11-1990

Exercise Tolerance and Alcohol Intake: Blood Pressure Relation

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Publication Info

Published in *Hypertension*, Volume 16, Issue 5, 1990, pages 501-507.
Hartung, G. H., Kohl, H. W., Blair, S. N., Lawrence, S. J., & Harrist, R. B. (1990). Exercise tolerance and alcohol intake: Blood pressure relation. *Hypertension, 16*(5), 501-507.
DOI: 10.1161/01.HYP.16.5.501

Exercise Tolerance and Alcohol Intake

Blood Pressure Relation

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The relations of systolic and diastolic blood pressures to alcohol intake and exercise tolerance levels in 15,612 men and 3,855 women were investigated. Alcohol intake was assessed by questionnaire and stratified into seven levels for men and six for women according to the ounces of ethanol consumed per week. Exercise tolerance was determined by maximal treadmill exercise testing and was categorized into six age-specific by sex-specific levels. Both systolic and diastolic blood pressure were significantly related to both alcohol intake and exercise tolerance levels in both men and women. These relations, which were positive for alcohol and negative for exercise tolerance, remained after covariance adjustment for age, body mass index, and cigarette smoking. Alcohol intake was not significantly correlated with exercise tolerance. The relation of blood pressure to alcohol was not linear because the blood pressure of moderate consumers of alcohol tended to be slightly lower than that of nondrinkers. Higher blood pressure was found only in drinkers whose ethanol intake exceeded 9.5 ounces (~285 ml or 19 drinks) per week. However, heavy drinkers in high exercise tolerance categories had no higher blood pressure than nondrinkers in low exercise tolerance groups. Exercise tolerance or physiological fitness appears to be important in quantifying the relation between alcohol intake and blood pressure and should be considered in describing this relation. (*Hypertension* 1990;16:501–507)

Recent cross-sectional epidemiological studies show a positive relation between alcohol consumption and blood pressure. This relation persists whether blood pressure is considered as a continuous variable or as the prevalence of hypertension.[1–7] Experimental studies involving controlled alcohol intake in volunteer subjects and in animals seem to support these epidemiological findings.[8,9]

On the other hand, there are several epidemiological studies that report low-to-moderate levels of alcohol intake may be associated with lower blood pressures than either no alcohol intake or high alcohol intake. The Canada Health Survey data show no consistent relation between either systolic blood pressure (SBP) or diastolic blood pressure (DBP) and alcohol consumption in either men or women.[10] Thus, the results from many of the epidemiological studies have been inconsistent with respect to the specific form of the relation between blood pressure and alcohol consumption. Some studies have found the relation to be positive and linear, whereas others have found that it is curvilinear, either "J" or "U" shaped.[11–14] These studies have shown stronger associations of blood pressure with abstention and elevated levels of alcohol intake than with moderate alcohol intake.

Many cross-sectional studies have shown that exercise training status or physical fitness are negatively related to blood pressure levels or prevalence of hypertension.[15–18] Also, SBP and DBP may decrease in response to an exercise training program in many normotensive and hypertensive subjects.[19–22]

The purpose of the present study was to investigate the joint relations of resting SBP and DBP with exercise tolerance level and self-reported alcohol intake. These relations were studied separately in men and women because sex differences in blood pressure response to alcohol consumption level have been reported in some studies.[3,7,12]

Methods

The study participants were patients seen at the Cooper Clinic, Dallas, Tex., for preventive medical examinations during the period 1971–1985. Most of

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Received August 28, 1989; accepted in revised form June 14, 1990.

