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THE EFFECTS OF ALCOHOL AT THREE SIMULATED AIRCRAFT CABIN CONDITIONS

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I. Introduction.

The effects of the consumption of alcohol are the subject of great interest to the scientific community. Social drinking is practiced by some 65% of the adult population of the United States today.[5] Alcohol is known to impair vision, produce certain types of muscular incoordination, produce euphoria, and remove inhibitions.[9] It has been blamed for many auto accidents[17,21,22] and has been associated with crime.[7,18] Problem drinking is the subject of much psychological,[12,25] physiological[14] and legislative[1] research. There is today much existing and pending legislation aimed at controlling the "excessive" use of alcohol, particularly in connection with automobile driving.

Blood alcohol levels, per se, are reported to be inadequate indices of an individual's ability to perform normally.[11,16] It appears to be important whether the blood alcohol levels are obtained on the increasing or decreasing portion of the curve after drinking has ceased. At a given concentration, individuals whose blood alcohol is decreasing perform better than those whose blood levels are still increasing.

It has been reported that alcohol effects on the body are similar to those of hypoxia.[13] It has also been suggested that oxygen therapy is useful in the treatment of both the acute alcoholic state and chronic alcoholism.[15,16] The possibility exists that oxygen lack and alcohol may have additive or even synergistic effects. These experiments were designed to study the combined effects of different alcohol levels under three different cabin conditions.

II. Methods.

Fifty-four male, paid volunteers (21 to 29 years old) were used as test subjects. Eighteen subjects each were exposed four hours singly or in pairs in an altitude chamber to one of three altitudes: ground level (1287 ft.), 12,000 ft., or 20,000 ft. The men at 20,000 ft. were supplied with a normal oxygen mixture through a demand-type regulator system. One-third of each group received 600 cc each of bourbon-flavored cola, one-third received 2.50 cc of 100 proof bourbon per kilogram of body weight in cola to total 600 cc and the remaining third received 1.25 cc of 100 proof bourbon per kilogram of body weight brought to 600 cc with cola.

The same time sequence was followed for each experiment and is shown in Table I. Heart rate was measured by three electrocardiogram electrodes, respiratory rate by a mercury-in-rubber strain gage, and internal body temperature by a calibrated thermistor probe inserted ten centimeters into the rectum. All three parameters were recorded simultaneously on a six-channel Grass recorder.

Skin temperatures were obtained with a calibrated Stoll-Hardy radiometer (Model HL4), with average skin temperature calculated from a seven-point system developed by Hardy and DuBois.[8] Blood oxygen saturation was determined with a Waters (Model XE-350) ear oximeter, and blood pressure by auscultation, using a pressure cuff and mercury sphygmomanometer.

Reaction time, determined as the manual response to an auditory stimulus, is reported as the time required to turn off a buzzer by pressing a key. Five time trials were conducted at each of the time periods during an exposure, and the average of the three best scores reported. A motor coordination test[3] consisted of making a three-line configuration in a square as rapidly as possible. Two 10-second practice trials were followed by a single 60-second test trial. Scores were the total number of squares containing the configurations.

A venous blood sample of three to five cc was drawn from each subject at each time period. Coagulation was prevented by 0.2 cc of a dessicated solution of sodium and ammonium oxalate, and the whole blood was stored at a temperature of 0.6 to 3.3°C until it could be analyzed. Alcohol levels of the blood were determined by the method of Syed[23] using a Technicon Autoanalyzer apparatus.

III. Results.

The data were treated by an analysis of variance technique for repeated measures, with a multiple-range test employed where appropriate.[24] The variables were: level of alcohol consumed, cabin condition, and time.

Analyses for *Respiratory Rate* showed no significant effects for any of the variables.

Heart Rate. A significant effect was exhibited for alcohol dosage level: the higher the level of alcohol, the higher the heart rate (Fig. 1). The analyses also showed a significant effect for time, with a maximum rate occurring at the one-hour measurement, and declining steadily thereafter.

For *Skin Temperature* there was a significant alcohol dosage effect with higher temperatures for those with alcohol (Fig. 2). There was also a time effect with the highest reading occurring at three hours.

With *Rectal Temperature* a significant effect was seen for time, with the highest reading coming at the end of the experiment. There was also a significant alcohol-time interaction (Fig. 3).

The *Oxygen Saturation* measures demonstrated no alcohol effect, but the altitude effect was seen. Readings for subjects at 20,000 ft. were not statistically different from readings obtained at ground level, however, both these groups had significantly higher readings than those subjects at 12,000 ft. (Fig. 4).

Blood Pressure analyses yielded significance for time effect, primarily due to a decreasing systolic pressure through time (Fig. 5). An alcohol-dose effect was also seen with the highest pulse pressure exhibited by those without alcohol and the lowest exhibited by those with the moderate alcohol dosage (Fig. 6). In addition, there was a cabin condition effect with men at 20,000 ft. on oxygen exhibiting the lowest blood pressure (Fig. 7).

Reaction Time gave no significant effects except for time. Scores improved with time, indicating a possible training effect.

For *Motor Coordination* there were no effects due to cabin condition or alcohol level, but improvement in score was seen with time. Some interactions were present. There was an alcohol-time interaction: the highest alcohol-dosage group started lowest and showed the most increase in score, while the moderate alcohol group was higher than the group without alcohol (Fig. 8). There was also a cabin condition-time interaction, with the 12,000 ft. group leveling off at one hour and the two groups with normal oxygen continuing to improve after that time (Fig. 9).

Blood Alcohol Concentration determinations demonstrated, of course, a difference due to alcohol dosage level. There was also a cabin condition effect, with those at 20,000 ft. on oxygen having the highest blood levels. A time effect was also seen, with the peak levels being reached at one hour. Those subjects receiving the moderate dose of alcohol revealed no significant differences in blood alcohol levels at any time period, due to cabin condition (Fig. 10). However, those receiving the high dosage of alcohol demonstrated a significantly higher blood level of alcohol at 20,000 ft. than at the other two cabin conditions (Fig. 11).

IV. Discussion.

The increased heart rates with increasing blood alcohol concentrations correspond to findings of other investigators.[6] The heart rate and blood alcohol concentration curves correlate well with the highest rates occurring at the same time as the highest blood alcohol concentrations.

The higher skin temperatures observed in subjects with the higher blood alcohol concentrations are consistent with the expected peripheral vasodilatory effect reported for alcohol.[4]

The no-alcohol subjects had the highest rectal temperature but showed little change through time. Those with the moderate alcohol dose started with a lower rectal temperature, but reached almost the same level as those without alcohol by the end of the test period, when their blood alcohol levels were negligible. Those receiving the higher alcohol dosage started with a lower rectal temperature, and it remained lower throughout the experiment. These responses might be assumed to be the results of two factors: (1) a greater rate of heat loss due to the higher skin temperatures of those with alcohol, and (2) a lower heat production when sedated or relaxed by the alcohol.

