Relation between Alcohol Consumption and Arterial Stiffness: a Cross-sectional Study of Middle-aged Japanese Women and Men

S. Sasaki ¹,²; E. Yoshioka, MD, PhD³; Y. Saijo, MD, PhD³; T. Kita, PhD³; E. Okada, PhD¹; A. Tamakoshi, MD, PhD¹; R. Kishi, MD, MPH, PhD⁵

¹Department of Public Health Sciences, Hokkaido University Graduate School of Medicine, Kita 15, Nishi 7, Kita-ku, Sapporo, 060-8638, Japan

²Department of Physical Therapy, Faculty of Human Science, Hokkaido Bunkyo University, 5-196-1 Kogane-chuo, Eniwa, 061-1449, Japan

³Department of Health Science, Asahikawa Medical University, Midorigaoka E2-1-1-1, Asahikawa, 078-8510, Japan

⁴Department of Medical Management and Informatics, Hokkaido Information University, Nishi-Nopporo 59-2, Ebetsu, 069-8585, Japan

⁵Center for Environmental and Health Sciences, Hokkaido University, Kita 12, Nishi 7, Kita-ku, Sapporo, 060-0812, Japan
Corresponding author

R. Kishi, MD, MPH, PhD, Center for Environmental and Health Sciences, Hokkaido University, Kita 12, Nishi 7, Kita-ku, Sapporo, 060-0812, Japan

Tel.: 81-11-706-4747; Fax: 81-11-706-4725; E-mail: rkishi@med.hokudai.ac.jp
Abstract

Epidemiological data indicate the existence of a J-shaped association between alcohol consumption and cardiovascular mobility and mortality. However, studies assessing the relationship between alcohol consumption and pulse wave velocity (PWV) as a marker of arterial stiffness have provided inconsistent results. In addition, data regarding the effect of alcohol on arterial stiffness in women has been limited. This study aimed to clarify the relationship between alcohol consumption and PWV among female and male workers in Japan. Study participants were local government employees in Hokkaido, Japan, who underwent annual health check-ups. All data were collected using self-administered questionnaires. The average daily alcohol consumption of the previous month, based on the alcohol concentration of each beverage type (g/day, ethanol equivalent), was estimated according to the frequency and amount of consumption. Data from 3893 participants (812 women and 3081 men) were analyzed. Compared with subjects who consumed <10 g/day, non-drinkers had significantly higher PWV in women. In men, compared with those who reportedly drank 20–39 g/day, non-drinkers and those who drank <20 g/day and ≥60 g/day had significantly higher PWV. Alcohol consumption showed a J-shaped association with PWV in men ($P$ for quadratic term <0.036) and marginally in women ($P$ <0.056). The results of stratified analyses by age groups showed a significant J-shaped association which was most notable for men ≥45 years ($P$ <0.005). In middle-aged Japanese women and men, light-to-moderate alcohol consumption is associated with lower PWV, which in turn
correlates with a reduction in vascular stiffness.

3 **Key Words:**

4 Alcohol consumption

5 Arterial stiffness

6 Brachial-ankle pulse wave velocity

7 Cardiovascular disease

8 Cardiovascular protection

9 Epidemiology

10

11 **Non-standard Abbreviations and Acronyms:**

12 *PWV,* pulse wave velocity

13 *baPWV,* brachial–ankle pulse wave velocity

14 *TC,* total cholesterol

15 *TG,* triglyceride

16 *ABI,* ankle–brachial index

17 *BMI,* body mass index

18 *HDL-C,* high-density lipoprotein cholesterol
1. **LDL-C**, low-density lipoprotein cholesterol
2. **SBP**, systolic blood pressure
3. **DBP**, diastolic blood pressure
4. **HR**, heart rate
Introduction

A large number of epidemiological studies have reported that light-to-moderate alcohol consumption reduces the risk of cardiovascular disease, whereas excessive alcohol consumption increases the risk in men and women in Western countries and Asia.[1-4] Mechanisms by which excessive alcohol consumption leads to increased cardiovascular risk have been linked to increased blood pressure, inhibition of platelet aggregation, and activation of the fibrinolytic system.[5, 6] The cardiovascular benefit of light-to-moderate alcohol consumption has been explained by its positive effect on lipid metabolism, platelet function, inflammatory processes, and endothelial function.[5-9] Therefore, alcohol has both beneficial and adverse effects on arteriosclerosis depending on the amount consumed.

