OTHER CLINICAL STUDIES

Impact of Body Weight on the Relationship between Alcohol Intake and Blood Pressure

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Abstract — Aims: The reduction of habitual alcohol drinking is recommended for the prevention of hypertension. Daily or weekly alcohol consumption, which is used for evaluation of the effects of alcohol drinking on blood pressure, is usually not corrected by body weight. In this study, the influence of body weight on the relationship between alcohol intake and blood pressure was investigated.

Methods: The subjects (27,005 healthy men at ages of 35–54 years) were divided into four groups by average daily ethanol intake [non-, light (<15 g per day), moderate (≥15 and <30 g per day) and heavy (≥30 g per day) drinkers]. The subjects were also divided into four quartile groups by body weight.

Results: Alcohol intake and the percentage of drinkers were not different in the four quartile groups of body weight. In the first and second quartiles of body weight, systolic and diastolic blood pressures were significantly higher in moderate and heavy drinkers than in non-drinkers, while systolic and diastolic blood pressures in the fourth quartile of body weight were significantly higher in heavy drinkers than in non-drinkers but were not significantly different in moderate drinkers and non-drinkers. The differences in systolic or diastolic blood pressure between non-drinkers and moderate drinkers and between non-drinkers and heavy drinkers became greater as body weight decreased. These results were not altered when age and smoking history were adjusted.

Conclusions: The results suggest that body weight modifies the relationship between alcohol consumption and blood pressure and thus should be taken into account when effects of alcohol on blood pressure are considered.

INTRODUCTION

Habitual alcohol drinking is known to be a major risk factor for hypertension. From various prospective and cross-sectional studies, it has been confirmed that blood pressure in heavy drinkers is higher than that in non-drinkers and that the reduction of alcohol intake causes decrease in blood pressure. The proportion of hypertension attributable to alcohol drinking has been estimated to be 5–30% (Klatsky, 2003), and the results of a meta-analysis study have shown that alcohol reduction is associated with significant reductions in the mean systolic and diastolic blood pressures of −3.31 and −2.04 mmHg, respectively (Xin et al., 2001). Thus, the reduction of alcohol consumption is recommended for the prevention and treatment of hypertension. It is generally accepted that daily alcohol intake should be restricted to <30 ml per day (the JNC 7 Report) or 20–30 g per day (2007 ESH/ESC Guidelines) for the prevention of hypertension for men (Chobanian et al., 2003; Mancia et al., 2007), and the limit of alcohol intake recommended for men with low body weight as well as for women is about half of the above limit (Chobanian et al., 2003). The amount of habitual alcohol consumption is evaluated by individual daily or weekly alcohol intake. Theoretically, the distribution of alcohol to each tissue after ingestion depends on the volume of body fluid, which is reflected by body weight. Therefore, sensitivity to the biological action of alcohol is expected to differ depending on body weight of persons when the same amount of alcohol is consumed. In addition, obesity is also a risk factor for hypertension (Doll et al., 2002; Rahmouni et al., 2005). Thus, body weight is assumed to be a potent confounder for the relationship between alcohol intake and blood pressure. However, alcohol consumption for the evaluation of alcohol effects on blood pressure was not corrected by the body weight of each subject in most previous alcohol-related epidemiological studies. Moreover, the limit of body weight-corrected alcohol intake, recommended from the viewpoint of prevention of hypertension, is unknown. Therefore, the purpose of this study was to determine whether the relationship between alcohol drinking and blood pressure is influenced by body weight and to investigate the relation of body weight-corrected alcohol intake to blood pressure.

METHODS

Subjects

The subjects were 27,005 male healthy workers aged from 35 to 54 years who had received periodic health examinations at workplaces in Yamagata Prefecture in Japan. Workers who were receiving therapy for any illnesses were excluded from the subjects of this study. The major illnesses for exclusion were hypertension (5.61%), peptic ulcer (3.30%), diabetes mellitus (1.99%), low back pain (1.20%), dyslipidemia (1.15%), liver disease (0.85%), hyperuricemia (0.88%), arrhythmia (0.49%) and ischemic heart disease (0.40%). A cross-sectional study was performed using a local population-based database of the above subjects. This study was approved by the Ethics Committee of Yamagata University School of Medicine.

