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METHODS
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RESULTS
Systolic blood pressure and pulse pressure were significantly higher in subjects receiving antihypertensive therapy than in subjects not receiving antihypertensive therapy, whereas diastolic blood pressure was not different between the two groups. In multivariate analysis with adjustment for age, smoking history, and body mass index (BMI), systolic and diastolic blood pressure and pulse pressure in the group not receiving antihypertensive therapy were significantly higher in heavy and very heavy drinkers than in nondrinkers, whereas in the group receiving antihypertensive therapy, systolic and diastolic blood pressure and pulse pressure were not different between each drinker group and the nondrinker group.

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The purpose of this study was, therefore, to clarify the relationships of alcohol intake with blood pressure and pulse pressure in the elderly and to determine whether and how these relationships are influenced by therapy for hypertension.

**METHODS**

**Subjects.** The subjects were male workers aged at ≥65 years \((n = 1,396)\) who had received periodic health examinations at workplaces in Yamagata Prefecture in Japan. All of the subjects were of Japanese origin. A cross-sectional study was performed using a local population-based database for the above subjects. This study was approved by the Ethics Committee of Yamagata University School of Medicine. Subjects with a current history of therapy for hypertension were defined as those receiving antihypertensive(s) in this study and thus were restricted to hypertensive patients treated with therapy using pharmacological approaches.

Average alcohol consumption of each subject per week was reported on questionnaires during health examinations at each workplace. In this study, occasional drinkers were excluded, and the data of nondrinkers were compared with the data of regular drinkers who drank almost every day because it is difficult to know the correct alcohol consumption of occasional drinkers. Usual weekly alcohol consumption was recorded in terms of the equivalent number of “go,” a traditional Japanese unit of amount of sake (rice wine). The amounts of other alcoholic beverages, including beer, wine, whiskey, and shochu (traditional Japanese distilled spirit), were converted and expressed as units of “go.” One “go” contains about 22 g of ethanol, and this amount was used to separate heavy drinkers from light drinkers because it is generally accepted that alcohol intake should be reduced to <30 ml or 20–30 g per day from the viewpoint of prevention of hypertension.\(^{18,19}\) Average daily alcohol intake (grams of ethanol per day) was then calculated. The subjects were divided into four groups according to ethanol consumption per day (nondrinkers; light drinkers: <22 g of ethanol per day; heavy drinkers: ≥22 g and <44 g of ethanol per day; very heavy drinkers: ≥44 g ethanol per day). History of cigarette smoking was also surveyed by questionnaires. Subjects who were receiving treatment for any illness were requested to state the names of diseases in a questionnaire at the health checkup.

**Measurements.** Height and body weight were measured with light clothes at the health checkup. Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters. Blood pressure was measured by trained nurses, who were part of the local health checkup company, with a mercury sphygmomanometer once on the day of the health checkup after each subject had rested quietly in a sitting position. Korotkoff phase V was used to define diastolic pressure. Cutoff values of high systolic blood pressure, high diastolic blood pressure, and high pulse pressure were defined as 140, 90, and 50 mm Hg, respectively.

**Statistical analysis.** Statistical analyses were performed using a computer software (SPSS version 16.0 J for Windows; SPSS, Chicago, IL). Mean values of each variable in the groups of subjects with and without therapy for hypertension were compared using Student’s unpaired \(t\)-test. In univariate analysis, mean values of each variable in the four groups divided by alcohol intake were compared using analysis of variance and subsequent Scheffé’s \(F\)-test. In multivariate analysis, mean values of each variable after adjustment for additional variables as below were compared among the four alcohol intake groups using analysis of covariance and then Student’s \(t\)-test after Bonferroni correction. Age, history of smoking, and BMI were adjusted for calculating means of systolic blood pressure, diastolic blood pressure, and pulse pressure. In logistic regression analysis, odds ratios of drinkers vs. nondrinkers for high systolic blood pressure, high diastolic blood pressure, or high pulse pressure were calculated after adjustment for age, history of smoking, and BMI. The percentages of drinkers and smokers and the prevalence of hypertension in the groups were compared using the \(\chi^2\) test for independence or Fisher’s exact probability test. \(P\) values <0.05 were defined as significant.

