Original Article

The longitudinal association between alcohol consumption and muscle strength: A population-based prospective study

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Abstract

Objectives: Studies have investigated the association between alcohol consumption and muscle mass and muscle disease. However, the relationship between alcohol consumption and muscle strength remains unclear. This study aimed to prospectively investigate the association between alcohol consumption and changes in muscle strength. **Methods:** This study evaluated 326 Japanese men and women over a 2-year period, assessing alcohol consumption using a brief, self-administered diet-history questionnaire. Muscle strength was assessed using a digital grip dynamometer. **Results:** In a non-adjusted model, alcohol consumption was positively correlated with a decline in muscle strength (p for trend = 0.002). After adjusting model 1 for age, sex, and body mass index, adjusting model 2 for health status and fully adjusting model 3, there was a significant positive association between alcohol consumption and a decline in muscle strength, and this association showed no change over the 2-year period (p for trend = 0.006). **Conclusion:** In this Japanese population, high alcohol consumption was associated with a greater decline in muscle strength. Future studies are needed to ascertain whether this relationship is present in other populations.

Keywords: Alcohol Consumption, Muscle Strength, Prospective Study, Japanese Adults, Drinking Habits

Introduction

Age-related declines in muscle strength are often an important antecedent of disability, and reduced muscle strength is associated with a higher risk of mortality in older populations[1]. Poor muscle strength has also been associated with a high prevalence of functional limitations[2] and with the presence of chronic diseases[3], both in middle-aged and older populations. Middle-aged Japanese men with reduced grip strength had a greater than 2-fold higher mortality risk than those with greater grip strength in a 6-year follow-up study[4].

In recent years, alcohol abuse has exacted staggering economic costs from society and remains a major public health problem. Alcohol use is a predictor of suicide[5] and is positively associated with increased blood pressure[6], risk of depression[7] and stroke[8]. A previous study showed that chronic consumption of alcohol-containing diet by rats produces a myopathy characterized by decreased skeletal muscle protein content and weight[9]. Another study indicated that alcohol consumption resulted in erosion of lean body mass[10]. These studies indicated that alcohol consumption was associated with a loss of muscle mass and a decline in muscle health. Given that muscle mass is positively associated with muscle strength[11], alcohol consumption might also be associated with a decline in muscle strength. However, previous studies have mainly focused on determining the association between alcohol consumption and muscle mass and disease. To our knowledge, no studies to date have investigated whether alcohol consumption is associated with muscle strength in the general population. We therefore designed a longitudinal study to investigate the relationship between alcohol consumption and changes in muscle strength in Japanese adults.

Methods

Population and setting

This longitudinal analysis employed data from the Oroshisho study, which was launched in 2008 and was based on annual health examinations at the Oroshisho Center, Sendai, Miyagi, Japan. Each participant underwent a medical examination and physical performance assessment and filled out a standard questionnaire during a face-to-face interview. Each participant also provided a blood sample.

Our study employed data collected in 2008 (as baseline) and 2010 (as follow-up). All participants provided written informed consent, and the study was approved by the Institutional Review Board of the Tohoku University Graduate School of Medicine. We recruited all participants who underwent the lifestyle-related illnesses and health examination A (n=1253) in 2008. Of these, 1154 agreed to participate and provided their consent for data analysis. Participants were excluded from the present analysis if data on their physical performance (grip strength) (n=573), nutrition intake (n=25), education (n=3), or occupation were missing (n=3). The 224 respondents with missing physical performance data after 2 years were also excluded. Our final study sample consisted of 326 participants (248 men and 78 women).

