ORIGINAL INVESTIGATION

Prospective Study of Moderate Alcohol Consumption and Risk of Hypertension in Young Women

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Background: Heavy alcohol consumption is associated with an increased risk of hypertension. However, the effect of moderate alcohol consumption; the specific effects of wine, beer, and liquor; and the pattern of drinking in relation to risk of hypertension among young women are unclear.

Methods: We prospectively examined the association between alcohol consumption and subsequent risk of hypertension among 70891 women 25 to 42 years of age.

Results: During the 8 years of follow-up, 4188 cases (5.9%) of incident hypertension were reported. After adjustment for multiple covariates, the association between alcohol consumption and risk of hypertension followed a J-shaped curve. Compared with nondrinkers, the risk of developing hypertension according to average number of drinks consumed per day was as follows: 0.25 or less, 0.96 (95% confidence interval [CI], 0.89-1.03); 0.26 to 0.50, 0.86 (95% CI, 0.75-0.98); 0.51 to 1.00, 0.92 (95% CI, 0.82-1.04); 1.01 to 1.50, 1.00 (95% CI, 0.80-1.24); 1.51 to 2.00, 1.20 (95% CI, 0.92-1.58); and more than 2.0 drinks, 1.31 (95% CI, 1.02-1.68). Exclusion of past drinkers yielded similar results. Among women in the highest category of alcohol consumption, there was a suggestion that the increased risk of hypertension was present regardless of the specific beverage consumed (beer, wine, or liquor). Episodic drinking, defined as consumption of more than 10.5 drinks over 3 or fewer days per week, was not associated with increased risk of hypertension (relative risk, 0.80; 95% CI, 0.51-1.23).

Conclusions: The association between alcohol consumption and risk of chronic hypertension in young women follows a J-shaped curve, with light drinkers demonstrating a modest decrease in risk and more regular heavy drinkers demonstrating an increase in risk.

Arch Intern Med. 2002;162:569-574

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HYPERTENSION is an important cause of disability and mortality and has been linked to several disorders, including coronary and cerebrovascular disease and renal insufficiency.[1-3] Persuasive epidemiologic evidence suggests that heavy alcohol consumption is strongly associated with increased risk of hypertension,[4] and approximately 3% to 8% of high blood pressure in women is attributable to alcohol consumption.[5] Activation of the sympathetic nervous system and alteration of vascular tone have been hypothesized as the probable mechanisms involved to explain this relationship.[6] Light to moderate drinking, a more socially acceptable behavior,[4] has been associated with a reduced risk of ischemic stroke[7] and coronary heart disease[8] among women. Despite these data, the effects of light to moderate drinking on blood pressure in young women have not been established.

The overwhelming number of studies that have examined the relationship between alcohol intake and risk of hypertension have been among men or limited to cross-sectional design.[4] More important, in the light to moderate range, it remains unclear whether the association is linear or J-shaped, or whether there is a threshold effect. Other issues that have not been adequately addressed include the individual effect of specific beverages (beer, wine, liquor) on blood pressure, and whether episodic or binge drinking is associated with increased risk of hypertension. To address these issues, we examined prospectively the association between alcohol intake and risk of hypertension during an 8-year period in a cohort of 70891 young women.

RESULTS

During the 8 years of follow-up (403151 person-years), 4188 incident cases of hy-

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SUBJECTS AND METHODS

STUDY POPULATION

The Nurses' Health Study II is a prospective cohort study of 116671 female nurses in the United States who were 25 to 42 years old at baseline in 1989. This cohort is followed up by biennial mailed questionnaires focusing on various lifestyle factors and health outcomes; the follow-up rate exceeds 90% for every 2-year period, and there is almost complete (98%) follow-up on mortality data.[9] The institutional review board of our hospital has approved this study.

