[redacted]

#90

U. S. NAVAL SCHOOL OF AVIATION MEDICINE AND RESEARCH
NAVAL AIR STATION
PENSACOLA, FLORIDA

RESEARCH REPORT

Submitted 1 September 1947

NM001 059.05.01

PROJECT NO. X-762(Av-390-k)

REPORT NO. One

TITLE: EFFECTS OF DECOMPRESSION ON THIRTY-FIVE SUBJECTS REPEATEDLY EXPOSED TO A SIMULATED ALTITUDE OF 20,000 FEET DURING APPROXIMATELY ONE MONTH

REPORT BY: H. A. Smedal
Commander H. A. Smedal (MC) USN

Ashton Graybiel
Captain Ashton Graybiel (MC) USN

APPROVED: Wilbur E. Kellum
Captain Wilbur E. Kellum (MC) USN
Acting Officer in Charge

RELEASED AND FORWARDED: Louis Iverson
Captain Louis Iverson (MC) USN
Senior Medical Officer, NAS

INTRODUCTION

A problem of much practical importance in aviation is concerned with the lowest altitude range in which persons will begin to complain of symptoms due to decompression. It is important in the care of flyers and in the proper evaluation of their complaints. It is also important in deciding the levels of cabin or cockpit pressure, in the case of pressurized aircraft. Although a few investigators have reported symptoms occurring in subjects rapidly decompressed to pressure altitudes of 25,000 feet or less, these observations were usually incidental and of a limited character. Accordingly, it was deemed worthwhile to study the problem further and the following account deals with the results of an experiment in which a relatively large number of subjects were exposed twice daily for a month to a pressure altitude of 20,000 feet. Particular attention was given to the symptomatology per se and the question of adaptation or deterioration of the subjects over the relatively long experimental period.

HISTORICAL

There is some evidence in the medical literature that symptoms from decompression may occur at relatively low altitudes. Gray (1) subjected healthy aviation cadets, supplied with additional oxygen, to simulated altitudes as low as 23,000 feet in a decompression chamber. In one series of tests, comprising 195 "man flights," the subjects were kept at altitude for 2 hours and were required to exercise every 5 minutes. Exercise consisted of 5 deep-knee bends followed by 5 push-ups. Severe symptoms did not occur but mild symptoms of decompression were observed in 12.8 percent. In a second series of tests, comprising 117 "man flights," the procedure was the same except that the subjects were exposed for only one hour. Severe bends were observed in 0.9 percent and mild symptoms in 6.8 percent.

Ferris and his associates (2) found that the degree of bends produced at 25,000 feet, when the subjects exercised (5 deep-knee bends every 3 minutes) was similar to that for resting subjects at 35,000 feet.

Mackensie and Riesen (3) exposed healthy subjects to pressure altitudes ranging from 14,000 to 28,000 feet for two hours. The subjects exercised every 10 minutes, performing 5 deep-knee bends and 5 arm extensions holding a 14 lb. weight. Symptoms of decompression illness necessitated descent in 36 percent at 26,000 feet. None were required to descend from simulated altitudes of 25,000 or 14,000 feet.

Smedal, Brown and Hoffman (4) subjected 1,731 flight students to a single 20-minute exposure in the decompression chamber either at room temperature or at -40° to -50° F. at simulated altitudes of 26,000, 28,000 and 30,000 feet. Exercise, consisting of 5 knee bends and 5 arm bends, was carried out every 3 minutes by each subject. At the lowest level (26,000 feet) decompression symptoms were experienced by 18.3 percent of the subjects at room temperature, and 10.6 percent at low temperatures. These symptoms were for the most part mild but in a few subjects, 1.4 percent under warm conditions and 0.4 percent under cold conditions, they

were severe enough to require removal of the subject from the chamber.

Houston (5) reported that 6 persons, who acted as observers in an experiment on acclimatization to anoxia, experienced painful joints or visual disturbances upon repeated exposures to altitudes of 17,000 to 20,000 feet. Allan (6) reported five cases of incapacitating decompression illness at relatively low altitudes. In each instance there was associated with the individual's symptoms a history of injury or evidence of bone disease at the site of the bends pain. In two instances the altitude at which, during flight, incapacitation occurred was 10,000 and 12,000 feet. It is of interest that this is well below the level, according to Nims (7), at which bubble formation can occur.

METHODS

Thirty-five healthy men ranging in age from 17 to 22 years, served as subjects. All were volunteers and the promise of "reward-leave" provided the incentive. All of the subjects were healthy; medical examinations were carried out both before and after the experiment.

A simulated altitude of 20,000 feet was obtained by the use of a decompression chamber. The rate of "ascent" was 10,000 feet per minute and "descent" 2,000 feet per minute. The duration of each test was 30 minutes at 20,000 feet. The temperature of the chamber ranged from 68° to 80° F.

The subjects were informed both with regard to the nature of decompression and the symptoms which might be experienced. Each was supplied with a standard A-14 mask and a diluter-demand oxygen regulator. Supplementary oxygen was used during each test until the 10,000 feet level was reached on descent. During the 30-minute exposure the subjects exercised every 5 minutes; this consisted of 5 deep-knee bends and 5 arm bends. After decompression each subject was interviewed and was asked to fill out a questionnaire which listed some common symptoms of decompression illness. The original questionnaire did not contain any mention of "fatigue" or "delayed symptoms." These symptoms, particularly fatigue, were forced on our attention by the voluntary complaints of the subjects, and, after the first week, were added to the questionnaire.