Pulse wave velocity (PWV) is known to be an early indicator of arterial stiffness, and its elevation is associated with the development of arteriosclerotic diseases.[10-12] The results of previous studies of the effect of alcohol consumption on PWV in men were inconsistent. A U-shaped association was reported in one study,[13] whereas no or positive association was observed in other studies.[14, 15] Moreover, studies investigating the relationship between alcohol consumption and PWV in women are limited. Although two previous studies in Dutch postmenopausal women and young women reported an inverse relationship between alcohol and PWV, [16, 17] the effects of alcohol on PWV, based on the amount of alcohol consumed, have not been evaluated.
In this study, we focused on the importance of the amount of alcohol while investigating the relationship between early cardiovascular markers, such as PWV an index of arterial stiffness, and alcohol consumption in Japanese middle-aged women and men.
Methods

Study Population

Participants were local government employees (2194 women and 8229 men, age: 35–62 years) in Sapporo City who underwent an annual health check-up between April 2003 and March 2004. Data were collected using a self-administered questionnaire, which included items related to alcohol consumption, clinical history, family history, smoking, exercise frequency, and educational background. The questionnaire was distributed to subjects before their annual health check-up and collected during the check-up. Completed questionnaires and written informed consent to review the data were obtained from 1051 women and 3962 men (response rate: women 47.9%, men 48.2%). A total of 1120 subjects were excluded for the following reasons: PWV not measured (n = 613), missing data for alcohol consumption and blood pressure (n = 22), low ankle–brachial pressure index [ABI, <0.9; n = 10; brachial–ankle (ba) PWV values in subjects with peripheral artery disease could not be accurately evaluated], subjects taking medication for hypertension (n = 354), or a history of coronary disease or stroke (n = 121). The final study group thus comprised 812 women and 3081 men.

This study was conducted with the written informed consent of all subjects and was approved by the institutional ethical board for epidemiological studies of Hokkaido University Graduate School of Medicine.
Assessment of alcohol consumption

Alcohol consumption was assessed using a self-administered questionnaire covering the previous month. Each subject was asked about average drinking frequency (days/week) and average amount of different types of alcoholic beverages consumed each time, including beer, sake (rice wine), shochu (traditional Japanese distilled spirit), whisky, wine, or other mixed drinks. The average daily alcohol consumption (g/day, ethanol equivalent) was calculated according to the frequency and amount of alcohol consumed using the following alcohol concentrations of each beverage type: 5% for beer, 15% for sake, 25% for shochu, 40% for whisky, 12% for wine, and 5% for other mixed drinks.[18]

The subjects were divided into the following five categories by sex: non-drinkers, <10 g/day, 10–19 g/day, 20–29 g/day, and ≥30 g/day for women and non-drinkers, <20 g/day, 20–39 g/day, 40–59 g/day, and ≥60 g/day for men. Categorical values were selected on the basis of the generally accepted guideline that alcohol consumption should be limited to no more than 10–20 g/day for women and no more than 20–30 g/day for men in order to prevent hypertension.[19]

PWV Measurements

A volume-plethysmographic device was used to measure baPWV (Form PWV/AVI; model BP-203RPE II, Colin Co., Komaki, Japan).[12] This device records a phonocardiogram, electrocardiogram, and volume pulse form and arterial blood pressure at the left and right brachial and
bilateral ankles. A time-phase analysis between right brachial and volume waveforms at both ankles was used for calculating baPWV. The characteristic points of waveforms were determined automatically, and the validity of baPWV measurements has been reported previously.[20] Blood pressure, heart rate (HR), and ABI were measured using a pulse-wave velocimeter concurrently with PWV measurement. ABI is the ratio of ankle systolic blood pressure (SBP) to brachial SBP. Right and left ABIs were measured simultaneously. In all studies, baPWV was obtained after at least 5 min of rest.

9 **Covariates**

Anthropometric measurements (height, body weight) at health check-ups were assessed using a standardized protocol. Body mass index (BMI) was calculated as weight (kg)/height (m)^2. Blood samples were drawn from the antecubital vein of seated subjects with minimal tourniquet use after a 12-h fast. Specimens were collected in siliconized glass vacuum tubes containing sodium fluoride for blood glucose. Total cholesterol (TC) levels were measured by an enzymatic method (Wako, Osaka, Japan), triglyceride (TG) levels by an enzymatic method (Daiichi Pure Chemicals, Tokyo, Japan), high-density lipoprotein cholesterol (HDL-C) levels by a direct method (Daiichi Pure Chemicals), and blood glucose by an amperometric method (Arkray, Kyoto, Japan).

Educational background was categorized as either “high school education or less” or “more than
high school.” Frequency of leisure time exercise (with perspiration) was categorized as “rarely or never,” “1–2 times/week,” or “3 times/week or more.” Smoking status was categorized as “non-smoker” (never smoked), “ex-smoker,” or “current smoker. We asked about current use of hormone (estrogen) replacement therapy in the questionnaire.

