# Patterns of Alcohol Consumption and the Metabolic Syndrome

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**Context and Objective:** Protective and detrimental associations have been reported between alcohol consumption and the metabolic syndrome. This may be due to variations in drinking patterns and different alcohol effects on the metabolic syndrome components. This study is designed to examine the relationship between alcohol consumption patterns and the metabolic syndrome.

**Design, Setting, Participants, and Measures:** The 1999–2002 National Health and Nutrition Examination Survey is a population-based survey of noninstitutionalized U.S. adults. Current drinkers aged 20–84 yr without cardiovascular disease who had complete data on the metabolic syndrome and drinking patterns were included in the analysis (n = 1529). The metabolic abnormalities comprising the metabolic syndrome included having three of the following: impaired fasting glucose/diabetes mellitus, high triglycerides, abdominal obesity, high blood pressure, and low high-density-lipoprotein cholesterol. Measures of alcohol consumption included usual quantity consumed, drinking frequency, and frequency of binge drinking.

**Results:** In multinomial logistic regression models controlling for demographics, family history of cardiovascular disease and diabetes, and lifestyle factors, increased risk of the metabolic syndrome was associated with daily consumption that exceeded U.S. dietary guideline recommendations (more than one drink per drinking day for women and more than two drinks per drinking day for men (odds ratio 1.60, 95% confidence interval 1.22–2.11) and binge drinking once per week or more [odds ratio (95% confidence interval) 1.51 (1.01–2.29]. By individual metabolic abnormality, drinking in excess of the dietary guidelines was associated with an increased risk of impaired fasting glucose/diabetes mellitus, hypertriglyceridemia, abdominal obesity, and high blood pressure.

**Conclusion:** Public health messages should emphasize the potential cardiometabolic risk associated with drinking in excess of national guidelines and binge drinking. **(*J Clin Endocrinol Metab* 93: 3833–3838, 2008)**

The metabolic syndrome, which is characterized by a cluster of key cardiovascular risk factors, abdominal obesity, dyslipidemia, hyperglycemia, and hypertension, has become one of the major public health challenges worldwide (1). The association of alcohol consumption with the metabolic syndrome is complex and controversial, as both protective and detrimental effects have been reported (2–4). Similarly, findings on the associations of alcohol consumption with cardiovascular outcomes are inconsistent (5–8). For example, a large population-based study in the United States reported that mild to moderate consumption of alcohol was associated with a lower prevalence of the metabolic syndrome, with a favorable influence on lipids, waist circumference, and fasting insulin in a comparison with current nondrinkers (4). In contrast, a large study in Korean adults suggested that there were adverse effects of alcohol consumption on all components of the metabolic syndrome except

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Abbreviations: CI, Confidence interval; HBP, high blood pressure; HDLC, high-density-lipoprotein cholesterol; NHANES, National Health and Nutrition Examination Survey; OR, odds ratio.

low high-density lipoprotein cholesterol (HDLC) (3). These discrepant results may be partly attributed to different consumption patterns in different study populations, even among those whose average daily alcohol consumption is similar.

A growing body of evidence points to the importance of alcohol consumption patterns as critically important predictors of alcohol-related health effects (9–12). Unfortunately, most studies looking at the relationship between alcohol consumption and chronic disease outcomes have focused on average daily alcohol consumption (or average volume), which can obscure large differences in drinking styles based on frequency, usual quantity, and above-modal drinking episodes (*e.g.* binge drinking), all of which may have independent and important effects. To date, we are not aware of previous studies examining the relationship between different alcohol consumption patterns and the metabolic syndrome or its constituent metabolic abnormalities. Such information is important because alcohol consumption and the metabolic syndrome are both common, and because physicians and patients would benefit from, but currently lack, specific knowledge about how drinking patterns may influence the risk of the metabolic syndrome and its related diseases, which comprise the leading causes of death in the United States. In this study, we examined the relationship between different dimensions of alcohol consumption and the metabolic syndrome in the United States using population-based data from the National Health and Nutrition Examination Survey (NHANES).

