Acute effects of moderate alcohol consumption on blood pressure and plasma catecholamines

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(Received 28 January/27 June 1983; accepted 11 November 1983)

Summary

1. This study examines the response of blood pressure, plasma catecholamines and cortisol to acute alcohol intake in young men with light to moderate drinking habits.

2. Ingestion of alcohol was associated with a highly significant increase in systolic blood pressure and heart rate which occurred before blood alcohol reached its peak concentration of 16.9 ± 1.1 mmol/l (80 mg/100 ml). After an initial non-specific rise, diastolic pressure fell below values observed after drinking water only. This predominant effect of alcohol on systolic blood pressure is also seen with chronic alcohol consumption.

3. Drinking water and non-alcoholic cold liquids caused a marked fall in plasma adrenaline and a transient rise in noradrenaline concentration. In contrast, drinking alcohol resulted in a relative rise in adrenaline and a delayed increase in noradrenaline concentration.

4. Blood glucose increased after alcohol, supporting a physiological effect of adrenaline on liver glycogenolysis. Plasma cortisol concentration was also significantly higher after drinking alcohol.

5. It is proposed that the relative rise in adrenaline together with higher cortisol levels, repeated over a variable period in susceptible individuals, are implicated in the elevation of blood pressure associated with long term alcohol consumption. It concurs with observations in man and experimental animals of a slow pressor mechanism mediated by adrenaline.

6. The study emphasized that an evaluation of the acute effects of alcohol requires careful measurement of blood pressure, precise assay of catecholamines and recognition of the confounding effects of drinking cold liquids.

Key words: alcohol, adrenaline, blood pressure, cortisol, noradrenaline, pressor mechanisms.

Introduction

The close relationship between alcohol consumption, blood pressure and the prevalence of hypertension has received renewed interest [1-3]. The mechanisms responsible for this pressor effect of alcohol are unknown. We have previously studied the effect of moderate habitual alcohol consumption on blood pressure and sympatho-adrenal activity in drinking and non-drinking males matched for age and weight [4]. Although drinkers had significantly higher systolic blood pressure, plasma catecholamines and cortisol were similar at rest and after various physiological stresses. It could be concluded that the higher blood pressure in drinkers is not caused by increased sympatho-adrenal activity. However, initiating mechanisms may be transient with each episode of drinking, or may become obscured by the development of secondary adaptive changes once higher blood pressure is established. We considered it important to examine under carefully controlled conditions the acute effects of moderate alcohol consumption on blood pressure and sympatho-adrenal hormones using precise and sensitive assays.

Methods

We studied the acute effects of alcohol consumption on heart rate, blood pressure and sympatho-
adrenal hormones in 14 male university students (mean 20.3 ± SEM 1.2 years and mean weight 72 ± SEM 2.3 kg) with light to moderate drinking habits assessed by a 7 day retrospective diary [3]. The students were paid a nominal sum and the protocol was approved by the Hospital's Ethics Committee. They were asked to avoid alcohol, coffee, tea and tobacco on the day of the study and reported to the laboratory after a light lunch. Subjects were studied recumbent as far as possible, in a quiet room where an indwelling needle was inserted into a forearm vein. After the subjects had been lying down for 20 min, heart rate and blood pressure were measured with an automatic oscillometric recorder (Dinamap, Applied Medical Research, U.S.A.). Blood samples were drawn for determination of plasma adrenaline, noradrenaline, cortisol, alcohol and glucose. Each subject then drank two 370 ml volumes of cold water (4°C), each over consecutive 10 min periods. Most were unable to drink lying down and adopted a semi-sitting position. Blood pressure and heart rate were recorded and blood samples were drawn at the end of each 10 min period, at 10 min intervals for 30 min and at 20 min intervals for a further 60 min. Subjects returned the following day for an identical study except that they now drank two 370 ml volumes of cold non-alcoholic beer (Birell, Cooper and Sons, South Australia), to each volume of which was added 0.5 ml of ethanol/kg of body weight. When necessary they were permitted to void urine after 60 min but this was timed to be completed at least 15 min before the next measurements and blood samples.

Seven of these subjects then participated in a further study on a separate occasion, drinking the non-alcoholic beer without alcohol added. The subjects were not told beforehand whether or not alcohol had been added to their drinks.

Blood samples for adrenaline and noradrenaline assay were collected in chilled tubes containing EGTA (0.25 mol/l) and glutathione (0.2 mol/l). Plasma was separated at 4°C, stored at -80°C and assayed by a modification [5] of the radioenzymatic method described by Peuler & Johnson [6]. All samples obtained from one subject during each study were assayed together. The interassay coefficient of variation was 12.7% for noradrenaline and 9.4% for adrenaline with a sensitivity limit of 0.10 nmol/l. Plasma cortisol was measured by radioimmunoassay, alcohol by enzymatic assay (Calbiochem Alcohol Kit) and glucose by autoanalyzer.