TABLE 1. Fitness Categories By Age (Treadmill Time Seconds)

Category	Age (yrs)				
	<30	30–39	40–45	50–59	>60
*Men**					
1 (Very Poor)	<840	<780	<690	<570	<380
2 (Poor)	840–1019	780–929	690–839	570–719	380–569
3 (Fair)	1,020–1,221	930–1,139	840–1,034	720–903	570–779
4 (Good)	1,222–1,379	1,140–1,329	1,035–1,236	904–1,124	780–959
5 (Excellent)	1,380–1,582	1,330–1,519	1,237–1,410	1,125–1,319	960–1,237
6 (Superior)	≥1,583	≥1,520	≥1,411	≥1,320	≥1,238
Women					
1 (Very Poor)	<600	<510	<420	<343	<242
2 (Poor)	600–719	510–644	420–549	343–446	242–359
3 (Fair)	720–899	645–809	550–719	447–559	360–479
4 (Good)	900–1,079	810–977	720–884	600–719	480–678
5 (Excellent)	1,080–1,259	978–1,135	885–1,019	720–899	679–879
6 (Superior)	≥1,260	≥1,136	≥1,020	≥900	≥880

*For men, maximal oxygen uptake (Vo_{2max}) can be estimated by the following: Vo_{2max} (ml/kg/min)=1.444×treadmill time (min)+14.99.[23]

the subjects were self-referred, 99% were white, and they were predominantly from the middle-to-upper socioeconomic strata. All patients, regardless of age, who were examined during the stated time period were included in the study. The actual age range of the subjects whose data were analyzed was 18–83 years with a mean of 41.5 (standard deviation 10.1) years. The mean age of the men was 41.7 (SD 9.8) years with a range of 18–83 and of the women 41.1 (SD 11.2) years with a range of 18–81.

The subjects originally gave their consent for the use of information obtained from their examinations for research, but because this was a retrospective study, informed consent was not obtained specifically for this project.

The data obtained from the Cooper Clinic consisted of more than 36,000 records of first visits of men and women to the clinic. Excluded from consideration for the present study were subjects who were known to be hypertensive, heart disease patients, or stroke patients. Also excluded were subjects who did not attain at least 85% of the age-predicted maximal heart rate on the treadmill tolerance test. Reasons for failure to reach this heart rate may have been because of medications such as β-adrenergic blockers or medical conditions that might suppress the heart rate response to exercise. Other reasons related to the unwillingness of the patient to continue the test to the 85% heart rate level also tend to preclude valid estimation of exercise tolerance.

After exclusions, the records of 23,585 men and 7,168 women remained for further analyses. Because only subjects for whom complete data were available could be used, the numbers were further reduced to 19,467, of which 15,612 were men and 3,855 were women. The missing data, which accounted for these exclusions, were mainly dietary records that contained the report of alcohol intake.

Level of exercise tolerance was estimated from the result of a maximal, multistage treadmill endurance test (Balke protocol). Six age-specific and sex-specific categories based on treadmill endurance time have been developed from long-term experience at the Institute for Aerobics Research/Cooper Clinic (see Table 1). Subjects were classified according to this system to characterize their exercise tolerance levels.

Height and weight were measured, and body mass index (BMI) was calculated as weight (kg) divided by height squared (m^2). Smoking habits were ascertained from questionnaire data with subjects classified as present smokers or nonsmokers (including former smokers).

Alcohol intake was classified according to questionnaire responses as to whether the subject ever drank alcoholic beverages and, if so, how many times per week a 12 oz (355 ml) beer, a 3 oz (~90 ml) glass of wine, or a drink containing 2 oz (~60 ml) of liquor were consumed. The resulting number of drinks per week was converted into ounces (and ml) of ethanol (ethyl alcohol) by estimating that beer is 4%, wine 12%, and liquor 40% ethanol. For example, the number of beers was multiplied by 0.48 (0.04×12 oz), wine by 0.36, and liquor by 0.8 to obtain total ounces of ethanol. Seven alcohol intake categories for men and six for women were created as shown in Table 2.