## Subjects and Methods

### Data source

Data were obtained from the 1999–2002 NHANES, a population-based survey of the noninstitutionalized U.S. population that includes both an interview and a physical examination. We restricted our analysis to current drinkers (participants who consumed 12 alcoholic drinks or more during the past 12 months) aged 20–84 yr who fasted no less than 8 h before the blood draw. We excluded those who had a diagnosis of cardiovascular disease (angina/heart attack/coronary heart disease, heart failure, stroke), who were pregnant, or who had reduced their consumption of alcohol following a doctor's advice. We made this last exclusion to ensure that drinking habits had not changed because of health conditions relevant to the study outcome. This yielded 1529 participants with complete data for evaluating the metabolic syndrome. Full details of the NHANES 1999–2002 design are available online (http://www.cdc.gov/nchs/about/major/nhanes/nhanes99_00.htm and http://www.cdc.gov/nchs/about/major/nhanes/nhanes01–02.htm).

### Measures

#### *Metabolic syndrome*

Definitions of the metabolic syndrome and its components are based on the National Cholesterol Education Program Adult Treatment Panel III (13). The metabolic syndrome was defined as having three or more of the following: 1) impaired fasting glucose (≥6.0 mmol/liter), diagnosis of diabetes mellitus and/or taking insulin or a diabetic pill, 2) raised plasma triglycerides (≥1.7 mmol/liter), 3) low HDLC (<1.04 mmol/liter in men and <1.29 mmol/liter in women, 4) abdominal obesity (waist circumference >102 cm in men and >88 cm in women), 5) elevated blood pressure (systolic/diastolic blood pressure ≥130/85 mm Hg or taking antihypertensive medication).

#### *Metabolic abnormality scale*

Although we analyzed the outcome of the metabolic syndrome (a dichotomous outcome, yes *vs.* no), this approach has been criticized because many persons without the syndrome have one or two metabolic abnormalities that would increase their risk of cardiovascular disease. Including these persons in the reference category underestimates cardiovascular risk in association with the metabolic syndrome (14). Furthermore, there are data showing that the number of metabolic abnormalities is directly related to risk of coronary atherosclerosis and cardiovascular events (14, 15). Therefore, we created a metabolic abnormality scale with categories of zero, one, two, or three or more metabolic abnormalities and examined whether various drinking patterns were associated with incremental increases in the scale.

#### *Alcohol consumption patterns*

Measures of current drinking patterns included frequency, usual quantity, drinking exceeding the U.S. dietary guidelines, and frequency of binge drinking. Frequency was assessed by asking: "in the past 12 months, how often did you drink any alcoholic beverages?" We grouped responses into three categories (<1 d/wk, 1–2 d/wk, ≥3 d/wk). Usual quantity was assessed by the question: "on those days when you drank alcoholic beverages, on the average, how many drinks did you have?" We grouped responses into three categories (one, two, and three or more drinks per drinking day). Men who consumed more than two drinks/drinking day (*i.e.* who usually drank three or more) and women who consumed more than one drink per drinking day (*i.e.* who usually drank two or more) were classified as drinking in excess of the U.S. dietary guidelines (16) and were defined as drinking exceeding the guideline. Frequency of binge drinking was assessed by asking the "number of days you had five or more drinks in the past 12 months." We grouped responses into three categories (no binge drinking, less than once per week, and once or more per week). Those who reported binge drinking once or more per week were defined as frequent binge drinkers (17).

#### *Covariates and potential confounders*

Demographic variables (age, sex, race/ethnicity, years of education), family history (heart attack, stroke, diabetes), dietary practice (sex specific quartiles of saturated fat intake and of dietary fiber intake), video-based physical inactivity (daily hours of TV, video, or computer use outside work), habitual daily activity level (sedentary, light, some moderate to vigorous activity), and tobacco use (never, former, and current smoker) were considered as covariates in the multivariate models.