Statistical analyses were performed using the Statistical Package for the Social Sciences. All data were analysed by repeated measures analysis of variance (AOV), examining the effects of treatment (type of drink) and time, and the Newman-Keuls test for within-group (time) comparisons and to evaluate the significance of between-group (treatment) differences. Values are means ± SEM.

Results

The 14 subjects taking part in this study were estimated from the questionnaire to drink 170 ± 55 ml of alcohol/week.

As seen in Fig. 1, there was a significant increase in systolic blood pressure with time after consumption of the drink with added alcohol \( F_{8,104} = 2.46, \ P = 0.02 \) (repeated measures AOV; degrees of freedom 8,104 refer to analysis of treatment–time interaction or effect of time only, and 1,13 refer to analysis of treatment effect only). This rise was apparent after the first drink and before there was a major increase in blood alcohol concentration \( P < 0.01 \) at 10 and 20 min

![Fig. 1](image-url)
compared with basal value at 0 min, Newman-Keuls test). Systolic pressure rapidly declined after the second drink. There was no change in systolic pressure when water was drunk. Diastolic pressure initially increased with both drinks (Fig. 1) ($F_{1,13} = 4.53, P < 0.0001$) but subsequently fell in the alcohol group ($F_{1,13} = 10.43, P < 0.007$), the fall coinciding with blood alcohol reaching its maximum concentration. There was a highly significant and immediate effect of alcohol on heart rate ($F_{1,13} = 22.91, P < 0.0004$), which was clearly evident in the higher values after alcohol throughout the study ($P < 0.01$, compared with corresponding values after water, Newman-Keuls test).

Both time and treatment markedly influenced plasma adrenaline concentration (Fig. 2) ($F_{8,104} = 5.79, P < 0.00001$). Twenty and 30 min after alcohol mean plasma adrenaline concentration was considerably higher than after water ($P < 0.01$), where levels sharply declined. Examination of individual values showed an increase of plasma adrenaline over basal levels at 20 min in seven of the 14 subjects drinking alcohol but only in one subject after drinking water. At 40 min, however, adrenaline concentrations were again similar. There was an obvious initial rise in noradrenaline concentration after both drinks (Fig. 2), which was short-lived after water but sustained after alcohol, indicating a significant effect of treatment with time ($F_{8,104} = 5.69, P < 0.00001$) and difference between the groups at 90 min ($P < 0.01$).

Although there was an overall fall in plasma cortisol concentration with time this was less marked after alcohol ($F_{8,104} = 6.13, P < 0.00001$), where levels were significantly higher at 30, 40 and 50 min ($P < 0.01$) than after water. Blood glucose concentration was significantly higher at 20, 30 and 40 min when alcohol was taken (Table 1).

To ensure that the changes observed were due to alcohol and not to the non-alcoholic beer to which it was added, the effects of drinking the non-alcoholic beer alone were examined in seven of the above subjects. As shown in Fig. 3, there was an early increase in diastolic pressure with time ($F_{4,8} = 2.34, P < 0.05$), similar to when they drank water. Contrary to the findings with alcohol, subsequent diastolic pressures did not differ. There were no significant changes in systolic pressure or heart rate. As before, a highly significant rise in plasma noradrenaline concentration ($F_{4,8} = 14.17, P < 0.00001$), was observed with time (Fig. 4) after completion of the first

TABLE 1. Effect of drinking alcohol (0.5 ml of ethanol/kg at 10 and 20 min), compared with water, on blood glucose

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>110</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>5.9±0.3</td>
<td>5.7±0.3</td>
<td>5.4±0.3</td>
<td>5.2±0.3</td>
<td>5.2±0.2</td>
<td>4.8±0.1</td>
</tr>
<tr>
<td>Alcohol</td>
<td>5.9±0.2</td>
<td>6.0±0.2</td>
<td>7.1±0.3**</td>
<td>7.8±0.4**</td>
<td>7.7±0.5**</td>
<td>4.8±0.3</td>
</tr>
</tbody>
</table>

Values are means ± SEM (n = 14). **Significantly different from water at $P < 0.001$. 

FIG. 2. Effect of drinking water (○–○) or non-alcoholic beer with added alcohol (●–●) on plasma concentration of adrenaline, noradrenaline, cortisol and ethanol in 14 men. For further explanation and significance of differences see Fig. 1.
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...confirming the specificity of the response to alcohol. There was a progressive fall with time in plasma cortisol concentration ($F_{8,48} = 7.79, P < 0.00001$) with no significant difference between the groups. There was no difference in blood glucose between drinking water and non-alcoholic beer.

