CLINICAL RESEARCH STUDY

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Type of Alcohol and Blood Pressure: The Copenhagen General Population Study

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ABSTRACT

BACKGROUND: Most adults ingest alcoholic beverages. Alcohol shows strong and positive associations with blood pressure (BP). We hypothesized that intake of red wine, white wine, beer, and spirits and dessert wine show similar associations with BP in the general population.

METHODS: We included 104,467 males and females aged 20-100 years in the analysis of the Danish general population. Alcohol use and type of alcohol were assessed by questionnaire. Blood pressure was measured by automated digital BP manometer. Multivariable linear regression models were used when analyzing the association between number of drinks per week and BP, stratified by sex and adjusted for relevant confounders. Each alcohol type (red wine, white wine, beer, and spirits and dessert wine) was analyzed in similar models including adjustment for other alcohol types.

RESULTS: Most of the subjects (76,943 [73.7%]) drank more than 1 type of alcohol. However, 12,093 (12.6%) consumed red wine only, 4288 (4.5%) beer only, 1815 (1.9%) white wine only, and 926 (1.0%) spirits and dessert wine only. There was a dose-response association between total drinks per week and systolic and diastolic BP (SBP, DBP) ($P < .001$). The crude difference was 11 mmHg SBP and 7 mmHg DBP between high (>35 drinks per week) and low (1-2 drinks per week) alcohol intake. Overall, SBP was increased by 0.15-0.17 mmHG, and DBP was increased by 0.08-0.15 mmHg per weekly drink. After stratification for age and sex, effects were slightly higher among females and among individuals aged less than 60 years.

CONCLUSION: Alcohol intake is associated with highly significant increased SPB and DBP. The effect is similar for red wine, white wine, beer, and spirits.

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KEYWORDS: Alcohol; Beer; Blood pressure; Red wine; Spirits; White wine

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INTRODUCTION

The average annual intake of alcohol in Europe is about 10 liters of pure alcohol per capita in the adult population. In Denmark, the annual intake per capita is 9.2 liters.[1] Alcohol is ingested in various types of beverages, in particular red wine, white wine, beer, and spirits. The alcohol types consumed in different European countries vary, with spirits as the dominating beverage in Eastern Europe, wine in wine-

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growing countries, and beer as the favored alcoholic drink in Western Europe and the northern nations.[2]

Considerable controversy exists regarding the pros and cons of alcohol intake with overall and, particularly, cardiovascular health.[3,4] The association between alcohol intake and blood pressure (BP) level has been examined in numerous epidemiological and clinical studies.[5] There is a positive and graded association between number of alcohol units (drinks) ingested and systolic and diastolic BP (SBP, DBP). Mendelian randomization studies[6] and controlled trials of reduction in alcohol intake among subjects with high BP show a causal association of alcohol and high BP.[7,8] It has been reported that alcohol use in some populations may account for > 15% of cases of hypertension.[7,8]

Many studies of alcohol intake and BP use total amount ingested for assessment of the exposure.[9] Most subjects ingest more than 1 type of alcohol. The separate effects of these alcohol types on BP have been insufficiently studied. It has been suggested that red wine in moderate amounts may be associated with lower BP in females, but not in males.[10] Furthermore, a beneficial effect of beer on endothelial tone has been suggested.[11] The effect of white wine and spirits on BP has, to our knowledge, not been reported previously, nor have the various types of beverages in the same population been analyzed separately.

A large population study from Copenhagen showed large differences in mortality, with red wine drinkers having a lower mortality compared with drinkers of beer and spirits.[12] This gives rise to a related hypothesis—that wine, compared with other types of alcohol, may exert different effects on cardiac risk factors such as BP.

We examined whether various types of alcohol have different associations with BP. In the present contemporary study of 104,467 males and females aged 20-100 years recruited from the general population, we studied the association of red wine, white wine, beer, and spirits with BP, adjusting for potential confounders.

CLINICAL SIGNIFICANCE

- Alcohol intake is associated with highly significant, dose-dependent increases in systolic and diastolic blood pressure.
- This blood pressure raising effect is similar in red wine, white wine, beer, and spirits.
- Alcohol intake less than or equal to 1 drink per day has a neutral effect on blood pressure.

METHODS

Population

We studied 104,467 individuals from the Copenhagen General Population Study,[13] recruited from November 25, 2003, to April 28, 2015. Individuals aged 20−100 years were invited from the general population, using the Danish Civil Registration System. Subjects reporting previous disease (cancer, myocardial infarction, or stroke) (n = 11,634) were excluded in a sensitivity analysis. All individuals were White and of Danish descent. At the date of examination, the participants completed a questionnaire on lifestyle and health, had a physical examination, and provided blood samples. The measurements at the examination were taken by dedicated trained healthcare personnel, who were also responsible for the quality control of the questionnaires.

The study was approved by a Danish ethical committee (H-KF-01-144/01), and all participants gave written informed consent.

Measurements

Alcohol intake was assessed by questionnaire. The subjects were asked to quantify their weekly number of drinks of red wine, white wine, beer, spirits, and dessert wine. One drink was measured as ∼12 grams of alcohol. The total amount of alcohol ingested was determined by adding the number of drinks in each category.

Smoking was assessed by questionnaire and categorized as "never smoker," "ex-smoker," "moderate smoker" (current smoker with < 15 grams of tobacco per day), and "heavy smoker" (current smoker with ≥ 15 grams of tobacco per day).

Dietary preference was assessed by questionnaire. Dietary preference was assessed as the degree to which a person adhered to the official dietary advice and was divided into 5 categories ("very high," "high," "intermediate," "low," and "very low").[14] Physical exercise in leisure time was assessed by questionnaire and reported in 4 groups ("very high," "high," "moderate," and "low"), as previously reported.[13] Resting heart rate was measured in the sitting position after 5 minutes of rest.

Pulmonary function was defined by forced expiratory volume in the first second (FEV_1) and assessed by spirometry on an EasyOne spirometer (ndd Medizintechnik AG, Zurich, Switzerland). The results are reported as percentage of expected FEV_1 standardized by age, sex, and height.

Height was measured without shoes to the nearest 0.1 cm. Weight was measured on a hospital scale. Body mass index (BMI) was calculated as weight (kg) divided by height (m) squared. Information about socioeconomic circumstances (education, family income, and cohabitation) and prior disease (diabetes, ischemic heart disease, and stroke) was obtained by questionnaire.

Blood pressure was measured by an automated digital BP monitor (Kivex, Hoersholm, Denmark). Systolic and diastolic BP were measured in the sitting position on the non-dominant arm after 5 minutes of rest. Only 1 reading was carried out, as suggested by the World Health Organization (WHO) guideline on epidemiological methods.[15] The measurements were carried out between 8 AM and 6 PM. Blood pressure medication was self-reported. Total cholesterol, low-density lipoprotein cholesterol, high density lipoprotein cholesterol, and triglycerides were measured by standard hospital methods in non-fasting conditions.