### Statistical analysis

We performed the analysis using SAS 9.0 (SAS Institute, Cary, NC) and SUDAAN 9.0 (Research Triangle Park, NC) to account for the complex sampling design. We used logistic regression analyses to obtain multivariate-adjusted odds ratios (ORs) for the metabolic syndrome and its components by drinking patterns. We used the metabolic abnormality scale as a dependent variable indicating level of cardiovascular risk. Multinomial logistic regression was thus performed using the MULTILOG procedure in SUDAAN, assuming the cumulative logit model. ORs and their 95% confidence intervals (CIs) for the metabolic abnormality scale were calculated in association with drinking patterns. An OR = 3 for drinking exceeding the guideline means that the odds of such drinkers being in a higher metabolic abnormality scale category is nearly 3 times the odds for drinkers not exceeding the drinking guideline. *P* values were two sided, with $P < 0.05$ considered significant and $0.05 < P < 0.10$ or less considered marginally significant.

There were no sex and drinking pattern interactions in the relationship between drinking patterns and the metabolic syndrome/metabolic abnormality scale. Therefore, the results were presented with two sexes combined.

## Results

The average age of current drinkers was 42 yr; 77% were non-Hispanic whites; 41% were high school graduates or received lower education. Overall, 52% of men and 67% of women reported that their usual alcohol consumption exceeded the U.S. dietary guidelines (*i.e.* men or women who usually drank more than two or one drinks, respectively). The prevalence of any past-year binge drinking was 52%, and men were more likely to binge drinking and binge drink frequently, compared with women. About 20% of men and 19% of women had the metabolic syndrome according to the National Cholesterol Education Program definition, and 72% of men and 68% of women had at least one metabolic abnormality. The other characteristics of current drinkers, stratified by sex, are presented in Table 1.

The associations of drinking patterns with the metabolic syndrome and the metabolic abnormality scale showed similar results; however, associations with the metabolic abnormality scale were more significant with narrower confidence intervals (Table 2). Higher usual drinking quantity, drinking exceeding the dietary guidelines, and binge drinking (once or more per week) were all associated with higher odds of the metabolic syndrome or a higher metabolic abnormality scale score, even after controlling for drinking frequency. On the other hand, higher drinking frequency (≥3 d/wk) was associated with a lower metabolic abnormality scale score after controlling for usual quantity.

The associations of drinking patterns with individual metabolic abnormalities that comprise the metabolic syndrome were also examined (Table 3). Drinking one or more times per week was associated with significantly lower odds of low HDLC and nonsignificantly reduced odds of having a higher waist circumference, compared with drinking once per week or less, but drinking three or more times per week was significantly associated with having high blood pressure (HBP). Higher usual drinking quantity (more than two drinks per drinking day) was associated with higher odds of impaired fasting glucose/diabetes mellitus, hypertriglyceridemia, abdominal obesity, and HBP. Drinking exceeding the guideline was associated with higher odds of hypertriglyceridemia, abdominal obesity, and HBP. Frequent binge drinking was associated with higher odds of hypertriglyceridemia and HBP.

## Discussion

This was a carefully controlled, population-based study of the relationship between several alcohol consumption patterns and the metabolic syndrome. Current drinkers who drank in excess