Alcohol consumption assessment

We assessed the participants' dietary history, which included alcohol consumption, using a brief self-administered diet-history questionnaire (BDHQ) covering the previous month. Based on an average intake frequency of 75 food items, we calculated the estimated daily intake of nutrients and food using the Japanese Standard Tables of Food Composition, fifth edition, for which the BDHQ has been validated[12,13]. To assess alcohol consumption, the participants were asked to state their drinking frequency (never, less than once a week, and ranging from "1 day a week" to "7 days a week"), and the type of alcoholic beverages consumed (Japanese sake, Japanese spirits [shochu], beer, whisky, or wine). Using this information, we calculated the daily alcohol consumption. The men and women were categorized into quartiles according to their baseline alcohol consumption (first quartile for non-drinkers, with the remainder divided into tertiles). The quartiles for the men and women were then combined to determine the final quartile. The ranges for the men's quartiles were 0 g/d for Q1, 0.01-10.05 g/d for Q2, 10.06-34.12 g/d for Q3, and >34.12 g/d for Q4. The ranges for the women's quartiles were 0 g/d for Q1, 0.01-2.29 g/d for Q2, 2.29-12.19 g/d for Q3, and >12.19 g/d for Q4.

Muscle strength assessment

We assessed muscle strength (in kg) through grip strength measured by a handheld dynamometer (TKK 5401 Takai Kiki Co., Tokyo, Japan). The participants stood with their arms and wrists by the sides of the body and were asked to exert maximum grip with each hand. The better of 2 results was chosen for analysis.

Assessment of other variables

Body mass index (BMI) was measured in kg/m^2. Depressive symptoms were assessed using the Japanese version of the self-rating depression scale, with a score ≥45 defined as depression[14]. Physical activity was assessed using the international physical activity questionnaire, and total daily physical activity was calculated as metabolic equivalents of task × h/week[15]. The participants' educational level was defined as the last qualification attained and divided into primary/secondary education and tertiary education. Occupation was divided into 2 categories: sedentary and other. Smoking status was defined as non-smoker or smoker. Marital status was categorized as married or other. Blood pressure was measured using an automatic blood pressure monitor (Yamasu 605; Kenzmedico Co., Ltd., Saitama, Japan). Hypertension was defined as a systolic blood pressure ≥140 mm Hg or a diastolic blood pressure ≥90 mm Hg. Participants undergoing anti-hypertensive drug therapy were also considered to have hypertension. We measured triglyceride and high- and low-density lipoprotein cholesterol levels using enzymatic methods with appropriate kits (Sekisui Medical Co., Ltd., Tokyo, Japan). Hyperlipidemia was defined as triglyceride levels ≥150 mg/dl, high-density lipoprotein levels <40 mg/dl or low-density lipoprotein levels ≥140 mg/dl. Participants undergoing anti-hyperlipidemia drug therapy were also considered to have hyperlipidemia. We measured fasting blood glucose concentrations using enzymatic methods (Eerotec Co., Ltd., Tokyo, Japan). Diabetes was defined as fasting blood glucose concentrations ≥126 mg/dl or undergoing anti-diabetic drug treatment.

Statistical analysis

We employed the baseline alcohol consumption (in quartiles) as the independent variable and the 2-year change in muscle strength as the dependent variable. Changes in muscle strength were calculated as the muscle strength during follow-up minus the baseline muscle strength. We selected the following variables as potential confounding factors: age, sex, BMI, hypertension, hyperlipidemia, diabetes, depressive symptoms, physical activity, educational level, marital status, occupation, smoking habits, total energy intake, total protein intake, C-reactive protein levels, and baseline grip strength. We employed an analysis of covariance to examine the association between alcohol consumption and the change in muscle strength. The results are presented as means with 95% confidence intervals (95% CI). For the data analysis, we employed the statistical package SPSS 17.0 (SPSS Inc., Chicago, IL) and considered $p<0.05$ as statistically significant.

Results

The participants' mean age was 45.6±10.8 years (range, 20-78 years) at baseline, with men accounting for 76.1% of the total population.

Table 1 shows the age- and sex-adjusted baseline

Table 1. Age and sex adjusted baseline characteristics of participant according to alcohol consumption[a].