The original plan was to expose each subject twice daily for 30 days. For various reasons, however, every subject missed one or more tests and at the end of 30 days it was found that by prolonging the experiment 4 days a group of 24 subjects would have received 56 exposures. The main analysis was carried out on this group which is hereafter referred to as the standard subject group.

Four control experiments were carried out. On the 9th, 15th, and 22nd days, the subjects were exposed to a simulated altitude of only 10,000 feet as a substitute for one of the regular tests. On the 29th experimental day the simulated altitude for the control test was 6,000 feet. These control

experiments followed the standard procedure in all respects except with regard to the slower rates of ascent and descent and the smaller degrees of decompression. There was nothing to suggest that the subjects were aware of the change in procedure.

Determination of the CO_2 tension of alveolar air was carried out in the case of 6 subjects. These subjects were selected in the second experimental week and 3 were chosen because they had few and 3 because they had many symptoms. Alveolar air samples were taken during the latter half of the exposure period.

Radiographs of the subject's right forearm, using a soft tissue exposure technique, were taken in 21 cases. Calculations of body specific gravity from these x-ray films were made by Commander R. P. Webster H(S), USNR, using a modification of his Method of Frustums. A correlation was made between the body specific gravity and the symptomatology.

In addition to the subject group there was available for study 6 technical observers, aged 20-25 years, who were decompressed in the chamber approximately once daily. Their experience otherwise was similar to that of the subject group except that they did not perform the exercise required of the regular subjects.

RESULTS

Table 1 shows the incidence of the various symptoms reported by the 35 subjects during 1,813 periods of decompression. All of the subjects except 1 had symptoms. All of the symptoms were mild or very mild with few exceptions.

Symptoms referable to muscle or joint were by far the most frequent, accounting for about 60 percent of the total. None were severe except in two instances which will be described later in detail. They were variously described as "stiffness," "ache," a "catch" or "charley-horse," a "twinge of pain" or "pain." The majority of these symptoms were located in or around the knee. The ache or pain would usually appear during the latter half of the exposure period while the subject was exercising. It might disappear shortly after exercise was discontinued or remain until the end of the exposure period.

Symptoms referable to the eye (lachrymation, burning, and grittiness) were second in frequency (20%). These symptoms were extremely mild and, with the exception of one subject who had persistent tearing, they were unimportant. Symptoms referable to the skin accounted for nearly 17 percent of the total incidence. These were all very mild and consisted mainly of localized areas of heat or cold sensations, tingling and itching. Substernal distress usually described as "burning" or "very slight pain" was an occasional complaint. There were two instances of visual disturbance; one subject complained of "blurred vision" and one other of "loss

of vision" lasting about one minute in association with a dizzy spell.

There were some delayed symptoms. A few subjects complained of joint pain following exposure. Fatigue was an extremely frequent symptom. After the first week each subject expressed an opinion, at the end of each test, as to whether the repeated exposure to decompression had led to a feeling of undue fatigue. His judgment was influenced mainly but not wholly by the immediately preceding exposure. From 50 to 80 percent of the subjects registered this complaint at every opportunity. In addition to being a common symptom fatigue was frequently severe. Many subjects stated that they became so tired that they lost appetite for food, required more sleep, and avoided sports and entertainment after the day's work. One subject became unfit for duty and was given two days' rest.

Either the decompression per se or some factor associated with it, such as anxiety, must have been responsible for the fatigue. Inasmuch as the participants were excused from the regular work during the hours required for making the tests, the fatigue could not be ascribed to an increase in length of working day. There was no doubt in the minds of the investigators that, with rare exceptions, fatigue was the only symptom which caused a significant decrease in the general fitness of a subject.

The standard subject group. The main analysis was carried out on the data obtained from the group of 24 subjects who were decompressed 56 times in 34 days. The individual incidence of the various symptoms is shown in Table 2. Twenty of the 24 subjects complained of muscle and joint symptoms but the distribution was uneven inasmuch as 9 subjects registered 194 of the 246 complaints. The distribution of the eye symptoms was even more uneven; 2 subjects registered 46, and 5 subjects registered 71 of the 79 eye complaints. There were 86 complaints referable to the skin and 48 of these were registered by 3 subjects. It is noteworthy that of the 165 complaints referable to eye and skin, 119 or 72 percent were registered by 5 subjects. The 11 instances of substernal distress were well distributed.

In Table 2 the subjects are ranked according to the incidence of symptoms. If this is allowed as a measure of "susceptibility" it is seen that there is no definite correlation between susceptibility to decompression symptoms and such factors as height, weight, and blood type. Following the lead of Hodes and Larrabee (8) an attempt was made to correlate alveolar CO_2 tension with susceptibility. During the second week 3 subjects were selected who had few symptoms and 3 who had many symptoms. Graph 1 compares the mean alveolar CO_2 tensions for the two groups on 8 occasions. The mean alveolar CO_2 tension for all determinations was 39.9 mm. Hg for the group with many symptoms and 36.4 for the group with few symptoms. The mean difference of 3.51 divided by the standard error difference gave a critical ratio of 0.865 which was considered not to be significant.