**TABLE 1.** Characteristics of current drinkers by sex

| Characteristic | Men (n = 961) | Women (n = 568) | All (n = 1529) |
|---|---|---|---|
| Continuous variables, mean (SE) | | | |
| Age, yr | 41.5 (0.8) | 43.4 (0.7) | 42.3 (0.7) |
| Categorical variables, % (SE) | | | |
| Race/ethnicity | | | |
| Non-Hispanic white | 74.3 (2.6) | 81.9 (2.0) | 77.4 (2.2) |
| Non-Hispanic black | 7.6 (1.3) | 7.7 (1.1) | 7.7 (1.1) |
| Mexican-American | 8.7 (1.2) | 4.0 (1.0) | 6.8 (1.0) |
| Other | 9.3 (2.0) | 6.3 (2.0) | 8.1 (1.8) |
| Education | | | |
| High school graduate or lower | 44.2 (2.6) | 35.5 (2.5) | 40.6 (2.3) |
| More than high school | 55.8 (2.6) | 64.5 (2.5) | 59.4 (2.3) |
| Frequency of alcohol consumption | | | |
| <1 d/wk | 32.5 (1.7) | 46.0 (2.0) | 37.9 (1.3) |
| 1–2 d/wk | 35.7 (1.9) | 31.3 (2.0) | 33.9 (1.4) |
| ≥3 d/wk | 31.8 (1.5) | 22.7 (1.9) | 28.1 (1.4) |
| Usual quantity (drinks/drinking per day) | | | |
| 1 | 19.3 (1.9) | 32.9 (2.3) | 24.8 (1.7) |
| 2 | 28.8 (1.7) | 38.3 (2.9) | 32.7 (1.9) |
| 3+ | 51.9 (2.6) | 28.8 (2.6) | 42.5 (2.3) |
| Drinking exceeding the U.S. dietary guidelines | 51.9 (2.6) | 67.1 (2.3) | 58.1 (1.8) |
| Frequency of binge drinking | | | |
| None | 35.5 (2.0) | 66.0 (2.1) | 47.9 (1.5) |
| Less than once per week | 44.5 (2.2) | 29.4 (1.9) | 38.4 (1.6) |
| ≥once per week | 20.0 (1.6) | 4.6 (1.0) | 13.7 (1.1) |
| Metabolic abnormalities | | | |
| Impaired fasting glucose/diabetes mellitus | 13.4 (1.4) | 8.0 (1.4) | 11.2 (1.1) |
| Abdominal obesity | 31.9 (2.5) | 45.3 (2.6) | 37.3 (2.0) |
| Hypertriglyceridemia | 36.0 (2.2) | 22.4 (1.8) | 30.5 (1.1) |
| Low HDLC | 29.0 (1.8) | 30.3 (2.4) | 29.5 (1.5) |
| HBP | 34.1 (2.0) | 27.8 (1.8) | 31.5 (1.5) |
| Number of metabolic abnormalities | | | |
| 0 | 28.3 (1.9) | 32.3 (2.6) | 29.9 (1.7) |
| 1 | 28.8 (1.8) | 28.2 (2.0) | 28.6 (1.1) |
| 2 | 22.5 (1.4) | 20.8 (2.6) | 21.8 (1.5) |
| 3+ | 20.4 (1.5) | 18.8 (1.7) | 19.7 (1.0) |

**TABLE 2.** Adjusted ORs of current drinkers having the metabolic syndrome or having more metabolic abnormalities that comprise the metabolic syndrome, by drinking patterns (n = 1529)[a]

| | Metabolic syndrome | | Metabolic abnormality scale[b] | |
|---|---|---|---|---|
| | AOR | 95% CI | AOR | 95% CI |
| Frequency of drinking | | | | |
| <1 d/wk | 1.00 | | 1.00 | |
| 1–2 d/wk | **0.57** | **0.35–0.91** | 0.74 | 0.54–1.01 |
| ≥3 d/wk | 0.84 | 0.51–1.37 | **0.70** | **0.51–0.95** |
| *P* for linear trend | 0.71 | | **0.02** | |
| Usual quantity (drinks/drinking per day) | | | | |
| 1 | 1.00 | 1.00 | 1.00 | |
| 2 | 1.12 | 0.68–1.85 | 1.36 | 0.95–1.95 |
| 3+ | **2.13** | **1.12–4.07** | **1.72** | **1.24–2.39** |
| *P* for linear trend | **0.02** | | **0.002** | |
| Drinking exceeding the U.S. dietary guidelines[c] | | | | |
| No | 1.00 | | 1.00 | |
| Yes | **1.56** | **1.02–2.40** | **1.60** | **1.22–2.11** |
| Frequency of binge drinking | | | | |
| None | 1.00 | 1.00 | 1.00 | |
| Less than once per week | 1.28 | 0.58–2.82 | 1.25 | 0.73–2.14 |
| Once or more per week | 1.84 | 0.96–3.50 | **1.51** | **1.01–2.29** |
| *P* for linear trend | 0.20 | | <0.001 | |

AOR, Adjusted odds ratios.

[a] All models were adjusted for age; sex; race/ethnicity; years of education; family history of coronary heart disease, stroke, or diabetes; dietary practice (saturated fat intake, dietary fiber intake); cigarette smoking status; habitual physical activity; and video-based physical inactivity. Models for drinking frequency were also adjusted for usual quantity, and models for usual quantity, drinking exceeding the dietary guideline, and frequency of binge drinking were also adjusted for drinking frequency. Values in boldface are statistically significant at $P < 0.05$.