Statistical Methods

Total number of drinks was calculated as the sum of drinks of red wine, white wine, beer, spirits, and dessert wine. Subjects were divided into 7 strata according to alcohol intake (0, 1-2, 3-7, 8-14, 15-21, 22-34 and >35 drinks per week). For demographics, the Pearson χ^2-test was performed to compare the distribution of the categorical variables and analysis of variance to compare means for continuous variables. Multivariable linear regression models were used when analyzing the association between number of drinks and BP adjusted for age, BMI, smoking, leisure time physical activity, education, and antihypertensive medication. The variable of interest—number of drinks—was analyzed both as a continuous variable with B-splines and as a categorical variable with 7 categories. In the main analysis, spirits and dessert wine were considered in the same category. Each alcohol type (white wine, red wine, beer, and spirits and dessert wine) was analyzed in similar models including adjustment for the other alcohol types. We included the other alcohol types to the models because individuals may consume more than 1 type of alcohol. Furthermore, we did not report the predicted values for the top 0.5% of alcohol intake, as predictions here led to very wide confidence intervals. The Wald test was used to compare the differences in BP for the various types of alcohol within categories of weekly alcohol intake with 0 drinks, as shown in Supplementary Figure 1 (available online). This is a discrete way of analyzing whether the splines seen in Figure 3 for the various types of alcohol are similar.

A sensitivity analysis with exclusion of subjects with prior cancer, myocardial infarction, or stroke was performed (Supplementary Figure 2, available online) to investigate whether the association between alcohol and blood pressure is modified by presence of these diseases. A second sensitivity analysis was carried out in subjects not on antihypertensive medication (Supplementary Figure 3, available online) to examine whether the association between alcohol and blood pressure is modified by antihypertensive medication. As only 1644 (1.6%) of the individuals reported more than 2 drinks of dessert wine per week, a third sensitivity analysis excluding dessert wine was performed, leaving spirits as a single category (Supplementary Figures 4 and 5, available online).

To compare the effects of the various types of alcohol on BP, we assessed the increase in BP per 1 drink per week for each type of alcohol in a fully adjusted linear regression model.

All statistical analysis was performed using R version 4.1.2 software (http://cran.rproject.org/). Two-sided P values < .05 were considered significant.

RESULTS

Baseline characteristics appear in Table 1. There were significant associations between alcohol intake and lifestyle, health, living conditions, and socioeconomic factors. Only 8.0% (n = 8402) of the population did not drink alcohol at all, whereas 2.6% (n = 2767) reported an alcohol intake of more than 35 drinks per week. Males had higher alcohol intake than females. Subjects who reported abstaining from alcohol differed from the other groups in many respects (eg, more lived alone and more reported being stressed). Most drinkers (76,943 [73.7%]) consumed more than 1 type of alcohol. However, 12,093 (12.6%) drank red wine only, 4288 (4.5%) beer only, 1815 (1.9%) white wine only, and 926 (1.0%) spirits and dessert wine only (Figure 1). The largest subset (18.2%) reported drinking all types of alcoholic beverages.

The association between weekly alcohol intake and BP is striking. The crude difference was 11 mmHg SBP and 7 mmHg DBP between high (> 35 drinks per week) and low (1-2 drinks per week) alcohol intakes, even though more subjects in the groups with higher intake received medication for high BP.

Figure 2 shows the multivariable adjusted association between total alcohol intake and BP in males and females separately. For both sexes, there was a strong and graded association between total alcohol intake and SBP, and DBP. Females had mean lower BP compared with males; however, the alcohol-BP associations were similar.

The associations between weekly alcohol intake in the forms of red wine, white wine, beer, and spirits and dessert wine are depicted in Figure 3. The associations between BP and red wine, white wine, and beer were broadly similar. Regarding spirits, DBP did not show a clear increasing or decreasing tendency.

We explored the differences in the effect of different alcohol types on SBP and DBP. Although no systematic differences were observed, a tendency for decreasing DBP with increasing consumption was observed in males (Supplementary Figure 1).

Overall, SBP increased by 0.15-0.17 mmHg and DBP increased by 0.08-0.15 mmHg per weekly drink of red wine, white wine, or beer. After stratification for age and sex, the effects were slightly higher among females and among individuals aged less than 60 years (Table 2).

The sensitivity analysis excluding subjects with cancer, myocardial infarction, or stroke showed similar results (Supplementary Figure 2, available online). This was also the case for the sensitivity analysis excluding subjects receiving antihypertensive pharmacological treatment (Supplementary Figure 3, available online) and for the analysis excluding dessert wine from the analyses (Supplementary Figures 4 and 5, available online).

DISCUSSION

In the present study, most adult Danish males and females consumed alcoholic beverages. In fact, only 8% were total

Table 1 Characteristics, Including Questionnaire Results and Examination Data, from the 104,467 Individuals in the Copenhagen General Population Study, Stratified by the Number of Drinks per Week*