EXPOSURE ASSESSMENT—ALCOHOL INTAKE

In 1989, the baseline questionnaire included questions on the average intake of alcoholic beverages (beer, wine, and liquor) during the past year. Nurses responded to the following question: "During the past year, what was your usual consumption of these (beer, wine, liquor) alcoholic beverages?" Intake of each beverage was ascertained in 9 categories (number of drinks): none or less than 1 per month, 1 to 3 per month, 1 per week, 2 to 4 per week, 5 to 6 per week, 7 to 13 per week, 14 to 24 per week, 25 to 39 per week, and 40 or more per week. Total amount of alcohol consumed was estimated at 12.8 g for a bottle or can of beer (12 oz), 11 g for a glass of wine (4 oz), and 14 g for a shot of liquor (1.5 oz). Total alcohol intake was computed as the sum of the intake from beer, wine, and liquor. Beverage-specific consumption was also calculated and analyzed separately. For analysis, a standard drink was considered 12 g of alcohol. In addition, women were asked to respond to the following: "In a typical week during the past year, on how many days did you consume an alcoholic beverage of any type?" A total of 8 responses was possible (0 to 7 days per week). Overall, these measures of frequency and quantity were used to define average number of drinks consumed per day and episodic drinking (see "Statistical Analysis" subsection).

Reliability and validity of the questionnaire measure of alcohol intake were evaluated in a subset of women participating in a similar study. Among 173 of these women, alcohol intake was assessed by multiple 1-week diet records in 1980 and by questionnaire in both 1980 and 1981. When compared with the diet records, the correlation was 0.86 for alcohol assessed from the questionnaire in 1980 and 0.90 for the 1981 questionnaire.[10] Alcohol intake as measured by each of the methods has been correlated with plasma concentrations of high-density lipoprotein ($r=0.40$, $P<.001$),[11] similar to the dose-response found in closely monitored metabolic studies.[12]

Baseline questions on history of alcohol consumption were used to define past drinkers and to identify women with past heavy alcohol use (≥40 drinks per week). Women in the latter group were excluded (see "Exclusions" subsection).

We examined the relationship between episodic drinking, or drinking large amounts of alcohol during a short period, and risk of hypertension by means of 2 different definitions: the primary definition, consumption of more than 10.5 drinks over 1 to 3 days per week, and a more strict definition, consumption of 12 or more drinks over 1 to 3 days per week.

ASSESSMENT OF COVARIATES

Exposure status for all potential confounders including height, weight, family history of hypertension, race, smoking, physical activity, history of elevated cholesterol level, and oral contraceptive use was defined by responses on the baseline questionnaire. Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters. In nurses, self-reported weights were highly correlated with actual measurements ($r=0.96$).[13] A validation study of recalled weight at 18 years of age compared recalled weight with records from physical examinations conducted at college or nursing school entrance. The correlation between recalled and measured BMI at age 18 years was 0.84 ($P<.01$).[14]

pertension (5.9%) were identified. The characteristics according to baseline alcohol consumption are presented in **Table 1**. A total of 27070 (38%) reported no drinking at baseline, and 957 (1%) reported an average alcohol consumption of more than 2 drinks per day. Mean BMI and the frequency of reported history of elevated cholesterol level reached a nadir among women who consumed 1.01 to 1.50 drinks per day. In addition, women who drank increasing amounts of alcohol were more likely to be current or past smokers and oral contraceptive users. Most other baseline characteristics were similar across the drinking categories.

In the age-adjusted analysis, the relative risk of hypertension according to level of alcohol consumption followed a J-shaped curve. After adjustment for other confounding factors including BMI, the J-shaped relationship became more pronounced (**Table 2**). Compared with women who abstained, the relative risk of hypertension was lowest among women drinking 0.25 to 0.50 drinks per day (RR, 0.86; 95% CI, 0.75-0.98) and highest among women drinking more than 2 drinks per day (RR, 1.31; 95% CI, 1.02-1.68). We explored which potential confounders altered the J-relationship and found that, after adjustment for BMI, addition of the other covariates to the model altered the shape only slightly. We explored the possibility that bias was introduced by including past drinkers in the nondrinker referent category; however, excluding past drinkers yielded the same J-relationship (data not shown). In this model, compared with abstainers, the risk of hypertension among past drinkers was 0.78 (95% CI, 0.52-1.15). The association between alcohol intake and risk of hypertension did not appreciably vary by level of any of the covariates examined (eg, BMI and smoking).

