The association of alcohol consumption with metabolic syndrome and its individual components: the Taichung Community Health Study

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Abbreviations: HDL-C, high density lipoprotein cholesterol; OR, odds ratios; CI, confidence interval; LDL-C, low density lipoprotein cholesterol

Abstract

Alcohol has both adverse and protective effects on the individual components of metabolic syndrome (MS). We hypothesize that alcohol consumption increases the risk of developing MS and that the consumption of different types of alcoholic beverages has different effects on the development of MS and its individual components. We enrolled 2358 men for this cross-sectional study. The data were collected from self-reported nutrition and lifestyle questionnaires. Individuals who drank at least once per week for 6 consecutive months were classified as current drinkers. Current drinkers were at a higher risk of developing MS, abdominal obesity, and high triglyceride levels, but they were at a lower risk of developing low HDL-C levels. The increased risk of developing MS, high triglyceride, and high fasting glucose levels, was dose dependent, whereas low HDL-C levels demonstrated a reverse relationship. The dose needed to reduce the risk of having low HDL-C levels was $\geqq$50 g per day. This dose, however, resulted in an increased risk of developing high fasting glucose and high triglyceride levels. Consuming mixed types of alcohol increased the risk of developing MS and abdominal obesity. Meanwhile, those who drank liquor or wine had a greater risk of developing high triglyceride or high fasting glucose levels, respectively. In conclusion, alcohol consumption dose-dependently increased the risk of developing MS and some of its individual components while

dose-dependently decreasing the risk of developing low HDL-C levels. The type of alcoholic beverage had different effects on the development of the individual components of MS.

Keywords: metabolic syndrome, alcohol, ethanol, triglyceride, obesity, glucose

1. Introduction

Metabolic syndrome is a cluster of diseases characterized by abdominal obesity, hypertriglyceridemia, low HDL-C levels, elevated blood glucose levels, and high blood pressure. Previous reports have shown that metabolic syndrome is associated with increased all-cause mortality [1] and the development of type 2 diabetes mellitus [2]. It is believed that having a sedentary lifestyle is a key determinant in the occurrence of metabolic syndrome. Other modifiable risk factors such as diet and cigarette smoking [3] also play an important role in the development of metabolic syndrome in individuals with a genetic predisposition for this group of diseases.

Alcohol has both adverse and protective effects on the individual components of metabolic syndrome. Previous reports have shown that alcohol consumption is positively associated with having abdominal obesity [4-6], high triglyceride levels [7,8], and high blood pressure [8-10]. However, quite a few studies have demonstrated that alcohol consumption has a protective effect on the development of metabolic syndrome by increasing HDL-C levels [7,8,11,12]. Although the results from some studies have shown a U-shaped association between alcohol consumption and plasma glucose levels, that relationship was based on a small number of studies which had different study designs and definitions [13,14]. Taking the inconsistent results of previous studies into consideration, it is unclear whether alcohol

consumption contributes to the development of metabolic syndrome. To make a cogent recommendation about alcohol consumption to patients with cardio-metabolic diseases, it is necessary to clarify the association of alcohol consumption with metabolic syndrome and its individual components. Because alcohol increases some risk factors for metabolic syndrome, we hypothesize that alcohol consumption increases the risk of developing metabolic syndrome and that different types of alcoholic beverages have different effects on the development of metabolic syndrome and its individual components. The aim of this study was to investigate the relationship among alcohol consumption, metabolic syndrome, and its individual components.

2. Methods and materials

2.1. Participants

The study subjects composed two different populations. The first population was from our previous community-based, cross-sectional study, conducted from October 2004 to September 2005, which estimated the prevalence of metabolic syndrome in Taichung city [15]. In that study, based on individuals' records from the Bureau of Households in Taichung city, we used a 2-stage sampling design to choose residents and ensured that the sampling rate was proportional to the number of residents within each stage. Among the 3530 eligible subjects, 2359 subjects (1147

men and 1212 women) agreed to participate, giving us a response rate of 66.83%. Using the same questionnaire, we recruited the second population (1256 men and 1231 women) during routine physical examinations at the Department of Family Medicine at China Medical University Hospital from January 2006 to December 2006. In this study, we restricted our analyses to men because the proportion of Taiwanese women who drank alcohol was too small. The final analysis was conducted with 2358 men after excluding 45 subjects with incomplete data for any of the following variables: alcohol drinking status, smoking status, physical activity, daily energy intake or the parameters for the diagnosis of metabolic syndrome. Informed consent was obtained from each participant, and the study was approved by the Human Research Committee of the China Medical University Hospital.