The results of the oxygen saturation findings were as expected for the altitude effect. Subjects at 20,000 ft. were on a normal oxygen mixture and their O_2 saturation readings were not statistically different from those obtained at ground level. Men at 12,000 ft. without supplemental oxygen had statistically lower readings than the other two groups.

In obtaining physiological measures it is often difficult to eliminate the psychological factors. Alcohol is reported to cause an elevated blood pressure,[9] yet with our subjects those with moderate alcohol doses had lower systolic pressures and pulse pressures than those without alcohol. This might be interpreted as indicating that the moderate alcohol group was less apprehensive concerning the testing situation than the control group. All subjects were naive. Although the blood pressures reported for the various cabin conditions are within physiological norms, there is a statistical difference for the 20,000 ft. readings. Decrease in blood pressure in men at 14,900 ft., particularly the systolic, has been suggested.[20]

The performance tests used for this study apparently were neither sensitive nor critical enough tests to detect differences due to single effects. Reaction time has been reported to deteriorate from 10 to 50% with blood alcohol levels of 0.1 to 0.2%,[9] while other authors state that reaction time results are varied and contradictory.[10]

Those subjects with normal oxygen (at ground level and at 20,000 ft.) improved in the motor coordination task after the first hour, while those at 12,000 ft. demonstrated little improvement after the one-hour measurement, indicating that perhaps hypoxia may have prevented the improvement seen at the other altitudes. On the motor coordination test the high alcohol dosage group started with the lowest score but showed the most improvement (an increase of 11 completions per minute) from the beginning score to the final score, while the other two groups gained only five completions per minute from initial to final reading.

The results of the blood alcohol determinations present data for which a suitable explanation is not apparent at this time. The blood levels of alcohol were highest at 20,000 ft. for those subjects receiving the higher alcohol dosage. There could possibly be some relationship to an increased body water loss at altitude with normal oxygen.[15] At this time, however, this appears to be an unlikely explanation, since an elevation in blood alcohol levels at 20,000 ft. was not seen with the moderate alcohol dosage group. Therefore, it appears that this phenomenon is dependent upon both dose and cabin condition. A search for explanations and methods of testing for mechanisms causing this result is planned for further study.

V. Summary.

In a study of 54 human subjects using three alcohol consumption levels and three simulated aircraft cabin conditions it was found that alcohol caused an increase in heart rate and an increase in skin temperature. Internal body temperature was lower with alcohol but did increase as blood alcohol levels decreased.

The performance tests used apparently were not critical enough to detect significant difference due to single variables although some interactions were evidenced.

Blood alcohol determinations for those receiving the high level of alcohol yielded significantly higher levels of blood alcohol for those at 20,000 ft. than at the other two cabin conditions. However, the readings at 20,000 ft. were not statistically different from readings obtained at the other conditions for those receiving the lower dose of alcohol. A suitable explanation for this finding is not apparent at this time.

Table I

At Employee Health Clinic
- Execution of Forms
- Physical Exam—Dress
- Milk—Toast

Orientation for Experiment—At Altitude Chamber.
- Explanation of test equipment and brief training on reaction timer and motor coordination test.

Application of electrode, pneumograph and other equipment.

Consumption of beverage (over 30 minute period, 1/6 per 5 min.)

Start of experimental period—Time zero
- Ascent to altitude

30 minute readings—begin at + 20 minutes
- Heart rate, respiratory rate, internal temperature and oxygen saturation—recorded simultaneously. Followed by:
  - blood pressure measurement
  - skin temperature readings
  - motor coordination task
  - reaction time task
  - drawing of blood sample (this occurs at approximately + 30 minutes)

60 minute readings—begin at + 50 minutes—repeat above schedule.

120 minute readings—begin at + 110 minutes—repeat above schedule.

180 minute readings—begin at + 170 minutes—repeat above schedule.

240 minute readings—begin at + 230 minutes—repeat above schedule.

Experiment concluded.

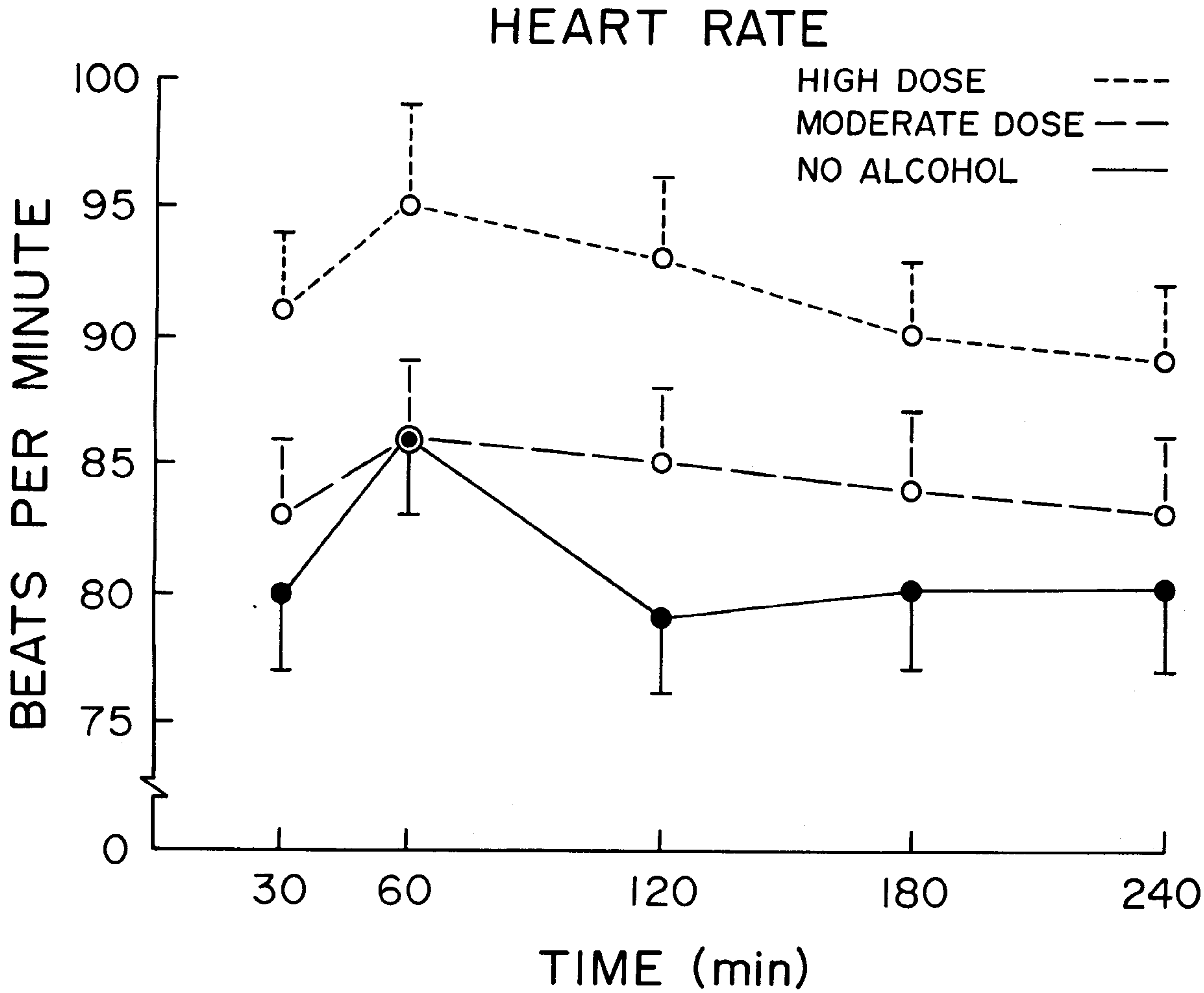

FIGURE 1. Heart rate expressed as a function of time for the three alcohol groups. Reported as means plus or minus standard error.

