <sup>a</sup>	100.5 ± 21.0 <sup>b</sup>	0.001
Triglycerides (mg/dL)	165.6 ± 107.4 <sup>a</sup>	177.4 ± 115.2 <sup>a</sup>	199.2 ± 127.6 <sup>b</sup>	0.001
HDL cholesterol (mg/dL)	45.2 ± 8.9 <sup>a</sup>	47.2 ± 9.5 <sup>b</sup>	49.4 ± 10.5 <sup>c</sup>	0.001

BMI, body mass index; BP, blood pressure; HDL, high-density lipoprotein.

Data are presented as means ± SD or n (%).

Superscript <sup>a,b,c</sup> indicate that values with same letters are not significantly different between groups using Turkey's multiple comparison test.

<sup>1)</sup> P-values were obtained by analysis of variance or the chi-square test.

whereas no statistically significant difference was shown with metabolic syndrome in moderate drinking male subjects. In heavy drinking male subjects, higher ORs were reported for increased blood pressure, FBS, and TG, which were statistically significant ( $P < 0.05$ ), while a decreased OR was reported for low HDL cholesterol ( $P < 0.001$ ) (Table 4).

#### ORs for metabolic syndrome and its individual abnormalities according to BMI and binge drinking

On binary logistic regression analysis, after adjusting for age, physical activity, and smoking (with no binge drinking as reference), the non-obese group showed a higher (OR = 1.52, 95% CI = 1.22-1.90) of having metabolic syndrome with binge

**Table 4.** Odds ratios and 95% confidence intervals for metabolic syndrome and its individual abnormalities according to BMI and weekly alcohol drinking level<sup>1)</sup>

	Alcohol drinking level (drinks/week)		
	None (0)	Moderate (≤ 14)	Heavy (> 14)
BMI < 25 (kg/m <sup>2</sup> ) (n = 3,613)			
BP ≥ 130/85 (mmHg)	1	1.25 (1.05-1.48)*	2.15 (1.72-2.69)**
FBS ≥ 100 (mg/dL)	1	1.16 (0.93-1.44)	1.69 (1.30-2.22)**
TG ≥ 150 (mg/dL)	1	1.13 (0.93-1.37)	1.81 (1.42-2.30)**
HDL-C < 40 (mg/dL)	1	0.60 (0.47-0.76)**	0.36 (0.25-0.51)**
WC ≥ 90 (cm)	1	1.04 (0.82-1.33)	0.98 (0.71-1.34)
Metabolic syndrome	1	1.04 (0.81-1.35)	1.40 (1.03-1.92)*
BMI ≥ 25 (kg/m <sup>2</sup> ) (n = 2,254)			
BP ≥ 130/85 (mmHg)	1	1.37 (1.08-1.74)*	1.74 (1.29-2.33)**
FBS ≥ 100 (mg/dL)	1	1.19 (0.92-1.54)	1.71 (1.27-2.31)**
TG ≥ 150 (mg/dL)	1	1.23 (0.98-1.55)	1.61 (1.23-2.12)*
HDL-C < 40 (mg/dL)	1	0.59 (0.46-0.76)**	0.43 (0.31-0.60)**
WC ≥ 90 (cm)	1	0.99 (0.76-1.31)	1.17 (0.84-1.64)
Metabolic syndrome	1	1.14 (0.91-1.44)	1.42 (1.08-1.87)*

BMI, body mass index; BP, blood pressure; FBS, fasting blood sugar; TG, triglycerides; HDL-C, high-density lipoprotein cholesterol; WC, waist circumference.

<sup>1)</sup> P-values were obtained by binary logistic regression analysis and adjusted for age, physical activity, and cigarette smoking.

\* P < 0.05, \*\* P < 0.001.

**Table 5.** Adjusted odds ratios and 95% confidence intervals for metabolic syndrome and its individual abnormalities according to BMI and binge drinking

	Non-binge drinking	Binge drinking	P-value <sup>1)</sup>
BMI < 25 (kg/m <sup>2</sup> ) (n = 3,613)			
BP ≥ 130/85 (mmHg)	1	1.38 (1.18-1.63)	< 0.001
FBS ≥ 100 (mg/dL)	1	1.36 (1.12-1.65)	0.002
TG ≥ 150 (mg/dL)	1	1.64 (1.39-1.95)	< 0.001
HDL-C < 40 (mg/dL)	1	0.58 (0.44-0.77)	< 0.001
WC ≥ 90 (cm)	1	1.28 (1.02-1.60)	0.030
Metabolic syndrome	1	1.52 (1.22-1.90)	< 0.001
BMI ≥ 25 kg/m <sup>2</sup> (n = 2,254)			
BP ≥ 130/85 (mmHg)	1	1.18 (0.96-1.43)	0.111
FBS ≥ 100 (mg/dL)	1	1.26 (1.04-1.54)	0.022
TG ≥ 150 (mg/dL)	1	1.32 (1.10-1.58)	0.003
HDL-C < 40 (mg/dL)	1	0.69 (0.55-0.87)	0.002
WC ≥ 90 (cm)	1	1.05 (0.85-1.31)	0.650
Metabolic syndrome	1	1.22 (1.02-1.47)	0.029

BMI, body mass index; BP, blood pressure; FBS, fasting blood sugar; TG, triglycerides; HDL-C, high-density lipoprotein cholesterol; WC, waist circumference.