2.2. Questionnaire

The data were collected from self-reported nutrition and lifestyle questionnaires. Items in the questionnaire explored basic demographic data, previous and current disease status, family history of disease, smoking habits, alcohol consumption, betel nut chewing, and physical activity status. The nutrition survey employed a food-intake frequency method to assess daily energy and nutrition intakes. Alcohol consumption was assessed by the type of beverages consumed, the age at onset of drinking, or age when the subject began to abstain, drinking frequency, and the

81 average amount of alcohol per drink. Individuals who drank at least once per week for
82 6 consecutive months were classified as current drinkers. Physical activity was
83 measured by the frequency, duration, and intensity of walking, jogging, running,
84 bicycle riding, swimming, aerobics, aerobic dancing, and other types of dancing, as
85 well as the frequency and duration of time the individual spent playing tennis, table
86 tennis, golf, basketball, or badminton.

87 ***2.3. Anthropometric measurements and laboratory analyses***

88 All participating subjects reported to the outpatient clinic of the Department of
89 Family Medicine after an overnight fast. They were weighed in light clothing, and
90 their heights were measured. Waist circumference was measured in a horizontal plane
91 midway between the inferior margin of the last rib and the crest of the ileum. The
92 circumference was measured to the nearest 1 mm. Blood pressure was recorded from
93 the right arm after the participant sat at rest for a period of 20 minutes. The mean of
94 two blood pressure recordings was used for statistical analyses. Fasting blood samples
95 were drawn between 08:00 and 10:00.

96 The plasma glucose level was determined using a glucose oxidase method
97 (Astra-8, Beckman, CA, USA). Plasma lipids were determined using an enzymatic
98 colorimetric method (Beckman Coulter Synchron LX-20, Brea, CA, USA).

99 ***2.4. Diagnosis of metabolic syndrome***

Metabolic syndrome was diagnosed using the American Heart Association/National Heart, Lung, and Blood Institute's criteria with minor modifications [16]: serum triglyceride level ≧1.69 mmol/l (150 mg/dl) or currently taking hypolipidemic agents; serum HDL-C level＜1.03 mmol/l (40 mg/dl); blood pressure ≧130/85 mmHg or currently taking antihypertensive medication; fasting plasma glucose ≧5.6 mmol/l (100 mg/dl) or currently taking oral antidiabetic medication; and waist circumference ≧90 cm.

2.5. Statistical analyses

All data are presented as the means ± standard deviation except alcohol drinking status, which was separated by the median (lower quantile-upper quantile). Using drinking status as a factor, continuous variables were analyzed with Student's t-test, and nominal variables were analyzed with the chi-square test to determine whether there were significant differences between the groups. A multiple logistic regression analysis was used to calculate the odds ratios, and the linear trend was evaluated using the trend test. Subjects without data for their education level (n =164) or household income (n= 361) were included in the multiple logistic regression analysis and the trend test. A *P*-value of less than 0.05 represented a statistically significant difference between the compared data sets. All analyses were performed with the statistical package SAS for Windows (Version 8.1, SAS Institute, Cary, N.C.,

USA).

3. Results

The characteristics of the study subjects are given in Table 1. Among the 2358 men, 1430 subjects (61%) had never drunk alcohol, and 928 subjects (39%) were current drinkers. The current drinkers were younger than the never drinkers. The percentage of subjects with an education level > 12^{th} grade was higher among the never drinkers than among the current drinkers, although the household income was similar between the two groups. The average daily amount of alcohol drinking in the current drinkers was 35.71 g. The drinking amount was the highest among liquor drinkers. The percentage of subjects who currently smoke was higher among the current drinkers. These subjects also had higher levels of physical activity and fat intake than the never drinkers. Fiber intake, however, was lower among the current drinkers. There were significant differences between the two groups in body mass index and waist circumference. The current drinkers had a higher proportion of subjects with high triglyceride levels than the never drinkers, but the percentage of subjects with low HDL-C levels was similar between the two groups. The proportion of subjects with high blood pressure and high fasting plasma glucose was also similar between the never drinkers and the current drinkers. Metabolic syndrome was more prevalent in the current drinkers than in the never drinkers.