6 Statistical Analyses

All analyses were performed for women and men separately. Data are presented as mean ± standard deviation, median (interquartile range) for variables with a skewed distribution, or percentages. TG values were log-transformed to achieve an approximately normal distribution. Differences in the distribution of variables according to alcohol consumption were tested for statistical significance using one-way ANOVA for continuous variables or the chi-square test for categorical variables. For regression analysis, we selected reference categories of alcohol consumption (<10 g/day for women and 20–39 g/day for men) for the following reasons: some Japanese cohort studies reported that <46 g/day of alcohol consumption reduced mortality from cardiovascular disease and incidence coronary heart disease in men.[3, 21] With regard to women, a previous study showed that women experience higher cardiovascular risk when men and women consume the same amount of alcohol because the genders metabolize ethanol differently.[22] Therefore, we decided to use a lower reference category for women than for men. Subsequently, we performed multiple liner regression
To investigate the association between alcohol consumption and mean baPWV, we used the following three models: 1 = adjusted for age, SBP, and HR; 2 = adjusted for model 1 variables plus menopausal status (for women), medication for diabetes, medication for hyperlipemia, BMI, TC, TG, HDL-C, and fasting blood sugar (FBS); and 3 = adjusted for model 2 plus lifestyle factors (educational background, frequency of exercise, and smoking status). In addition, to investigate the non-linear relationship between alcohol consumption and baPWV, the estimated quantitative median value for each category of alcohol consumption was included as linear and quadratic terms in the model. Finally, to clarify the effect of age on the relation between alcohol and baPWV, we performed stratified analyses by age group in men only, because the sample size was too small to analyze in women. All analyses were conducted using JMP Pro software, version 10.0.0 for Windows (SAS Institute, Cary, NC, USA), and statistical significance was defined as a two-tailed $P$ value of $<0.05$. 
Results

A large number of women (46.7%) reported no consumption of alcohol compared with men (27.7%). Characteristics of women participants stratified by the category of alcohol consumption are reported in Table 1. The mean PWV value was the lowest in the subjects belonging to the <10 g/day alcohol consumption category compared with non-drinkers and subjects belonging to the heavier categories of alcohol consumption, and was elevated with an increase in the amount of alcohol consumed. SBP and diastolic blood pressure (DBP), HDL-C, and uric acid showed a positive linear trend related to alcohol consumption, whereas low-density lipoprotein cholesterol (LDL-C) showed an inverse linear trend. Table 2 shows the characteristics of male participants based on the alcohol consumption category. The mean PWV value, age, and TG levels were the lowest in subjects belonging to the <20 g/day alcohol consumption category compared with non-drinkers and subjects belonging to the heavier categories of alcohol consumption. The mean PWV value increased with an increase in the amount of alcohol consumed. SBP, DBP, HDL-C, FBS, and uric acid showed a positive linear trend related to alcohol consumption, whereas LDL-C showed an inverse linear trend. The results of multiple linear regression analysis for alcohol consumption and PWV by sex, adjusted for potential confounders, are presented in Tables 3 and 4. In women, non-drinkers had significantly elevated PWV compared with subjects consuming <10 g/day of alcohol. In men, compared with those who consumed 20–39 g/day of alcohol, non-drinkers and those who consumed <20 g/day and ≥60
g/day of alcohol had significantly elevated PWV. There was no change in this finding after adjustment
for the hormone replacement therapy included in the final models. In the present study, postmenopausal hormone replacement therapy did not affect the association between alcohol consumption and PWV. A J-shaped association between alcohol consumption and PWV was significant for men and marginally significant for women, after adjustment for various arteriosclerotic risk factors (P for quadratic term = 0.056 in women and 0.036 in men). We also examined effect modification by age group (<45 years and ≥45 years) for men (Table 5). A significant J-shaped association was found for men ≥45 years (P for quadratic term = 0.005), but not for the younger age group. (P for quadratic term = 0.938).
Discussion

The present study showed that in women, non-drinking was significantly associated with higher PWV compared with drinking of <10 g/day of alcohol. In men, non-drinkers and those who drank <20 g/day and ≥60 g/day had significantly higher PWV compared with those who drank 20–39 g/day. We examined whether the effects of alcohol consumption on PWV were linear or not, by testing a quadratic term in the model containing potential confounders. A J-shaped association between alcohol consumption and PWV was significant for men and marginally significant for women. In the analyses stratified by age group, the protective effect of light alcohol consumption was evident only for men >45 years.

To the best of our knowledge, there are a limited number of studies reporting the association between alcohol consumption and PWV in women. A cross-sectional study in Japanese–American women evaluating drinking history reported that the risk for high PWV was lower among current drinkers and ex-drinkers than among non-drinkers.[23] Two cross-sectional studies in Dutch women suggested that light-to-moderate alcohol consumption, evaluated on the basis of glass per day or week, is associated with lower PWV.[16, 17] The advantages of our study include large sample size and more detailed estimation of the average daily alcohol consumption. Our results demonstrated that women who consumed a low amount of alcohol (1–10 g/day) had lower PWV compared with non-drinkers. This association was not affected by controlling for potential confounders. However, a
J-shaped association between alcohol consumption and PWV was marginal in women. It may be that the numbers of women in our study, particularly in the group of 20-29g/day and 30g/day, were too small for statistical detection of a J-shaped association. Further research is needed to clarify the effect of alcohol consumption on arterial stiffness in women.