A correlation was made between susceptibility and body specific gravity in the case of 21 of the 24 subjects. The results are shown in Table 3; the correlation of +.33 is considered to be of no significance.

A chief consideration in the present study was related to the possibility that, with repeated exposures, subjects would change in their susceptibility to decompression symptoms. Graph (2) shows the daily incidence of symptoms expressed as percent of man-exposures. It is seen that there is a tendency for the incidence to rise until the 18th day, after which it falls sharply. Table 4 shows the weekly incidence for the various symptoms and displays the same general tendencies as are shown in Graph 2. Even more striking are the results for the symptoms referable to muscle and joint; the number of complaints per man-exposure rose from 12.4 percent during the first week to 24.3 during the third, then fell to 5.1 during the fifth week (six days only).

Graph 3 shows the daily incidence of fatigue expressed as percent of man-exposures. Data is lacking for the first week hence only a partial comparison is possible with the incidence of the other symptoms as shown in Graph 2. However, Graph 3 shows that there was a gradual decrease in the number of complaints of fatigue in the latter part of the experimental period.

Because of the mildness and the subjective nature of the decompression symptoms it was decided to introduce a control test in which the subjects were exposed to a simulated altitude of only 10,000 feet. This was first done on the 9th experimental day and it was surprising to find that there were about the same number of complaints as usual (Table 5). This was repeated at approximately weekly intervals and the simulated altitude in the last control test was only 6,000 feet. The results are shown in Tables 5 and 6. Table 5 shows the incidence of the various symptoms in the four control tests and Table 6 the individual incidence. If the data in Table 5 is compared with Table 4 it is seen that the incidence of symptoms for the several control tests corresponds closely to the incidence of symptoms for the week in which the control test was made. From the data in Tables 6 and 2 it is seen that the incidence of muscle and joint symptoms was slightly greater but that the incidences of other symptoms far less during the control runs when compared with the regular runs.

Sixteen of the 24 subjects complained of bone and joint symptoms during the control tests; 4 of the remaining 8 did not have these symptoms even during the regular exposures. Aside from muscle and joint symptoms there were only 7 complaints registered by three subjects.

The results of the control tests raises the question as to whether all of the symptoms can be ascribed to factors other than decompression. The arguments in favor of the symptoms being due to decompression include the following. First, the symptoms as they were described by the subject were characteristic of decompression symptoms. Second, the muscle and joint symptoms, which comprised over 70 percent of the

total, usually occurred in relation to exercise and toward the end of the exposure period; relationships which would be expected if decompression were a factor. Third, there were two instances of severe bends (described below) which left no doubt but that decompression symptoms might be expected at the 20,000 feet level.

The arguments which cast doubt on the genuineness of many of the decompression symptoms include the following. First, the total incidence of symptoms was as great during the control as during the regular tests. This argument however is not final inasmuch as the control tests were not "perfect." Thus, it is yet to be proven that decompression to a simulated altitude of 10,000 feet within two minutes if not a factor in producing symptoms such as those observed. Furthermore, the control tests were not made until the subjects had experienced symptoms and the experimental procedure strongly favored conditioning to these symptoms once they were expected. Second, there was a sharp decline in the number of complaints toward the end of the experimental period. The impression is generally held that susceptibility to decompression symptoms increases rather than decreases if these symptoms are severe and are experienced frequently. This being true, the decline in number of complaints could be more readily attributed to adjustment or adaptation to factors other than decompression. Here again definite proof is lacking. There are instances on record of subjects who, on frequent exposure to decompression first experienced symptoms then lost them. It may well be that persons can become adapted to mild degrees of decompression but become increasingly susceptible if exposed to severe degrees of decompression.

The observer group. Tables 7 and 8 summarize the data obtained in the case of 6 observers who were exposed to decompression about half as often as the regular subjects. It is seen that although the total incidence of symptoms per man-exposure is the same as for the standard group there is a much lower incidence of muscle and joint symptoms and a higher incidence of the other symptoms. The fewer number of complaints referable to muscle and joint was probably due to the fact that the observers did not carry out the regular exercise. From the data in Table 8 it is seen that there were great variations in the weekly incidence of symptoms. This may have been due in part to the small number of individuals in the group. It is probably significant however that no symptoms were registered during the fifth week.

The observer group did not report having any symptoms during the control experiments. This fact loses much of its significance however because all of the observers realized the nature of the control tests.

Special case reports. There were 2 subjects who stood apart from the others in that they suffered severe joint symptoms during decompression. These symptoms and the circumstances which favored their occurrence are described in detail inasmuch as they are of more than passing interest. It should be mentioned that these two persons were not included in the standard subject group.

C. G., a sailor, 19 years of age, was unusually well and strong and medical examination revealed no abnormality. His regular duties involved underwater diving to depths varying from 30 to 90 feet. During the tests in the decompression chamber he frequently complained of mild joint symptoms in relation to exercise. One morning, following a day in which he dove 5 times to a depth of 30 feet, he experienced mild pain in the right knee during a regular test in the decompression chamber. During the test on the afternoon of the same day, having made no underwater dives meanwhile, he developed such severe pain in the right knee that he was unable to complete the test and was removed from the chamber. In view of his diving duties it was decided that he should not continue to serve as a subject.