Average weekly alcohol consumption of each subject was reported on questionnaires during health examinations at each workplace, and the mean daily alcohol intake (grams of ethanol per day) was calculated. The alcoholic beverages include beer, wine, sake (rice wine), whisky and shochu (traditional Japanese distilled spirit). The subjects were divided into four subgroups according to ethanol consumption per day (non-drinkers; light drinkers, <15 g of ethanol per day; moderate drinkers, ≥15 g and <30 g of ethanol per day; heavy drinkers, ≥30 g of ethanol per day). The values of 15 and 30 g per day were used to separate moderate drinkers from light drinkers and to separate heavy drinkers from moderate drinkers, respectively, because the reduction of daily alcohol intake to <30 ml or 20–30 g per day is recommended for the prevention of hypertension.
for men (Chobanian et al., 2003; Mancia et al., 2007), and the limit of alcohol intake recommended for persons with low body weight is about half of the above limit (Chobanian et al., 2003). Histories of current cigarette smoking and illness were also surveyed by questionnaires.

**Measurements**

Blood pressure was measured by trained nurses with a mercury sphygmomanometer after each subject had rested quietly in a sitting position for at least 5 min. The Korotkoff phase V was used to define diastolic pressure. Body weight and height were measured with light clothes. Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters.

**Statistical analysis**

Statistical analyses were performed using computer software (SPSS version 16.0 J for Windows, Chicago, IL, USA). In univariate analyses, the mean values of each variable in the four groups divided by alcohol intake or in the four quartile groups divided by body weight were compared using the analysis of variance (ANOVA) and subsequent Scheffé’s F-test. The mean values of body weight in smokers and nonsmokers were compared using Student’s unpaired t-test. In multivariate analyses, the mean values of systolic and diastolic blood pressures, calculated after adjustment for age and history of smoking, were compared among the four alcohol intake groups using ANOVA and subsequent Student’s t-test after Bonferroni’s correction. The percentages of smokers and drinkers in the groups were compared using the chi-square test for independence. Pearson’s correlation coefficient was calculated in regression analysis. Probability (P) values <0.05 were defined as significant.

**RESULTS**

**Profiles of subjects in different body weight groups**

Table 1 shows profiles of subjects. The age and percentage of smokers became younger and lower, respectively, as body weight increased. The body weight of smokers was significantly lower than that of non-smokers [65.2 ± 10.2 kg (smokers) versus 66.8 ± 9.7 kg (non-smokers), P < 0.01]. BMI became higher as body weight increased. Alcohol intake, expressed as g ethanol per day, was not different among the four quartile groups of body weight, while alcohol intake, expressed as g ethanol per kg weight per day, became lower with an increase in body weight. Systolic and diastolic blood pressures became higher as body weight increased. In the second, third and fourth quartile groups of body weight, systolic and diastolic blood pressures were significantly higher than those in the first quartile group. There was a tendency for age to be slightly younger as body weight increased (Table 1), while no significant relationship was shown between age and BMI (mean ± standard deviation of age (years) in each quartile of BMI: first quartile, 44.6 ± 5.3; second quartile, 44.6 ± 5.4; third quartile, 44.9 ± 5.3; fourth quartile, 44.6 ± 5.3). A slight but significant inverse correlation was shown between age and body weight [Pearson’s correlation coefficient: −0.170 (P < 0.01)], while there was no significant correlation between age and BMI [Pearson’s correlation coefficient: −0.006 (P = 0.294)]. Thus, age was significantly associated with body weight but not with BMI in the subjects of this study. On the other hand, there was a strong association between body weight and BMI [Pearson’s correlation coefficient: 0.865 (P < 0.01)].