The blood pressure used was the lowest of six measurements taken by a trained technician using a mercury sphygmomanometer, inflatable cuff, and stethoscope. Two measurements were made in each arm in the supine, the sitting, and the standing positions. The pressure at the fifth Korotkoff phase (disappearance of sound) was taken as the diastolic pressure. In a subset of 754 subjects, we computed correlation coefficients (r) between the lowest and the mean of all six pressure values and the lowest and the mean of the remaining five values. The correla-

TABLE 2. **Alcohol Intake Categories**

Category	Ethanol		Drinks/week
	oz/week	ml/week	
0	0	0	0
1	>0–≤1	>0–<30	>0–2
2	>1–≤2.5	>30–≤75	>2–5
3	>2.5–≤5	>75–≤150	>5–10
4	>5–≤9.5	>150–≤285	>10–19
5	>9.5–≤14.5	>285–≤435	>19–29
6	>14.5	>435	>29*

*Categories 5 and 6 were combined for women because of the small number of subjects in the higher category.

tions obtained were 0.96 for SBP and 0.90 for DBP for the six values and 0.94 for SBP and 0.86 for DBP for the mean of five values.

Data Analyses

The 15,612 men and 3,855 women for whom all necessary data were available were included in the analysis. Analysis of variance was used to determine the effect of exercise level and alcohol intake level on SBP and DBP for men and women separately. Analysis of covariance by a multiple regression method using age, body mass index, and smoking status as covariates was used to correct for effects of these variables in the various exercise tolerance–alcohol consumption groups. A value of $p<0.01$ was set for judging the statistical significance of the computed F ratios. The χ^2 analyses were carried out on cross-tabulations of alcohol in six or seven categories by blood pressure in two categories.

Results

The results of covariance analyses with adjustment for age, BMI, smoking status, and the other independent variable (exercise tolerance or alcohol) showed statistically significant independent effects of both alcohol intake and exercise tolerance on both SBP and DBP in men and in women. Figure 1 depicts the adjusted three-dimensional relations between SBP and DBP, respectively, and alcohol intake and exercise tolerance level for men. Figure 2 shows the adjusted three-dimensional relations for women between SBP and DBP, respectively, and alcohol intake and exercise tolerance level.

Alcohol intake was positively and exercise tolerance negatively associated with blood pressure in both sexes. Analysis of covariance showed no significant interactions between alcohol intake and exercise tolerance level for either sex, indicating that the influences of each factor on blood pressure (SBP or DBP) were constant across the levels of the other factor. Age and BMI were positively related and smoking status was negatively related to SBP and DBP in both men and women ($p<0.001$).

Correlation coefficients between the independent and dependent variables and the covariates are as follows: For men, correlations of 0.08, −0.21, 0.21,

