# Effect of Alcohol on Acute Ventilatory Adaptation to Mild Hypoxia at Moderate Altitude

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■ *Objective:* To evaluate the influence of alcohol on acute adaptation to mild hypoxia at moderate altitude.
■ *Design:* Randomized, double-blind, placebo-controlled crossover trial.
■ *Setting:* University clinic and mountaineering resort at altitudes of 171 m and 3000 m, respectively, in the Austrian Alps.
■ *Participants:* 10 healthy male alpinists, 22 to 24 years of age.
■ *Intervention:* Single dose of 50 g of alcohol or placebo at altitudes of 171 m and 3000 m.
■ *Main Outcome Measures:* Arterial oxygen pressure ($Pao_2$) and arterial carbon dioxide pressure ($Paco_2$) before and 1 hour after consumption of alcohol or placebo.
■ *Results:* At an altitude of 171 m, 50 g of alcohol caused no statistical change in $Pao_2$ and $Paco_2$ (median $Pao_2$, 91.5 compared with 90.5 mm Hg [$P = 0.89$]; median $Paco_2$, 37.5 compared with 36.0 mm Hg [$P = 0.41$]). At an altitude of 3000 m, the median $Pao_2$ decreased from 69.0 to 64.0 mm Hg, a median decrease in the paired difference of 4.0 mm Hg (95.1% CI, 1.5 to 6.5 mm Hg; $P < 0.01$), and the median $Paco_2$ increased from 32.5 to 34.0 mm Hg, a median increase in the paired difference of 3.0 mm Hg (95.1% CI, 2.0 to 4.0 mm Hg; $P < 0.01$) 1 hour after drinking 50 g of alcohol. Placebo did not influence $Pao_2$ or $Paco_2$ at either altitude.
■ *Conclusion:* Alcohol inhibits the initial stages of adequate acute ventilatory adaptation to mild hypoxia at moderate altitude. Caution in the use of alcoholic beverages at moderate altitude is therefore necessary.

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Scientific research in alpine medicine has dealt primarily with small groups of healthy, athletic persons at high altitude, even though most mountain tours are at moderate altitude and most mountaineers are not trained athletes. In recent years, more emphasis has been placed on studying general tourist populations at moderate altitudes. The reported incidence of acute mountain sickness at moderate altitudes ranges from 1.4% to 25%; the variation is mainly related to the different instruments used for assessment (1). The effect of alcohol on adaptation to moderate altitude has not been clearly investigated. Several articles and texts (2–4) recommend minimizing alcohol use to prevent or ameliorate altitude symptoms. However, Honigman and colleagues (5) found that the incidence of acute mountain sickness was no higher in tourists who consumed alcohol than in those who did not. Hyperventilation is the basis of adaptation to high altitude (6). We evaluated the influence of alcohol on acute adaptation to mild hypoxia at moderate altitude (3000 m).

## Methods

Our study was a randomized, double-blind, placebo-controlled crossover trial (7). The mean age (±SD) of the 10 male volunteers was 22.6 ± 0.84 years; mean weight was 76.3 ± 4.8 kg; and mean height was 1.79 ± 0.06 m. All volunteers gave informed consent. All participants were healthy nonsmokers, took no medication, and did not drink alcohol more than twice a month. All lived at low altitudes but had previously spent leisure time in the mountains. Physical fitness was not measured but was presumed to be very good to excellent. No participant was underweight or overweight. Lung function at rest was normal in all participants, no participant had a history of hyper-reactive airways.

Participants were randomly assigned to drink either 1 L of a beverage containing 50 g alcohol or 1 L of an otherwise identical beverage containing no alcohol at an altitude of 171 m. After a 3-day interval, which included cable car transport and 4 hours of adaptation time at an altitude of 3000 m, the participants again drank their assigned beverage. The same procedure was done after a 1-week interval, at which time participants crossed over to the other study branch. Capillary blood samples were obtained from the arterialized ear lobe (8) before and 1 hour after alcohol consumption. Samples were obtained between 1200 h and 1300 h at similar conditions, and ambient temperature was constant at 21 °C at 171 m (air-conditioned university clinic) and at 18 °C at 3000 m of altitude (mountain restaurant). Blood samples were stored with ice water in an insulated container. Arterial oxygen tension ($Pao_2$) and arterial carbon dioxide tension ($Paco_2$) were analyzed within 2 hours using a BGE Blood Gas Analyser (Instrumentation Laboratory, Milan, Italy). Quiet breathing frequency was evaluated by counting, and the alcohol content of expiratory breath was measured at the same time with an Alcometer (Alco-sensor IV, Intoximeters, Inc., St. Louis, Missouri).

### Statistical Analysis

Direct comparison of the differences of blood gas analysis before and after alcohol or placebo consumption and direct comparison of the differences in breathing frequency before and after alcohol or placebo consumption at each altitude was done using the Wilcoxon signed-rank test. Data are expressed as medians, and 95.1% CIs for the median paired differences are reported (9). $P$ values $< 0.05$ were considered significant.