**Associations of alcohol intake with blood pressure in subjects in different body weight groups**

Relationships between alcohol intake and blood pressure in subjects of each body weight quartile and overall subjects are displayed in Table 2. In all four quartile groups of body weight, systolic and diastolic blood pressures were significantly higher in heavy drinkers than in non-drinkers and there were no significant differences in systolic and diastolic blood pressures between non-drinkers and light drinkers. In the first and second quartile groups of body weight, systolic and diastolic blood pressures were significantly higher in moderate drinkers than in non-drinkers, while no significant differences in systolic and diastolic blood pressures between non-drinkers and moderate drinkers were observed in the fourth quartile group of body weight. There were tendencies for systolic and diastolic blood pressures to be higher with an increase in body weight in each group divided by alcohol intake. There were also tendencies for the differences in systolic and diastolic blood pressures between non-drinkers and moderate drinkers and between non-drinkers and heavy drinkers to be greater with a decrease in body weight. The differences in systolic and diastolic blood pressures between non-drinkers and heavy drinkers in the first quartile of body weight were more than two times greater than the differences in the fourth quartile of body weight [Δsystolic blood pressure, 8.1 mmHg (first quartile) versus 3.6 mmHg (fourth quartile); Δdiastolic blood pressure, 5.6 mmHg (first quartile) versus 2.7 mmHg (fourth quartile)]. The above relationships of alcohol intake with systolic and diastolic blood pressures were not altered by adjustment for age and history of smoking in multivariate analyses (Fig. 1), except for a significant difference in systolic blood pressure after adjustment for age and history of smoking between non-drinkers and moderate drinkers in the third quartile group of body weight (Fig. 1A).

**Relationships between alcohol intake and blood pressure in overall subjects**

Figure 2 shows the results of multivariate analyses for the relationships between alcohol intake and blood pressure in overall subjects. When the subjects were divided into four groups by average ethanol intake per day as shown in Table 2, systolic and diastolic blood pressures were significantly higher in moderate (>15, <30 g/day) and heavy drinkers (≥30 g/day) than in non-drinkers but were not significantly different in light (<0, <15 g/day) drinkers compared to systolic and diastolic blood pressures in non-drinkers (Fig. 2A). Then, the subjects were also divided into four groups by average ethanol intake per body weight per day. The border values used in this classification were defined as approximate values of the above border values (15 and 30 g ethanol/kg/day) divided by the mean body weight of overall subjects. When the subjects were divided into four groups by average ethanol intake per body weight per day, systolic and diastolic blood pressures were significantly higher in light (>0, <0.23 g ethanol/kg body weight/day),
Table 1. Profiles of subjects in different body weight groups and overall subjects

<table>
<thead>
<tr>
<th>Quartile of BW</th>
<th>First quartile of BW (n = 6651)</th>
<th>Second quartile of BW (n = 6737)</th>
<th>Third quartile of BW (n = 6928)</th>
<th>Fourth quartile of BW (n = 6689)</th>
<th>Overall subjects (n = 27,005)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>45.7 ± 5.2</td>
<td>45.1 ± 5.3††</td>
<td>44.4 ± 5.3††</td>
<td>43.5 ± 5.2††</td>
<td>44.7 ± 5.3</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>54.6 ± 3.6</td>
<td>62.4 ± 1.7††</td>
<td>68.6 ± 2.0††</td>
<td>79.3 ± 6.6††</td>
<td>66.3 ± 9.8</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>20.29 ± 1.65</td>
<td>22.42 ± 1.52††</td>
<td>24.08 ± 1.58††</td>
<td>26.87 ± 2.48††</td>
<td>23.42 ± 3.02</td>
</tr>
<tr>
<td>Cigarette smokers (%)</td>
<td>74.7</td>
<td>67.8††</td>
<td>64.9††</td>
<td>64.0††</td>
<td>67.8</td>
</tr>
<tr>
<td>Alcohol intake</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g ethanol/day</td>
<td>31.58 ± 31.23</td>
<td>31.95 ± 31.06</td>
<td>31.84 ± 30.08</td>
<td>31.03 ± 30.67</td>
<td>31.60 ± 30.76</td>
</tr>
<tr>
<td>g ethanol/kg BW/day</td>
<td>0.580 ± 0.576</td>
<td>0.512 ± 0.498†</td>
<td>0.465 ± 0.439†</td>
<td>0.395 ± 0.391†</td>
<td>0.488 ± 0.485</td>
</tr>
<tr>
<td>Alcohol drinkers (%)</td>
<td>75.7</td>
<td>77.3</td>
<td>79.0</td>
<td>77.5</td>
<td>77.4</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>123.7 ± 15.4</td>
<td>126.2 ± 15.3††</td>
<td>129.0 ± 15.4††</td>
<td>133.4 ± 15.5††</td>
<td>128.1 ± 15.8</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>73.7 ± 10.2</td>
<td>75.8 ± 10.4††</td>
<td>78.3 ± 10.4††</td>
<td>82.0 ± 11.1††</td>
<td>77.5 ± 11.0</td>
</tr>
</tbody>
</table>