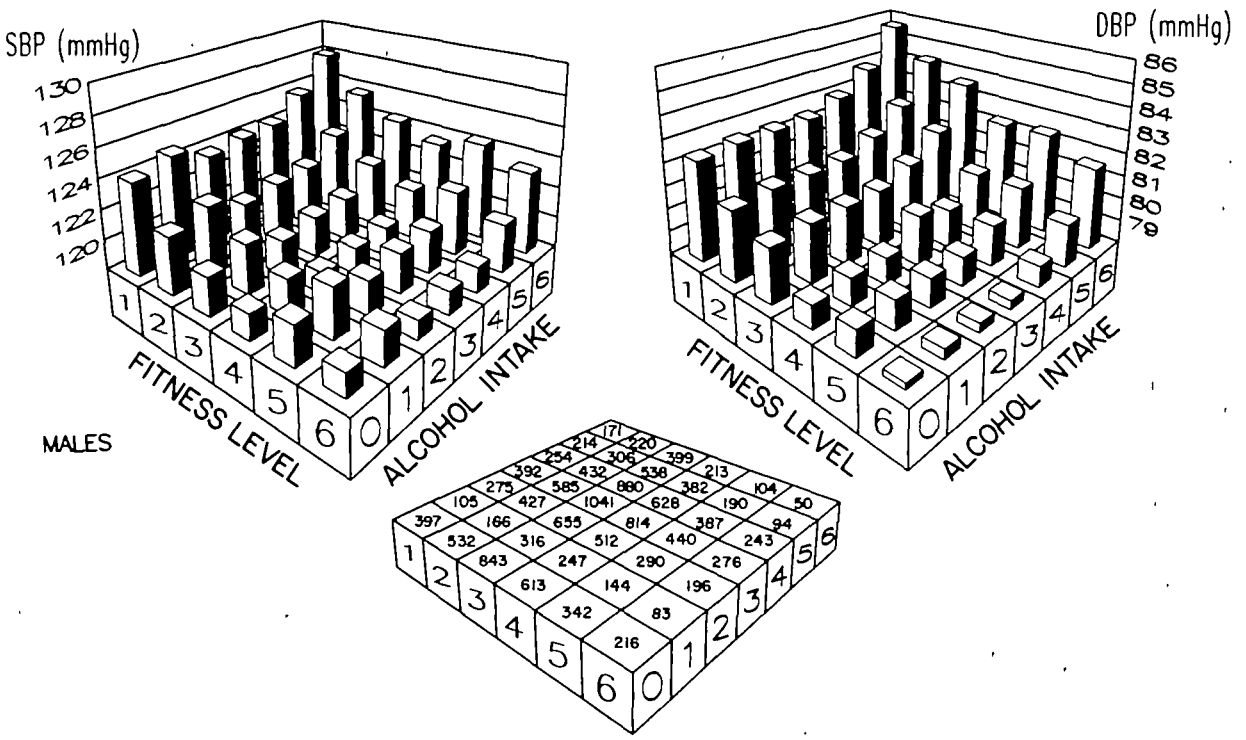

FIGURE 1. *Mean systolic blood pressure (SBP)* (left panel) *and mean diastolic blood pressure (DBP)* (right panel) *adjusted for age, body mass index, and smoking; by alcohol intake category and fitness level for men. Number of subjects in each cell is shown between the figures.*