Case 2. R. D. K., a sailor, 19 years of age, was well and strong and was considered to be of average susceptibility to symptoms of decompression. One morning, following a standard test exposure, he took part in another decompression test without our knowledge. This test, which was carried out in a different chamber, exposed him to a simulated altitude of 30,000 feet for 20 minutes and 35,000 feet for 10 minutes, with the temperature at -30° to -40° F. While exercising at 35,000 feet he developed pain in one knee which was not incapacitating. On the afternoon of the same day, while taking part in the second regular exposure to 20,000 feet he developed such severe pain in the knee joint that it was necessary to remove him from the chamber. This case is particularly instructive in pointing out the possibility of the development of decompression symptoms at relatively low altitude following previous exposure with symptoms at high altitude.

DISCUSSION

When subjects are exposed to severe degrees of decompression they experience certain symptoms and present certain signs which are characteristic of decompression illness. With exposure to progressively smaller degrees of decompression the symptomatology becomes progressively milder, fewer subjects are affected until finally symptoms disappear or appear only if some additional etiologic factor is present. Our experience demonstrates the difficulty in determining whether certain very mild complaints made by a subject exposed to moderate decompression are indeed due to this factor.

This difficulty cannot be resolved by the use of naive subjects because many mild symptoms will be missed. On the other hand if the sub-

jects are fully informed, as was the case in our experiment, there is the danger that suggestion and overattention to normal stimuli may lead the subject wrongly to ascribe certain symptoms to decompression. We did not anticipate all of the difficulties in diagnosis. Furthermore our last minute effort in introducing control tests proved to be insufficient. Hence great caution has been used in interpreting the results.

There were a few instances in which there was no doubt but that decompression was an etiologic factor in the production of symptoms. This was most clearly illustrated by the two special case reports but also shown in other cases by the severity of the symptoms or the presence of some sign such as tearing.

Exercise is very helpful in making the subject more susceptible to muscle and joint symptoms during decompression but some form of exercise other than deep knee bends is preferable inasmuch as slight symptoms may accompany this exercise under ordinary conditions. If our findings are re-evaluated leaving out muscle and joint symptoms, a much stronger argument could be put forth that the complaints were caused by decompression.

An extremely interesting question is raised by the possibility that fatigue may be the most important symptom due to mild decompression and the limiting factor in deciding on the level to which persons may be frequently decompressed without too much loss in physical fitness. We are inclined to the opinion that decompression per se was a factor in producing fatigue in our subjects. More experiments are required however to evaluate fully and accurately this important complaint.

The question of adaptation or deterioration of the subjects over a period of nearly 5 weeks may be considered from two points of view. If the incidence of the symptoms are allowed as a measure of susceptibility it would appear that there was a moderate increase during the first two weeks then a fall which carried well below the original level. If it is assumed that the majority of symptoms were not due to decompression it can be concluded at least that an increase in susceptibility was not demonstrated.

CONCLUSIONS

1. When healthy young subjects breathing supplementary oxygen were exposed to a pressure altitude of 20,000 feet for 30 minutes both morning and afternoon over a period of a month it was found that:

   a. With rare exceptions there were no severe symptoms of decompression.

   b. Symptoms requiring recompression of the subject may occur if additional etiologic factors are present.

c. The most important symptom was fatigue but the exact role of decompression in its causation still remains to be evaluated.

d. The repeated exposures did not lead to an increase in severity of symptoms.

e. If the incidence of symptoms is allowed as a measure of susceptibility our data suggests that, after a temporary increase in susceptibility, there is a sharp fall to well below the initial level suggesting that adaptation to mild decompression occurs.

2. Great care must be used in planning experiments of this character, particularly with regard to the manner of eliciting complaints and to the establishment of rigid control tests.

3. A serious error would not be made in using a pressure altitude of 20,000 feet for the level of cabin or cockpit pressurization.

* * * * *

The assistance of Lt. Comdr. W. B. Clark, Lt. W. H. Jarvis, and Florence Krueger, PhM2 V-10, USNR, is gratefully acknowledged.

BIBLIOGRAPHY

1. Gray, J. S. Aeroembolism induced by exercise in Cadets at 23,000 feet. AAF School of Aviation Medicine Research Report No. 227, Jan. 26, 1944.

2. Ferris, E. B., Jr., J. P. Webb, Geo. Engle and Estelle W. Brown. A comparative study of decompression sickness under varied conditions of exercise, altitude and denitrogenation. CAM report No. 363, 1944.

3. Mackensie, C. G., and A. H. Riesen. The production by moderate exercise of a high incidence of bends at altitudes of 26,000 to 28,000 feet. J.A.M.A. 124:499-501, 1944.

4. Smedal, H. A., E. B. Brown and C. E. Hoffman. The incidence of bends pain in a short exposure to simulated altitudes of 26,000, 28,000 and 30,000 feet. J. of Aviat. Med., Vol. 17, Feb., 1946.

5. Houston, C. S. Occurrence of bends, scotomata and hemianopsia at altitudes below 20,000 feet. J. of Aviat. Med., Vol. 18, April, 1947.