Means with standard deviations of age, body weight (BW), body mass index, alcohol intake and blood pressure, and percentages of cigarette smokers and alcohol drinkers are shown. Quartile groups of body weight were prepared as follows: the values of body weight were arranged in ascending order, and then the subjects were divided into four groups of approximately equal sizes. SBP, systolic blood pressure; DBP, diastolic blood pressure. Significant differences from the first quartile group of body weight (††P < 0.01).

Table 2. Univariate analyses of the relationships between alcohol intake and blood pressure in subjects of each quartile group of body weight and overall subjects

<table>
<thead>
<tr>
<th>Quartile of BW</th>
<th>First quartile of BW (n = 6651)</th>
<th>Second quartile of BW (n = 6737)</th>
<th>Third quartile of BW (n = 6928)</th>
<th>Fourth quartile of BW (n = 6689)</th>
<th>Overall subjects (n = 27,005)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-drinkers (0 g/day)</td>
<td>(n = 1615)</td>
<td>(n = 1531)</td>
<td>(n = 1458)</td>
<td>(n = 1507)</td>
<td>(n = 6111)</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>119.8 ± 13.7</td>
<td>123.4 ± 14.4††</td>
<td>126.3 ± 14.6††</td>
<td>132.1 ± 15.6††</td>
<td>125.3 ± 15.3</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>70.8 ± 9.1</td>
<td>73.4 ± 9.9††</td>
<td>76.3 ± 9.9††</td>
<td>80.8 ± 11.4††</td>
<td>75.2 ± 10.8</td>
</tr>
<tr>
<td>Light drinkers (&gt;0, &lt;15 g/day)</td>
<td>(n = 715)</td>
<td>(n = 731)</td>
<td>(n = 811)</td>
<td>(n = 857)</td>
<td>(n = 3114)</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>120.2 ± 14.3</td>
<td>121.8 ± 13.7††</td>
<td>126.4 ± 14.9††</td>
<td>131.8 ± 14.9††</td>
<td>125.3 ± 15.2</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>71.6 ± 9.5</td>
<td>73.1 ± 9.2††</td>
<td>76.7 ± 10.1††</td>
<td>80.8 ± 10.4††</td>
<td>75.8 ± 10.5</td>
</tr>
<tr>
<td>Moderate drinkers (≥15, &lt;30 g/day)</td>
<td>(n = 1765)</td>
<td>(n = 1828)</td>
<td>(n = 1946)</td>
<td>(n = 1752)</td>
<td>(n = 7291)</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>122.8 ± 14.5**</td>
<td>125.4 ± 15.0**,††</td>
<td>127.7 ± 14.6††</td>
<td>132.0 ± 14.9††</td>
<td>127.0 ± 15.1**</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>73.4 ± 9.9**</td>
<td>75.3 ± 10.0**,††</td>
<td>77.5 ± 9.7**,††</td>
<td>81.3 ± 11.2††</td>
<td>76.9 ± 10.6**</td>
</tr>
<tr>
<td>Heavy drinkers (≥30 g/day)</td>
<td>(n = 2556)</td>
<td>(n = 2647)</td>
<td>(n = 2713)</td>
<td>(n = 2573)</td>
<td>(n = 10,489)</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>127.9 ± 16.3**</td>
<td>129.5 ± 15.8**,††</td>
<td>132.2 ± 16.0**,††</td>
<td>135.7 ± 15.6**,††</td>
<td>131.3 ± 16.2**</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>76.4 ± 10.7**</td>
<td>78.1 ± 10.7**,††</td>
<td>80.5 ± 10.8**,††</td>
<td>83.5 ± 10.8**,††</td>
<td>79.6 ± 11.1**</td>
</tr>
</tbody>
</table>

Means with standard deviations of systolic blood pressure (SBP) and diastolic blood pressure (DBP) are shown. Quartile groups of body weight (BW) were prepared as follows: the values of body weight were arranged in ascending order, and then the subjects were divided into four groups of approximately equal sizes. Significant differences from the non-drinker group (*P < 0.05; **P < 0.01) or the first quartile group of body weight (††P < 0.01).