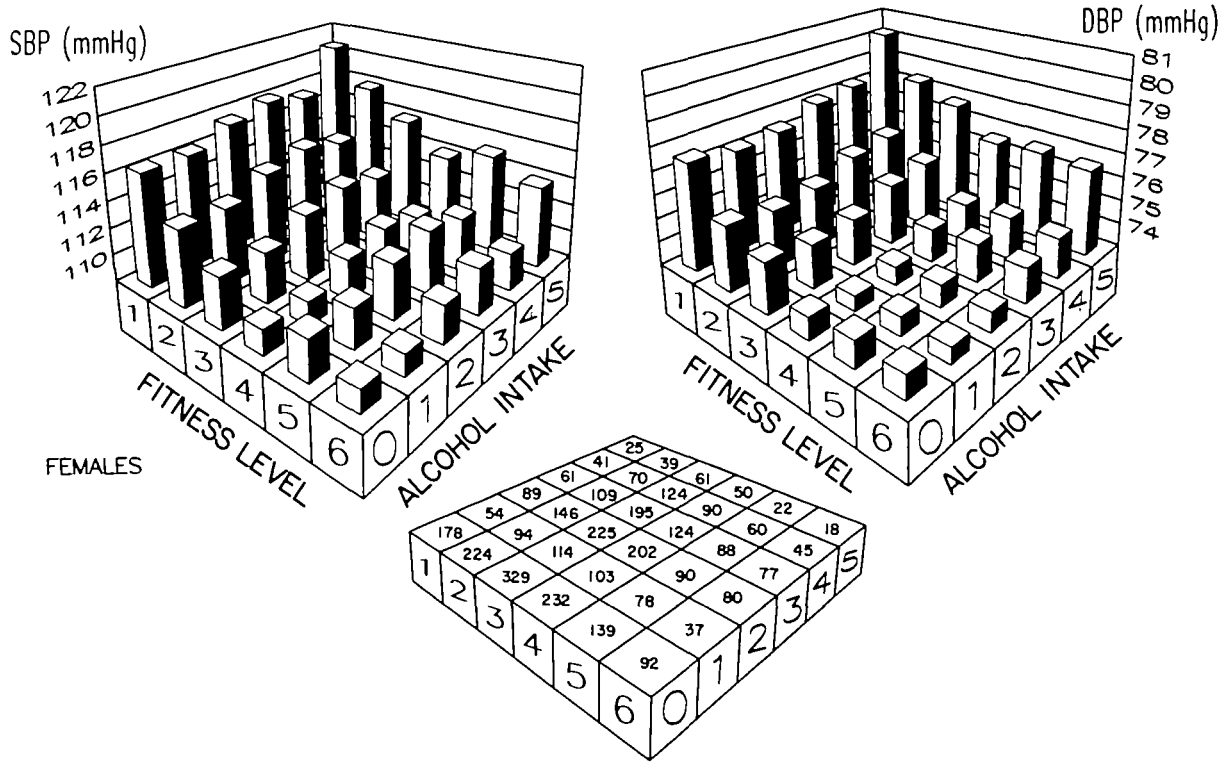

FIGURE 2. *Mean systolic blood pressure (SBP)* (left panel) *and mean diastolic blood pressure (DBP)* (left panel) *adjusted for age, body mass index, and smoking; by alcohol intake category and fitness level for women. Number of subjects in each cell is shown between the figures.*

and 0.20 were found between SBP and alcohol intake, exercise tolerance, age, and BMI, respectively. Similar relations were found for the same variables and DBP. For women, the correlations were 0.05, −0.31, 0.38, and 0.27 between SBP and alcohol intake, exercise tolerance, age, and BMI, respectively, with similar associations between those variables and DBP.

Mean alcohol intake by exercise tolerance level for men and women is presented in Table 3. Analysis of variance revealed a significant ($p<0.01$) difference in alcohol consumption over the six exercise tolerance levels for the men but not for the women. The men in the middle levels of exercise tolerance consumed more alcohol than those in the low or high levels. Table 4 shows that a higher proportion of men than women were "heavy" drinkers (18.4% versus 5.5%), and a higher proportion of women than men were alcohol abstainers (29.4% versus 18.8%).

For both men and women, the proportion of subjects having an SBP of 140 mm Hg or greater was calculated for each alcohol consumption category. Similarly, the proportion of subjects having a DBP of 90 mm Hg or greater was calculated and both results are displayed in Table 5. The hypothesis that the classification of the subjects with regard to elevated blood pressure and alcohol intake level are independent was tested by calculating a χ^2 statistic. The hypothesis of independence was rejected ($p<0.001$) for both DBP and SBP for the men, but in neither for the women. For all alcohol intake categories, 20.1% of the men and 8.9% of the women had DBP greater than 90 mm Hg, and 12.4% of the men and 6.6% of the women had SBP greater than 140 mm Hg, even though those previously diagnosed as hypertensive were excluded from the study.

TABLE 3. Adjusted Mean Alcohol Intake By Fitness Category*

Fitness category	Alcohol intake (oz/wk)	
	Men	Women
1	4.65	2.50
	(1,808)	(448)
2	5.06	2.30
	(2,668)	(682)
3	5.44	2.63
	(4,672)	(1,048)
4	5.24	2.65
	(3,409)	(851)
5	5.12	2.39
	(1,897)	(477)
6	5.09	2.91
	(1,158)	
Fitness main effect, $p<$	0.01	0.19

Numbers in parentheses are number of subjects.
*Adjusted for age, smoking, and body mass index.

TABLE 4. Proportion of Subjects in Alcohol Intake Categories By Sex (Percent of Total)

Sex	Nondrinker (category 0)	Moderate (category 1–4)	Heavy (category 5–6)
Male	18.7	62.7	18.7
Female	29.4	65.0	5.5

Discussion

These data suggest that exercise tolerance level must be considered, in addition to age, smoking, and BMI when examining the relation between blood pressure and alcohol intake. The association of exercise tolerance with blood pressure appears to be even stronger than the relation of alcohol intake and blood pressure and similar to that of age and BMI. It is the concurrent association of exercise tolerance and alcohol intake with blood pressure that is the major new finding of this study. This association can be seen in Figures 1 and 2, which show that for any alcohol intake category, there is a simultaneous relation of exercise tolerance level with blood pressure.