6. Allan, J. H. Traumatic calcification, a precipitating factor in bends pain. J. of Aviat. Med., Vol. 16, August, 1945.

7. Nims, L. F. A physical theory of decompression sickness. Yale Aeromedical Research Unit, Report No. 55, May, 1947.

8. Hodes, R. and M. G. Larrabee. The relation between alveolar CO_2 tension and susceptibility to decompression sickness. Am. J. of Physiology, Vol. 147, Dec., 1946.

TABLE I

INCIDENCE OF SYMPTOMS IN 35 SUBJECTS EXPOSED TO 20,000 FEET FOR 30 MINUTES TWICE DAILY DURING APPROXIMATELY 1 MONTH

1813 MAN EXPOSURES

	SYMPTOM	INCIDENCE	% MAN EXPOSURES	% INCIDENCE
EYE	LACHRYMATION	54	2.9	9.1
EYE	BURNING	57	3.1	9.6
EYE	GRITTINESS	8	0.4	1.3
SKIN	TEMPERATURE SENSATIONS	42	2.3	7.1
SKIN	TINGLING	41	2.2	6.9
SKIN	FORMICATION	3	0.2	0.5
SKIN	ITCHING	13	0.7	2.2
	MUSCLE AND JOINT PAIN	346	19.0	58.2
	SUBSTERNAL DISTRESS	24	1.3	4.0
	DIZZINESS	5	0.2	0.8
	VISUAL SYMPTOMS	2	0.1	0.3
TOTAL	NO	595		
TOTAL	%	32.8		

TABLE 2

INCIDENCE OF SYMPTOMS IN GROUP OF 24 SUBJECTS EXPOSED TO 20,000 FEET FOR 30 MINUTES 56 TIMES IN 34 DAYS

	HEIGHT (Inches)	WEIGHT	AGE	BLOOD TYPE	SPECIFIC GRAVITY	EYE: WATERING	EYE: BURNING	EYE: GRITTINESS	SKIN: TEMPERATURE SENSATIONS	SKIN: TINGLING	SKIN: FORMICATION	SKIN: ITCHING	MUSCLE AND JOINT PAIN	SUBSTERNAL DISTRESS	DIZZINESS	VISUAL SYMPTOMS	TOTAL
WRIGHT	66	150	17	O	1.068	22					3		26	1			52
CALDWELL	70	128	19	A	Not Obtained Authors		9		1	14		2	24		1		51
FAGAN	70	190	19	O	1.066	4	3		10	7	2		18	3			47
BALL	71	135	19	A	1.088	4	20						16		3		43
REED	71	178	18	O	1.066				2				34				36
HELMS	70.5	156	18	A	1.071	1	6	2	6	3		3	3	1			25
SMITH	65	136	19	A	1.084	1							20	2			23
BARBER	72	175	18	A	1.068								21				21
MELLAND	69	165	19	B	1.070				1				19				20
AULICINO	68	140	19	B	1.082	1		1	1	7			8	1			19
BRADFORD	68	170	18	A	1.074								16				16
SEA	65	135	18	A	1.071			1	1			1	7	1			11
BROWN	68	119	22	A	1.078		1		1	1	1	1	4	1			10
MILHAM	67	135	19	O	1.070				5			3	1			1	10
PARHIALA	71	162	19	O	1.072								9				9
LoBONTE	71	175	19	A	1.072				1				6	1			8
BRIDGES	70.5	150	19	A	Not Obtained Av. Bold				1	1		1	4				7
STEVENS	72	180	19	AB	1.090		1						4				5
FENWICK	69	150	19	A	1.073		1						4				5
WINFIELD	63.5	130	19	A	1.076	1				1			2				4
FRANSISCO	70	154	18	O	Not Obtained Av. Bold				1	1							2
ROBINSON	70.5	153	18	O	1.077				2								2
HEESCH	71	185	17	B	1.075				1								1
EMERSON	70	155	18	A	1.090 Mean 1.074												0
TOTAL SYMPTOMS						34	41	4	34	38	3	11	246	11	4	1	428
PERCENT						7.9	9.6	0.9	7.9	8.8	0.7	2.5	57.4	2.5	0.9	0.2	
PERCENT MAN EXPOSURES						2.7	3.3	0.3	2.7	3.1	0.2	0.9	20.0	0.9	0.3	0.08	

TABLE 3

CORRELATION OF SPECIFIC GRAVITY AND SYMPTOM INCIDENCE IN 21 OF 24 SUBJECTS WITH 56 EXPOSURES TO 20,000 FEET IN 34 DAYS

	SUBJECTS WITH HIGH SPECIFIC GRAVITY	SUBJECTS WITH LOW SPECIFIC GRAVITY
HIGHER THAN AVERAGE INCIDENCE OF SYMPTOMS	3	6
LOWER THAN AVERAGE INCIDENCE OF SYMPTOMS	6 1/2	5 1/2