For beer, wine, and liquor, we examined separate models including only women who reported consumption of a specific beverage compared with abstainers. Thereafter, we included all women in the cohort by simultaneously including indicator variables for categories of consumption of beer, wine, and liquor into a single logistic model. The purpose of this analysis was to determine the independent effect of each beverage adjusted for the consumption of the other beverages. The overall results were similar (data not shown), and the re-

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ASSESSMENT OF INCIDENT HYPERTENSION

In 1989, women reported a history of hypertension and their usual systolic and diastolic blood pressure (7 categories). On questionnaires sent biennially from 1991 to 1997, women were asked to report development of physician-diagnosed hypertension in the preceding 2 years. We examined the validity of the response to this question in 2 populations of similar nurses. The false-positive rate was examined in a sample of 100 nurses reporting a diagnosis of high blood pressure.[15] Sixty-two gave permission to review their medical records, and complete records were obtained for 51 women. All had recorded values of blood pressure greater than 140/90 mm Hg, and for 39 (77%), blood pressure was greater than 160/95. To investigate the false-negative rate, blood pressure was measured in a sample of 161 nurses without a history of high blood pressure. Among these women, 7% had a blood pressure greater than 140/90 mm Hg, but none had a blood pressure greater than 160/95 mm Hg.

EXCLUSIONS

A total of 116 671 women were enrolled in the Nurses' Health Study II in 1989. We excluded women who reported a history of hypertension before 1991 (n = 7847); no physical examination within 2 years of the baseline questionnaire or a report of a systolic blood pressure of 135 mm Hg or more or a diastolic blood pressure of 90 mm Hg or more; history of myocardial infarction, cancer (except nonmelanoma skin cancer), diabetes, stroke, seizures, or hepatitis (infectious or otherwise); antihypertensive medication use; or alcohol intake of more than 40 drinks per week at any age. We also excluded women who gave birth during the follow-up period (n = 22 936), because pregnancy may have altered future alcohol consumption. All exclusions were made before the analyses. A total of 70 891 women remained eligible for analysis, and among these women, approximately 98% had 4 years or more of follow-up.

STATISTICAL ANALYSIS

Alcohol consumption assessed in 1989 was divided into 7 categories—none, 0.25 drink per day or less , 0.26 to 0.50, 0.51 to 1.00, 1.01 to 1.50, 1.51 to 2.00, and more than 2.00 drinks per day—and modeled as indicator variables to allow for nonlinear associations. For all analyses, nondrinkers (never drinkers and past drinkers) were considered the referent category, and all analyses were repeated after exclusion of past drinkers from the referent category.

To determine whether a change in drinking pattern over time may have affected our findings, we compared the results of analyses based on the cumulative incidence restricted to the first 4 years of follow-up (from 1989 to1993) with results when the cumulative incidence was ascertained with up to 8 years of follow-up. The results did not materially change when either period was used; thus, data with 8 years of follow-up are presented.

We calculated relative risks as the incidence of hypertension among women with a given alcohol intake divided by the corresponding rate among abstainers. In addition, stratified analyses were performed to assess the possibility of confounding and effect modification. To test for effect modification, we added to the multivariate model the product of the interaction term (as indicator variables) and each of the levels of alcohol consumption. Exposures were not updated, and thus logistic regression was used to adjust for potential confounding factors.

Beverage-specific effects were examined both in models that included only those reporting consumption of a single beverage and in models with all women combined to assess the independent effect of each beverage adjusted for the consumption of the other beverages. In the analyses of episodic drinking, the model also included women who drank regularly (5-7 days per week) and those who drank less frequently (1-4 days per week). We calculated 95% confidence intervals (CIs) for each relative risk (RR) and 2-sided *P* values for all analyses.

sults of the all-inclusive model are presented in **Table 3**. There was a suggestion that light-beer drinking was inversely associated with risk of hypertension. Although there were few cases in the higher categories of consumption (eg, >0.5 drink per day), risk tended to increase beyond consumption of 1.0 drink per day regardless of the specific beverage consumed.