In men, a few studies investigating the effect of alcohol on PWV have reported conflicting results. A follow-up study in Japanese men suggested that alcohol consumption was not related to PWV.[14] Whereas a longitudinal study and a cross-sectional study in Japanese men reported that alcohol consumption was associated with increased PWV.[15, 24] Cross-sectional studies in Dutch middle-aged men and a follow-up study in Japanese men suggested the protective effects of light-to-moderate alcohol consumption on PWV.[13, 25] Consistent with these two studies, we found a J-shaped association between alcohol consumption and PWV. However, the sample size of the previous two studies was comparatively small, while that of ours was larger. Men who did not consume alcohol and those who consumed <20 g/day and ≥60 g/day of alcohol had significantly higher PWV compared with those who consumed 20–39 g/day of alcohol. We also examined effect modification by age among men; a J-shaped association was evident for men >45 years, but not for younger male adults. Consistent with the present study, a cross-sectional study reported that the protective effect of alcohol on PWV was not evident in young Dutch men.[17] They suggested that the beneficial effect obtained by moderate alcohol consumption in younger adults may be negligible.
for lower risk of coronary heart disease. The association between alcohol consumption and PWV, as a marker of early stage atherosclerosis, might be influenced by age.

With regard to both women and men, our results indicated that light-to-moderate alcohol consumption among healthy Japanese workers was associated with reduced PWV, a marker of arterial stiffness. It would represent a plausible explanation for the beneficial health effect of alcohol. Some Japanese cohort studies reported that light to moderate alcohol consumption, <23g/day for women and <46g/day for men, was associated with a reduced risk of cardiovascular disease. [3, 21]

The mechanisms underlying the association between alcohol consumption and arterial stiffness are not completely understood. The protective effect on arteriosclerosis induced by light-to-moderate alcohol consumption may involve increasing HDL-C and improving lipid metabolic pathways.[6, 26]

In this study, the association between alcohol consumption and PWV remained after adjustments for serum lipid levels. The hypothesized beneficial relationship between alcohol consumption and arterial stiffness might also be associated with a decrease in inflammatory mediators such as interleukin-6, C-reactive protein, and tumor necrosis factor-alpha, improving insulin sensitivity and insulin resistance, and improving various metabolic pathways, such as vascular endothelial cell nitric oxide production.[6, 7, 27, 28] In contrast, excess alcohol consumption may elevate blood pressure,[6] an important determinant of arterial stiffness, through several mechanisms, such as influencing the vascular smooth muscle or stimulating the sympathetic nervous system or the
renin–angiotensin–aldosterone system.[29] Therefore, the effects of alcohol consumption on arterial stiffness have a dual contribution to the J-shaped association. These diverse mechanisms should be considered when evaluating the protective and adverse effect of alcohol on arterial stiffness.

Several limitations should be considered when interpreting our results. First, because our study had a cross-sectional design, the causal nature of the association between alcohol consumption and PWV cannot be determined. Second, because the response rate of our study was rather low (women 47.9%, men 48.2%), our subjects might not necessarily be representative of the general group of civil servants in Japan. However, because the average amount of alcohol consumed in our study did not differ from that by the general Japanese population,[30] we believe that our results were minimally affected by the population segment evaluated. Third, we relied on self-reported alcohol consumption in the present study, which could be susceptible to misclassification, particularly by those belonging to the heavier drinking category.[31] However, since we observed a positive correlation between alcohol consumption and HDL-C, selective underestimation of heavy drinkers seems unlikely. Fourth, although we focused on the importance of the amount of alcohol consumed, information on drinking patterns may be equally important. However, the percentage of heavy drinkers who reported consumption of a large amount of alcohol at one time was less than 2% for both women and men. Thus, it appears that binge drinking rarely occurred among our subjects. Fifth, we also considered the possibility of confounding dietary factors, which have not been measured in detail. Japanese
The results of our study indicate that light-to-moderate alcohol consumption may be associated with reduced PWV as a marker of arterial stiffness in middle-aged Japanese women and men. Since the effect of alcohol consumption on arterial stiffness may contribute to a reduction in the incidence of cardiovascular disease, further research is needed to examine the most appropriate amount of alcohol, which could be suggested as a modifiable lifestyle factor.
Sources of Funding

This work was supported in part by a Grant-in-Aid for Young Scientists from the Ministry of Education, Culture, Sports, Science and Technology of Japan and a Grant-in-Aid for Scientific Research from the Ministry of Health, Labor and Welfare of Japan.

Disclosures

The authors declare no conflict of interest.

Acknowledgments

We wish to thank Mr. Manabu Shojiguchi, Mr. Hiroyuki Arizuka, Ms. Toyoko Enomoto, Mr. Takanori Mogi, Mr. Naoto Sasaki, Mr. Takeshi Tsuda, Ms. Tomoko Arihara, Dr. Toshiyuki Hayashi, Ms. Chizuko Sato, and Dr. Takehito Nakanbayashi for their excellent assistance with data collection, and Ms. Akemi Onodera, Ms. Maki Fukushima, and Ms. Aki Yasuike for their assistance with baPWV measurements. The authors also are grateful to Sharon Hanley of the Hokkaido University for her help in proofreading the English manuscript.
References


13. Matsumoto, C., Tomiyama, H., Yamada, J., Yoshida, M., Shiina, K., Nagata, M., and 
Yamashina, A. (2009). Association of blood pressure levels with the effects of alcohol 

factors for the incidence of aortic stiffness by serial aortic pulse wave velocity 

Tatara, K. (2001). Association of alcohol consumption with increase in aortic stiffness: a 

16. Sierksma, A., Lebrun, C.E., van der Schouw, Y.T., Grobbee, D.E., Lamberts, S.W., 
and aortic wave reflections: a cross-sectional study in healthy postmenopausal women. 