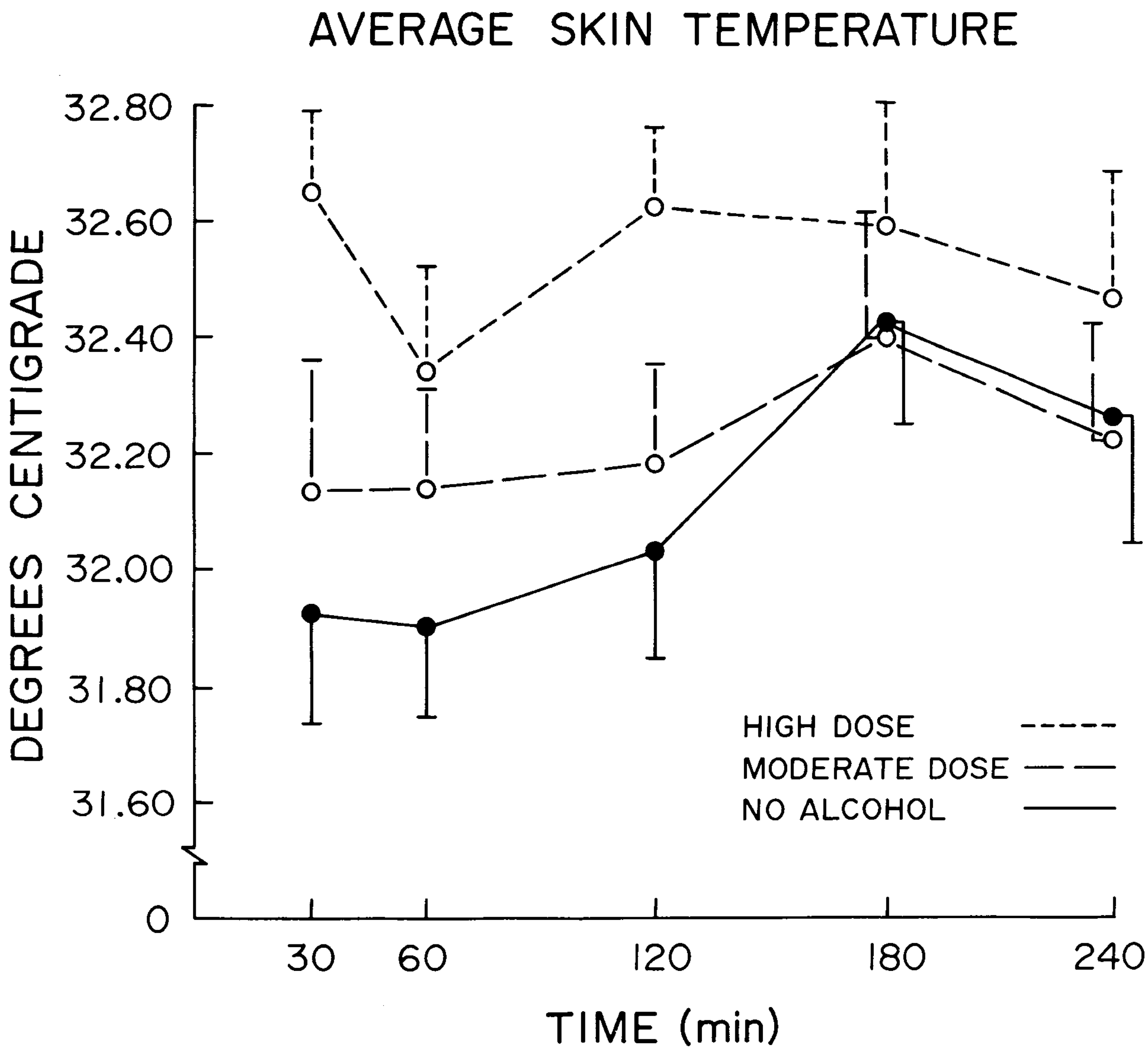

FIGURE 2. Average skin temperature in degrees Centigrade expressed as a function of time for the three alcohol groups. Reported as means plus or minus standard error.