	Number of Drinks per Week							
	0 (n = 8402)	1-2 (n = 10,837)	3-7 (n = 29,576)	8-14 (n = 28,003)	15-21 (n = 14,724)	22-35 (n = 10,158)	>35 (n = 2767)	*P* Value
Male sex	2255/8402 (27)	2982/10,837 (28)	10,814/29,576 (37)	12,915/28,003 (46)	8790/14724 (60)	7648/10158 (75)	2397/2767 (87)	<.0001
Age, years	57 ± 14	54 ± 14	56 ± 13	59 ± 13	61 ± 12	62 ± 11	61 ± 10	<.0001
Systolic blood pressure, mmHg	140 ± 22	138 ± 21	139 ± 21	142 ± 21	145 ± 21	147 ± 21	150 ± 21	<.0001
Diastolic blood pressure, mmHg	83 ± 12	83 ± 11	83 ± 11	84 ± 11	86 ± 11	87 ± 11	89 ± 12	<.0001
Blood pressure medication	1576/7423 (21)	1627/9686 (17)	4532/26,410 (17)	5123/25,110 (20)	2942/13273 (22)	2401/9257 (26)	704/2521 (28)	<.0001
BMI, kg/m^2	27.0 ± 5.3	26.2 ± 4.7	25.9 ± 4.3	25.8 ± 3.9	26.1 ± 3.8	26.6 ± 3.7	27.3 ± 4.1	<.0001
Smoking†								<.0001
Never-smoker	3469/8102 (43)	5042/10,409 (48)	13,547/28,307 (48)	11,140/26,796 (42)	4689/14125 (33)	2543/9791 (26)	543/2663 (20)	
Former smoker	2804/8102 (35)	3781/10,409 (36)	10,807/28,307 (38)	11,731/26,796 (44)	6858/14125 (49)	4950/9791 (51)	1194/2663 (45)	
Moderate smoker	701/8102 (9)	734/10,409 (7)	2012/28,307 (7)	2047/26,796 (8)	1205/14125 (9)	880/9791 (9)	198/2663 (7)	
Heavy smoker	1128/8102 (14)	852/10,409 (8)	1941/28,307 (7)	1878/26,796 (7)	1373/14125 (10)	1418/9791 (14)	728/2663 (27)	
FEV_1 in % of predicted	94 ± 18	97 ± 16	98 ± 16	98 ± 17	98 ± 17	96 ± 17	92 ± 18	<.0001
Physical activity in leisure time								<.0001
Low	910/8294 (11)	839/10,749 (8)	1586/29,373 (5)	1321/27,820 (5)	701/14638 (5)	581/10,109 (6)	276/2759 (10)	
Moderate	3886/8294 (47)	4784/10,749 (45)	12,275/29,373 (42)	11,316/27,820 (41)	5895/14638 (40)	4098/10,109 (41)	1145/2759 (42)	
High	2959/8294 (36)	4459/10,749 (41)	13,574/29,373 (46)	13,232/27,820 (48)	7020/14638 (48)	4674/10,109 (46)	1145/2759 (42)	
Very high	539/8294 (6)	667/10,749 (6)	1938/29,373 (7)	1951/27,820 (7)	1022/14638 (7)	756/10,109 (7)	193/2759 (7)	
Living alone	2796/8386 (33)	2770/10,824 (26)	6340/29,552 (21)	5320/27,977 (19)	2616/14714 (18)	1757/10,150 (17)	660/2766 (24)	<.0001
Nervous or stressed	2586/8371 (31)	3012/10,793 (28)	7132/29,488 (24)	6138/27,915 (22)	3049/14676 (21)	2047/10,138 (20)	684/2756 (25)	<.0001
Adherence to dietary guidelines								<.0001
Very high	723/7457 (10)	1054/9854 (11)	3052/27,211 (11)	2833/25,873 (11)	1237/13655 (9)	642/9387 (7)	104/2525 (4)	
High	785/7457 (11)	1082/9854 (11)	3222/27,211 (12)	3233/25,873 (12)	1712/13655 (13)	1109/9387 (12)	224/2525 (9)	
Intermediate	4175/7457 (56)	5939/9854 (60)	16709/27,211 (61)	15893/25,873 (61)	8286/13655 (61)	5525/9387 (59)	1334/2525 (53)	
Low	799/7457 (11)	911/9854 (9)	2093/27,211 (8)	1859/25,873 (7)	1072/13655 (8)	802/9387 (9)	253/2525 (10)	
Very low	975/7457 (13)	868/9854 (9)	2135/27,211 (8)	2055/25,873 (8)	1348/13655 (10)	1309/9387 (14)	610/2525 (24)	
Education								<.0001
<Middle school	1088/8369 (13)	925/10,809 (9)	2521/29,497 (9)	2609/27,937 (9)	1315/14677 (9)	1009/10,124 (10)	320/2760 (12)	
Middle school	3495/8369 (42)	3891/10,809 (36)	10,672/29,497 (36)	10,857/27,937 (39)	6007/14677 (41)	4389/10,124 (43)	1250/2760 (45)	
High school	2979/8369 (36)	4381/10,809 (41)	10,850/29,497 (37)	8964/27,937 (32)	4255/14677 (29)	2610/10,124 (26)	666/2760 (24)	
University	807/8369 (10)	1612/10,809 (15)	5454/29,497 (18)	5507/27,937 (20)	3100/14677 (21)	2116/10,124 (21)	524/2760 (19)	
Income								<.0001
Low	1876/8268 (23)	1472/10,673 (14)	3316/29,228 (11)	3004/27,664 (11)	1419/14568 (10)	966/10,074 (10)	353/2744 (13)	
Moderate	3886/8268 (47)	4723/10,673 (44)	12,209/29,228 (42)	11,792/27,664 (43)	6421/14568 (44)	4731/10,074 (47)	1444/2744 (53)	
High income	2506/8268 (30)	4478/10,673 (42)	13,703/29,228 (47)	12,868/27,664 (47)	6728/14568 (46)	4377/10,074 (43)	947/2744 (35)	

Table 1 (*Continued*)

	Number of Drinks per Week							
	0 (n = 8402)	1-2 (n = 10,837)	3-7 (n = 29,576)	8-14 (n = 28,003)	15-21 (n = 14,724)	22-35 (n = 10,158)	>35 (n = 2767)	*P* Value
Resting heart rate, bpm	74 ± 13	72 ± 12	71 ± 12	71 ± 12	72 ± 12	73 ± 13	77 ± 14	<.0001
Diabetes	500/8356 (6)	393/10,801 (4)	952/29,450 (3)	966/27,908 (3)	511/14664 (3)	466/10,129 (5)	166/2754 (6)	<.0001
Cholesterol, mmol/l	5.46 ± 1.14	5.42 ± 1.08	5.51 ± 1.06	5.61 ± 1.06	5.70 ± 1.05	5.76 ± 1.07	5.82 ± 1.12	<.0001
HDL cholesterol, mmol/l	1.48 ± 0.47	1.54 ± 0.47	1.61 ± 0.50	1.66 ± 0.52	1.69 ± 0.54	1.68 ± 0.55	1.69 ± 0.57	<.0001
LDL cholesterol, mmol/l	3.24 ± 1.00	3.19 ± 0.95	3.21 ± 0.93	3.24 ± 0.94	3.26 ± 0.94	3.27 ± 0.97	3.23 ± 1.02	<.0001
Triglycerides, mmol/l	1.71 ± 1.12	1.58 ± 1.01	1.60 ± 1.06	1.62 ± 1.03	1.73 ± 1.17	1.88 ± 1.26	2.13 ± 1.52	<.0001

*Data are n/N (%) or mean ± standard deviation.

†Moderate smoker, current smoker with < 15 grams of tobacco per day; heavy smoker, current smoker with ≥ 15 grams of tobacco per day.BMI = body mass index; BP = blood pressure; bpm = beats per minute; FEV_1 = forced expiratory volume in 1 second; HDL = high-density lipoprotein; LDL = low-density lipoprotein.

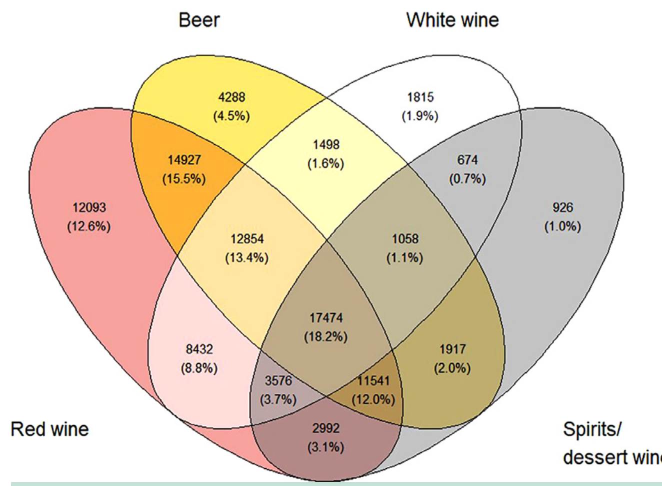

Figure 1 Venn-diagram showing the joined distribution (n [%]) of alcohol types (red wine in red, white wine in white, beer in yellow, and spirits in gray) among the participants who drank alcohol.

abstainers. The majority (about 60%) drank between 1 and 21 drinks per week, commonly in the form of red wine and beer. Most subjects ingested more than 1 type of alcohol.