Discussion

Little reliable information is available on the acute effects of moderate alcohol consumption on blood pressure and plasma catecholamines. Previously either no change [7] or a small rise in heart rate and diastolic blood pressure [8] were reported after moderate amounts of alcohol. Indeed, it appears to have become accepted that acute ingestion of alcohol does not affect blood pressure [9]. Although we have demonstrated a consistent haemodynamic effect, the changes were relatively small, indicating the need for careful measurements under controlled conditions. Use of an automatic blood pressure recorder greatly facilitated detection of these changes by eliminating observer variability and error. Interpretation of blood pressure changes, particularly diastolic pressure, is also complicated by a non-specific rise in pressure due to drinking. Whether this is due to the low temperature or volume effect of the drink, or to the subjects partly sitting up to drink, is not known. The relevance of the acute rise in systolic blood pressure to the long term effect of alcohol is strongly supported by epidemiological evidence of a predominant effect on systolic pressure [2-4].

Increased urinary catecholamines have been reported during heavy alcohol consumption [10, 11], a situation quite different from our study where mean blood alcohol concentration only reached $16.9 \pm 1.1$ mmol/l (80 mg/100 ml). The availability of sensitive and precise assays of plasma adrenaline and noradrenaline has allowed a careful reappraisal of the response to alcohol. Firstly, it has uncovered small but nevertheless important and highly significant responses to drinking cold liquids. Failure to recognize and control for these changes could result in the erroneous belief that they were due to alcohol. Furthermore the effects of alcohol on plasma catecholamines need to be interpreted in the light of the effects of drinking cold liquids alone. The early response in adrenaline and the sustained rise in noradrenaline after alcohol therefore represent a relative increase in these plasma levels. Also, in seven of the 14 subjects studied, a definite increase in plasma adrenaline concentration followed alcohol drinking. That this...
change in plasma adrenaline concentration is of physiological significance is suggested by the rise in blood glucose, which is presumably a secondary effect of adrenaline on the liver. Adrenaline measured in forearm venous blood also underestimates arterial levels because of tissue re-uptake and conjugation [12], and therefore alcohol may increase adrenaline concentration at active receptor sites more than is indicated by the measurements reported here.

The rise in systolic pressure and heart rate and the lack of fall in plasma adrenaline concentration occurred before there was any substantial increase in blood alcohol concentration. This resembles the 'cephalic' phase of metabolic regulation raising plasma catecholamines in anticipation of a metabolic need [13]. It is conceivable that these responses are mediated by smell, taste or other visceral afferents modifying sympatho-adrenal outflow. Rising blood alcohol concentration may also directly stimulate adrenal medullary secretion or influence adrenaline disposal mechanisms.

The findings suggest a causal relationship between the level of circulating adrenaline, the early rise in systolic blood pressure and heart rate, and the later fall in diastolic pressure. This is most readily explained by a rise in cardiac output and a decrease in peripheral resistance (due to stimulation of vascular \( \beta_2 \) receptors), effects which are reproduced by slow intravenous infusion of adrenaline [14]. Alcohol, as a peripheral vasodilator, may also contribute directly to the fall in diastolic pressure.

The persistent elevation of plasma noradrenaline could be a reflex sympathetic response to falling diastolic pressure, or to enhanced neuronal release due to adrenaline stimulating presynaptic \( \beta \)-adrenoceptors [15].

Alcohol given acutely to non-alcoholics usually [16], but not invariably [17], increases plasma cortisol. Although we found only small changes in cortisol levels specifically associated with alcohol ingestion, these may add to the pressor action of alcohol by amplifying the cardiac and vascular effects of catecholamines [18].

Although an actual increase in plasma adrenaline concentration was observed in only 50% of subjects drinking alcohol, the overall response has to be viewed against the effect of cold fluids tending to decrease levels. Individual susceptibility may well determine the magnitude of this response and any ensuing blood pressure changes.

Adrenaline has been proposed as the cause of essential hypertension [19] and a sustained rise in blood pressure has been observed in rats continuously infused with small amounts of adrenaline [15]. Such a slow pressor mechanism may require only small increments in plasma adrenaline or cortisol to produce a gradual increase in blood pressure and it is tempting to speculate that this mechanism is implicated in the pressor effect of alcohol. It is likely that the effects of alcohol are dose-dependent and that larger amounts result in quantitatively greater responses.

Acknowledgments

This investigation was supported by the Raine Foundation of the University of Western Australia and the National Health and Medical Research Council.

References