In this study group, blood pressure was positively associated with alcohol intake in both men and women. The relation, however, was not linear throughout the range of alcohol intake levels. These associations were seen for both SBP and DBP and remained after adjustment for possible confounding variables. Lower alcohol intake levels (categories 1–4) did not appear to be associated with significantly higher blood pressures than was nondrinking (category 0) in either sex. It was not until the fifth alcohol intake level and beyond (approximately 9.5 oz or ~285 ml ethanol/wk or about 19 average drinks) that blood pressure appeared to increase with alcohol consumption.

These findings are consistent with those of other studies that have found a significant positive association between alcohol intake and blood pressure.[1,3,4] The results are also consistent with studies that have noted blood pressures in moderate alcohol consumers were lower than or equal to those of nondrinkers.[11,12,17]

We recognize that the self-referral of subjects to a preventive medicine center may introduce some bias into the data collected because of a lack of random assignment or a control group for comparison. We believe that these factors may limit somewhat the general applicability of the results, but we think that the levels of exercise tolerance and alcohol intake represented are characteristic of a large segment of the population.

Also the exclusion of subjects whose records did not contain alcohol consumption information may introduce some bias, because we do not know the reason for the lack of this data. If heavier drinkers had omitted this question to hide their drinking habit, then this would bias the results. Because almost as many men admitted to drinking amounts that placed them in categories 5 and 6 as those who said that they did not drink alcohol, we believe that this was an unlikely cause of not obtaining the alcohol intake information. It is just as likely that nondrinkers saw the question as not pertaining to them and failed to respond.

We cannot rule out misclassification as a possible source of bias in these data. Indeed, any study of self-reported alcohol intake must contend with such a possibility, especially denial of any alcohol use by heavy drinkers. In this study, that possibility could have contributed to the finding of equal or slightly higher blood pressures in the nondrinking category than in the "moderate" alcohol intake levels.

The exclusion of known hypertensive individuals in the analyses may tend to bias the results by eliminating subjects whose blood pressure might be more responsive to alcohol. However, this exclusion also eliminates subjects whose blood pressure response to alcohol might be artificially altered because of antihypertensive medications. In several studies that excluded subjects receiving treatment for hypertension,[1,2] the relation of alcohol and blood pressure was essentially linear after adjustment for confounding factors. In another study,[4] analyses were repeated with hypertensive participants taking medication ex-

TABLE 5. Percentage of Subjects With Elevated Blood Pressure By Alcohol Intake Category

	Alcohol intake category (from Table 2)						
Classification	0	1	2	3	4	5	6
DBP							
>90 mm Hg							
Men	19.6	18.1	18.3	18.3	19.0	22.9	31.0
Women	9.0	7.1	8.4	8.4	9.6	14.2	...
SBP							
>140 mm Hg							
Men	12.2	11.2	11.3	11.3	11.2	15.0	18.6
Women	7.7	6.0	6.7	5.3	5.5	9.0	...
Total *N*							
Men	3,290	1,174	2,645	3,996	3,189	1,958	1,266
Women	1,425	632	1,049	948	531	267	...

DBP, diastolic blood pressure; SBP, systolic blood pressure; *N*, number of subjects.

cluded, and the result was essentially the same (i.e., a graded linear relation after adjustment).

Jackson and others[12] found a U-shaped relation between alcohol intake and blood pressure in men and older women as well as in hypertensive patients and those who were unaware of their hypertension. Coates and associates[10] found that including hypertensive patients under treatment in their analyses made no difference in the finding that there was no relation between alcohol intake and blood pressure.

Blood pressure was negatively related to exercise tolerance level in both sexes. The relation tended to be more linear than that for blood pressure with alcohol, and it persisted for both SBP and DBP after adjustment for potential confounders. There did appear to be a plateau of blood pressure for both sexes by exercise tolerance level. Blood pressure was higher in the less fit categories and was progressively lower until exercise tolerance category 4, then remained relatively constant through category 6.