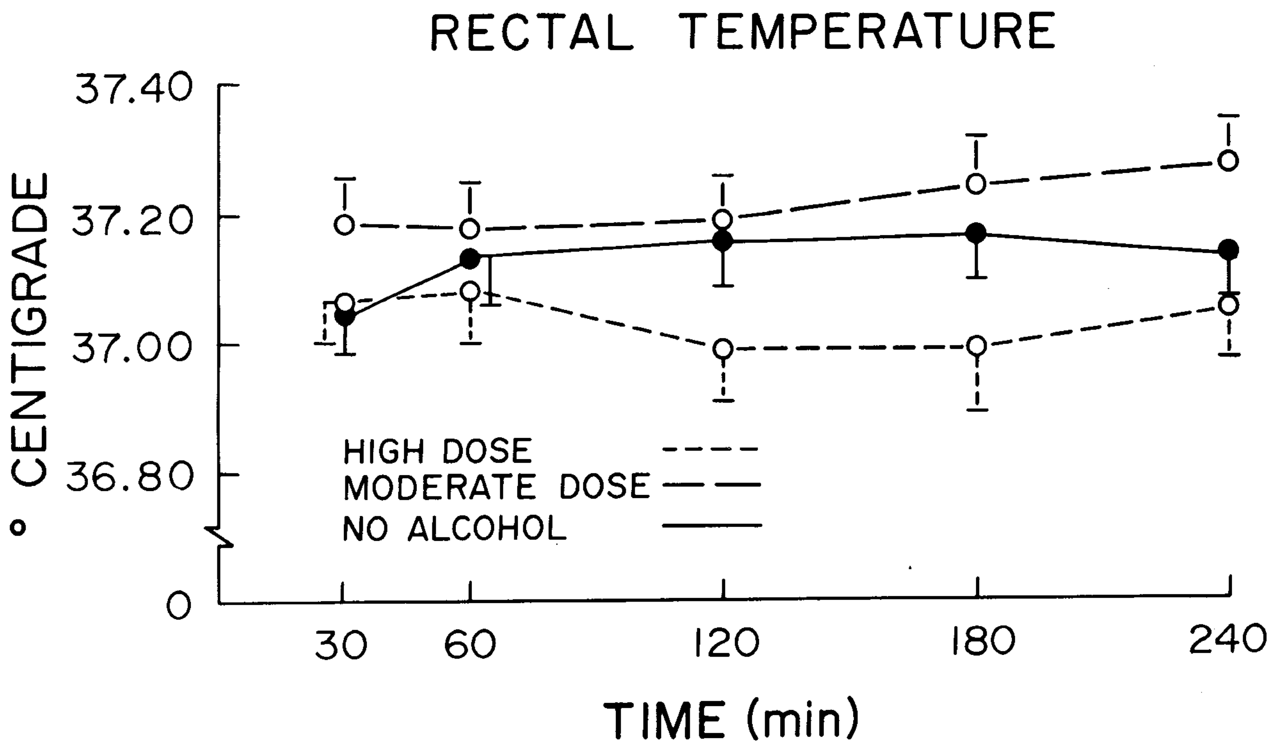

FIGURE 3. Rectal temperature in degrees Centigrade expressed as a function of time for the three alcohol groups. Reported as means plus or minus standard error.

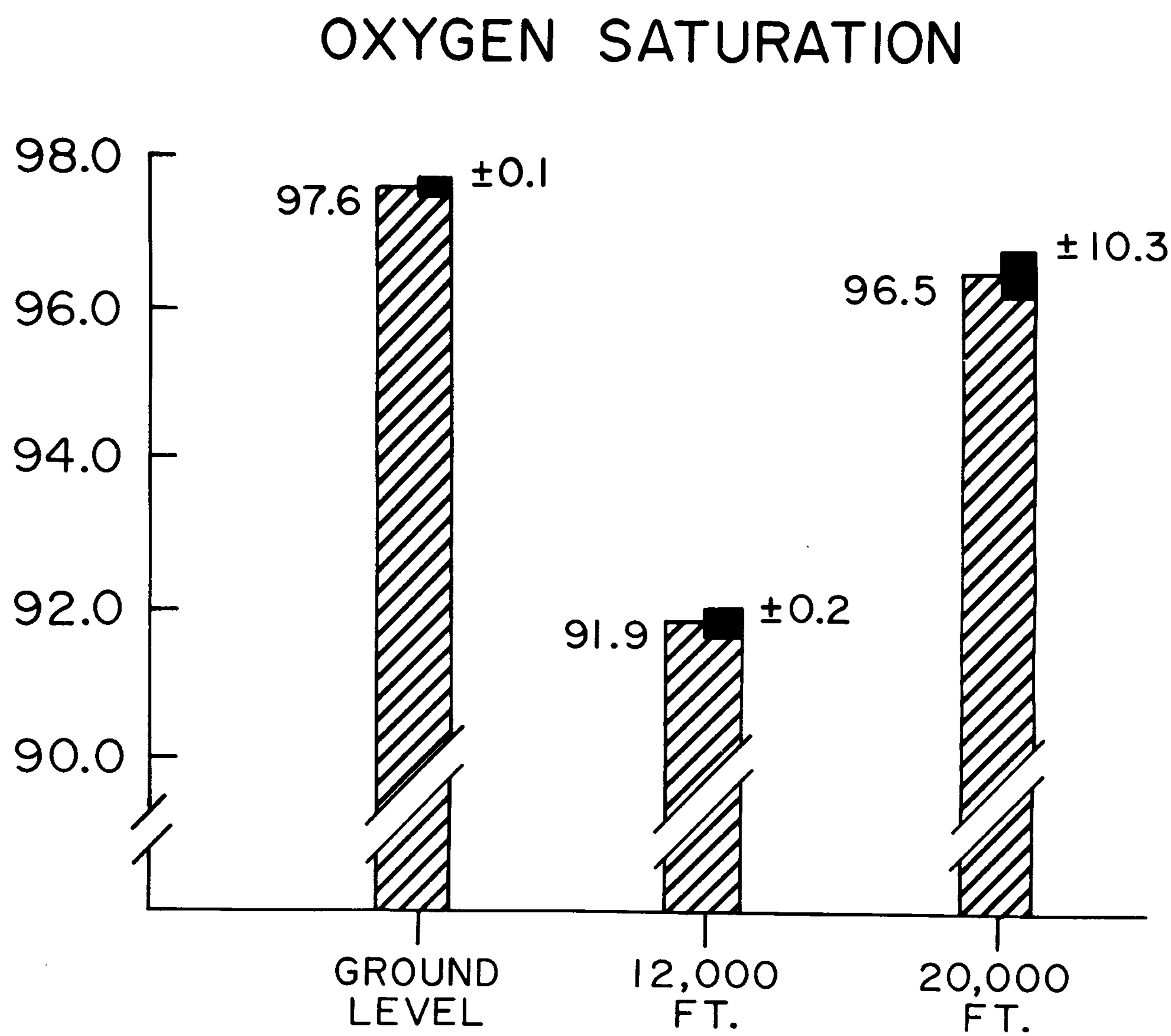

FIGURE 4. Oxygen saturation expressed as percentage saturation for three cabin conditions. Reported as means plus or minus standard error.