Finally, we examined different patterns of alcohol consumption and risk of hypertension. In our initial analyses (Table 2), we found a suggestion of an increased risk of hypertension among women consuming more than 1.5 drinks per day. Therefore, we initially examined risk by means of the following definition of episodic drinking: consumption of more than 10.5 drinks (>1.5 drinks per day × 7 days) over 1 to 3 days. After adjustment for potential confounders, the risk of hypertension was not increased among women in this category of consumption (n = 469) (RR, 0.80; 95% CI, 0.51-1.23), but was increased among women who drank more than 1.5 drinks per day for at least 5 days per week (n = 1190) (RR, 1.44; 95% CI, 1.15-1.81). The risk among women who drank 1.5 drinks per day or less but who drank for at least 5 days per week was not increased (n = 2175) (RR, 0.99; 95% CI, 0.81-1.22). We then used a more strict definition of episodic drinking: consumption of at least 12 drinks over 1 to 3 days. Even with this more strict definition, episodic drinkers were not at increased risk of chronic hypertension (RR, 1.03; 95% CI, 0.61-1.74), but with only 16 cases in this category, we could not exclude the possibility of risk.

COMMENT

In this study of 70 891 women, the association between alcohol intake and risk of hypertension followed a J-shaped curve. Among women who consumed on average 0.26 to 0.50 drink per day, the risk of developing hypertension was lower by 14% compared with nondrinkers. An increased risk of hypertension was evident beyond consumption of 2 drinks per day, but when episodic drinkers were separated from this analysis, elevated risk was evident among regular drinkers who consumed more than 1.5 drinks per day. We did not observe a beverage-specific effect, and we also did not observe a positive as-

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Table 1. Baseline Characteristics of 70 891 Women According to Average Alcoholic Drinks per Day*

Characteristic	None (n = 27 070)	Average No. of Drinks per Day ≤0.25 (n = 26 152)	0.26-0.50 (n = 6290)	0.51-1.00 (n = 7618)	1.01-1.50 (n = 1820)	1.51-2.00 (n = 984)	>2.00 (n = 957)
Age, y	35.3	35.1	35.3	35.0	35.6	35.3	35.9
BMI, kg/m^2	24.3	23.8	22.9	22.9	22.7	23.0	23.5
White, %	87	91	93	93	93	91	92
Smoking status, %							
Never	73	65	56	50	44	34	32
Current	11	14	16	19	21	35	38
Past	16	21	28	31	35	31	30
Elevated cholesterol, %	11	11	9	9	8	12	10
Family history of hypertension, %	51	51	50	51	50	50	53
Physical activity, METs/wk	27	28	31	32	31	33	32
OC use, %							
Never	19	15	12	12	11	9	11
Current	9	12	14	15	14	15	14
Past	72	73	74	73	75	76	75

*Values are means unless otherwise specified. BMI indicates body mass index; METs, metabolic equivalents; and OC, oral contraceptive.

Table 2. Risk of Hypertension According to Average Alcoholic Drinks per Day in 70 891 Women*

	Nondrinkers	Average No. of Drinks per Day ≤0.25	0.25-0.50	0.51-1.00	1.01-1.50	1.51-2.00	>2.00
Person-years	153 451	148 757	35 979	43 585	10 400	5576	5403
Total No.	27 070	26 152	6290	7618	1820	984	957
No. of cases	1781	1518	291	366	95	63	74
Age-adjusted RR (95% CI)	1.0	0.88 (0.82-0.94)	0.70 (0.62-0.79)	0.72 (0.65-0.81)	0.79 (0.64-0.97)	0.97 (0.76-1.25)	1.18 (0.94-1.49)
Multivariate RR† (95% CI)	1.0	0.96 (0.89-1.03)	0.86 (0.75-0.98)	0.92 (0.82-1.04)	1.00 (0.80-1.24)	1.20 (0.92-1.58)	1.31 (1.02-1.68)

*RR indicates relative risk; CI, confidence interval.
†Multivariate model adjusting for age, body mass index, race, smoking, history of elevated cholesterol level, family history of hypertension, physical activity, and oral contraceptive use.

sociation between episodic drinking and increased risk of chronic hypertension.