There was a highly significant positive and graded association between total alcohol intake and BP. The crude difference in SBP in the groups with low alcohol intake compared with the groups with high alcohol intake was >10 mmHg, a difference of clinical importance.[16] Similar, albeit slightly lower absolute differences were found in DBP. The association between alcohol intake and BP was similar in males and females.

There were no significant differences in the effects of alcohol in the form of red wine, white wine, and beer, regardless of age group and sex, although the effect was slightly less pronounced in the older age groups.

We found no convincing evidence of a beneficial effect of red wine in either sex on BP. Assessment of the effects of the combined group of spirits and dessert wine showed comparable results.

Reassuringly, the sensitivity analyses showed almost identical associations as the main study.

Biological Explanations

Acute intake of alcohol induces vasodilatation while also increasing adrenergic activation, resulting in increased heart rate, and slightly decreasing BP.[17] The effects seem to disappear in about 12 hours. The present analysis demonstrated a dose-dependent direct effect on BP, with higher daily alcohol intakes correlating with increases in BP. The BP increases were generally nonexistent to modest for ≤ 1 drink per day but rose linearly for intakes > 1 drink per day. The major contributor to the alcohol hypertensive effect might have been loss of relaxation due to inflammation, and oxidative injury to the endothelium by angiotensin II leading to inhibition of endothelium-dependent nitric

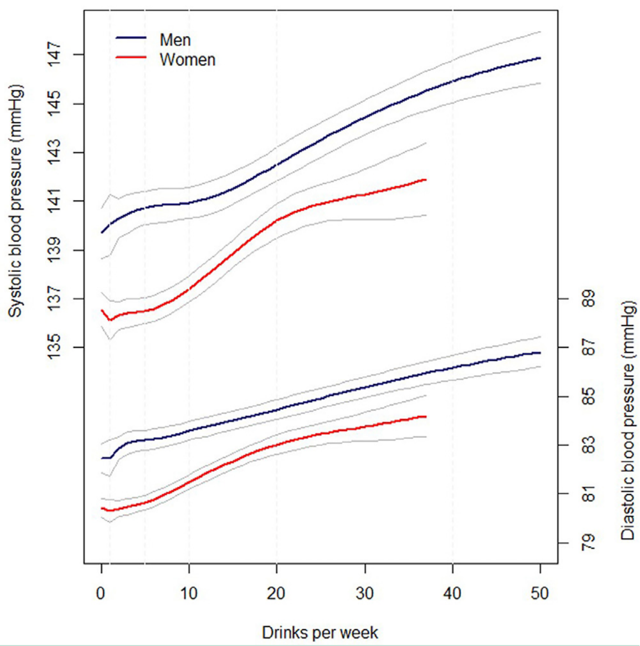

Figure 2 Associations between total weekly alcohol intake and systolic and diastolic blood pressure in males (blue) and females (red) depicted by B-splines from a multivariable linear regression model adjusted for age, body mass index, smoking, leisure time physical activity, education, and antihypertensive medication.

oxide production, as suggested by Husain et al.[18] Withdrawal symptoms might have also played a role.[19]

Beer may have some effect on vascular tone.[20] The effects of flavonoids in red wine are still disputed.[21] We are not aware of studies of specific effects of white wine. Because the effects on BP are similar across the various types of alcohol, it is likely that the ethanol itself is the culprit.

There is concordance between alcohol intake and smoking.[22] There were more heavy smokers in the groups with high alcohol intake, whereas never-smokers were more prevalent in abstainers and subjects with low consumption. Smokers tend to have lower BP than non-smokers.[23] Thus, the association between smoking and alcohol intake cannot explain the BP-alcohol association.

Epidemiology

The relationship between alcohol and BP has been reported in numerous population studies, case series, and clinical trials. Higher alcohol intake is uniformly associated with increasing BP.[5,17−19] Randomized studies of reducing alcohol intake or abstaining from alcohol show significant decreases in BP.[7,8] Similarly, Mendelian randomization studies document the causal effect of alcohol intake on BP.[6] None of these studies differentiated between types of alcohol.

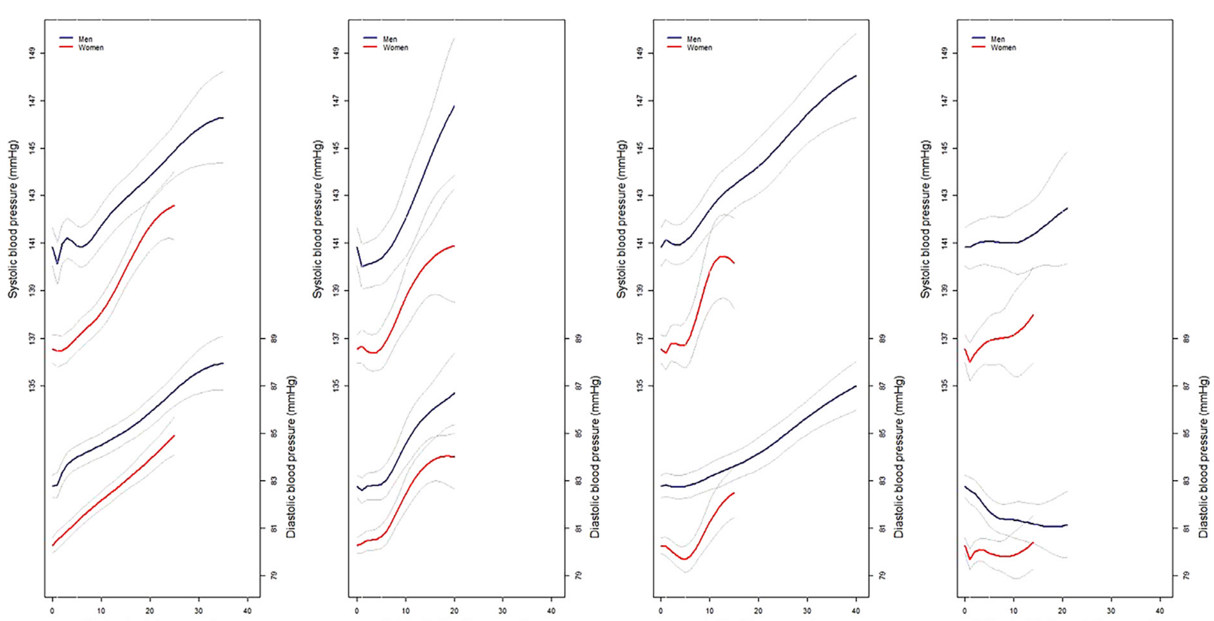

Figure 3 Associations between type-specific alcohol intake and systolic and diastolic blood pressure in males (blue) and females (red) depicted by B-splines from a multivariable linear regression model adjusted for age, body mass index, smoking, leisure time physical activity, education, and antihypertensive medication, including adjustment for the other alcohol types.