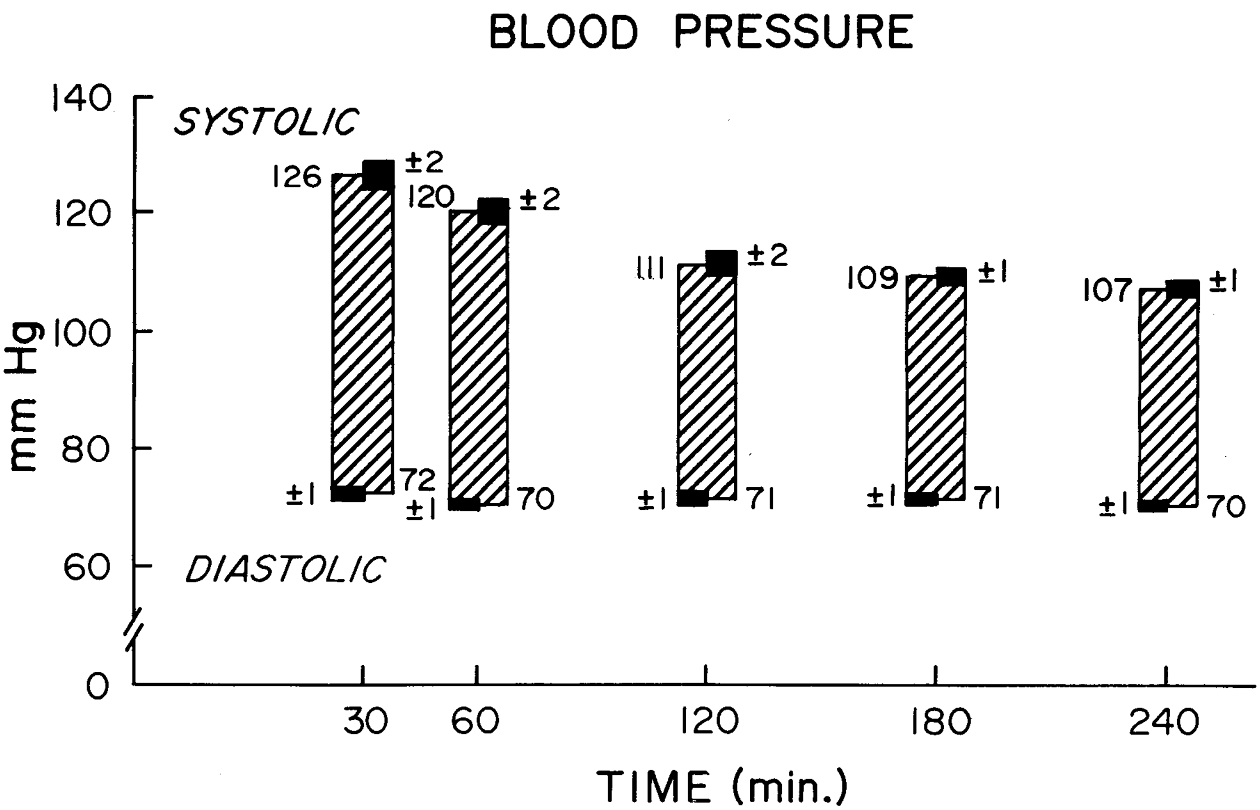

FIGURE 5. Blood pressure (systolic and diastolic) expressed in millimeters of mercury as a function of time. Reported as means plus or minus standard error.

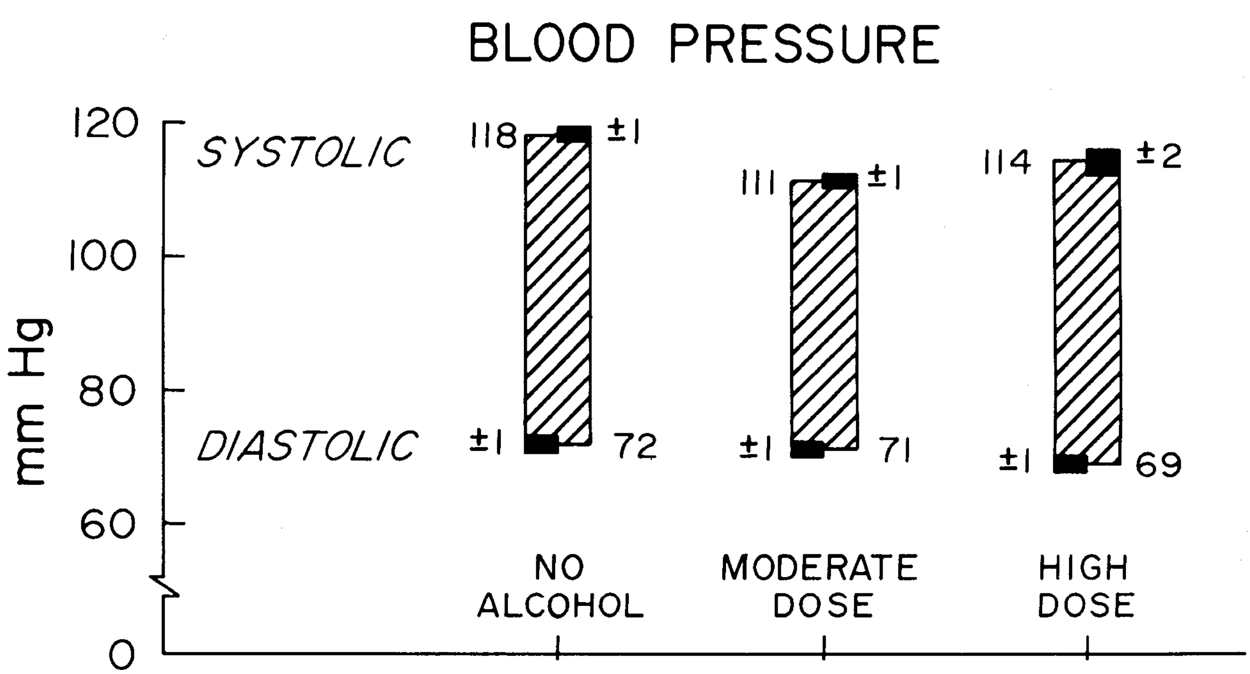

FIGURE 6. Blood pressure (systolic and diastolic) expressed in millimeters of mercury for the three alcohol groups. Reported as means plus or minus standard error.

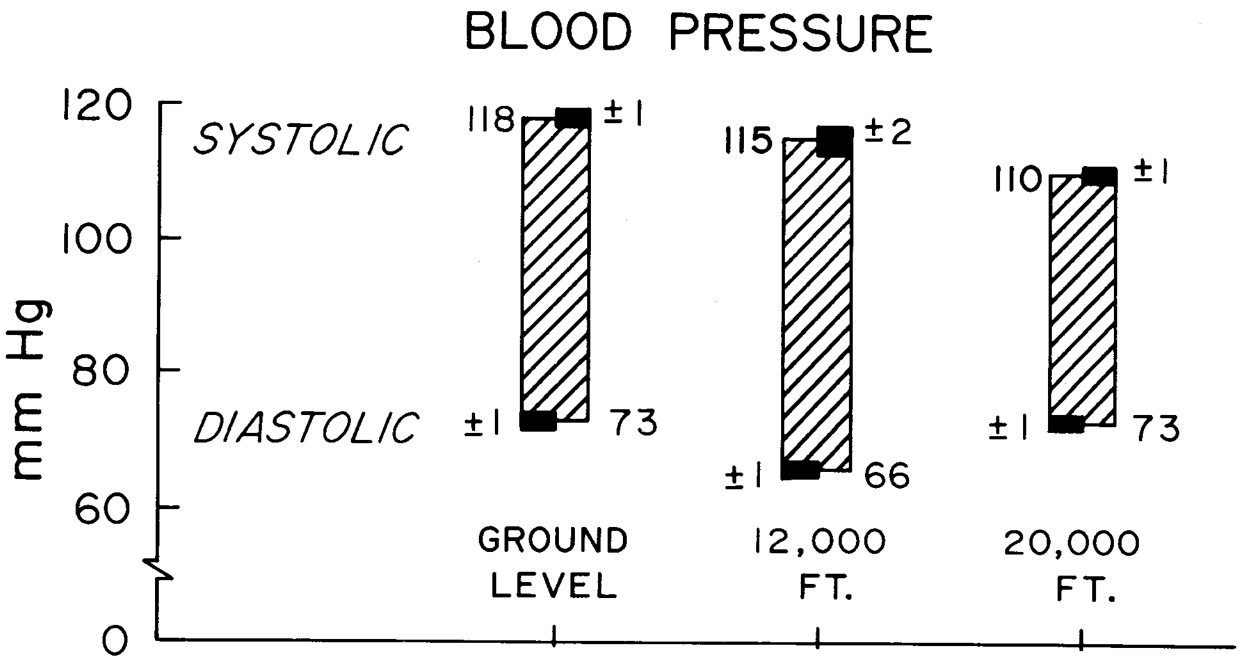

FIGURE 7. Blood pressure (systolic and diastolic) expressed in millimeters of mercury for three cabin conditions. Reported as means plus or minus standard error.