138 After controlling for other covariates, the current drinkers were at a
139 significantly higher risk of developing metabolic syndrome ($P = 0.0307$), abdominal
140 obesity ($P = 0.0154$), and high triglyceride levels ($P = 0.0090$), but they were at a
141 lower risk of developing low HDL-C levels ($P = 0.0175$) than the never drinkers. The
142 risk of developing high fasting glucose levels and high blood pressure was similar
143 between the two groups (Table 2).
144 There was a significant, dose-dependent relationship among the amount of
145 alcohol consumed, the development of metabolic syndrome ($P = 0.0312$ for trend),
146 high triglyceride levels ($P = 0.0004$ for trend), and high fasting glucose levels ($p =$
147 0.0058 for trend). The dose-dependent relationship between the amount of alcohol
148 consumed and low HDL-C levels was reversed ($P < 0.0001$ for trend) (Table 3). The
149 dose associated with the development of low HDL-C levels was $\geqq$50 g per day ($P <$
150 0.0001); however, that dose of alcohol increased the risk of developing high fasting
151 glucose levels ($P = 0.0090$) and high triglyceride levels ($P = 0.0055$) (Table 3).
152 As shown in Table 4, having a mixed type of alcohol consumption was
153 associated with the development of metabolic syndrome ($P = 0.0397$) and abdominal
154 obesity ($P = 0.0069$). Liquor-drinking significantly increased the likelihood of
155 developing high triglyceride levels ($P = 0.0003$), and wine consumption was
156 associated with a greater risk of developing high fasting glucose levels ($P = 0.0408$).

4. Discussion

This study showed that alcohol consumption increased the risk of developing metabolic syndrome and some of its individual components in a dose-dependent manner. Triglyceride levels were significantly higher in subjects who consumed $\geq$10 g of alcohol per day. Drinking more than 50 g of alcohol per day significantly decreased the risk of developing low HDL-C levels but increased the risk of developing high fasting glucose levels. The type of alcoholic beverages consumed was not related to the development of metabolic syndrome. Consuming mixed types of alcohol, however, increased the risk of developing metabolic syndrome.

The results from previous studies on the relationship between alcohol consumption and the development of metabolic syndrome are inconsistent. Some studies have reported that the association is positively linear [17,18], others have demonstrated that the relationship is inversely linear [19,20], some have seen a J-shaped relationship [21], and one study showed that there was no relationship between alcohol consumption and metabolic syndrome [22]. In this study, we demonstrated a positive, linear relationship between alcohol consumption and metabolic syndrome. The discrepancies in past study results may be partly attributed to different study populations and different consumption patterns. Ethnic differences may also play a role in the discrepancy. For example, a previous report showed that

176 an individual's HDL_2-C level was positively associated with alcohol consumption in
177 Caucasian Americans but not in African Americans [23]. That study also
178 demonstrated that heavy alcohol consumption was associated with higher triglyceride
179 levels in African Americans but not in Caucasian Americans [23].
180 The results of this study were consistent with previous reports that alcohol
181 consumption increases the risk of developing abdominal obesity [4-6] and high
182 triglyceride levels [7,8] while lowering the risk of having low HDL-C levels
183 [7,8,11,12]; however, our results contrast with those of some studies that showed that
184 current drinkers had a lower risk of developing abdominal obesity [24,25] and high
185 blood pressure [8-10]. A meta-analysis showed that moderate alcohol consumption
186 lowers the risk of developing type 2 diabetes, but that this effect disappears in
187 subjects who drank ≧48 g of alcohol per day [9]. Similarly, we found that the
188 consumption of more than 50 g of alcohol per day significantly increased the subject's
189 risk of developing high fasting glucose levels.
190 Freiberg, et al. showed that the risk of developing metabolic syndrome differed
191 depending on the type of alcoholic beverages consumed [19]. In contrast, Djousse et
192 al. demonstrated that alcohol consumption was associated with a lower prevalence of
193 metabolic syndrome irrespective of the type of alcoholic beverages that were
194 consumed [20]. In this study, the association between alcohol consumption and