*$r = +.33$

*CORRELATION CALCULATED BY PEARSONS COSINE π METHOD

TABLE 4

WEEKLY INCIDENCE OF SYMPTOMS IN 24 SUBJETS EXPOSED TO 20,000 FEET FOR 30 MINUTES, 56 TIMES IN 34 DAYS

	SYMPTOM		1ST WEEK 322 MAN EXP.	2ND WEEK 282 MAN EXP.	3RD WEEK 296 MAN EXP.	4TH WEEK 306 MAN EXP.	5TH WEEK 138 MAN EXP.	TOTAL 1344 MAN EXP.
EYE	LACHRYMATION	NO	5	10	10	7	2	34
		%	1.5	3.5	3.3	2.2	1.4	2.5
	BURNING	NO	9	5	5	15	7	41
		%	2.7	1.8	1.7	4.9	5.1	3.1
	GRITTINESS	NO	2	1	0	1	0	4
		%	0.6	0.4	0	0.3	0	0.3
SKIN	TEMPERATURE SENSATIONS	NO	16	6	11	0	1	34
		%	4.9	2.1	3.7	0	0.7	2.5
	TINGLING	NO	12	9	16	1	0	38
		%	3.7	3.2	5.4	0.3	0	2.8
	FORMICATION	NO	1	0	2	0	0	3
		%	0.3	0	0.3	0	0	0.2
	ITCHING	NO	4	1	0	4	2	11
		%	1.2	0.4	0	1.3	1.4	0.8
	MUSCLE AND JOINT PAIN	NO	40	55	72	72	7	246
		%	12.4	19.5	24.3	23.5	5.1	18.3
	SUBSTERNAL DISTRESS	NO	3	2	4	2	0	11
		%	0.9	0.7	1.4	0.7	0	0.8
	DIZZINESS	NO	0	1	1	2	0	4
		%	0	0.4	0.3	0.7	0	0.3
	VISUAL SYMPTOMS	NO	0	1	0	0	0	1
		%	0	0.4	0	0	0	0.07
	TOTAL INCIDENCE		92	91	121	104	19	427
	% MAN EXPOSURES		28.6	32.3	40.9	33.9	13.8	

TABLE 5

INCIDENCE OF SYMPTOMS IN 4 CONTROL EXPERIMENTS INVOLVING THE GROUP OF 24 SUBJECTS

	SYMPTOM	9TH DAY ALT. 10,000 FT. 23 MAN EXP.	15TH DAY ALT. 10,000 FT. 24 MAN EXP.	22ND DAY ALT. 10,000 FT. 24 MAN EXP.	29TH DAY ALT. 6,000 FT. 22 MAN EXP.	TOTAL 93 MAN EXP. NO	%
EYE	LACHRYMATION	0	0	0	0	0	0
EYE	BURNING	0	0	1	1	2	2.1
EYE	GRITTINESS	0	0	0	0	0	0
SKIN	TEMPERATURE SENSATIONS	0	0.	1	0	1	1
SKIN	TINGLING	0	0	0	0	0	0
SKIN	FORMICATION	0	0	1	0	1	1
SKIN	ITCHING	0	0	1	0	1	1
	MUSCLE AND JOINT PAINS	7	5	6	3	21	22.5
	SUBSTERNAL DISTRESS	0	1	0	0	1	1
	DIZZINESS	0	0	0	0	0	0
	VISUAL SYMPTOMS	0	0	0	0	0	0
	TOTAL. INCIDENCE	7	6	10	4	27	29
	% INCIDENCE	25.9	22.2	37.0	14.8		

TABLE 6

INCIDENCE OF SYMPTOMS DURING 4 CONTROL EXPERIMENTS INVOLVING SUBJECT GROUP OF 24

	EYE			SKIN								
	WATERING	BURNING	GRITTINESS	TEMPERATURE SENSATIONS	YAWNING	FORNICATION	ITCHING	MUSCLE AND JOINT PAIN	SUBSTERNAL DISTRESS	DIZZINESS	VISUAL SYMPTOMS	TOTAL
WRIGHT								2				2
CALDWELL							/	2				2
FAGAN								1				1
BALL		2						1				3
REED								2				2
HELMS								1				1
SMITH								1				1
BARRER								2				2
MELLAND												0
AULICINO								1	1			2
BRADFORD								1				1
SEA								1				1
BROWN												0
MILHAM				1		1	1					3
PARHIALA								1				1
LoBONTE								1				1
BRIDGES								1				1
STEVENS								2				2
FENWICK												0
WINFIELD								1				1
FRANSISCO												0
ROBINSON												0
HEESCH												0
EMERSON												0
TOTAL SYMPTOMS		2		1		1	1	21	1			27
PERCENT		7.4		3.7		3.7	3.7	77.7	3.7			
PERCENT MAN EXPOSURES		2.1		1.0		1.0	1.0	22.3	1.0			

TABLE 7

INCIDENCE OF SYMPTOMS IN 6 OBSERVERS EXPOSED TO 20,000 FEET DAILY FOR 30 MINUTES DURING A PERIOD OF APPROXIMATELY 1 MONTH