Table 2 Association Between Alcohol Intake (Both Total and Type-Specific) and Blood Pressure in Multivariable Models*

	Total	*P* Value	Red Wine	White Wine	Beer	Spirits	*P* Value†	*P* Value‡
Systolic blood pressure (mmHg)								
All	**0.14**	–	**0.17**	**0.15**	**0.15**	0.00	<.0001	.42
Females	**0.20**	<.0001	**0.24**	**0.19**	**0.12**	**0.16**	.01	.01
Males	**0.10**		**0.12**	**0.09**	**0.16**	**-0.06**	<.0001	.07
Aged < 60	**0.15**	.02	**0.14**	**0.10**	**0.20**	0.07	.001	.007
Aged ≥ 60	**0.12**		**0.20**	**0.18**	**0.08**	-0.04	<.0001	<.0001
Diastolic blood pressure (mmHg)								
All	**0.09**	–	**0.15**	**0.14**	**0.08**	**-0.08**	<.0001	<.0001
Females	**0.13**	<.0001	**0.18**	**0.15**	**0.04**	0.01	<.0001	<.0001
Males	**0.07**		**0.13**	**0.12**	**0.08**	**-0.11**	<.0001	<.0001
Aged < 60	**0.13**	<.0001	**0.18**	**0.16**	**0.11**	-0.01	<.0001	<.0001
Aged ≥ 60	**0.05**		**0.12**	**0.12**	0.01	**-0.10**	<.0001	<.0001

*Adjusted for sex, age, body mass index, smoking, leisure time physical activity, education, and antihypertensive medication with or without stratification for sex or age. The estimates show beta values (mmhg per drink/week) based on linear regression analyses. Coefficients in bold indicate statistical significance (i.e., there is a significant effect of on drink of alcohol per week on blood pressure), and those in plain letters indicate non-significance.

†Comparison between all types of alcohol (beer, white wine, red wine, and spirits).

‡Comparison between beer, white wine, and red wine.

There are a few clinical and epidemiological studies of the different alcohol types and BP. Some studies suggest that low intake of red wine may reduce BP particularly in females. We found no evidence for a BP lowering effect of red wine in either sex. In contrast to our findings, one study found no effect of beer drinking on BP.[11]

Public Health Consequences and Clinical Implications

The present study showed that alcohol consumption is associated with dose-dependent increases in blood pressure, an effect common to all types of alcohol. Therefore, with respect to blood pressure, there is nothing to be gained by directing alcohol intake from one type to another type.

The consumption of alcohol is universal among nations.[20] Globally, high blood pressure is the most important risk factor for cardiovascular morbidity and mortality.[24,25] Controlled trials show that alcohol abstinence or reduction in intake is followed by decreased blood pressure. Even moderate decrease in population blood pressure may reduce the burden of blood pressure-related morbidity and mortality.[16,26] It should be an urgent matter of public health to reduce population alcohol use, as advised by the WHO and the Danish health authorities.[27] More robust methods, including increased taxation and decreasing availability of alcoholic drinks may be considered. The WHO and other agencies also advise increased availability of counselling and treatment for alcohol abuse.

In the clinical setting, a careful assessment of alcohol intake is warranted.[28] All types of alcoholic beverages should be recorded. When assessing the need for antihypertensive treatment, alcohol intake should be considered. Reducing all alcohol use to ≤ 1drink per day should always be advised, and this recommendation should supplement pharmacological treatment for the management of hypertension.

Strengths and Limitations

The strength of the study is the large population sample, recruited from the general population. Although non-responders may have different alcohol intakes compared with responders, we think that the alcohol use reported in the present sample is representative of Danish alcohol habits.[1] A sampling bias due to left truncation could affect the results (eg, when those who died before recruitment from alcohol use bias results toward the null). We did not record the time of the last drink. However, as the examinations were carried out during daytime, it can be assumed that in most participants more than 8 hours elapsed from alcohol intake to BP assessment, and acute effect of alcohol on BP is likely minimal.[29] The examination methods in other respects were standard.

Information about alcohol intake is self-reported, which may lead to underreporting.[30] Furthermore, because illness could be related to alcohol intake and BP, health status confounding or reverse causation might have been present. The group of total abstainers differed in most respects from the other groups, and could have potentially included ex-drinkers with poor health.[31,32] Reporting of alcohol intake may well be different in males and females, and in different age groups, which may bias our results.

The population is composed of ethnic Danes. Other populations are likely to have different alcohol intake, for both total amount and types of alcoholic beverages ingested.[20] There are no data suggesting different associations between alcohol consumption and BP in other populations.[9,33]

Although we carried out a careful assessment of covariates, residual confounding from unmeasured confounders can never be ruled out in populations studies. Moreover, because this was a cross-sectional study, no causal inferences can be drawn. However, the causal effect of alcohol use on blood pressure is well established from numerous other studies.[5,6]

CONCLUSIONS

This study found a strong and graded association between alcohol intake and blood pressure. The difference in systolic and diastolic blood pressure in the groups with low and high alcohol intake, was about 11 and 7 mmHg, respectively. The effect was similar for various types of alcoholic beverages (red wine, white wine, beer, and spirits).

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SUPPLEMENTARY DATA

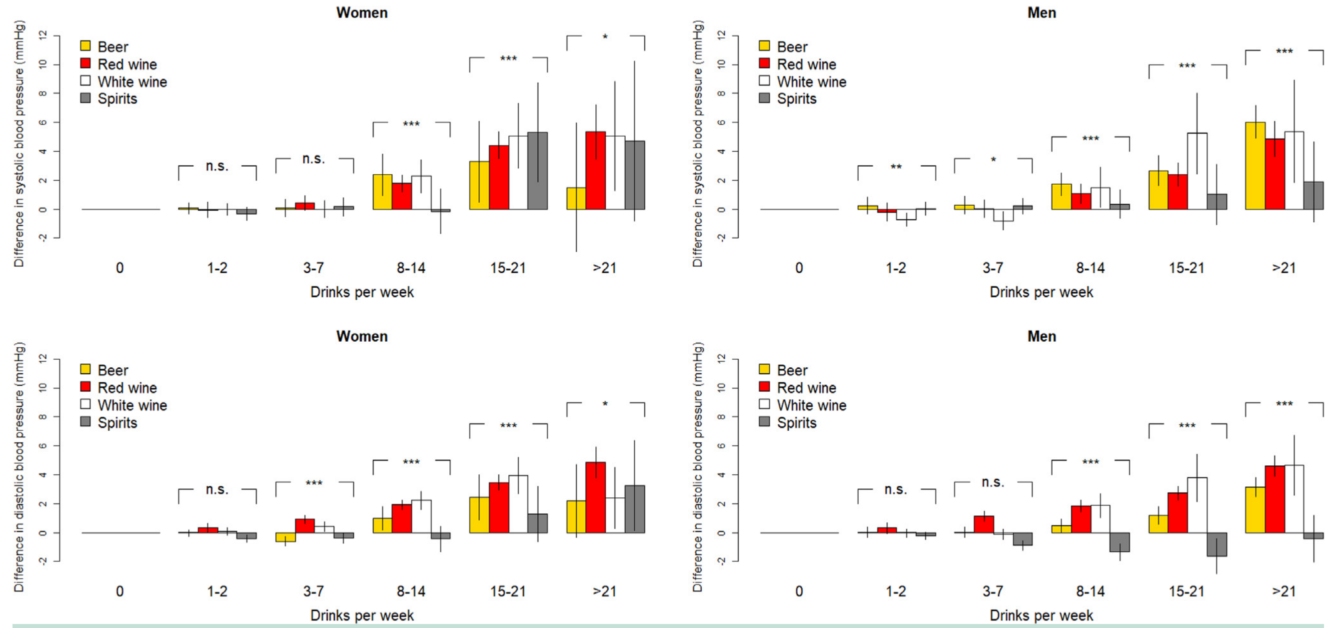
Supplementary data to this article can be found online at https://doi.org/10.1016/j.amjmed.2024.05.001.