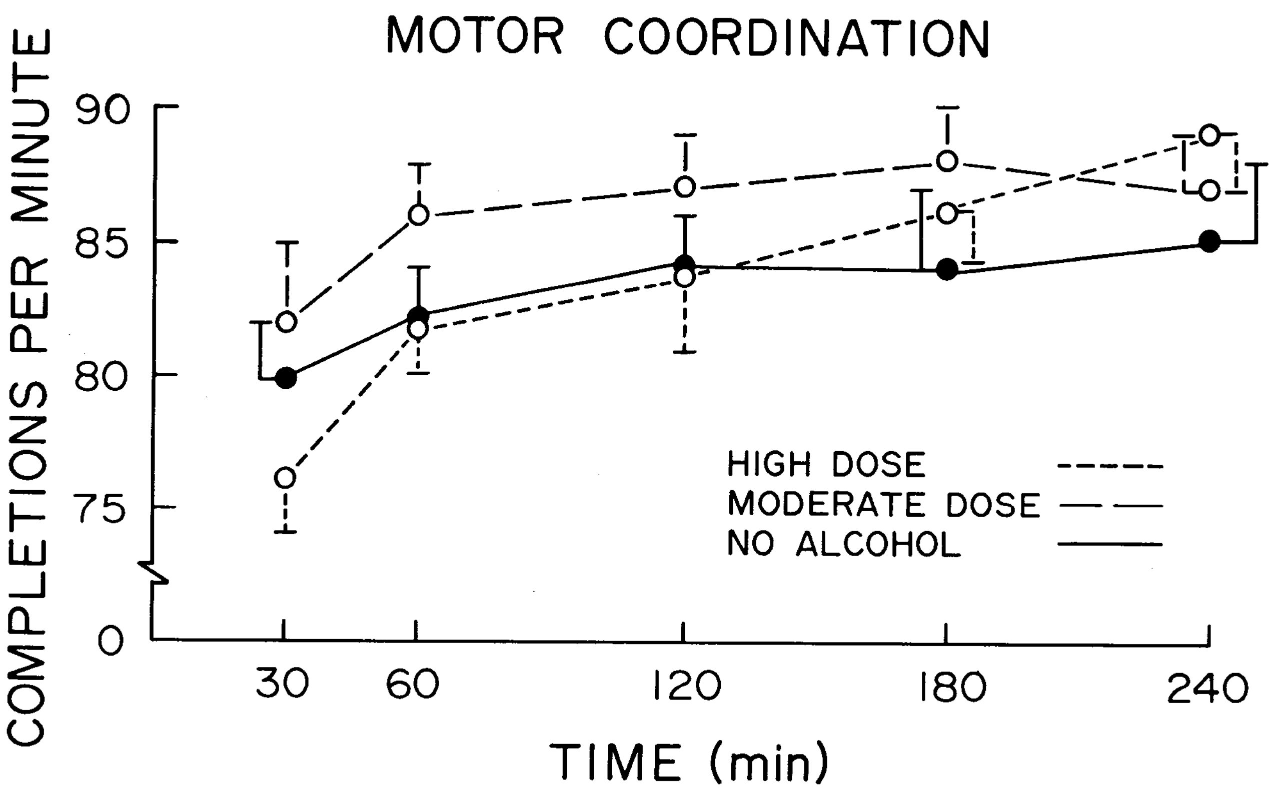

FIGURE 8. Motor coordination expressed as the number of completions per minute for the three alcohol groups as a function of time. Reported as means plus or minus standard error.