**RESULTS**

**Comparison of each variable between groups with and without therapy for hypertension**

Table 1 shows profiles of overall subjects and subjects receiving or not receiving therapy for hypertension. Percentages of drinkers and smokers were significantly higher and lower, respectively, in the group receiving therapy for hypertension than in the group not receiving antihypertensive therapy. Age, BMI, systolic blood pressure, and pulse pressure were significantly higher in the group with therapy for hypertension than in the group without antihypertensive therapy; whereas diastolic blood pressure was not different between the groups. About half of the subjects receiving antihypertensive treatment showed blood pressure within the normal range (systolic blood pressure <140 mm Hg and diastolic blood pressure <90 mm Hg). Prevalence of diastolic hypertension and prevalence of severe systolic hypertension were comparable between the subject groups with and without antihypertensive treatment.

**Univariate analysis of the relationship between alcohol intake and each variable related to blood pressure in overall subjects**

In overall subjects, systolic blood pressure and diastolic blood pressure were significantly higher in heavy and very heavy drinkers than in nondrinkers, and pulse pressure was significantly higher in very heavy drinkers than in nondrinkers (Table 2).

**Multivariate analysis of the relationship between alcohol intake and each variable related to blood pressure in overall subjects**

Mean levels of systolic blood pressure, diastolic blood pressure, and pulse pressure of overall subjects after adjustment for age, history of smoking, and BMI were significantly higher in heavy and very heavy drinkers than in nondrinkers (Figure 1a–c).
Univariate analysis of the relationships between alcohol intake and each variable related to blood pressure in the subject groups with and without therapy for hypertension
In the group of subjects without therapy for hypertension, systolic blood pressure and diastolic blood pressure were significantly higher in heavy and very heavy drinkers than in nondrinkers, and pulse pressure was significantly higher in very heavy drinkers than in nondrinkers (Table 2). In the group with therapy for hypertension, systolic blood pressure, diastolic blood pressure, and pulse pressure were not different between each drinker group and the nondrinker group (Table 2).

Multivariate analysis of the relationships between alcohol intake and each variable related to blood pressure in the subject groups with and without therapy for hypertension
In the group of subjects without therapy for hypertension, systolic blood pressure, diastolic blood pressure, and pulse pressure after adjustment for age, smoking history, and BMI were significantly higher in heavy and very heavy drinkers than in nondrinkers (Figure 2a–c). In the group of subjects with therapy for hypertension, no significant difference was found in adjusted systolic blood pressure, diastolic blood pressure, and pulse pressure between each drinker group and the nondrinker group (Figure 2a–c). Relationships of alcohol intake with blood pressure and pulse pressure were also investigated in the subjects showing hypertension and not receiving therapy for hypertension. In subjects who were hypertensive and not on therapy, systolic blood pressure and pulse pressure were significantly higher in very heavy drinkers than in nondrinkers (Figure 3a,c), whereas diastolic blood pressure in each drinker group was not significantly different from diastolic blood pressure in the nondrinker group (Figure 3b).

Logistic regression analysis of the relationships between alcohol intake and each variable related to blood pressure in the subject groups with and without therapy for hypertension
In logistic regression analysis, odds ratios of drinkers vs. nondrinkers were calculated after adjusting for age, history of smoking, and BMI. Odds ratios of heavy and very heavy drinkers vs. nondrinkers for high systolic blood pressure, high diastolic blood pressure, and high pulse pressure were significantly high in subjects not receiving therapy for hypertension but were not significant in subjects receiving therapy for hypertension (Table 3). These results agree with the results of comparison of means of blood pressure–related variables among the alcohol groups (Figure 2 and Table 2).