[b] Metabolic abnormality scale is an ordinal scale based on the number of metabolic abnormalities (zero, one, two, or three or more). The OR refers to the odds of being in the next higher category of the metabolic abnormality scale, compared with the reference group.

[c] U.S. dietary guidelines gave the definition of moderation as the consumption of up to one drink per day for most women and up to two drinks per day for most men.

of the U.S. dietary guidelines (*i.e.* men who usually consumed three or more drinks or women who usually consumed two or more drinks) and frequent binge drinkers were at significantly increased risk of the metabolic syndrome, compared with other current drinkers. By individual metabolic component, those who typically consumed more than two drinks per drinking day were

**TABLE 3.** Adjusted ORs and 95% CIs of current drinkers having the metabolic abnormalities that comprise the metabolic syndrome, by drinking patterns[a]

| | Impaired fasting glucose/diabetes mellitus | Hypertriglyceridemia | Low HDLC | Abdominal obesity | HBP |
|---|---|---|---|---|---|
| Frequency | | | | | |
| <1 d/wk | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 1–2 d/wk | 0.75 (0.33–1.70) | 0.86 (0.51–1.44) | **0.43 (0.27–0.68)** | 1.01 (0.66–1.55) | 1.18 (0.69–2.02) |
| ≥3 d/wk | 1.32 (0.63–2.76) | 0.84 (0.53–1.35) | **0.33 (0.20–0.55)** | 0.62 (0.37–1.03) | **2.00 (1.28–3.01)** |
| Usual quantity (drinks per drinking day) | | | | | |
| 1 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2 | 1.42 (0.67–3.02) | 1.36 (0.74–2.51) | 1.70 (0.87–3.34) | 1.48 (0.86–2.55) | 1.40 (0.76–2.57) |
| 3+ | **2.96 (1.06–8.31)** | **2.37 (1.16–4.84)** | 1.64 (0.88–3.07) | **1.80 (1.22–2.66)** | **1.80 (1.13–2.86)** |
| Drinking exceeding the U.S. dietary guidelines[b] | | | | | |
| No | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Yes | 1.84 (0.70–4.84) | **1.74 (1.06–2.86)** | 1.20 (0.70–2.05) | **1.77 (1.30–2.40)** | **1.72 (1.23–2.41)** |
| Frequency of binge drinking | | | | | |
| None | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Less than once per week | 1.22 (0.50–3.01) | 1.21 (0.66–2.25) | 0.79 (0.42–1.48) | 1.36 (0.82–2.26) | 1.56 (0.88–2.75) |
| Once or more per week | 1.85 (0.60–5.69) | **1.71 (1.12–2.63)** | 0.56 (0.26–1.19) | 1.53 (0.81–2.89) | **2.08 (1.11–3.90)** |

[a] Adjusted for age; sex; race/ethnicity; years of education; family history of coronary heart disease, stroke, or diabetes; dietary practice (saturated fat intake, dietary fiber intake); cigarette smoking status; habitual physical activity; and video-based physical inactivity. Models for drinking frequency were also adjusted for usual quantity, and models for usual quantity and drinking exceeding the U.S. dietary guideline were adjusted for drinking frequency. Values in boldface are statistically significant at $P < 0.05$.

[b] U.S. dietary guidelines gave the definition of moderation as the consumption of up to one drink per day for most women and up to two drinks per day for most men.

at increased risk for four of the five components of the metabolic syndrome including HBP, high triglycerides, increased abdominal girth, and elevated blood glucose. Taken together, these findings add to the growing body of evidence suggesting that excessive per-occasion consumption is the primary risk factor for both acute and chronic alcohol-related problems (18). These findings also lend strong support for current public health and clinical guidelines around low-risk alcohol consumption and health warnings related to binge drinking.