	Categories of alcohol consumption				trend p[b]
	Q1 (Low)	Q2	Q3	Q4 (High)	
n	75	83	83	85	
Sex (men; %)	61.3	80.7	80.7	80.0	0.017
Age (years)	46.1 (43.7, 48.6)[c]	44.2 (41.9, 46.5)	45.5 (43.2, 47.8)	46.6 (44.4, 48.9)	0.609
BMI (kg/m²)	22.8 (22.1, 23.5)	23.3 (22.6, 24.0)	22.9 (22.2, 23.6)	22.7 (22.0 , 23.3)	0.589
Total energy intake (kcal/d)	1835.6 (1700.1, 1971.2)	1788.5 (1661.0, 1916.0)	1975.9 (1848.7, 2103.1)	2063.0 (1937.2, 2188.7)	0.004
Total protein intake (g/d)	62.9 (57.4, 68.4)	64.1 (59.0, 69.3)	69.2 (64.1, 74.4)	66.5 (61.4, 71.6)	0.191
Vitamin D (mg/d)	10.4 (8.5, 12.3)	11.8 (10.0, 13.6)	13.1 (11.3, 14.9)	13.2 (11.5, 15.0)	0.018
Calcium (mg/d)	496.6 (443.6, 549.6)	498.6 (448.7, 548.5)	510.8 (461.0, 560.5)	457.0 (407.7, 506.2)	0.36
PA (≥ 23 METs h/week; %)	46.7	33.7	43.4	35.3	0.192
Education level ≥12years (%)	14.7	25.3	33.7	23.5	0.235
Occupation (desk work; %)	57.3	48.2	48.2	47.1	0.719
Marital status (Married; %)	53.3	73.5	68.7	78.8	0.015
Smoking (%)	42.7	34.9	33.7	49.4	0.773
Hypertension (%)	13.3	20.5	26.5	38.8	0.001
Diabetes (%)	4.0	7.2	6.0	4.7	0.686
Hyperlipidemia (%)	48.0	41.0	43.4	42.4	0.231
Depressive symptom (%)	40.0	25.3	31.3	31.8	0.462
hsCRP (mg/L)	0.90 (-0.02, 1.82)	1.67 (0.80, 2.54)	0.84 (-0.21, 1.70)	1.12 (0.27, 1.97)	0.932
Grip strength (kg)[d]	39.3 (38.0, 40.6)	40.2 (39.0, 41.4)	40.3 (39.1, 41.4)	40.8 (39.6, 42.1)	0.122

[a] BMI: body mass index; PA: physical activity; hsCRP: high sensitivity C-reactive protein. [b] Obtained using ANCOVA for continuous variables and multiple logistic regression analysis for proportional variables. [c] Mean; 95% CI in parentheses (all such values). [d] Additionally adjusted for BMI, total nutrition intake, PA, education level, occupation, marital status, smoking, hypertension, diabetes, hyperlipidemia, depressive symptoms, hsCRP.

Table 2. Longitudinal association between baseline alcohol consumption and subsequent 2 years decline in muscle strength (kg)[a].

	Categories of alcohol consumption				trend p[b]
	Q1 (Low)	Q2	Q3	Q4 (High)	
All participants (n)	75	83	83	85	
Crude	-0.94 (-1.68, -0.19)	-1.32 (-2.02, -0.61)	-1.67 (-2.38, -0.97)	-2.54 (-3.24, -1.85)	0.002
Model 1[c]	-1.09 (-1.84, -0.34)	-1.28 (-1.99, -0.58)	-1.62 (-2.32, -0.92)	-2.49 (-3.18, -1.79)	0.006
Model 2[d]	-1.02 (-1.76, -0.28)	-1.36 (-2.06, -0.67)	-1.61 (-2.29, -0.93)	-2.48 (-3.18, -1.78)	0.006
Model 3[e]	-0.97 (-1.72, -0.22)	-1.40 (-2.09, -0.70)	-1.60 (-2.28, -0.92)	-2.50 (-3.22, -1.79)	0.006

[a] Variables are expressed as estimated geometrics means (95% CI). [b] Obtained using ANCOVA.
[c] Adjusted for age, sex. [d] Further adjusted for BMI, physical activity, educational level, marital status, occupation, smoking habits, total energy intake, total protein intake, calcium intake, vitamin D intake, C-reactive protein and baseline value of grip strength. [e] Further adjusted for hypertension, hyperlipidemia, diabetes, and depressive symptoms.