17. van den Elzen, A.P., Sierksma, A., Oren, A., Vos, L.E., Witteman, J.C., Grobbee, D.E., 


Management of Arterial Hypertension: The Task Force for the Management of Arterial 
Hypertension of the European Society of Hypertension (ESH) and of the European Society 


22. Di Castelnuovo, A., Costanzo, S., Bagnardi, V., Donati, M.B., Iacoviello, L., and de Gaetano, 
meta-analysis of 34 prospective studies. Arch Intern Med 166, 2437-2445.

23. Namekata, T., Moore, D., Suzuki, K., Mori, M., Hatano, S., Hayashi, C., Abe, N., and 


Table 1. Characteristics according to average daily alcohol consumption for women (n = 812)

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Total</th>
<th>Alcohol consumption (g/day)</th>
<th>P value&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Non-drinkers</td>
<td>&lt;10</td>
<td></td>
</tr>
<tr>
<td>Number</td>
<td>812</td>
<td>812</td>
<td>381</td>
<td>145</td>
</tr>
<tr>
<td>baPWV (cm/s)</td>
<td>812</td>
<td>1240 ± 176</td>
<td>1243 ± 178</td>
<td>1212 ± 163</td>
</tr>
<tr>
<td>Age</td>
<td>812</td>
<td>46.5 ± 7.1</td>
<td>47.4 ± 7.4</td>
<td>45.6 ± 6.4</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>812</td>
<td>113.6 ± 15.1</td>
<td>112.4 ± 14.8</td>
<td>112.7 ± 14.4</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>812</td>
<td>68.7 ± 10.0</td>
<td>67.5 ± 9.2</td>
<td>68.4 ± 10.7</td>
</tr>
<tr>
<td>HR</td>
<td>812</td>
<td>59.5 ± 8.1</td>
<td>59.5 ± 8.1</td>
<td>60.0 ± 8.8</td>
</tr>
<tr>
<td>BMI</td>
<td>812</td>
<td>21.7 ± 3.2</td>
<td>21.8 ± 3.4</td>
<td>21.8 ± 3.2</td>
</tr>
<tr>
<td>TC (mg/dl)</td>
<td>812</td>
<td>197.5 ± 32.4</td>
<td>209.6 ± 32.3</td>
<td>206.6 ± 31.7</td>
</tr>
<tr>
<td>HG (mg/dl)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>812</td>
<td>68.3 (66.1, 70.6)</td>
<td>67.6 (64.5, 70.7)</td>
<td>64.5 (60.0, 69.4)</td>
</tr>
<tr>
<td>HDL-C (mg/dl)</td>
<td>812</td>
<td>70.2 ± 15.0</td>
<td>67.9 ± 14.7</td>
<td>69.3 ± 14.3</td>
</tr>
<tr>
<td>LDL-C (mg/dl)</td>
<td>812</td>
<td>121.6 ± 30.3</td>
<td>126.4 ± 29.5</td>
<td>122.6 ± 30.7</td>
</tr>
<tr>
<td>Fasting glucose (mg/dl)</td>
<td>812</td>
<td>88.1 ± 13.8</td>
<td>87.3 ± 11.6</td>
<td>88.8 ± 22.3</td>
</tr>
<tr>
<td>Uric acid (mg/dl)</td>
<td>812</td>
<td>4.5 ± 1.0</td>
<td>4.3 ± 1.0</td>
<td>4.4 ± 1.0</td>
</tr>
<tr>
<td>Menopause</td>
<td>812</td>
<td>301 (37.3%)</td>
<td>162 (42.9%)</td>
<td>42 (29.2%)</td>
</tr>
<tr>
<td>Yes</td>
<td>812</td>
<td>506 (62.7%)</td>
<td>216 (57.1%)</td>
<td>102 (70.8%)</td>
</tr>
<tr>
<td>No</td>
<td>812</td>
<td>301 (37.3%)</td>
<td>162 (42.9%)</td>
<td>42 (29.2%)</td>
</tr>
<tr>
<td>Variable</td>
<td>Yes</td>
<td>No</td>
<td>p-value</td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------------</td>
<td>----------------------</td>
<td>---------------------</td>
<td>---------</td>
<td></td>
</tr>
<tr>
<td>Medication for hyperlipemia</td>
<td>5 (0.6%)</td>
<td>807 (99.4%)</td>
<td>0.249</td>
<td></td>
</tr>
<tr>
<td>Educational background</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥High school</td>
<td>462 (56.9%)</td>
<td>350 (43.1%)</td>
<td>0.058</td>
<td></td>
</tr>
<tr>
<td>&lt;High school</td>
<td>200 (52.5%)</td>
<td>181 (47.5%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency of exercise</td>
<td>546 (67.2%)</td>
<td>259 (68.0%)</td>
<td>0.498</td>
<td></td>
</tr>
<tr>
<td>Rarely or never</td>
<td>200 (52.5%)</td>
<td>259 (68.0%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1–2 times/week</td>
<td>92 (63.5%)</td>
<td>88 (60.7%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 times/week or more</td>
<td>82 (64.8%)</td>
<td>82 (65.6%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoking status</td>
<td>114 (78.6%)</td>
<td>112 (76.6%)</td>
<td>&lt;0.0001</td>
<td></td>
</tr>
<tr>
<td>Non-smoker</td>
<td>114 (78.6%)</td>
<td>112 (76.6%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ex-smoker</td>
<td>82 (65.6%)</td>
<td>82 (65.6%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td>203 (25.0%)</td>
<td>77 (20.2%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Variables are presented as mean ± standard deviation (SD), geometric mean (95% confidence interval [CI]), or number (percentage).