NO STANDARD EXERCISE — 153 MAN EXPOSURES

SYMPTOMS

OBSERVER	EYE			TEMPERATURE SENSATIONS	SKIN			MUSCLE AND JOINT PAIN	SUBSTERNAL DISTRESS	DIZZINESS	VISUAL SYMPTOMS	TOTAL	
	LACHRYMATION	BURNING	GRITTINESS		TINGLING	FORMICATION	ITCHING					NO	%
ALBRITTON	0	1	0	0	0	0	0	1	0	0	0	2	4.6
BILLINGS	0	0	0	1	0	0	1	1	0	0	0	3	6.9
FOSTER	2	5	0	1	6	0	4	2	0	0	1	21	48.8
HOWELL	1	1	0	2	2	0	0	0	0	0	0	6	13.9
SCHULTZ	0	0	0	2	3	0	0	0	0	1	0	6	13.9
YODER	1	0	0	1	0	0	0	2	0	1	0	5	11.6
TOTAL NO	4	7	0	7	11	0	5	6	0	2	1	43	
TOTAL % Man Exposures	2.6	4.6	0	4.6	7.2	0	3.3	3.9	0	1.3	0.6		

GRAPH I

COMPARISON OF ALVEOLAR CO_2 TENSION IN 3 SUBJECTS WITH FEW AND 3 SUBJECTS WITH MANY SYMPTOMS DURING DECOMPRESSION

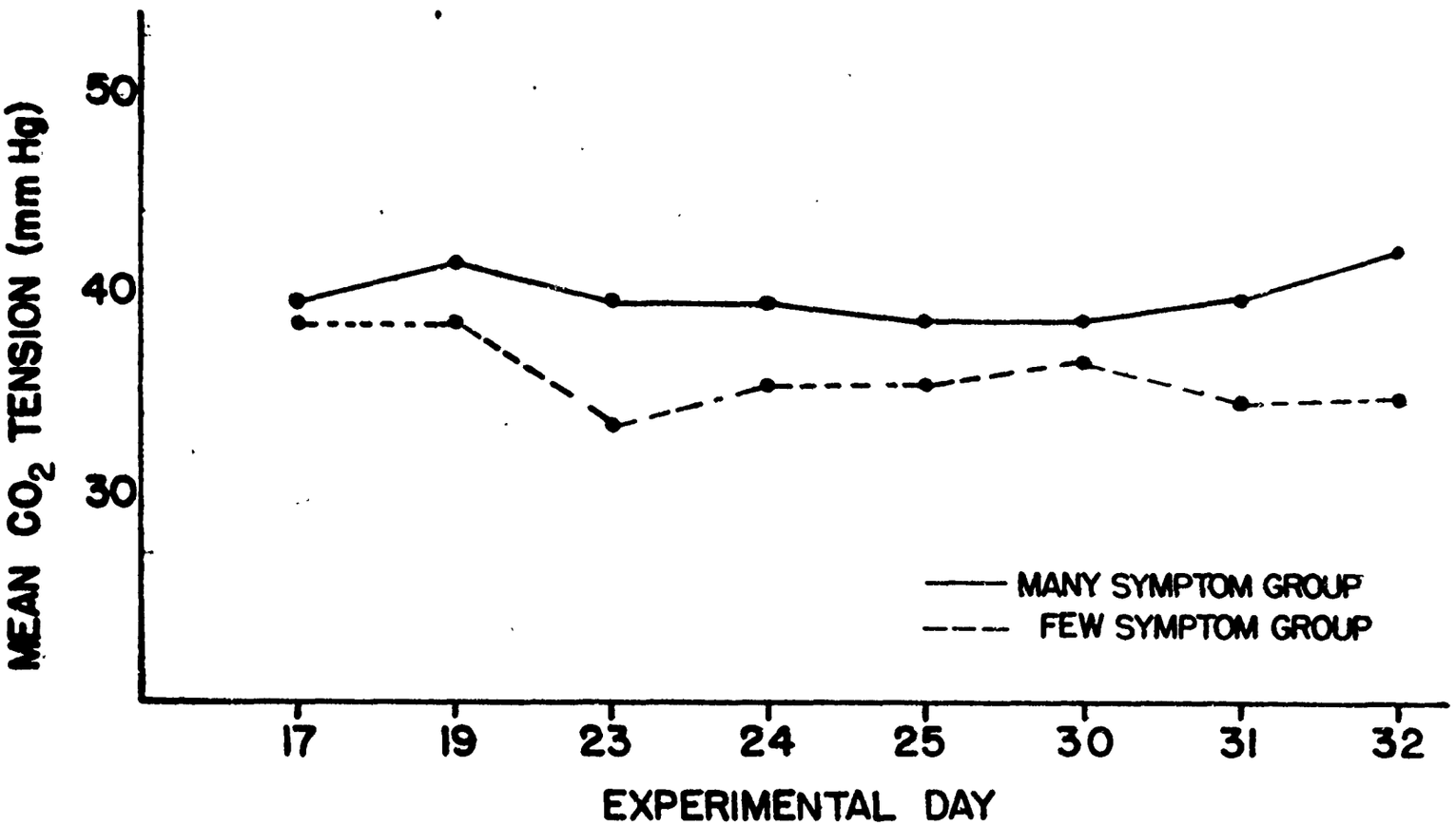


TABLE 8

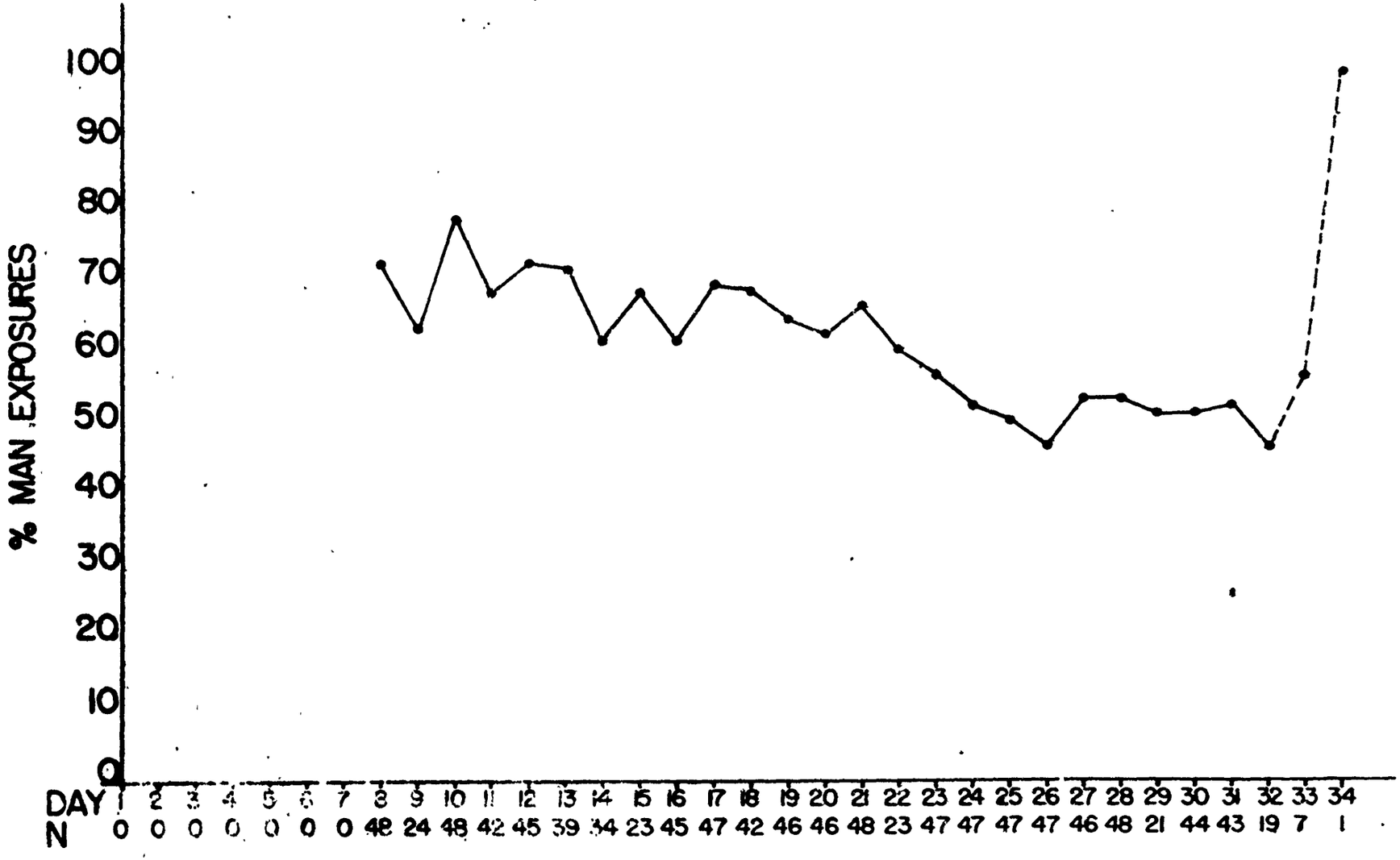
WEEKLY INCIDENCE OF SYMPTOMS IN 6 OBSERVERS EXPOSED DAILY TO 20,000 FEET FOR 30 MINUTES DURING APPROXIMATELY I MONTH