Fig. 1. Multivariate analyses of the relationships between alcohol intake and blood pressure in subjects of each quartile group of body weight. Means with standard errors of systolic blood pressure and diastolic blood pressure are shown. Quartile groups of body weight were prepared as follows: the values of body weight were arranged in ascending order, and then the subjects were divided into four groups of approximately equal sizes. Subjects in each quartile group of body weight were divided into four subgroups according to ethanol consumption per day (non-drinkers; light drinkers, <15 g of ethanol per day; moderate drinkers, ≥15 g and <30 g of ethanol per day; heavy drinkers, ≥30 g of ethanol per day). Asterisks denote significant differences from non-drinkers (*P < 0.05; **P < 0.01).
Fig. 2. Multivariate analyses of the relationships between alcohol intake and blood pressure in overall subjects. Means with standard errors of systolic blood pressure and diastolic blood pressure are shown. Overall subjects were divided into four groups by average alcohol intake using units of alcohol intake: g ethanol/day (A) or g ethanol/kg body weight/day (B). The border values (0.23 and 0.46 g ethanol/kg body weight/day), separating the groups using the unit of g ethanol/kg body weight/day, were defined as the approximate values of the other border values (15 and 30 g ethanol/day) divided by the mean body weight of overall subjects. Asterisks denote significant differences from non-drinkers (∗∗P < 0.01).

moderate (≥0.23, <0.46 g ethanol/kg body weight/day) and heavy drinkers (≥0.46 g ethanol/kg body weight/day) than in non-drinkers (Fig. 2B). More linear relationships of alcohol intake with systolic and diastolic blood pressures were obtained when the unit of ethanol intake per body weight per day was used (Fig. 2B) compared with the results of analyses using the unit of ethanol intake per day (Fig. 2A).

**Associations of alcohol intake with blood pressure in subjects in different BMI groups**

Systolic blood pressure was significantly higher in moderate and heavy drinkers than in non-drinkers in the first, second and third quartile groups of BMI, while in the fourth quartile group of BMI, systolic blood pressure was significantly higher in heavy drinkers than in non-drinkers but was not significantly different in moderate drinkers and non-drinkers (Fig. 3A). Diastolic blood pressure was significantly higher in moderate and heavy drinkers than in non-drinkers in all four quartile groups of BMI, and the difference in diastolic blood pressure of moderate drinkers and non-drinkers tended to be greater in subjects with lower BMI (Fig. 3B).

**DISCUSSION**

In the present study, the blood pressure of subjects with low body weight was higher in moderate and heavy drinkers than in non-drinkers, while the blood pressure of subjects with high body weight was higher in heavy drinkers than in non-drinkers but was not different in moderate drinkers and non-drinkers. This study also showed that the differences in blood pressure between moderate drinkers and non-drinkers and between heavy drinkers and non-drinkers tended to be greater in subject groups with lower body weight. Therefore, the association of alcohol intake with blood pressure was stronger in subjects with low body weight than in those with high body weight, and this finding was also observed when the three subject groups of non-drinkers, light-to-moderate drinkers (<30 g/day) and heavy drinkers (≥30 g/day) were used for analysis (data not shown). These results suggest that men with low body weight are more prone to be influenced by habitual alcohol drinking than are men with high body weight and agree with the concept of the JNC 7 Report, in which men with low body weight are recommended to restrict alcohol consumption to half of that for normal men (Chobanian et al., 2003). However, precise
Fig. 3. Multivariate analyses of the relationships between alcohol intake and blood pressure in subjects of each quartile group of body mass index (BMI). Means with standard errors of systolic blood pressure and diastolic blood pressure are shown. Quartile groups of BMI were prepared as follows: the values of BMI were arranged in ascending order, and then the subjects were divided into four groups of approximately equal sizes. Subjects in each quartile group of BMI were divided into four subgroups according to ethanol consumption per day (non-drinkers; light drinkers, <15 g of ethanol per day; moderate drinkers, 15 g to <30 g of ethanol per day; heavy drinkers, ≥30 g of ethanol per day). Asterisks denote significant differences from non-drinkers (*P < 0.05; **P < 0.01).