195 metabolic syndrome was not related to type of alcoholic beverages consumed. The
196 reason for the discrepancy among these studies is not clear.
197 This study had some limitations. First, the smoking and alcohol drinking statuses
198 were based on the results of self-reported questionnaires; therefore, some of the
199 individuals may have been misclassified. Second, this was a cross-sectional study, and
200 we did not evaluate or consider longitudinal changes in the participants' habits. Third,
201 although we adjusted for a variety of potential confounders, residual confounding
202 factors are still possible.
203 In conclusion, the results of this study indicate that the risk of developing
204 metabolic syndrome is greater among current drinkers than among never drinkers. In
205 addition, the increased risk of developing metabolic syndrome and many of its
206 individual components, namely high triglyceride and fasting glucose levels, was dose
207 dependent. The type of alcoholic beverages consumed had different effects on the
208 development of the individual components of metabolic syndrome; however, it was
209 not related to the development of metabolic syndrome. The fact that the consumption
210 of a moderate amount of alcoholic beverages has been shown to have protective
211 cardiovascular effects may outweigh the negative effects of consuming alcohol.

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Table 1 Characteristics of the study subjects categorized by alcohol consumption

Characteristic (N=2358)	Never drinker （n=1430）	Current drinker （n=928）	*P*-value
Age (yrs)	51.95 ±12.78	50.47±10.19	0.0018
Education level (grade) #			<.0001
＜9	236(17.81)	178(20.48)	
9-12	551(41.58)	457(52.59)	
＞12	538(40.60)	234(26.93)	
Household income (USD/month)*			0.3801
＜1250	269(22.47)	159(19.88)	
1250-4000	562(46.95)	390(48.75)	
＞4000	366(30.58)	251(31.38)	
Alcohol drinking status**			
Total amount (g/day)	-	35.71 (14.29-107.14)	
Beer drinker (g/day)	-	35.71 (12.50-107.14)	
Wine drinker (g/day)	-	26.79 (10.71-71.43)	
Liquor drinker (g/day)	-	42.86 (17.86-107.14)	
Mixed drinker (g/day)	-	28.57 (13.39-89.29)	
Smoking status			<.0001
Never	876(61.26)	290(31.25)	
Former smoker	180(12.59)	171(18.43)	
Current smoker	374(26.15)	467(50.32)	
Physical activity (MET-hour/week)	10.97±18.02	14.02±22.65	0.0006
Daily energy intake			
Total calories (Kcal)	2527.49±578.49	2513.68±570.87	0.5692

Carbohydrate (g)	476.80±111.71	469.22±110.16	0.1055
Fat (g)	31.84±10.79	33.04±11.61	0.0116
Protein (g)	78.72±19.77	80.24±20.34	0.0715
Fiber (g)	6.58±2.05	6.41±2.06	0.0483
Anthropometric measures			
Body mass index (kg/m^2)	24.23±3.25	24.78±3.18	<.0001
Total cholesterol (mmol/l)	5.13±0.95	5.25±0.96	0.0017
Metabolic syndrome parameters			
Waist circumference ≧90 cm	375(26.22)	298(32.11)	0.0021
Triglycerides ≥ 1.69 mmol/l (150 mg/dl) or on medication	437(30.56)	361(38.90)	<.0001
HDL-C < 1.03 mmol/l (40 mg/dl)	859(60.07)	528(56.90)	0.1339
Blood pressure ≥ 130/85 mmHg or on medication	572(40.00)	385(41.49)	0.4923
Fasting plasma glucose ≥ 5.6 mmol/l (100 mg/dl) or on medication	412(28.81)	281(30.28)	0.4592
Prevalence of metabolic syndrome	447(31.26)	333(35.88)	0.0223

Data are presented as means ± SD or n (%); MET = metabolic equivalent.

164 subjects (n = 105 in never group; n = 59 in current group) without data for education level

*361 subjects (n = 233 in never group; n = 128 in current group) without data for household income

**The alcohol drinking amount was separated at the median (lower-upper quantile).

Table 2 Association of metabolic syndrome and its components with current alcohol drinking

	Never (n=1430)	Current (n=928)	
		crude OR	adjusted OR
Metabolic syndrome	1.00	1.23(1.03-1.47)	1.24(1.02-1.50)
Abdominal obesity	1.00	1.33(1.11-1.60)	1.27(1.05-1.55)
High triglyceride	1.00	1.45(1.22-1.72)	1.29(1.07-1.57)
Low HDL-C	1.00	0.88(0.74-1.04)	0.80(0.67-0.96)
High fasting glucose	1.00	1.07(0.90-1.29)	1.15(0.94-1.41)
High blood pressure	1.00	1.06(0.90-1.26)	1.19(0.98-1.43)