SUPPLEMENTAL MATERIAL

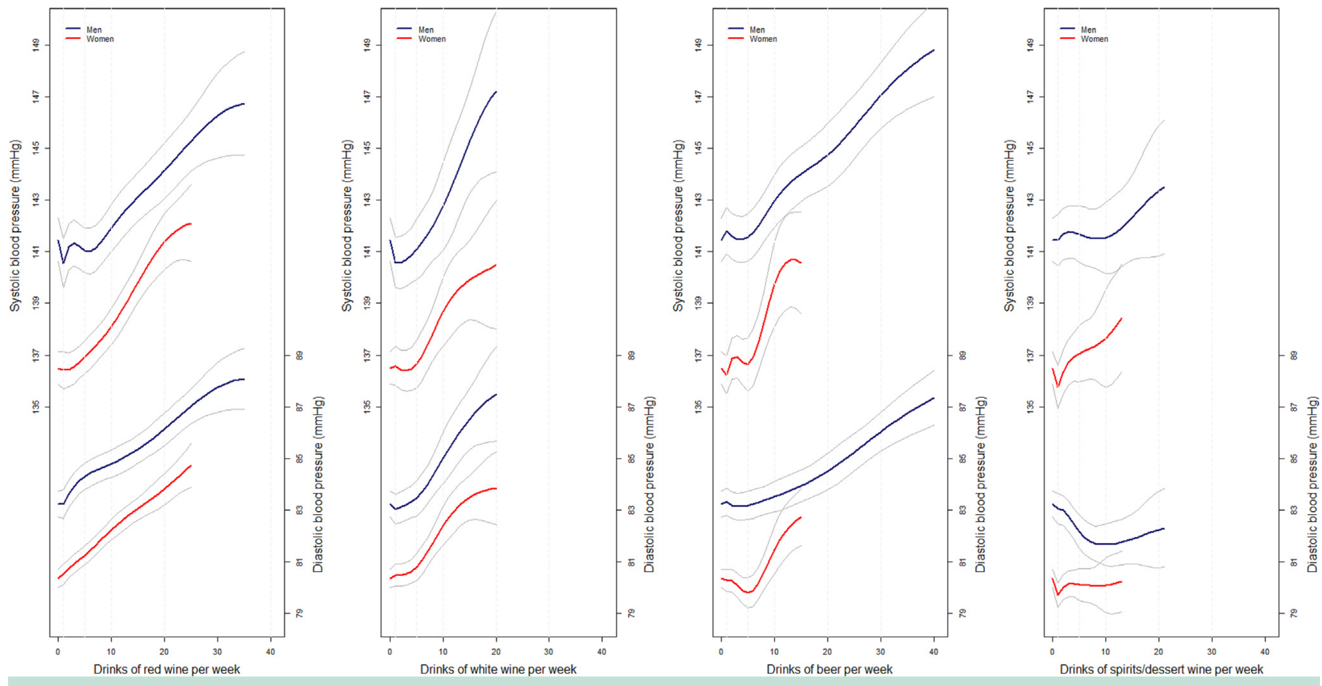
Supplementary Table 1 Characteristics, including questionnaire results and examination data, from the 92,833 individuals in the Copenhagen General Population Study free of cancer and MACE, stratified by the number of drinks/week.