Table 3. Sex-specific longitudinal association between baseline alcohol consumption and subsequent 2 years decline in muscle strength (kg)[a].

	Categories of alcohol consumption (g/day)				trend p[b]
Men	Q1 (0)	Q2 (0.01-10.05)	Q3 (10.06-34.12)	Q4 (> 34.12)	
n	46	67	67	68	
Crude	-1.16 (-2.17, -0.14)	-1.62 (-2.46, -0.78)	-1.91 (-2.75, -1.06)	-2.78 (-3.62, -1.94)	0.015
Model 1[c]	-1.16 (-2.18, -0.14)	-1.63 (-2.48, -0.79)	-1.90 (-2.75, -1.06)	-2.77 (-3.61, -1.93)	0.016
Model 2[d]	-0.84 (-1.89, 0.21)	-1.74 (-2.59, -0.89)	-1.96 (-2.79, -1.14)	-2.82 (-3.68, -1.96)	0.006
Model 3[e]	-0.80 (-1.88, 0.27)	-1.78 (-2.65, -0.92)	-1.93 (-2.77, -1.10)	-2.83 (-3.71, -1.96)	0.007
Women	Q1 (0)	Q2 (0.01-2.29)	Q3 (2.29-12.19)	Q4 (> 12.19)	
n	29	16	16	17	
Crude	-0.58 (-1.40, 0.24)	-0.04 (-1.15, 1.06)	-0.68 (-1.79, 0.42)	-1.59 (-2.67, -0.52)	0.096
Model 1[c]	-0.53 (-1.35, 0.30)	-0.05 (-1.16, 1.05)	-0.78 (-1.90, 0.34)	-1.59 (-2.66, -0.52)	0.078
Model 2[d]	-0.65 (-1.47, 0.18)	-0.37 (-1.57, 0.82)	-0.42 (-1.55, 0.71)	-1.43 (-2.52, -0.33)	0.304
Model 3[e]	-0.49 (-1.31, 0.33)	-0.35 (-1.51, 0.82)	-0.43 (-1.55, 0.68)	-1.71 (-2.82, -0.59)	0.114

[a] Variables are expressed as estimated geometrics means (95% CI). [b] Obtained using ANCOVA. [c] Adjusted for age. [d] Further adjusted for BMI, physical activity, educational level, marital status, occupation, smoking habits, total energy intake, total protein intake, calcium intake, vitamin D intake, C-reactive protein and baseline value of grip strength. [e] Further adjusted for hypertension, hyperlipidemia, diabetes, and depressive symptoms.

characteristics of the study participants according to alcohol consumption, which was positively associated with total energy intake and vitamin D intake (*p* for trend = 0.004 and 0.018, respectively). As the alcohol consumption increased, the proportion of participants who were men, married, and hypertensive increased significantly (*p* for trend <0.017, 0.015, and 0.001, respectively).

Table 2 presents the association between alcohol consumption and the decline in muscle strength after 2 years of follow-up. As shown in the crude model, the mean declines in muscle strength according to alcohol consumption quartile were -0.94 (95% CI: -1.68 − -0.19) for Q1 (low), -1.32 (95% CI: -2.02 − -0.61) for Q2, -1.67 (95% CI: -2.38 − -0.97) for Q3, and -2.54 (-3.24 − -1.85) for Q4 (high) (*p* for trend = 0.002). After adjusting model 1 for age, sex, and BMI, high alcohol consumption was also associated with an obvious decline in muscle strength over 2 years (p for trend = 0.006). After adjusting model 2 for health status, the results remained significant and similar to those of model 1 (*p* for trend = 0.006). After fully adjusting model 3, this significant positive association between alcohol consumption and a decline in muscle strength over 2 years did not change (*p* for trend = 0.006). We also performed a sex-stratified analysis for the association between alcohol consumption and grip strength (Table 3). The same association with Table 2 was found in the male participants. However, no significant association was found in the female participants.