aLog-transformed data were analyzed, and means (95% CI) were back-transformed.
bResults of one-way ANOVA for continuous variables and the chi-square test or Fisher exact test for categorical variables are presented.
Table 2. Characteristics according to average daily alcohol consumption for men (n = 3081)

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Total</th>
<th>Non-drinkers</th>
<th>&lt;20</th>
<th>20–39</th>
<th>40–59</th>
<th>60≤</th>
<th>P value&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>3081</td>
<td>853</td>
<td>709</td>
<td>586</td>
<td>418</td>
<td>515</td>
<td></td>
<td></td>
</tr>
<tr>
<td>baPWV (cm/s)</td>
<td>3081</td>
<td>1350±187</td>
<td>1329±179</td>
<td>1320±168</td>
<td>1345±178</td>
<td>1380±193</td>
<td>1405±215</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Age</td>
<td>3081</td>
<td>47.9±6.9</td>
<td>48.2±7.2</td>
<td>46.9±7.0</td>
<td>47.8±6.7</td>
<td>48.5±6.5</td>
<td>48.5±6.5</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>3081</td>
<td>121.2±14.4</td>
<td>117.9±13.5</td>
<td>118.3±13.3</td>
<td>122.5±14.0</td>
<td>124.8±14.7</td>
<td>126.2±14.8</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>3081</td>
<td>76.7±10.4</td>
<td>74.1±9.6</td>
<td>74.6±10.0</td>
<td>77.9±10.2</td>
<td>79.4±10.2</td>
<td>80.5±10.8</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>HR</td>
<td>3081</td>
<td>60.4±9.3</td>
<td>60.7±9.5</td>
<td>59.9±9.1</td>
<td>60.2±9.3</td>
<td>59.7±9.0</td>
<td>61.5±9.7</td>
<td>0.014</td>
</tr>
<tr>
<td>BMI</td>
<td>3081</td>
<td>23.7±2.9</td>
<td>23.8±3.1</td>
<td>23.5±3.0</td>
<td>23.9±2.7</td>
<td>23.5±2.6</td>
<td>23.8±2.8</td>
<td>0.149</td>
</tr>
<tr>
<td>TC (mg/dl)</td>
<td>3081</td>
<td>207.6±33.5</td>
<td>209.3±33.5</td>
<td>206.8±33.2</td>
<td>207.2±33.6</td>
<td>207.8±33.9</td>
<td>206.1±33.3</td>
<td>0.459</td>
</tr>
<tr>
<td>TG (mg/dl)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3081</td>
<td>106.8</td>
<td>105.7</td>
<td>99.7</td>
<td>108.9</td>
<td>109.2</td>
<td>114.8</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>(104.8, 108.8)</td>
<td></td>
<td>(102.2, 109.3)</td>
<td>(96.0, 103.5)</td>
<td>(104.0, 114.0)</td>
<td>(104.2, 114.5)</td>
<td>(109.6, 120.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HDL-C (mg/dl)</td>
<td>3081</td>
<td>56.8±14.3</td>
<td>51.5±12.2</td>
<td>56.1±12.8</td>
<td>57.5±15.5</td>
<td>61.0±14.4</td>
<td>62.0±15.2</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>LDL-C (mg/dl)</td>
<td>3081</td>
<td>126.3±31.7</td>
<td>133.8±30.9</td>
<td>127.9±30.0</td>
<td>124.1±32.4</td>
<td>122.2±31.6</td>
<td>117.5±31.8</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Fasting glucose (mg/dl)</td>
<td>3081</td>
<td>95.2±20.8</td>
<td>93.4±18.1</td>
<td>93.8±19.1</td>
<td>94.8±19.1</td>
<td>96.3±20.5</td>
<td>99.8±27.5</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Uric acid (mg/dl)</td>
<td>3081</td>
<td>5.9±1.2</td>
<td>5.7±1.1</td>
<td>5.8±1.1</td>
<td>5.9±1.2</td>
<td>6.1±1.2</td>
<td>6.0±1.2</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Medication for diabetes (mg/dl)</td>
<td>3081</td>
<td>0.421</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>61</td>
<td>22 (2.6%)</td>
<td>10 (1.7%)</td>
<td>16 (2.3%)</td>
<td>5 (1.2%)</td>
<td>8 (1.6%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>---------------------</td>
<td>----------------------</td>
<td>---------------------</td>
<td>----------------------</td>
<td>---------------------</td>
<td>----------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medication for hyperlipemia</td>
<td>3020 (98.0%)</td>
<td>831 (97.4%)</td>
<td>576 (98.3%)</td>
<td>693 (97.7%)</td>
<td>413 (98.8%)</td>
<td>507 (98.4%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>118 (3.8%)</td>
<td>39 (4.6%)</td>
<td>19 (3.2%)</td>
<td>32 (4.5%)</td>
<td>15 (3.6%)</td>
<td>13 (2.5%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>2963 (96.2%)</td>
<td>814 (95.4%)</td>
<td>567 (96.8%)</td>
<td>677 (95.5%)</td>
<td>403 (96.4%)</td>
<td>502 (97.5%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Educational background</td>
<td>3081</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥High school</td>
<td>1317 (42.7%)</td>
<td>330 (38.7%)</td>
<td>377 (53.2%)</td>
<td>252 (43.0%)</td>
<td>168 (36.7%)</td>
<td>189 (36.7%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;High school</td>
<td>1765 (57.3%)</td>
<td>523 (61.3%)</td>
<td>332 (46.8%)</td>
<td>334 (57.0%)</td>
<td>250 (59.8%)</td>
<td>326 (63.3%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency of exercise</td>
<td>3078</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rarely or never</td>
<td>1684 (54.7%)</td>
<td>495 (58.1%)</td>
<td>354 (50.0%)</td>
<td>325 (55.5%)</td>
<td>223 (53.4%)</td>
<td>287 (55.8%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1–2 times/week</td>
<td>897 (29.1%)</td>
<td>224 (26.3%)</td>
<td>240 (33.9%)</td>
<td>181 (30.9%)</td>
<td>122 (29.2%)</td>
<td>129 (25.1%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 times/week or more</td>
<td>498 (16.2%)</td>
<td>133 (15.6%)</td>
<td>114 (16.1%)</td>
<td>80 (13.7%)</td>
<td>73 (17.5%)</td>
<td>98 (19.1%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoking status</td>
<td>3081</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-smoker</td>
<td>729 (23.7%)</td>
<td>233 (27.3%)</td>
<td>234 (33.0%)</td>
<td>117 (20.0%)</td>
<td>71 (17.0%)</td>
<td>73 (14.2%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ex-smoker</td>
<td>802 (26.0%)</td>
<td>181 (21.2%)</td>
<td>207 (29.2%)</td>
<td>163 (27.8%)</td>
<td>121 (29.0%)</td>
<td>130 (25.2%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td>1551 (50.3%)</td>
<td>439 (51.5%)</td>
<td>268 (37.8%)</td>
<td>306 (52.2%)</td>
<td>226 (54.1%)</td>
<td>312 (60.6%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Variables are presented as mean ± SD, geometric mean (95% CI), or number (percentage).