standards for the limit of alcohol intake for the prevention of hypertension have not so far been defined for persons with low body weight. Moreover, there have been no studies demonstrating that sensitivity to alcohol in relation to blood pressure strongly depends on body weight. In overall subjects, blood pressure in light drinkers (<15 g ethanol/day) was not significantly different compared with that in non-drinkers, while blood pressure in drinkers with alcohol intake of <0.23 g ethanol/kg body weight/day, which corresponds to the approximate level of 15 g ethanol (borderline for light drinkers) divided by the mean body weight of overall subjects, was significantly higher than blood pressure in non-drinkers, and a more linear relationship between alcohol intake and blood pressure was obtained by using body weight-corrected alcohol intake as a variable. Therefore, correction of alcohol intake by body weight is useful for more accurate evaluation of the effects of alcohol on blood pressure. Further studies in which body weight is taken into account are needed to determine the upper limit of alcohol intake for the prevention of hypertension. Obesity is known to be a risk factor for hypertension (Doll et al., 2002; Rahmouni et al., 2005), and blood pressure of subjects with low body weight was much lower than blood pressure of subjects with high body weight in the present study. Thus, it also remains to be determined whether even heavy drinking is allowed for persons who have low body weight and relatively low blood pressure, although there are possibilities of the other health problems caused by heavy drinking. When the same amount of alcohol is consumed, body weight is expected to influence individual sensitivity to alcohol more strongly than BMI that is a good indicator of obesity. Therefore, body weight, but not BMI, was used for classification of subjects in the present study.

In the Kaiser-Permanente study using 83,947 subjects of three races with 83.5% of white, a similar alcohol–blood pressure relationship was shown in tertiles of BMI (Klatsky et al., 1977). On the other hand, a recent study using 1168 SHE Chinese has shown that blood pressure was higher in drinkers than in non-drinkers in subjects with low BMI and this difference was not observed in subjects with high BMI, while there was no interaction between alcohol intake and BMI in relation to blood pressure in 520 HAN Chinese (Li et al., 2006). These findings suggest that there is a racial difference in the influence of BMI on the alcohol–blood pressure relationship. In the present study using 27,005 Japanese, the association of alcohol intake with blood pressure was stronger in subjects with lower BMI than in subjects with higher BMI in an analysis using quartile groups of BMI instead of body weight, and this finding is in line with the results of the analysis using quartile groups of body weight, except for a slight but significant difference in diastolic blood pressure of moderate drinkers and non-drinkers in the fourth quartile group of BMI (Fig. 3B) but not in the fourth quartile group of body weight (Table 2 and Fig. 1B). This difference suggests that body weight is more tightly related to modification of the alcohol–blood pressure association than is BMI. However, it is difficult to determine which factor, body weight or adiposity reflected by BMI, modifies the association between alcohol intake and blood pressure since there is a strong correlation between body weight and BMI.

The mean amount of alcohol consumption per day was not different among the four quartile groups of body weight, and this resulted in the tendency for alcohol consumption corrected by body weight to be higher in the lower quartile group of body weight. Thus, men with lower body weight consumed more alcohol per body weight than did those with higher body weight in the population of the present study, and there is a possibility of greater tolerance to alcohol in men with lower body weight. Our previous cross-sectional study has also shown that BMI was not different in non-, light and heavy drinkers (Wakabayashi and Kobaba-Wakabayashi, 2002). However, the relation between alcohol consumption and body weight remains an enigma among nutritionists (Jéquier, 1999), and future studies are needed to determine whether alcohol consumption affects body weight. On the other hand, the percentage of smokers was significantly higher in subjects with lower body weight and the body weight was significantly lower in smokers...
than in non-smokers, and these results agree with the fact that smoking is associated with the reduction of body weight (Higgins and Kjelsberg, 1967; Jacobs and Gottenborg, 1981). The mean age and the percentage of smokers were different among the quartile groups of body weight in the present study, and blood pressure is influenced by both age (Kotchen et al., 1982; Whelton, 1994) and smoking (Omvik, 1996). Then, multivariate analyses adjusting for age and history of smoking were also performed, but the results of the univariate analyses were not altered in the multivariate analyses. Although the association between alcohol intake and blood pressure has been shown to be weaker in non-smokers than in smokers (Keil et al., 1989, 1991; van Leer et al., 1994; Wakabayashi, 2008), the finding of the present study that the association between alcohol intake and blood pressure was stronger in subjects with low body weight than in subjects with high body weight was also observed when only non-smokers were used for analysis (data not shown). Therefore, the influence of body weight on the relationship between alcohol intake and blood pressure was independent of smoking history. Both in the age strata of <45 years and ≥45 years, the association between alcohol intake and blood pressure was stronger in subjects with low body weight than in subjects with high body weight (data not shown), and thus age does not confound the interaction of alcohol and body weight in relation to blood pressure. Therefore, the influence of body weight on the relationships between alcohol intake and blood pressure was independent of age and history of smoking.