<sup>1)</sup> P-values were obtained using binary logistic regression analysis and adjusted for age, physical activity, and cigarette smoking.

drinking ( $P < 0.001$ ) (Table 5), and the non-obese binge drinking group had a higher OR of having increased blood pressure, FBS, TG, and waist circumference ( $P < 0.05$ ) and a decreased OR of having low HDL cholesterol ( $P < 0.001$ ) (Table 5). The obese binge drinking group had a higher OR of having increased FBS and TG ( $P < 0.05$ ) and a decreased OR of having low HDL cholesterol ( $P < 0.05$ ) (Table 5), and there was a significant association with metabolic syndrome (OR = 1.22, 95% CI = 1.02-1.47).

**Table 6.** Adjusted odds ratios and 95% confidence intervals for metabolic syndrome according to BMI and drinking status<sup>1)</sup>

Alcohol drinking status	BMI < 25 kg/m <sup>2</sup> (n = 3,613)	BMI ≥ 25 kg/m <sup>2</sup> (n = 2,254)
	1	1
Nondrinking		
Moderate drinking without BD	0.91 (0.77-1.28)	1.12 (0.88-1.41)
Moderate drinking with BD	1.43 (0.98-2.08)	1.23 (0.92-1.71)
Heavy drinking without BD	0.99 (0.57-1.70)	1.49 (0.88-2.52)
Heavy drinking with BD	1.56 (1.12-2.18)*	1.42 (1.07-1.88)*

BMI, body mass index; BD, binge drinking.

<sup>1)</sup> P-values were obtained using binary logistic regression analysis and adjusted for age, physical activity, and cigarette smoking.

\* P < 0.05

ORs for metabolic syndrome according to BMI, weekly alcohol drinking level, and binge drinking

On binary logistic regression analysis, after adjusting for age, physical activity, and smoking (with nondrinking as reference), the non-obese group had higher OR of having metabolic syndrome with the habit of both heavy drinking and binge drinking (OR = 1.56, 95% CI = 1.12-2.18). In the obese group, a significantly higher OR of having metabolic syndrome (OR = 1.42, 95% CI = 1.07-1.88) was also observed with both heavy drinking and binge drinking ( $P < 0.05$ ) (Table 6).

## DISCUSSION

In this study, the habit of heavy drinking with binge drinking was associated with increased risk of metabolic syndrome in both non-obese and obese groups, but heavy drinking without binge drinking did not increase the risk of metabolic syndrome in both groups. Previous studies [3,4,15,16] only analyzed alcohol drinking levels or the habit of binge drinking but did not consider the degree of obesity or the concurrence of heavy drinking with binge drinking. This study, however, investigated the presence of heavy drinking and binge drinking in association with BMI.

This study further found that moderate drinking (≤ 14 drinks/week) was not associated with metabolic syndrome in both obese and non-obese groups. In previous studies, moderate drinking was linked to a decreased risk of metabolic syndrome [4,20], whereas other studies showed no association [15,16]. A prospective study of adult males by Kim *et al.* [21] demonstrated an increased risk of metabolic syndrome with heavy (≥ 30.0 g/day) and moderate (15.0-29.9 g/day) drinking in a group with continuous drinking. However, in a study by Santos *et al.* [16], both heavy (≥ 30 g/day) and moderate (0.1-29 g/day) drinking were not related to metabolic syndrome. Wakabayashi reported that among Japanese men with BMI ≥ 25 kg/m<sup>2</sup>, the odds of having metabolic syndrome were low in light drinkers (< 22 g/day) and high in very heavy drinkers (≥ 44 g/day), compared with nondrinkers [22]; however, the study did not include individuals with BMI < 25 kg/m<sup>2</sup>. There is no standard for accurately measuring alcohol consumption; hence, there can be discrepancies between the amount of drinking reported by study participants and the actual amount of alcohol consumed. Moreover, due to lack of an internationally established definition of the standard drinking amount, drinking criteria were incons-

istent in previous studies, leading to inconsistent results and conclusions. Various confounding variables such as age, sex, socioeconomic status, the amount of food intake in conjunction with drinking, physical activity, smoking, drinking pattern, and BMI can also affect the relationship between alcohol drinking and metabolic syndrome. Therefore, differences in confounding variables that were adjusted for in each study should be considered.