*Log-transformed data were analyzed, and means (95% CI) were back-transformed.

Results of one-way ANOVA for continuous variables and the chi-square test for categorical variables are presented.
Table 3. Linear regression coefficients (95% CI) for baPWV (cm/s) according to average daily alcohol consumption for women

<table>
<thead>
<tr>
<th>Alcohol consumption (g/day)</th>
<th>Non-drinkers</th>
<th>&lt;10</th>
<th>10–19</th>
<th>20–29</th>
<th>30≤</th>
<th>Linear term</th>
<th>Quadratic term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude</td>
<td>812</td>
<td>31.15 (-2.43, 64.74)</td>
<td>Ref.</td>
<td>7.22 (-34.79, 49.23)</td>
<td>58.61 (7.50, 109.72)</td>
<td>63.83 (18.40, 109.27)</td>
<td>0.401</td>
</tr>
<tr>
<td>Model 1</td>
<td>812</td>
<td>24.24 (2.70, 45.78)</td>
<td>Ref.</td>
<td>11.22 (-15.62, 38.06)</td>
<td>18.09 (-14.69, 50.86)</td>
<td>23.56 (-5.70, 52.83)</td>
<td>0.169</td>
</tr>
<tr>
<td>Model 2</td>
<td>812</td>
<td>26.63 (5.60, 47.66)</td>
<td>Ref.</td>
<td>6.28 (-20.09, 32.65)</td>
<td>14.58 (-17.68, 46.83)</td>
<td>17.61 (-11.55, 46.78)</td>
<td>0.046</td>
</tr>
<tr>
<td>Model 3</td>
<td>812</td>
<td>26.49 (5.35, 47.63)</td>
<td>Ref.</td>
<td>4.78 (-21.69, 31.25)</td>
<td>11.09 (-21.70, 43.87)</td>
<td>13.99 (-15.75, 43.73)</td>
<td>0.032</td>
</tr>
</tbody>
</table>

Model 1: Adjusted for age, SBP, and HR.