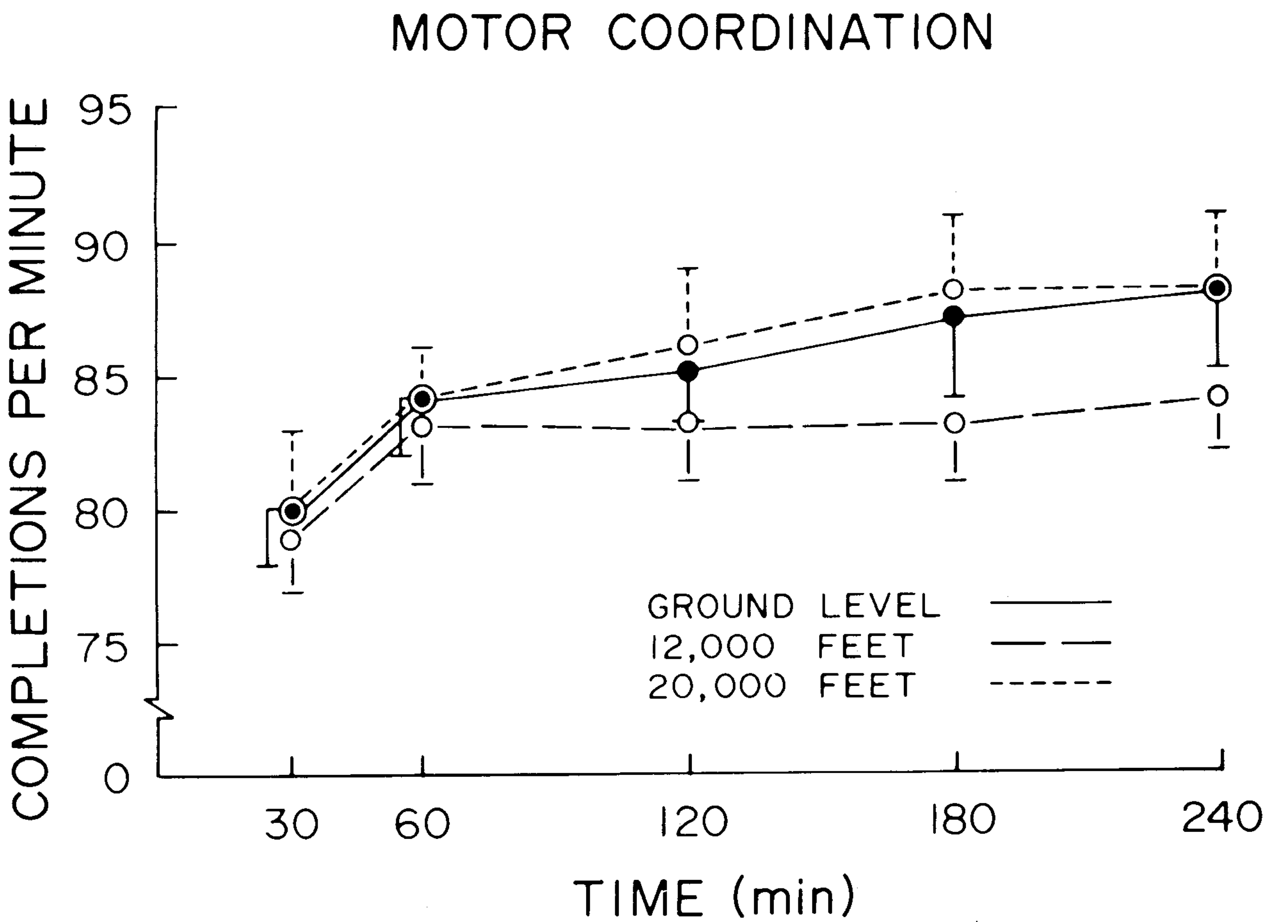

FIGURE 9. Motor coordination expressed as the number of completions per minute for three cabin conditions as a function of time. Reported as means plus or minus standard error.

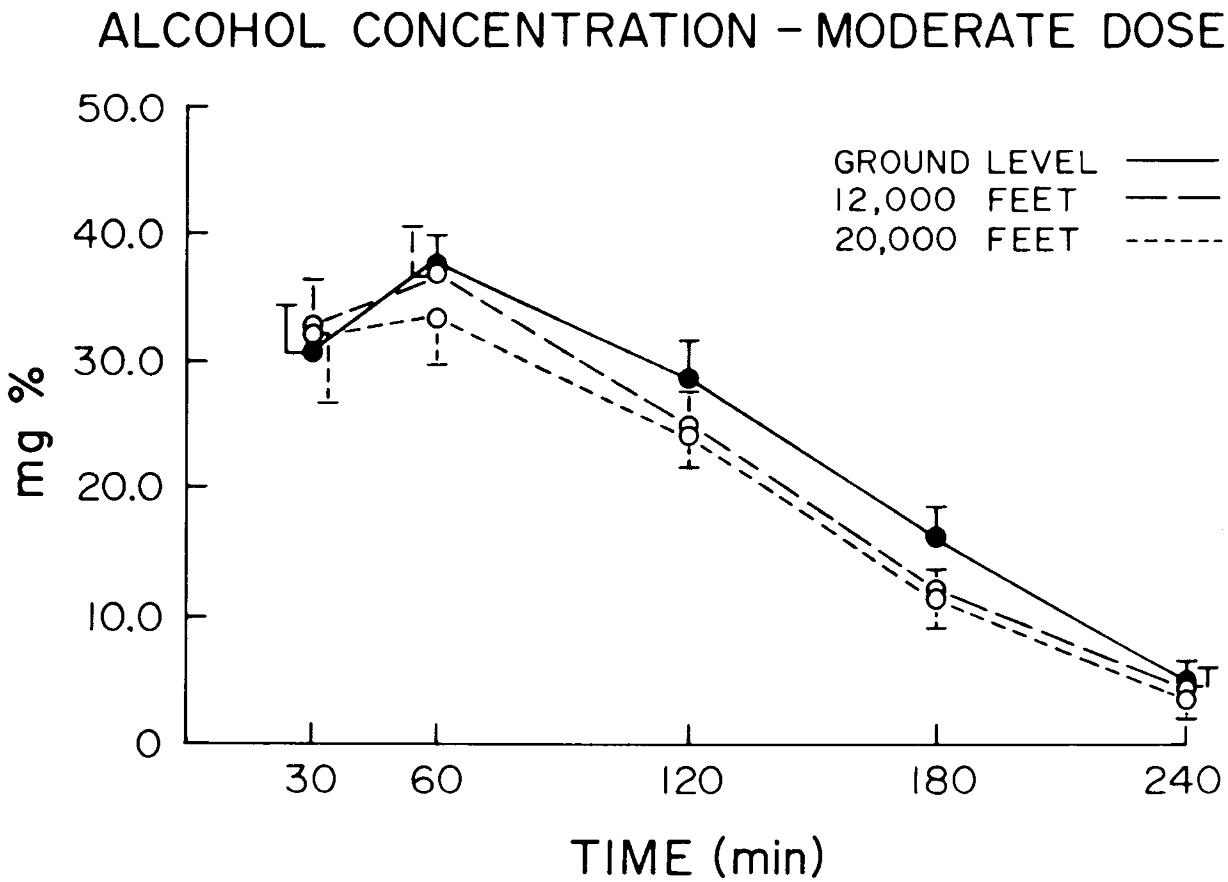

FIGURE 10. Blood alcohol concentration for the moderate dose expressed as milligrams percent for three cabin conditions as a function of time. Reported as means plus or minus standard error.