153 MAN EXPOSURES

	SYMPTOM	1ST WEEK 35 MAN EXP.	2ND WEEK 35 MAN EXP.	3RD WEEK 33 MAN EXP.	4TH WEEK 33 MAN EXP.	5TH WEEK 17 MAN EXP.	TOTAL NO	TOTAL %
EYE	LACHRYMATION	3	1	0	1	0	5	9.8
EYE	BURNING	3	2	0	2	0	7	13.7
EYE	GRITTINESS	0	0	0	0	0	0	0
SKIN	TEMPERATURE SENSATIONS	7	1	0	0	0	8	15.7
SKIN	TINGLING	8	2	1	2	0	13	25.5
SKIN	FORMICATION	0	0	0	0	0	0	0
SKIN	ITCHING	1	1	3	1	0	6	11.8
	MUSCLE AND JOINT PAIN	4	3	0	2	0	9	17.6
	SUBSTERNAL DISTRESS	0	0	0	0	0	0	0
	DIZZINESS	1	0	0	1	0	2	3.9
	VISUAL SYMPTOMS	0	0	0	1	0	1	1.9
TOTAL	NO	27	10	4	10	0	51	
TOTAL	% Man Exposures	77.1	28.6	12.1	30.3	0	33.3	

GRAPH 3

INCIDENCE OF FATIGUE IN SUBJECT GROUP OF 24 EXPOSED TO 20,000 FEET TWICE DAILY FOR 34 DAYS



GRAPH 2

DAILY INCIDENCE OF SYMPTOMS IN 24 SUBJECTS
EXPOSED TO 20,000 FEET TWICE DAILY FOR 34 DAYS