Model 2: Model 1+ adjusted for menopause, medication for diabetes, medication for hyperlipemia, BMI, TC, log TG, HDL-C, and FBS.

Model 3: Model 2+ adjusted for lifestyle factors (education, exercise, and smoking).
Table 4. Linear regression coefficients (95% CI) for baPWV (cm/s) according to average daily alcohol for men

<table>
<thead>
<tr>
<th>n</th>
<th>Alcohol consumption (g/day)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non-drinkers</td>
<td>&lt;20</td>
</tr>
<tr>
<td></td>
<td>Crude</td>
<td>3081</td>
</tr>
<tr>
<td></td>
<td>Model 1</td>
<td>3081</td>
</tr>
<tr>
<td></td>
<td>Model 2</td>
<td>3081</td>
</tr>
<tr>
<td></td>
<td>Model 3</td>
<td>3078</td>
</tr>
</tbody>
</table>

Model 1: Adjusted for age, SBP, and HR.

Model 2: Model 1+ adjusted for medication for diabetes, medication for hyperlipemia, BMI, TC, log TG, HDL-C, and FBS.

Model 3: Model 2+ adjusted for lifestyle factors (education, exercise, and smoking).
Table 5. Linear regression coefficients (95% CI) for baPWV (cm/s) according to average daily alcohol consumption by age for men

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Alcohol consumption (g/day)</th>
<th></th>
<th></th>
<th></th>
<th>Linear term</th>
<th>Quadratic term</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;45</td>
<td></td>
<td>Non-drinkers</td>
<td>&lt;20</td>
<td>20–39</td>
<td>40–59</td>
<td>60≤</td>
<td></td>
</tr>
<tr>
<td>Crude</td>
<td>1031</td>
<td>277</td>
<td>281</td>
<td>196</td>
<td>121</td>
<td>156</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Crude</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>19.02 (−12.49, 50.54)</td>
</tr>
<tr>
<td></td>
<td>Model 1</td>
<td>1031</td>
<td>8.29 (−11.49, 28.06)</td>
<td>8.26 (−11.36, 27.88)</td>
<td>Ref.</td>
<td>15.05 (−9.19, 39.23)</td>
<td>1.82 (−20.85, 24.48)</td>
</tr>
<tr>
<td></td>
<td>Model 2</td>
<td>1031</td>
<td>13.79 (−6.13, 33.72)</td>
<td>11.30 (−8.23, 30.82)</td>
<td>Ref.</td>
<td>11.98 (−12.09, 36.05)</td>
<td>−3.05 (−25.69, 19.60)</td>
</tr>
<tr>
<td></td>
<td>Model 3</td>
<td>1031</td>
<td>12.73 (−7.25, 32.71)</td>
<td>12.19 (−7.47, 31.86)</td>
<td>Ref.</td>
<td>12.42 (−11.61, 36.46)</td>
<td>−5.54 (−28.37, 17.28)</td>
</tr>
<tr>
<td>45≤</td>
<td></td>
<td>576</td>
<td>428</td>
<td>390</td>
<td>297</td>
<td>359</td>
<td></td>
</tr>
<tr>
<td>Crude</td>
<td>2050</td>
<td>−17.26 (−42.23, 7.71)</td>
<td>−20.57 (−47.23, 6.08)</td>
<td>Ref.</td>
<td>35.17 (5.85, 64.50)</td>
<td>63.73 (35.88, 91.57)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Model 1</td>
<td>2050</td>
<td>22.06 (3.79, 40.34)</td>
<td>15.55 (−3.90, 35.01)</td>
<td>Ref.</td>
<td>16.25 (−5.11, 37.61)</td>
<td>36.49 (16.21, 56.78)</td>
<td>0.389</td>
</tr>
<tr>
<td>Model 2</td>
<td>2050</td>
<td>20.46 (2.47, 38.44)</td>
<td>14.57 (−4.28, 33.43)</td>
<td>Ref.</td>
<td>13.56 (−7.17, 34.29)</td>
<td>32.29 (12.44, 52.14)</td>
<td>0.352</td>
</tr>
<tr>
<td>Model 3</td>
<td>2047</td>
<td>19.76 (1.72, 37.80)</td>
<td>16.79 (−2.26, 35.84)</td>
<td>Ref.</td>
<td>13.63 (−7.09, 34.35)</td>
<td>32.87 (12.97, 52.76)</td>
<td>0.390</td>
</tr>
</tbody>
</table>

Model 1: Adjusted for SBP, and HR.

Model 2: Model 1+ adjusted for medication for diabetes, medication for hyperlipemia, BMI, TC, log TG, HDL-C, and FBS.

Model 3: Model 2+ adjusted for lifestyle factors (education, exercise, and smoking).