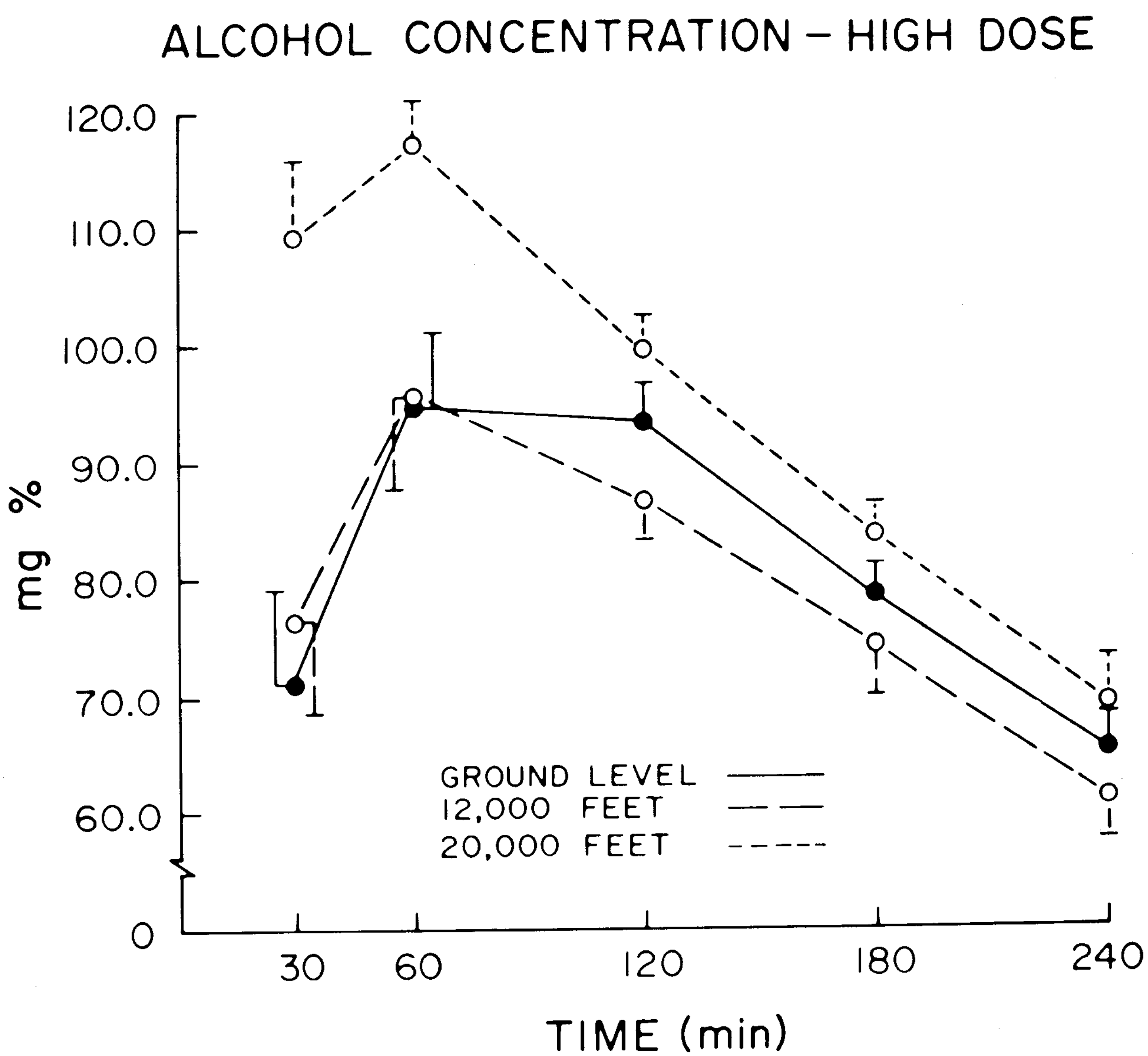

FIGURE 11. Blood alcohol concentration for the high dose expressed as milligrams percent for three cabin conditions as a function of time. Reported as means plus or minus standard error.

BIBLIOGRAPHY

1. ANDREASSON, R.: "Report of the Working Party (V) on the Prevention of Accidents Due to Alcohol" in *Alcohol and Road Traffic Conference Proceedings*, pp. 109–110, British Medical Association, London, 1962.
2. DAVIS, C. N. and H. F. ROBERTSON: "Oxygen in the Treatment of Acute Alcoholic Intoxication," *Quart. J. Stud. Alcohol*, 10(1) : 59–62, 1949.
3. General Aptitude Test Battery, B–1002, Section 1: Administration and Scoring, Bureau of Employment Security, U.S. Dept. of Labor, Washington, D.C., 1965.
4. GOODMAN, L. S. and A. GILMAN: *The Pharmacological Basis of Therapeutics*, p. 100, The MacMillan Co., New York, 1960.
5. GREENBERG, L.: "The Metabolism and Pharmacology of Alcohol," *Acad. Med. N. J. Bul.*, 9(3) : 136–142, 1963.
6. GROLLMAN, A.: *Pharmacology and Therapeutics*, pp. 103–104, Lea and Febiger, Philadelphia, 1965.
7. GUZE, S. B., et al.: "Psychiatric Illness and Crime with Particular Reference to Alcoholism: A Study of 223 Criminals," *J. Nerv. Ment. Dis.*, 134: 512–521, 1962.
8. HARDY, J. D. and E. E. DUBOIS: "The Technic of Measuring Radiation and Convection," *J. Nutrition*, 15: 461–475, 1938.
9. HULPIEU, H. R. and R. N. HARGER: "The Alcohols" in *Pharmacology in Medicine*, Edited by Victor A. Drill, McGraw-Hill, New York, 1958.
10. JELLINEK, E. M. and R. A. MCFARLAND: "Analysis of Psychological Experiments on the Effects of Alcohol," *Quart. J. Stud. Alcohol*, 1: 273–371, 1940.
11. KALANT, H.: "The Pharmacology of Alcohol Intoxication," *Quart. J. Stud. Alcohol*, 22: Suppl. 4, 1–23, 1961.
12. MAYFIELD, D. and D. ALLEN: "Alcohol and Affect: A Psychopharmacological Study," *Am. J. Psychiat.*, 123: 1346–1351, 1967.
13. MCFARLAND, R. A. and A. L. BARACH: "The Relationship between Alcoholic Intoxication and Anoxemia," *Am. J. Med. Sci.*, 192(2) : 186–198, 1936.
14. MENDELSON, J. H., S. STEIN, and M. T. MCGUIRE: "Comparative Psychophysiological Studies of Alcoholic and Nonalcoholic Subjects Undergoing Experimentally Induced Ethanol Intoxication," *Psychosomat. Med.*, 28: 1–12, 1966.
15. MILLER, S. U.: "Increased Human Body Water Loss at Reduced Ambient Pressure," *Aerospace Med.*, 33: 689–691, 1962.
16. NEWMAN, H. and M. ABRAMSON: "Relation of Alcohol Concentration to Intoxication," *Proc. Soc. Exp. Biol. Med.*, 48: 509–513, 1941.
17. POPHAM, R. E.: "Alcoholism and Traffic Accidents," *Quart. J. Stud. Alcohol*, 17: 225–232, 1956.
18. ROBINS, E., et al.: "The Communication of Suicidal Intent: A Study of 134 Consecutive Cases of Successful (Completed) Suicide," *Am. J. Psychiat.*, 115: 724–733, 1959.
19. ROBINSON, L. J. and S. SELESNICK: "The Treatment of Acute Alcoholism," *J.A.M.A.*, 105(22) : 1734–1738, 1935.
20. ROTTA, A., et al.: "Pulmonary Circulation at Sea Level and at High Altitude," *J. Appl. Physiol.*, 9(3) : 328–336, 1956.
21. SELZER, M. L.: "Alcohol Impairment, Alcoholism, and Traffic Accidents," *Univ. of Mich. Med. Center J.*, 32(5) : 238–241, 1966.
22. SELZER, M. L. and S. WEISS: "Alcoholism and Traffic Fatalities: Study in Futility," *Am. J. Psychiat.*, 122(2) : 762–767, 1966.
23. SYED, R. A.: "Enzymatic Determination of Ethyl Alcohol by an Automated Fluorometric Technique," *Symposium on Automation in Analytical Chemistry*, Technicon, Inc., New York, 1967.
24. WINER, B. J.: *Statistical Principles in Experimental Design*, McGraw-Hill, New York, 1962.
25. ZWIRLING, I., et al.: "Interdisciplinary Approach to Alcohol Addiction," in *American Handbook of Psychiatry*, pp. 634–644, Edited by S. Arieti, Basic Books, New York, 1959.