## Results

Drinking the placebo beverage at an altitude of 171 m did not change $Pao_2$ or $Paco_2$ ($Pao_2$ was 91 mm Hg before and after drinking; $Paco_2$ was 38 mm Hg before and after drinking). Drinking the placebo beverage at an

**Table 1. Blood Gas Analysis in 10 Participants at Low and Moderate Altitudes before and after Alcohol Consumption***

| Participant | Low Altitude (171 m) | | | | Moderate Altitude (3000 m) | | | |
|---|---|---|---|---|---|---|---|---|
| | Before Alcohol | | One Hour after 50 g of Alcohol | | Before Alcohol | | One Hour after 50 g of Alcohol | |
| | $PaO_2$ | $PaCO_2$ | $PaO_2$ | $PaCO_2$ | $PaO_2$ | $PaCO_2$ | $PaO_2$ | $PaCO_2$ |
| 1 | 90 | 37 | 92 | 36 | 65 | 30 | 64 | 34 |
| 2 | 92 | 38 | 88 | 40 | 70 | 28 | 68 | 33 |
| 3 | 94 | 37 | 95 | 36 | 67 | 32 | 64 | 34 |
| 4 | 91 | 34 | 92 | 34 | 65 | 33 | 65 | 37 |
| 5 | 94 | 40 | 91 | 38 | 71 | 29 | 66 | 33 |
| 6 | 88 | 39 | 88 | 38 | 64 | 33 | 63 | 35 |
| 7 | 92 | 33 | 96 | 36 | 70 | 33 | 62 | 37 |
| 8 | 94 | 38 | 90 | 36 | 68 | 30 | 62 | 32 |
| 9 | 82 | 36 | 86 | 35 | 72 | 33 | 64 | 36 |
| 10 | 90 | 38 | 90 | 36 | 72 | 34 | 66 | 36 |

* $PaCO_2$ = arterial carbon dioxide pressure; $PaO_2$ = arterial oxygen pressure.

altitude of 3000 m did not produce a statistical change in $PaO_2$ (68.5 mm Hg before and 68.0 mm Hg after drinking; $P = 0.81$) or in $PaCO_2$ (31 mm Hg before and after drinking).

Results of the blood gas analysis before and after drinking 50 g of alcohol are shown in detail in Table 1. No statistical change was seen at 171 m for $PaO_2$ (91.5 mm Hg before and 90.5 mm Hg after drinking; $P = 0.89$) or for $PaCO_2$ (37.5 mm Hg before and 36.0 mm Hg after drinking; $P = 0.41$). At 3000 m, $PaO_2$ decreased from 69 to 64 mm Hg (a median decrease in the paired difference of 4.0 mm Hg [95.1% CI, 1.5 mm Hg to 6.5 mm Hg; $P < 0.01$]) and median $PaCO_2$ increased from 32.5 mm Hg to 34.0 mm Hg (a median increase in the paired difference of 3.0 mm Hg [95.1% CI, 2.0 to 4.0 mm Hg; $P < 0.01$]).

Placebo did not influence breathing frequency at 171 m (13 breaths/min before and after drinking; $P = 1.00$) or at 3000 m (15.5 breaths/min before and after drinking). Alcohol did not influence breathing frequency at 171 m (12.5 breaths/min before and after drinking). At 3000 m, alcohol decreased breathing frequency from 15 to 14 breaths/min, a median decrease in the paired differences of 1.5 breaths/min (95% CI, 1.0 to 2.0; $P = 0.008$). Breath alcohol testing was initially negative in all participants and was negative after placebo. One hour after drinking 50 g of alcohol, the mean breath alcohol level was $0.31 \pm 0.04$ mg/L at 171 m and $0.30 \pm 0.02$ mg/L at 3000 m. The possibility of any effect of test order or treatment carryover was tested using the baseline readings of each period and group (7). No significant effects were found for $PaO_2$, $PaCO_2$, or breathing frequency.

## Discussion

The incidence of alcohol use at moderate altitude is high: Honigman and colleagues (5) found that 1996 of 3108 tourists (64%) drank alcoholic beverages at moderate altitude. The implication of alcohol use on adaptation to high altitude has not been systematically investigated. The amount of alcohol used as a test dose in our study equals the average alcohol content of 1 L of beer. Breath alcohol was equal at both altitudes. The mean alcohol dose was 0.66 g/kg; the blood alcohol concentration was $0.065\% \pm 0.007\%$ and was calculated using a blood/breath ratio of 2100. In this range, the beginning of decrements in cognitive ability, motor coordination, and sensory perception in nontolerant persons can be detected by special tests. However, we did not observe any apparent influence in the behavior of the participants; no participant showed signs or symptoms of acute mountain sickness. Respiratory depression in alcohol intoxication occurs at very high alcohol levels (above 0.35%) in normal participants (10). The test dose of alcohol was rapidly consumed in 15 minutes. Alcometer testing was done after a 1-hour interval to ensure that alcohol resorption was completed.