Elevation of HDL cholesterol is known to be a major explanatory factor for beneficial effects of moderate drinking on pathogenesis of athero-thrombotic disease (Rimm et al., 1999). In all four quartile groups of body weight, HDL cholesterol was significantly higher in light, moderate and heavy drinkers than in non-drinkers (data not shown), and thus body weight is thought not to modify the association between alcohol intake and HDL cholesterol, while body weight confounds the association between alcohol intake and blood pressure. This difference may be due to higher sensitivity of HDL cholesterol to alcohol than the sensitivity of blood pressure to alcohol, since HDL cholesterol of all four quartile groups of body weight was significantly higher in light drinkers than in non-drinkers, while no significant difference in blood pressure of light drinkers and non-drinkers was found in any of the four quartile groups of body weight.

Possible reasons for causing biases exist in this study. There is a considerable possibility of bias due to self-reported questionnaires, in which drinkers underestimate their alcohol intake. Although subjects who were receiving therapy for any illness were excluded from the subjects of this study, drinkers with health problems including obesity might more frequently underreport alcohol intake than drinkers without health problems. If this is true, the difference between actual alcohol intake and reported alcohol intake of drinkers is expected to be greater in subjects with high body weight than in subjects with low body weight. However, even under this condition, blood pressure was higher in moderate drinkers than in non-drinkers in the first, second and third quartile groups of body weight but not in the fourth quartile group. Therefore, the bias caused by underreporting alcohol intake in drinkers may not alter the conclusion of this study that the association of alcohol intake with blood pressure is stronger in persons with low body weight than in persons with high body weight. There is also a possibility of bias resulting from the assessment of smoking history by using self-reported questionnaires. Data on the length of individual smoking history were not available in this study, and this also causes a bias, since smoking is a major risk factor for atherosclerotic disease, and thus the length of smoking history is associated with the progression of atherosclerosis, which is involved in pathogenesis of hypertension. Drinking pattern, including choice of beverage and binge drinking, might be related to body weight and difference in drinking pattern possibly causes a bias in the present study. There are various lifestyle-related factors that affect blood pressure, such as heredity (family history of hypertension), dietary mineral intake, coffee intake, food frequency assessment (fat and salt intake), physical activity, insulin resistance, socioeconomic status and stressful lifestyle, which were not included in the database used in the present study. There are possibilities of bias related to measurements, such as unclear duration of rest just before the measurement of blood pressure, single measurement of blood pressure, variation of blood pressure measurement by different operators and generic measurement of body weight and height. Although individual sensitivity to alcohol is known to be affected by genetic difference in alcohol-metabolizing enzymes in Asians (Mizoi et al., 1979; Harada et al., 1981), data on polymorphism of alcohol-metabolizing enzymes were not surveyed in the present study. Thus, there is a possibility of bias caused by polymorphisms of alcohol-metabolizing enzymes. However, this may not alter the conclusion of the present study about the interaction between alcohol intake and body weight in relation to blood pressure since there is no evidence of an association between body weight and polymorphisms of alcohol-metabolizing enzymes. Furthermore, prospective studies are needed to clarify causal relationships among alcohol intake, body weight and blood pressure.

In summary, body weight modifies the relationships between alcohol consumption and blood pressure and thus should be taken into account when effects of alcohol on blood pressure are considered. The findings of this study will be useful for the prevention of hypertension and future investigations on the relationships between alcohol and hypertension.

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