	Number of drinks per week							
	0 (N=7393)	1-2 (N=9764)	3-7 (N=26594)	8-14 (N=24769)	15-21 (N=12974)	22-35 (N=8876)	>35 (N=2463)	P-value
Male sex	1956/7393 (26)	2679/9764 (27)	9678/26594 (36)	11322/24769 (46)	7718/12974 (59)	6643/8876 (75)	2135/2463 (87)	<0.0001
Age, years	55 ± 14	53 ± 13	55 ± 13	58 ± 12	60 ± 12	61 ± 11	61 ± 10	<0.0001
Systolic blood pressure, mmHg	139 ± 22	137 ± 21	139 ± 21	141 ± 21	144 ± 21	147 ± 21	150 ± 21	<0.0001
Diastolic blood pressure, mmHg	83 ± 12	83 ± 11	83 ± 11	84 ± 11	86 ± 11	87 ± 11	89 ± 12	<0.0001
Blood pressure medication	1212/6533 (19)	1264/8757 (14)	3552/23791 (15)	4002/22251 (18)	2308/11710 (20)	1896/8106 (23)	572/2252 (25)	<0.0001
BMI, kg/m2	26.9 ± 5.3	26.1 ± 4.7	25.8 ± 4.3	25.7 ± 3.9	26.0 ± 3.7	26.6 ± 3.7	27.3 ± 4.1	<0.0001
Smoking								<0.0001
Never-smoker	3074/7116 (43)	4655/9379 (50)	12404/25428 (49)	10053/23678 (42)	4208/12428 (34)	2275/8546 (27)	482/2366 (20)	
Former smoker	2411/7116 (34)	3312/9379 (35)	9445/25428 (37)	10107/23678 (43)	5901/12428 (47)	4209/8546 (49)	1026/2366 (43)	
Current smoker, <15 g tobacco/day	616/7116 (9)	665/9379 (7)	1834/25428 (7)	1846/23678 (8)	1079/12428 (9)	786/8546 (9)	177/2366 (7)	
Current smoker, 15 g tobacco/day	1015/7116 (14)	747/9379 (8)	1745/25428 (7)	1672/23678 (7)	1240/12428 (10)	1276/8546 (15)	681/2366 (29)	
FEV_1 in % of predicted	95 ± 17	97 ± 15	98 ± 16	98 ± 16	98 ± 17	96 ± 17	93 ± 18	<0.0001
Physical activity in leisure time								<0.0001
Low	775/7305 (11)	750/9692 (8)	1425/26437 (5)	1146/24620 (5)	616/12915 (5)	517/8837 (6)	244/2457 (10)	
Moderate	3381/7305 (46)	4236/9692 (44)	10873/26437 (41)	9815/24620 (40)	5123/12915 (40)	3501/8837 (40)	1016/2457 (41)	
High	2653/7305 (36)	4076/9692 (42)	12338/26437 (47)	11878/24620 (48)	6257/12915 (48)	4136/8837 (47)	1030/2457 (42)	
Very high	496/7305 (7)	630/9692 (7)	1801/26437 (7)	1781/24620 (7)	919/12915 (7)	683/8837 (8)	167/2457 (7)	
Living alone	2355/7381 (32)	2378/9751 (24)	5427/26572 (20)	4537/24749 (18)	2228/12967 (17)	1499/8869 (17)	576/2462 (23)	<0.0001
Nervous or stressed	2301/7365 (31)	2756/9728 (28)	6508/26518 (25)	5531/24695 (22)	2724/12933 (21)	1842/8859 (21)	623/2455 (25)	<0.0001
Adherence to dietary guidelines								<0.0001
Very high	628/6580 (10)	923/8905 (10)	2709/24535 (11)	2477/22947 (11)	1074/12059 (9)	560/8209 (7)	87/2259 (4)	
High	694/6580 (11)	985/8905 (11)	2881/24535 (12)	2846/22947 (12)	1516/12059 (13)	966/8209 (12)	196/2259 (9)	
Intermediate	3717/6580 (56)	5391/8905 (61)	15188/24535 (62)	14181/22947 (62)	7325/12059 (61)	4815/8209 (59)	1198/2259 (53)	
Low	705/6580 (11)	845/8905 (9)	1892/24535 (8)	1680/22947 (7)	977/12059 (8)	715/8209 (9)	229/2259 (10)	
Very low	836/6580 (13)	761/8905 (9)	1865/24535 (8)	1763/22947 (8)	1167/12059 (10)	1153/8209 (14)	549/2259 (24)	
Education								<0.0001
<Middle school	847/7364 (12)	731/9738 (8)	1965/26529 (7)	2070/24714 (8)	1072/12934 (8)	819/8845 (9)	275/2457 (11)	
Middle school	3000/7364 (41)	3389/9738 (35)	9385/26529 (35)	9400/24714 (38)	5239/12934 (41)	3822/8845 (43)	1123/2457 (46)	
High school	2771/7364 (38)	4127/9738 (42)	10110/26529 (38)	8229/24714 (33)	3823/12934 (30)	2347/8845 (27)	601/2457 (24)	
University	746/7364 (10)	1491/9738 (15)	5069/26529 (19)	5015/24714 (20)	2800/12934 (22)	1857/8845 (21)	458/2457 (19)	
Income								<0.0001
Low	1513/7279 (21)	1175/9625 (12)	2614/26303 (10)	2432/24490 (10)	1142/12851 (9)	780/8805 (9)	312/2442 (13)	
Moderate	3408/7279 (47)	4221/9625 (44)	10778/26303 (41)	10126/24490 (41)	5494/12851 (43)	4053/8805 (46)	1261/2442 (52)	
High income	2358/7279 (32)	4229/9625 (44)	12911/26303 (49)	11932/24490 (49)	6215/12851 (48)	3972/8805 (45)	869/2442 (36)	
Resting heart rate, bpm	74 ± 13	72 ± 12	71 ± 12	71 ± 12	71 ± 12	73 ± 13	77 ± 14	<0.0001
Diabetes	384/7357 (5)	312/9735 (3)	753/26481 (3)	734/24689 (3)	401/12923 (3)	367/8850 (4)	137/2450 (6)	<0.0001
Cholesterol, mmol/l	5.48 ± 1.12	5.43 ± 1.07	5.52 ± 1.04	5.64 ± 1.05	5.75 ± 1.03	5.81 ± 1.05	5.87 ± 1.11	<0.0001
HDL cholesterol, mmol/l	1.47 ± 0.47	1.54 ± 0.47	1.60 ± 0.50	1.67 ± 0.52	1.69 ± 0.54	1.68 ± 0.55	1.69 ± 0.57	<0.0001
LDL cholesterol, mmol/l	3.27 ± 0.99	3.20 ± 0.93	3.23 ± 0.92	3.27 ± 0.93	3.30 ± 0.93	3.32 ± 0.96	3.28 ± 1.02	<0.0001
Triglycerides, mmol/l	1.70 ± 1.13	1.57 ± 1.01	1.58 ± 1.03	1.61 ± 1.04	1.73 ± 1.14	1.87 ± 1.26	2.14 ± 1.56	<0.0001

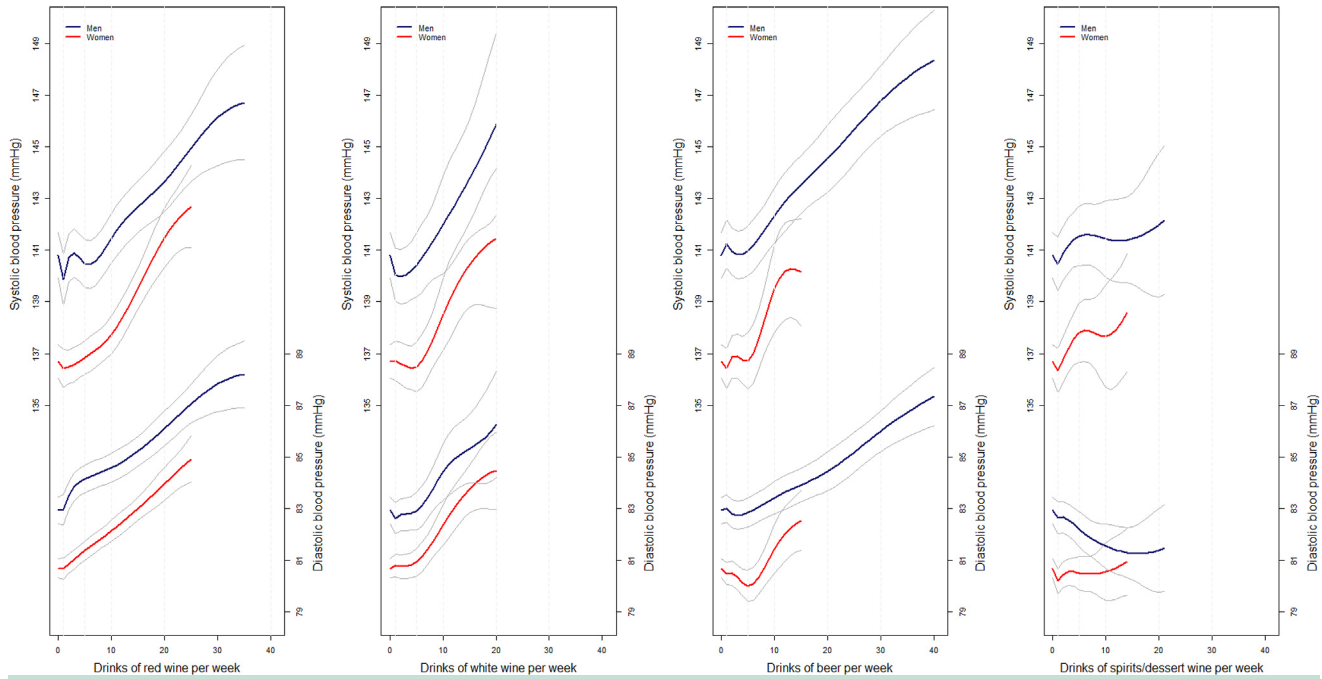
Data are n (%), n/N (%) or mean ± SD. Abbreviations: BMI, body mass index; FEV_1, forced expiratory volume in 1 second; BP, blood pressure; bpm, beats per minute; HDL, high-density lipoprotein; LDL, low-density lipoprotein.