The initial blood gas samples were obtained under stable conditions at both altitudes. Arterialized ear lobe blood samples are accurate and reliable, with no statistical difference in levels of arterial $PaO_2$ and $PaCO_2$ (8, 11). The high $PaO_2$ values in our participants indicate that little ventilation–perfusion mismatch was present. Baseline $PaO_2$ was decreased at 3000 m because of the decrease in barometric pressure (520 compared with 740 mm Hg at an altitude of 171 m) in both test conditions. At an altitude of 171 m, 50 g of alcohol had no negative effects on respiration. At 3000 m, 50 g alcohol caused impaired breathing. The respiratory rate (the only direct measure of ventilation that we used) decreased, and presumably the minute ventilation also decreased; these results explain the blood gas changes.

Unfortunately, it was not possible to record the mechanics of ventilation because plethysmography was not available at the moderate altitude. The evaluation of resting quiet breathing by pneumotachography was not possible because participants started to hyperventilate during the maneuver. Breathing frequency was therefore evaluated by counting quietly. The increase in $PaCO_2$ indicates an inadequate ventilatory response to moderate altitude. An alcohol-induced ventilation–perfusion mismatch that would have explained the decreased $PaO_2$ did not seem to occur. Regarding ventilation, no participant showed signs of bronchospasm after alcohol administration, and, because no history of hyper-reactive airways was present, bronchoconstriction probably did not cause the decrease in $PaO_2$. Regarding pulmonary perfusion, in contrast to its systemic venodilatory actions, alcohol increases pulmonary artery pressure, probably because of pulmonary vascular constriction (12). This effect could potentially induce

a further increase in elevated pulmonary artery pressure in persons with hypoxia but is unlikely to have contributed to the decrease at moderate altitude.

A similar depression of ventilation at moderate altitude was previously reported for persons receiving diazepam: Small doses of diazepam (< 0.1 mg/kg), which are relatively safe at low altitudes, can inhibit a satisfactory acute ventilatory response at moderate altitudes (13). Ventilatory adaptation to hypobaric hypoxia is an active process evolving over hours to days. Only the initial stages of ventilatory adaptation were studied in our trial. Altitude tolerance and altitude adaptation depend on hyperventilation, which is induced by the carotid bodies, although this effect is partly counteracted by the negative feedback resulting from the reduction in $Paco_2$. An effect related to altitude adaptation or an unspecific effect on ventilation as a reason for ventilatory depression at an altitude of 3000 m after alcohol consumption was ruled out by the findings in the placebo test. We must presume that a dose of 50 mg of alcohol, which does not affect respiration at low altitudes, can inhibit an satisfactory acute ventilatory response at moderate altitudes. We therefore recommend caution when using alcoholic beverages at moderate altitudes.

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**References**

1. **Roeggla G, Roeggla M, Wagner A.** Acute mountain sickness at moderate altitudes [Letter]. Ann Intern Med. 1993;119:633.
2. **Hackett PH, Roach RC, Sutton JR.** High altitude medicine. In: Auerbach PS, Geehr EC; eds. Management of Wilderness and Environmental Emergencies. 2d ed. New York: C.V. Mosby; 1989:1-34.
3. **Johnson TS, Rock PB.** Current concepts. Acute mountain sickness. N Engl J Med. 1988;319:841-5.
4. **Houston CS.** Going Higher: The Story of Man at High Altitude. Boston: Little, Brown; 1987.
5. **Honigman B, Theis MK, Koziol-McLaine J, Roach R, Yip R, Houston C, et al.** Acute mountain sickness in a general tourist population at moderate altitudes. Ann Intern Med. 1993;118:587-92.
6. **Ward MP, Milledge JS, West JB.** High Altitude Medicine and Physiology. London: Chapman and Hall; 1989:90.
7. **Hills M, Armitage P.** The two-period cross-over clinical trial. Br J Clin Pharmacol. 1979;8:7-20.
8. **Spiro SG, Dowdeswell IR.** Arterialized ear lobe blood samples for blood gas tensions. Br J Dis Chest. 1976;70:263-8.
9. **Campbell MJ, Gardner MJ.** Calculating confidence intervals for some non-parametric analyses. Br Med J. 1988;296:1454-6.
10. **Ellehorn MJ, Barceloux DG.** Medical Toxicology. New York: Elsevier; 1988:782-97.
11. **Pitkin AD, Roberts CM, Wedzicha JA.** Arterialised earlobe blood gas analysis: an underused technique. Thorax. 1994;49:364-6.
12. **Koskinen P, Kupari M, Nieminen MS, Suokas A, Totterman K, Pajari R, et al.** Effects of alcohol on systemic and pulmonary hemodynamics in normal humans. Clin Cardiol. 1986;9:479-82.
13. **Roeggla G, Roeggla M, Wagner A, Seidler D, Podolsky A.** Effect of low dose sedation with diazepam on ventilatory response at moderate altitude. Wien Klin Wochenschr. 1994;106:649-51.