Exercise tolerance level appears to be a strong potential factor in the relation of alcohol and blood pressure in this population. For women there was an adjusted mean difference of −6.8 mm Hg in SBP and −3.6 mm Hg in DBP from the lowest exercise tolerance groups to the highest regardless of alcohol intake. The corresponding differences for men were −4.7 mm Hg for SBP and −4.1 mm Hg for DBP. For both men and women and for both SBP and DBP, the most fit, highest consumers of alcohol had blood pressures that were not higher than the least fit nondrinkers.

In a clinical setting, there are several accurate methods of assessment of exercise tolerance such as the exercise stress test or measurement of maximal oxygen uptake on a treadmill or bicycle ergometer. In field work, submaximal bicycle or stepping tests have been shown to provide valid estimates of exercise tolerance level.[24] For large scale epidemiological surveys, the methods of assessment are usually less precise,[25] but a recent report has indicated that acceptable validity can be obtained using a mail survey to estimate fitness.[26]

Whether alcohol intake might be related to blood pressure levels commonly accepted as "borderline" hypertension or moderately elevated pressure (90 mm Hg DBP or 140 mm Hg SBP) was explored. The significant relation found for men using a χ^2 test might be related to the greater percentage of consumers of larger amounts of alcohol. This method of assessing differences in blood pressure with increasing alcohol intake also showed no major change in the percentage of subjects in the borderline category until alcohol category 5 was reached. This pattern was evident for both DBP and SBP and for both men and women but with more pronounced increases in the men.

It is recognized that factors such as environmental temperature, time of day, and emotional state may affect blood pressures in a predictable manner. These factors might alter the estimated levels of hypertension prevalence in studies such as the present one where only one series of measurements is used and hypertension is defined by a sharp blood pressure cut-off.

Despite the exclusion of known hypertensive individuals, the percentage of subjects with elevated blood pressure (140/90 mm Hg or greater) in the present study was higher than that reported by Arkwright et al[1] in 491 men. In that study, only 9% of the highest alcohol intake group had DBP 90 mm Hg or greater and 12% had SBP 140 mm Hg or greater after exclusion of hypertensive patients undergoing treatment. Their SBP finding was consistent with the results of the present study, but the DBP prevalence of hypertension was more than twice that of men in this study. Among nondrinkers, only 2.6% and 3.4% had similarly elevated SBP and DBP, respectively, in the Arkwright study, whereas the nondrinkers in the present study did not differ from moderate drinkers in percentage of elevated DBP or SBP.

The mechanisms for the effects of either exercise or alcohol on blood pressure are unknown. However, it has been suggested that acute vasodilation with exercise could result in a chronic reduction in vascular resistance.[22] Reduction in resting heart rate resulting from exercise training could also result in decreased cardiac output and blood pressure in hypertensive individuals.[22] Withdrawal from alcohol as opposed to recent drinking has been proposed as a mechanism for the alcohol–blood pressure association in population studies.[27,28]

Although there was a significant difference in mean adjusted alcohol intake among the exercise tolerance levels for the men, there was not a trend for the more fit groups to drink less alcohol, and in fact, the moderately fit men consumed more alcohol than either the low or high exercise tolerance categories (Table 3). There was no difference in adjusted alcohol intake among the exercise tolerance levels for the women, yet there were significant blood pressure differences.

In conclusion, there is, first, a concurrent association of both exercise tolerance and alcohol intake with blood pressure in both men and women. Second, increased blood pressure appears to be associated with alcohol consumption mainly at higher intake levels (more than 9.5 oz or ~285 ml ethanol/wk) in both men and women. Third, blood pressure tends to be correlated more strongly with exercise tolerance than it does with alcohol intake in both men and women. Fourth, blood pressure is negatively associated with exercise tolerance, with higher tolerance groups of men and women having lower blood pressure levels. Fifth, exercise tolerance level (along with age and BMI) should be considered when studying the relation between blood pressure and alcohol intake.

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KEY WORDS • blood pressure • alcohol drinking • exertion