Here, heavy drinking (> 14 drinks/week), including the presence of binge drinking, was analyzed, and the results showed no increased risk of metabolic syndrome with heavy drinking in the absence of binge drinking. The increased risk only occurred with binge drinking in both obese and non-obese groups. These findings indicate that the amount of alcohol consumed on one occasion, in addition to the total amount of alcohol consumed weekly, is more specifically associated with metabolic syndrome. In a study by Fan *et al.* [15] the risk of metabolic syndrome increased with having  $\geq 3$  drinks/day or with binge drinking. A study by Lee also showed an increased risk of metabolic syndrome when both men and women engaged in binge drinking more than once a week [23]. Furthermore, in a study of male adults by Im *et al.* [21] the risk of metabolic syndrome increased with binge drinking in light, moderate, and heavy drinkers compared with nondrinkers, similar to the results of heavy drinking in the present study; however, differences in terms of BMI were not examined.

The mechanism by which alcohol drinking is associated with metabolic syndrome remains unclear. Alcohol suppresses lipid oxidation, and the non-oxidized fat is preferentially deposited in the abdominal area [25]; furthermore, chronic alcohol consumption leads to an increased cortisol release due to stimulation of the hypothalamic-pituitary-adrenal axis [26]. This endocrine change due to alcohol drink may increase abdominal fat deposition [27]. The increased abdominal fat mass in alcohol drinkers may induce insulin resistance, leading to increased blood pressure, blood glucose, and TGs. In addition, activation of the sympathetic nervous system, impairment of baroreceptors, and stimulation of the renin-angiotensin-aldosterone system by heavy drinking may lead to hypertension [28]. A recent study showed that binge drinking induces systemic insulin resistance by impairing hypothalamic insulin action in rats [29]. Based on the aforementioned reasons, it is presumed that heavy or binge drinking increases blood pressure, blood sugar, and TGs, canceling the positive effect of increased HDL cholesterol increase [4,15,21,30,31] and ultimately increasing the risk of metabolic syndrome. This is in concert with the current study, which demonstrated that heavy drinking or binge drinking decreased the risk of low HDL cholesterol but increased the risk of high blood pressure and elevated blood sugar and TG levels.

The association between heavy drinking or binge drinking and a decreased risk of low HDL cholesterol is explained by the fact alcohol consumption increases HDL cholesterol [32,33]. However, the underlying mechanisms whereby alcohol drinking enhance HDL cholesterol levels are not yet fully clear. Alcohol may increase the hepatic production and secretion of apolipoproteins and lipoprotein particles, increase triglyceride lipase concentrations, and decrease removal of circulating HDL

cholesterol [32,34]. Alcohol may reduce the concentration and activity of plasma cholesteryl ester transfer protein, which transfers plasma cholesteryl esters from HDL particles to other lipoproteins. This leads to an increase in HDL [35].

One of the strengths of this study is that through face-to-face examination, the doctors confirmed the questionnaires answered by the study subjects, which allowed more accurate examination of the association between alcohol drinking and metabolic syndrome. To confirm responses to the questions, doctors asked the questions in the questionnaire again at the time of medical examination, confirmed that it matched the answer from the self-questionnaire, and corrected any responses accordingly. Moreover, a large number of subjects (5,867 subjects) participated in the study. However, the study has several limitations. First, because of the study's cross-sectional design, a causal relationship could not be established between BMI, drinking status, and metabolic syndrome. Second, data were limited to subjects from one university hospital, and only adult male subjects were studied due to the small number of women who are heavy drinkers; hence, the findings do not represent the whole population. Third, despite the effects of alcohol on energy intake and food intake, this study did not consider diet. Lastly, the study subjects may have not reported the actual amount of alcohol consumption.

In conclusion, the concurrence of heavy drinking and binge drinking was associated with increased risk of metabolic syndrome in both non-obese and obese groups. These findings suggest specific associations of metabolic syndrome with the amount of alcohol consumed on one occasion in addition to the total amount of alcohol consumed weekly, regardless of the BMI of alcohol drinkers. Therefore, the negative metabolic effects of alcohol on the human body can be prevented by implementing guidelines that set the proper amount of alcohol that can be consumed on one occasion. A successful implementation would require proactive education of non-obese and obese people to enhance their awareness that heavy and binge drinking can increase the risk of metabolic syndrome. Future prospective studies are also needed to clarify the causal relationship between alcohol drinking and metabolic syndrome according to varying degrees of obesity.

## CONFLICT OF INTEREST

The author declares no potential conflicts of interests.

## ORCID

Jung Eun Oh: <http://orcid.org/0000-0001-9117-0571>

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