**Table 1** Profiles of subjects

<table>
<thead>
<tr>
<th></th>
<th>Overall</th>
<th>Therapy for hypertension (–)</th>
<th>Therapy for hypertension (+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of subjects</td>
<td>1,396 (100%)</td>
<td>883 (100%)</td>
<td>513 (100%)</td>
</tr>
<tr>
<td>Nondrinkers</td>
<td>482 (34.5%)</td>
<td>328 (37.1%)</td>
<td>154 (30.0%)</td>
</tr>
<tr>
<td>Light drinkers</td>
<td>216 (15.5%)</td>
<td>129 (14.6%)</td>
<td>87 (17.0%)</td>
</tr>
<tr>
<td>Heavy drinkers</td>
<td>492 (35.2%)</td>
<td>297 (33.6%)</td>
<td>195 (38.0%)</td>
</tr>
<tr>
<td>Very heavy drinkers</td>
<td>206 (14.8%)</td>
<td>129 (14.6%)</td>
<td>77 (15.0%)</td>
</tr>
<tr>
<td>Total drinkers</td>
<td>914 (65.5%)</td>
<td>555 (62.9%)</td>
<td>359 (70.0%) **</td>
</tr>
<tr>
<td>Age (years)</td>
<td>68.5 ± 3.8</td>
<td>68.2 ± 3.5</td>
<td>69.1 ± 4.2**</td>
</tr>
<tr>
<td>Percentage of smokers (%)</td>
<td>35.9</td>
<td>38.7</td>
<td>31.0**</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>23.37 ± 2.78</td>
<td>22.97 ± 2.64</td>
<td>24.07 ± 2.88**</td>
</tr>
<tr>
<td>Systolic blood pressure (mm Hg)</td>
<td>136.2 ± 15.9</td>
<td>134.0 ± 15.6</td>
<td>140.0 ± 15.6**</td>
</tr>
<tr>
<td>Diastolic blood pressure (mm Hg)</td>
<td>77.6 ± 9.9</td>
<td>77.3 ± 9.9</td>
<td>78.1 ± 10.0</td>
</tr>
<tr>
<td>High systolic blood pressure (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥140 mm Hg</td>
<td>41.1</td>
<td>34.5</td>
<td>52.4**</td>
</tr>
<tr>
<td>≥160 mm Hg</td>
<td>7.7</td>
<td>6.0</td>
<td>10.7**</td>
</tr>
<tr>
<td>≥180 mm Hg</td>
<td>0.9</td>
<td>0.9</td>
<td>1.0</td>
</tr>
<tr>
<td>High diastolic blood pressure (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥90 mm Hg</td>
<td>12.9</td>
<td>12.2</td>
<td>14.0</td>
</tr>
<tr>
<td>≥100 mm Hg</td>
<td>2.1</td>
<td>2.2</td>
<td>2.1</td>
</tr>
<tr>
<td>≥110 mm Hg</td>
<td>0.4</td>
<td>0.4</td>
<td>0.2</td>
</tr>
<tr>
<td>Pulse pressure (mm Hg)</td>
<td>58.6 ± 12.1</td>
<td>56.6 ± 11.4</td>
<td>61.9 ± 12.6**</td>
</tr>
</tbody>
</table>

Number of subjects, percentages of drinkers, smokers, and subjects with hypertension, and means with standard deviations of each variable are shown. Asterisks denote significant differences from nondrinkers (**P < 0.01).
Odds ratios of light drinkers vs. nondrinkers for high systolic blood pressure, high diastolic blood pressure, and high pulse pressure were not significant in both subject groups receiving and not receiving therapy for hypertension (data not shown).

**DISCUSSION**

This study showed that blood pressure and pulse pressure in older men were significantly higher in heavy and very heavy drinkers than in nondrinkers, and these associations of alcohol intake with blood pressure and pulse pressure were found in subjects not receiving therapy for hypertension but not in those receiving antihypertensive therapy. These findings were supported by the results of logistic regression analysis of the relationships between alcohol intake and each variable related to blood pressure. Therefore, antihypertensive therapy is thought to be effective for suppression of alcohol-induced blood pressure elevation in the elderly. This is the first study showing that the alcohol–blood pressure relationship is strongly modified by history of antihypertensive therapy in the elderly.

There has been limited information on the alcohol–blood pressure relationship in the elderly. A J-shaped relationship between alcohol intake and blood pressure in the elderly has recently been shown in reports from Greece and China. However, in the present study using Japanese men, there were tendencies for blood pressure and pulse pressure to be higher...
with an increase in alcohol intake, and no significant difference was found in blood pressure and pulse pressure between light drinkers and nondrinkers (Figure 1a–c). Thus, there were no depressing effects of light drinking (<22 g/day) on blood pressure and pulse pressure in subjects of this study. One possible reason for the discrepancy between the results of the present study and the results of the above studies is a racial and/or ethnic difference in the effect of light drinking on blood pressure. Differences in categorization of drinkers by alcohol intake, common kind of alcoholic beverage, and mean age of subjects also possibly explain the different findings on the relationship of light drinking with blood pressure between the Greek and Chinese cohorts and the Japanese cohort used in the present study.

There is a possibility that sensitivity to alcohol regarding blood pressure differs by level of blood pressure: people with higher blood pressure might be less sensitive to alcohol than people with lower blood pressure. However, in the present study, the mean diastolic blood pressure levels were comparable in the subject groups with and without antihypertensive treatment. Therefore, the observed difference in the sensitivity of diastolic blood pressure to alcohol between these groups was not due to difference in blood pressure levels.