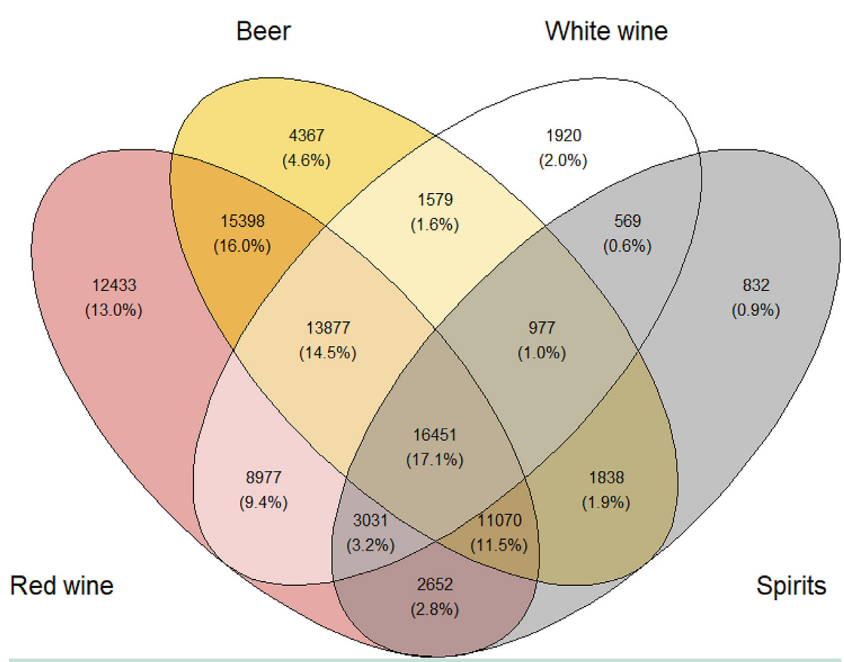
Supplementary Figure 1 Differences in systolic and diastolic blood pressure according to type-specific alcohol intake categories in women and men.



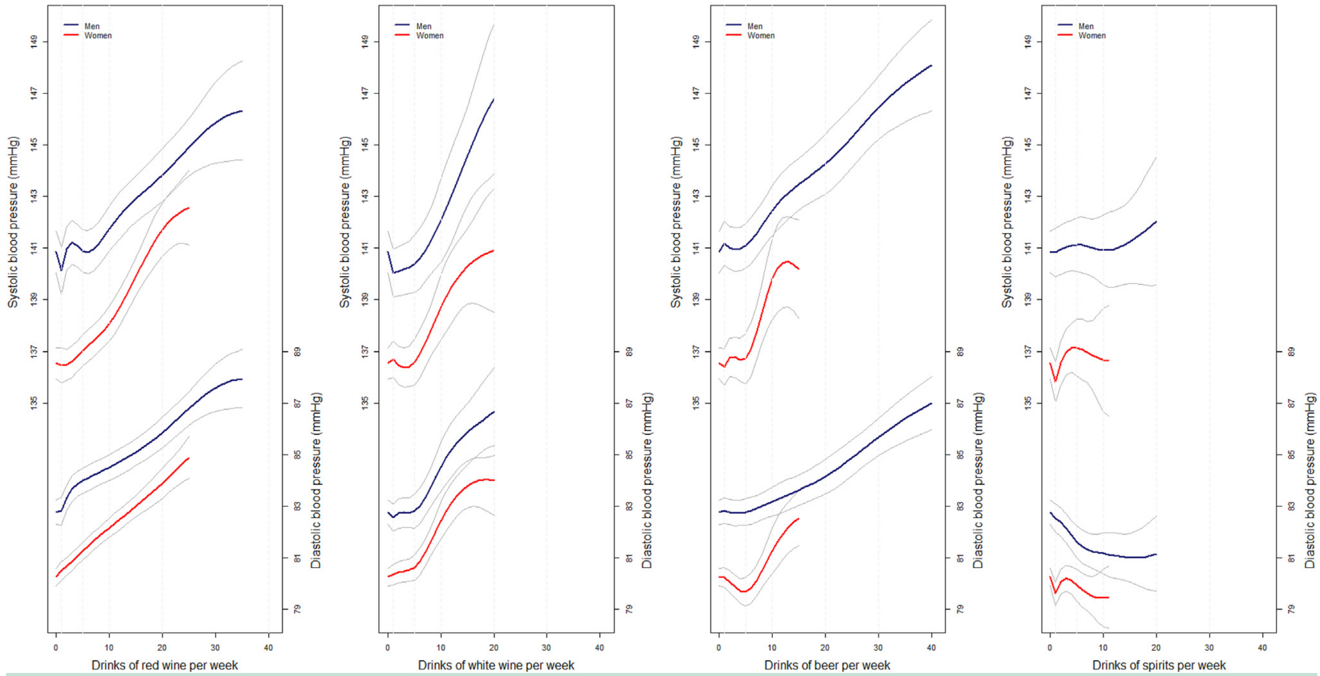
Supplementary Figure 2 Associations between type-specific alcohol intake and systolic and diastolic blood pressure in men (blue) and women (red) free of cancer and MACE, depicted by B-splines from a multivariable linear regression model adjusted for age, BMI, smoking, leisure time physical activity, education, and antihypertensive medication including adjustment for the other alcohol types.



Supplementary Figure 3 Associations between type-specific alcohol intake and systolic and diastolic blood pressure in men (blue) and women (red) free of cancer and MACE, depicted by B-splines from a multivariable linear regression model adjusted for age, BMI, smoking, leisure time physical activity, education, and antihypertensive medication including adjustment for the other alcohol types.



Supplementary Figure 4 Venn-diagram showing the joined distribution (n (%)) of alcohol types (red wine in red, white wine in white, beer in yellow, and spirits in grey) among individuals who drink alcohol (dessert wine has been excluded from the anaysis).



Supplementary Figure 5 Associations between type-specific alcohol intake and systolic and diastolic blood pressure in men (blue) and women (red) depicted by B-splines from a multivariable linear regression model adjusted for age, BMI, smoking, leisure time physical activity, education, and antihypertensive medication including adjustment for the other alcohol types, when dessert wine has been excluded from the analyses.