Discussion

The present longitudinal study shows that high alcohol consumption (when compared with low and medium alcohol

consumption) was more likely to be associated with a decline in muscle strength after 2 years, even after adjusting for age, sex, lifestyle factors, health conditions, nutrition intake, and high-sensitivity C-reactive protein levels. To our knowledge, this is the first study to examine the longitudinal association between alcohol consumption and muscle strength in healthy Japanese adults. No previous study has examined this association in the general population.

The results of an interventional study on 159 men (58 controls and 101 individuals with alcoholism) confirmed that muscle wasting and weakness appear relatively early in the course of chronic alcoholism[16] and partially agreed with the results of our study. A population-based, cross-sectional study of white American women aged 65 or older suggested that moderate drinkers have better physical function than nondrinkers[17], a finding that is not consistent with our study, which could be explained by the samples' different ages, alcohol consumption and female composition. In our study, we performed a sex-stratified analysis and found a significant association between alcohol consumption and grip strength in the male participants but not in the female participants.

Certain mechanisms might explain the association between high alcohol consumption and lower muscle strength, such as the potential loss of muscle mass caused by alcohol consumption. Studies have indicated that long-term alcohol consumption results in a protracted imbalance in protein homeostasis, manifesting as a decrease in muscle mass and a reduced cross-sectional area for type II fiber-rich muscle[16,18], which could indirectly decrease muscle strength due to the relationship between high muscle mass and high muscle strength[11]. However, this would not explain why we observed an association between alcohol consumption and muscle

strength only in the men. Previous studies have indicated that alcohol impairs skeletal muscle protein synthesis[19] and is associated with inflammation[20]. However, women present higher muscle protein synthesis than men[21,22], and female hormones can serve as a protective factor against inflammatory processes[23], which can weaken alcohol's action on muscle strength. The lack of association between alcohol consumption and grip strength in the female participants could also have been due to an insufficient sample size (n=78). Further study is needed to determine whether alcohol consumption affects muscle strength in women.

A previous study found a high level of malnutrition and risk related to poor appetite and diet quality in a population undergoing alcohol treatment[24]. We therefore considered that high alcohol consumption might be associated with low energy intake, which could result in decreased muscle strength. Our study, however, found a positive association between alcohol consumption and total energy intake (Pearson's correlation, r=0.225, p<0.001), a result consistent with that of previous studies[25,26]. Although we added total energy intake to the confounding factors, the main results were not changed.

According to the Ministerial Notification No. 430 of the Ministry of Health, Labour and Welfare, the Japanese recommendation for alcohol consumption is 40 g/d for men and 20 g/d for women[27]. The average alcohol consumption of the drinking population in our study was 27.4 g/d for men and 12 g/d for women, which was much lower than the recommended amount but does not change the fact that, even within the recommended limits, higher alcohol consumption is associated with decreased muscle strength in the Japanese population. These results are expected to provide important information in the field of preventive medicine and have implications for health guidelines.

Given that this was a follow-up study, the temporal association between the explanatory variables and outcomes was clearer. However, this study had several limitations that are worth discussing. First, the food consumption data were based on the BDHQ. Although the validity of the BDHQ has been verified[12], the participants' actual dietary habits were not observed. Second, although we adjusted the models for a considerable number of confounding factors, we could not exclude the possibility that other covariates could have mediated the association between alcohol consumption and grip strength. Third, data from the participants excluded from the statistical analyses and from those who did not participate in the follow-up could have influenced the results. The differences between participants and nonparticipants for all independent variables were examined; however, there were no significant differences.

The present prospective study found a significant inverse association between alcohol consumption and a change in muscle strength in Japanese adults. Further epidemiological research and randomized trials are needed to ascertain whether this inverse relationship exists in other populations.

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