Presented with odds ratios (OR) (95% CI). The model is adjusted for age, education level, smoking status, physical activity, fat intake, fiber intake and lipid medication. Subjects without data for education level or household income were included in the analyses. A multiple logistic regression analysis was used to calculate the OR. The current drinkers were at a significantly higher risk of developing metabolic syndrome, abdominal obesity, and high triglyceride levels, but they were at a lower risk of developing low HDL-C levels than the never drinkers. The risk of developing high fasting glucose levels and high blood pressure was similar between the two groups.

Table 3 Association of metabolic syndrome and its components with an alcohol drinking amount

		Current drinkers (n = 928)				
Drinking amount (g/day)	never	> 0, < 10	≧10, < 30	≧30, < 50	≧ 50	*P* for trend
N	1430	491	231	77	129	
Metabolic syndrome	1.00	1.18(0.94-1.49)	1.25(0.92-1.71)	1.53(0.94-2.50)	1.32(0.87-1.95)	0.0312
Abdominal obesity	1.00	1.34(1.06-1.69)	1.08(0.78-1.49)	1.50(0.91-2.47)	1.26(0.84-1.90)	0.0806
High triglycerides	1.00	1.10(0.87-1.39)	1.48(1.09-2.02)	1.57(0.96-2.55)	1.74(1.18-2.56)	0.0004
Low HDL-C	1.00	0.95(0.77-1.18)	0.78(0.58-1.05)	0.79(0.49-1.27)	0.41(0.28-0.60)	<.0001
High fasting glucose	1.00	1.00(0.78-1.27)	1.23(0.89-1.69)	1.42(0.85-2.37)	1.72(1.15-2.59)	0.0058
High blood pressure	1.00	1.18(0.94-1.48)	1.24(0.91-1.67)	1.07(0.65-1.76)	1.19(0.80-1.77)	0.1845

Presented with adjusted OR (95% CI). The model is adjusted for age, education level, smoking status, physical activity, fat intake, fiber intake

and lipid medication. Subjects without data for education level or household income were included in the analyses. A multiple logistic regression analysis was used to calculate the OR, and the linear trend was evaluated using the trend test. There was a significant, dose-dependent relationship among the amount of alcohol consumed and the development of metabolic syndrome, high triglyceride levels, and high fasting glucose levels, whereas low HDL-C levels had the reversed relationship. The dose associated with developing low HDL-C levels was ≧50 g per day; however, that dose increased the risk of developing high fasting glucose levels and high triglyceride levels.

Table 4 Association of metabolic syndrome and its components with alcoholic beverages

	Adjusted OR (95% CI)				
	Never	Beer	Wine	Liquor	Mixed types
N	1430	106	160	466	196
Metabolic syndrome	1	0.90(0.57-1.43)	1.33(0.93-1.89)	1.17(0.91-1.50)	1.41(1.02-1.96)
Abdominal obesity	1	1.21(0.77-1.89)	1.18(0.82-1.70)	1.20(0.93-1.55)	1.58(1.13-2.20)
High triglyceride	1	0.85(0.53,1.35)	1.19(0.82-1.72)	1.58(1.23-2.02)	1.21(0.86,1.69)
Low HDL-C	1	0.78(0.52-1.18)	0.93(0.66-1.30)	0.86(0.68-1.10)	1.01(0.73-1.39)
High fasting glucose	1	1.04(0.65-1.67)	1.45(1.02-2.07)	0.98(0.75-1.28)	1.26(0.89-1.77)
High blood pressure	1	0.93(0.60-1.44)	1.15(0.81-1.64)	1.11(0.87-1.42)	1.13(0.81-1.57)

A multiple logistic regression analysis was used to calculate the OR. The model is adjusted for age, education level, smoking status, physical activity, fat intake, fiber intake, drinking amount, and lipid medication. Subjects without data for education level or household income were included in the analyses. Consuming mixed types of alcohol was associated with the development of metabolic syndrome and abdominal obesity. Meanwhile, those that consumed liquor or wine had a greater risk of developing high triglyceride or high fasting glucose levels, respectively.