This study suggests that alcohol-induced elevation of not only blood pressure but also pulse pressure in the elderly is suppressed by antihypertensive therapy. Pulse pressure has been shown to be superior to systolic blood pressure in predicting risk for cardiovascular disease at ≥60 years. Thus, antihypertensive therapy is thought to prevent cardiovascular disease through suppressing elevation of both blood pressure and pulse pressure in heavy drinkers. Although there is no evidence to suggest that drug therapy for hypertension reduces the blood pressure–elevating effect of heavy drinking, the results of the present study suggest that blood pressure control is not made worse by alcohol drinking in patients receiving treatment with antihypertensives. Because of a variety of alcohol-induced disorders besides hypertension, the obvious recommendation to lower alcohol intake is also applicable to heavy drinkers receiving drug therapy for hypertension.

Limitations of this study are as follows. Blood pressure of each subject was measured only on one visit, and the measurement was not performed by a single nurse. These may cause information biases in this study. There is a possibility of a bias caused by under-reporting amount of alcohol intake in the self-reported questionnaire. Subjects receiving antihypertensive therapy are expected to under-report their own alcohol intake more frequently and more considerably than subjects not receiving antihypertensive therapy. If a heavy or very heavy drinker with high blood pressure is being treated for hypertension but reports little or no alcohol use, this subject will be analyzed as a light or nondrinker. If this under-reporting were a sufficiently systematic bias, such misclassification would result in an overestimation of average blood pressure in the non- or light drinker group and an underestimation of average blood pressure in the heavy or very heavy drinker group. Sick alcohol-quitters may also confound the associations of alcohol intake with blood pressure and pulse pressure. The relationships between alcohol intake and blood pressure are possibly confounded by various factors such as nutrition, diet including salt intake, physical activity, habitual exercise, and socioeconomic status, which were not surveyed in this study. Information on alcohol beverage type and binge drinking pattern, which are possible confounders for the alcohol–blood pressure relationship, was also not available in this study, although no consistent beverage-specific associations with hypertension have been reported. Because a gender difference in the degree of association between alcohol intake and blood pressure has been reported, further studies are needed to clarify effects of antihypertensive treatment on the relationship between alcohol and blood pressure in women. There is a difference in sensitivity to alcohol due to polymorphism of alcohol-metabolizing enzymes. Thus, difference in alcohol sensitivity is also a potential modifier of the alcohol–blood pressure relationship in this study, although blood pressure modification by differences in the activity of acetaldehyde dehydrogenase 2 is controversial. Circadian blood pressure variation has been reported to be higher in heavy drinkers than in nondrinkers. Therefore, it would be of interest to know whether and how antihypertensive treatment influences the relationship between alcohol intake and circadian blood pressure variation. Because the present study was a cross-sectional study, further prospective studies are needed to clarify causal relationships of alcohol with blood pressure and pulse pressure in elderly people receiving and not receiving antihypertensive therapy.

In conclusion, alcohol intake was associated with blood pressure in older men not receiving therapy for hypertension but not in those receiving antihypertensive therapy. Thus, antihypertensive therapy is thought to suppress alcohol-associated elevation of blood pressure in the elderly. This interpretation is in line with the fact that the differential of added nonpharmacological measures may be minimal when patients with hypertension are treated by an agent or several agents with strong hypotenstive effects. Although this indicates the possibility that changes in drinking do not have a substantial impact on

### Table 3 | Logistic regression analysis of the relationships of excessive alcohol intake with prevalence of high systolic blood pressure, high diastolic blood pressure, and high pulse pressure in subjects receiving therapy for hypertension and in subjects not receiving therapy for hypertension

<table>
<thead>
<tr>
<th></th>
<th>Therapy for hypertension (−)</th>
<th>Therapy for hypertension (+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High systolic BP</td>
<td>1.62** (1.18–2.23)</td>
<td>1.29 (0.86–1.95)</td>
</tr>
<tr>
<td>High diastolic BP</td>
<td>1.77* (1.10–2.85)</td>
<td>0.93 (0.52–1.67)</td>
</tr>
<tr>
<td>High pulse pressure</td>
<td>1.91** (1.35–2.70)</td>
<td>1.06 (0.60–1.89)</td>
</tr>
</tbody>
</table>

Odds ratios with 95% confidence intervals in parentheses are shown. Odds ratios of heavy and very heavy drinkers vs. nondrinkers for high systolic blood pressure, high diastolic blood pressure, and high pulse pressure were calculated after adjusting for age, history of smoking, and body mass index. BP, blood pressure.

Asterisks denote significant odds ratios (*P < 0.05, **P < 0.01).
blood pressure among treated hypertensives, such a hypothesis should be examined in longitudinal studies and preferably in clinical trials.

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