More than 130 cross-sectional publications have addressed the relationship of moderate alcohol consumption and risk of hypertension.[4] These studies have reported discrepant findings, with differences that can be attributed to chance, bias, or unadjusted confounding. Prospective studies have not focused specifically on the relationship between moderate drinking and blood pressure, and instead support a threshold association for hypertension, with an increased risk among women who consume 2 or more drinks per day.[4] Witteman et al[16] examined the alcohol–blood pressure relationship in the Nurses' Health Study I among more than 58 000 women aged 34 to 59 years. Women consuming less than 1 drink per day had a slightly lower risk of hypertension (RR, 0.9; 95% CI, 0.8-1.0), whereas women consuming 2 to 3 drinks per day had an adjusted RR of 1.4 (95% CI, 1.2-1.7). In our cohort of even younger women, we too found a J-shaped relationship with a reduced risk among women consuming up to one-half glass of an alcoholic beverage per day. Furthermore, the risk of hypertension was increased by 44% among women who drank more than 1.5 drinks per day at least 5 days per week. This threshold is slightly lower than that previously reported and may relate to a more precise assessment of drinking pattern.

Some have argued that the J-shaped relationship to hypertension may be the result of previously hypertensive individuals lowering their alcohol intake.[17] If these individuals are included in the reference category, the risk of hypertension among those considered nondrinkers may be falsely elevated. We excluded women who at baseline reported hypertension, an elevated systolic or diastolic blood pressure, use of antihypertensive medications, hypertension-related conditions (ie, myocardial infarction, diabetes, or stroke), or past consumption of excessive amounts of alcohol. We also examined models with and without past drinkers in the reference category, since past drinkers may have stopped drinking for other medical reasons,[18] but the results did not materially change from those in Table 2.

There is strong interest in beverage-specific health effects, with some suggesting that red wine is the most effective beverage with respect to cardiovascular risk reduction.[19,20] Beverage-specific effects may be due to differences in the constituents of each beverage, or consumption of a specific beverage may be a marker for a more beneficial drinking pattern.[21] For example, in Western society, wine tends to be consumed in smaller amounts with meals,[22] which may blunt the alcohol–blood pressure association.[23] In addition, an individual's preference for one beverage type over another has

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Table 3. Risk of Hypertension According to Average Drinks of a Specific Beverage Consumed per Day

Beverage	Average No. of Drinks per Day*	Person-Years	Hypertension	Multivariate RR (95% CI)†
Nondrinker	0	153 451	1781	1.00 (Reference)
Beer	≤0.25	79 446	678	0.88 (0.80-0.96)
	0.26-0.50	26 034	195	0.84 (0.72-0.99)
	0.51-1.00	7052	41	0.65 (0.47-0.90)
	≥1.01	5133	62	1.28 (0.98-1.69)
Wine	≤0.25	143 607	1390	0.96 (0.89-1.04)
	0.26-0.50	35 289	307	0.99 (0.86-1.31)
	0.51-1.00	13 412	144	1.10 (0.87-1.38)
	≥1.01	1290	18	1.28 (1.00-1.64)
Liquor	≤0.25	95 984	981	1.03 (0.95-1.12)
	0.26-0.50	16 030	158	1.05 (0.88-1.24)
	0.51-1.00	3616	42	1.18 (0.86-1.64)
	≥1.01	2411	35	1.22 (0.85-1.76)

*Because the numbers of women in certain categories were small, categories were collapsed to obtain more stable estimates.
†Multivariate model adjusting for age, body mass index, race, smoking, history of elevated cholesterol level, family history of hypertension, physical activity, and oral contraceptive use. RR indicates relative risk; CI, confidence interval.