Although this was a study about the metabolic syndrome and not cardiovascular disease, elements of the metabolic syndrome and the syndrome itself convey important cardiac risk, and other studies show that excessive drinking is associated with an increased risk of cardiovascular disease. It is important to note that more than half of drinkers in this study reported drinking in excess of the U.S. dietary guidelines and binge drinking. This further reinforces the need for caution in promoting potential benefits of alcohol consumption. As is the case for many other studies, a large proportion of drinkers who drank in excess of the dietary guideline or who binge drink would have been classified as moderate drinkers if average volume (drinks per day) had been used (19, 20) (data not shown). Because drinking patterns impose influences above and beyond whatever drinking volume can explain (21), it is important to include measures of drinking pattern in alcohol-related epidemiological studies.

Two observational U.S. studies with fairly large samples concluded that current, moderate alcohol consumption (based on average daily volume) was associated with a lower prevalence of the metabolic syndrome, compared with nondrinkers (2, 4). The problem of using average daily consumption as an exposure variable were discussed in the introduction of the paper; the issue of whether nondrinkers represent an appropriate reference group for studies of the effects of alcohol on coronary heart disease is debatable (18, 22, 23). Nondrinkers are a heterogeneous group consisting of former drinkers, lifelong abstainers, and irregular abstainers. Former drinkers may have stopped their drinking in response to poor health; lifetime abstainers may abstain for a variety of reasons such as poor socioeconomic status, health problems, and religious or lifestyle preference (7, 24–27). Statistical adjustment is not sufficient to rule out confounding of imperfectly measured variables, unmeasured or unknown confounders (28). Thus, the inference in previous studies from comparisons with nondrinkers that alcohol consumption has protective effects may be attributable to selection bias and residual or uncontrolled confounding (7, 24–26). For these reasons and because excessive alcohol consumption is a leading preventable cause of death in the United States (29), the dietary guidelines and the American Heart Association recommend against initiating alcohol consumption or drinking more frequently on the basis of health considerations (16, 30).

The association of more frequent drinking with lower risks of the metabolic syndrome and low HDLC than infrequent drinking is consistent with the notion that a pattern of light, frequent drinking reduces cardiovascular risk modestly by increasing levels of HDLC. A metaanalysis showed that the drinking level corresponding to the nadir of the J or U curve is far lower than one drink per day (18). However, risk of the metabolic syndrome and its components other than low HDLC increases at higher levels of alcohol intake. It is believed that increased HDLC in association with regular alcohol consumption can partly explain the cardiometabolic protective effect of moderate alcohol intake (18, 22). Elevation of HDLC caused by alcohol consumption, however, may be accompanied by other unfavorable cardiovascular risks and various components of the metabolic syndrome (3, 31). For example, we found that the direction of association of frequency of drinking with low HDLC (inverse) was opposite to that with HBP (positive). These findings are consistent with reports that alcohol intake was significantly associated with elevated HDLC and blood pressure in a dose-dependent manner (32–35). Actually, HDLC concentrations can even be used to identify heavy drinkers (33). Moreover, an increased blood concentration of HDLC in alcoholics was highly correlated with liver damage (36). More recently the inverse association of HDLC and coronary mortality was found to be less marked at higher levels of alcohol intake (37), indicating that the increase of HDLC may not be translated proportionally into cardioprotective benefits. A study among a Korean population (3) suggested a significant direct dose-response relation of the ORs between alcohol consumption and the metabolic syndrome in both the high and low HDLC groups. Therefore, any conclusion on the benefit of moderate drinking based solely on increased HDLC should be reevaluated.

Because most Americans drink alcohol and because more than half of current drinkers in our study drank in excess of the dietary guidelines limits and reported binge drinking, prevention efforts for established cardiovascular risk factors, including those that comprise the metabolic syndrome, should focus on reducing alcohol consumption to safer levels among those who already drink alcohol. However, few physicians screen their patients about alcohol use (38) despite evidence-based guidelines recommending such screening (39). Furthermore, few patients or physicians are knowledgeable about guidelines that define low-risk or moderate drinking in the United States (40, 41). In addition to alcohol screening and brief counseling interventions, effective public health measures to reduce excessive drinking include increasing the price of alcohol through excise taxes or other means, reducing alcohol outlet density and hours of sale, and enforcing laws prohibiting the sale of alcohol to underage or intoxicated persons (42).

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