been correlated with demographic and behavioral factors that may influence blood pressure, such as exercise and diet.[4,18] After controlling for many of these lifestyle factors, the risk of developing hypertension in the highest categories of consumption across all beverages was similar. The number of women drinking at the extremes of consumption, however, was small, and so the CIs were wide. We did find that light-beer drinking was protective against chronic hypertension. Cross-sectional data from Japan also suggest a protective blood pressure effect among exclusive beer drinking compared with drinking other beverages.[24] Given the overlapping CIs associated with the beverage-specific estimates, however, further studies are needed to verify these results and to assess whether any protective effect is due to the nonalcoholic ingredients associated with beer consumption or to other lifestyle factors associated with beer consumption.

The health effects of drinking may depend on drinking pattern,[25] and failure to differentiate episodic from regular drinkers may obscure real associations.[4,26] Although some cross-sectional studies suggest that daily drinking is associated with a stronger alcohol–blood pressure association than episodic drinking,[25,26] others do not.[27] We found that the risk of hypertension was increased among more regular (eg, daily) drinkers who consumed more than 1.5 drinks per day, but not among episodic drinkers. Indeed, removal of episodic drinkers from our initial analysis demonstrated that, among more regular drinkers, risk was increased at a level slightly lower (1.5 vs 2.0 drinks per day) than that previously reported.[4] Adverse consequences of episodic drinking, including acute cerebrovascular and cardiovascular events[28,29] and injury,[30] however, suggest that this behavior is unsafe for other reasons.

We were unable to assess the short-term effects of alcohol consumption on blood pressure.[31] Therefore, although episodic drinking may have been associated with acute elevation in blood pressure,[32] in our study this behavior was not associated with chronic hypertension unless heavier consumption extended to most days of the week. The biological mechanisms of alcohol-induced hypertension are not clear, but investigators continue to debate whether the hypertensive effect is due to withdrawal or directly mediated by alcohol itself.[6,33] Although we initially excluded past heavy users of alcohol, we subsequently examined these women to assess the effect of drinking 25 or more drinks per week before the start of the study and found no noticeable elevated risk (RR, 1.02; 95% CI, 0.72-1.46) of hypertension. We could not, however, assess whether these women were binge or regular drinkers and the time since their last drink. Nonetheless, this result suggests that the ill effects of heavy past drinking, at least with respect to risk of developing chronic hypertension, do not persist.

The limitations of this study deserve mention. We relied on self-reported diagnosis of hypertension, the validity of which was discussed in detail herein. In addition, self-reported physician diagnosis of hypertension was a strong predictor of myocardial infarction and stroke among women participating in the Nurses' Health Study I.[34] We also relied on self-reported consumption of alcohol, the validity of which was also described. It is likely that the greatest degree of reporting error occurs at the highest levels of consumption. Therefore, the level of consumption at which we attribute increased risk (>1.5 drinks per day) may be a modest underestimate, but the level of intake associated with a slight decrease in risk of hypertension (≤0.5 drinks per day) is unlikely to be substantially biased. Finally, we studied mainly white nurses; therefore, our results may not pertain to women of other racial or ethnic groups.

In conclusion, prospective data on light to moderate alcohol consumption and risk of hypertension in young women are sparse. Our prospective study of 70 891 women suggests that the association between alcohol consumption and risk of hypertension follows a J-shaped curve that is still present even after adjustment for potential confounding factors and several possible biases. These data exclude a strong effect of moderate alcohol consumption and risk of chronic hypertension. Our re-

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sults also suggest that the risk of hypertension with heavy drinking (>1.5 drinks per day) is evident regardless of beverage consumed. Finally, whereas episodic drinking does not appear to increase a woman's risk of hypertension, regular consumption of more than 1.5 drinks per day is associated with an increased risk. These data refine our understanding of alcohol consumption and risk of hypertension and may be used by primary physicians in counseling young women.

Accepted for publication July 17, 2001.

This study was supported by research grants HL-03804, HL-03533, and AA-11181 from the National Institutes of Health, Bethesda, Md.

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