Physiologic Effects of Exposure to Increased Oxygen Tension at 5 psia

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A PREVIOUS STUDY [10] reported the effect on man of exposure to an atmosphere consisting primarily of oxygen at reduced total pressure (190 mm. Hg). Arterial desaturation was found in two of eight test subjects at the conclusion of 17 days, suggesting the possibility of atelectasis being present. This was not confirmed by either x-ray or vital capacity data. Atelectasis had been noted, however, at oxygen partial pressures of 418 mm. Hg during the course of a seven-day experiment.[8] Since it has been proposed that future manned spacecraft missions utilize an oxygen atmosphere at a total pressure of 5 psia (258 mm. Hg), it was desirable to amplify the results of previous studies with experiments in the anticipated atmosphere. The purpose of the experiments reported here was to observe the possible development of pulmonary atelectasis utilizing arterial and alveolar oxygen and carbon dioxide partial pressures, vital capacity, posterior-anterior chest x-ray, and clinical examination as indicators. Psychomotor performance was included to determine the gross effect of atelectasis (if present) on the functional capability of the test subjects.

METHODS

The two 14-day experiments were conducted in the two-man space cabin simulator described previously.[13] The atmosphere was maintained by the injection of externally stored gaseous oxygen into the simulator and by the absorption of carbon dioxide by on-board stores of baralyme. Total pressure was sensed by an absolute pressure transducer, partial pressure of oxygen (Po_2) by a Beckman oxygen analyzer. Model F-3; and Pco_2 by a Beckman carbon dioxide analyzer, Model 15-A. The PH_2O was calculated from relative humidity data obtained with an El-Tronic hygrometer, Model 101C, and from temperature data obtained with a Minneapolis-Honeywell resistance bulb, Model 6630. These results were verified with a modified Assman-type wet bulb-dry bulb thermometer. Nitrogen was calculated by difference, or determined with a gas chromatograph, using a molecular sieve column with periodic checks against a Waters nitrogen analyzer, Model A-6. The ambient gaseous conditions that were maintained during these tests are shown in Table I. Mean cabin temperature was 21.6° C and mean relative humidity was 42.4 per cent.

TABLE I. SUMMARY OF ENVIRONMENTAL CONDITIONS

Parameter	mm. Hg
Total pressure	259.0
Oxygen partial pressure	243.0
Carbon dioxide partial pressure	2.8
Water vapor partial pressure	8.2
Nitrogen partial pressure *	5.0

* By difference—see text.

The four test subjects (all volunteers and all Air Force pilots) had the physical characteristics shown in Table II. During the experiments, the men wore loose-fitting, cotton clothing. Prior to ascent to altitude, all subjects received a minimum of 2.5 hours of preoxygenation for bends protection.

TABLE II. PHYSICAL CHARACTERISTICS OF TEST SUBJECTS

	Subject Number			
	15	16	17	18
Height (in.)	70.0	69.0	68.5	71.0
(cm.)	177.8	175.3	174.0	180.3
Weight (lbs.)	154.5	159.5	147.0	136.0
(kg.)	70.2	72.5	66.8	61.8
Age (yrs.)	23	24	27	26
Body surface area (m^2)	1.87	1.88	1.80	1.79

The daily schedule of the subjects (Table III) was set to provide the men with a 5-hour period at night for uninterrupted sleep. The two "regular testing" periods were for collecting physiologic data as well as providing an opportunity for the men inside the simulator to relax completely. The schedule was rotated

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TABLE III. TEST SUBJECT DAILY SCHEDULE

Time of Day	Day 1 and all odd days		Day 2 and all even days	
	On-Duty	Off-Duty	On-Duty	Off-Duty
0700-0900	Testing	Testing	Testing	Testing
0900-1100	15, 17 *	16, 18 *	16, 18	15, 17
1100-1300	16, 18	15, 17	15, 17	16, 18
1300-1500	15, 17	16, 18	16, 18	15, 17
1500-1700	16, 18	15, 17	15, 17	16, 18
1700-1900	15, 17	16, 18	16, 18	15, 17
1900-2100	Testing	Testing	Testing	Testing
2100-0200	16, 18	15, 17	15, 17	16, 18
0200-0700	15, 17	16, 18	16, 18	15, 17

* Indicates test subject identification number.

daily in order to obtain both physiologic and performance data on both men at different times during the normal, earth-oriented, 24-hour day. Table IV shows the frequency of sampling of the various parameters measured during each of these experiments, as well as the general schedule followed during each testing period.

The variables considered to be of primary importance in these experiments were arterial oxygen and carbon dioxide partial pressure (P_aO_2 and P_aCO_2 respectively), arterial pH, arterial saturation (calculated from the Dill, et al.,[3] nomogram), alveolar oxygen (P_AO_2) and carbon dioxide (P_ACO_2), hematocrit, vital capacity, posterior-anterior chest x-ray at altitude and psychomotor performance. With the exception of preflight control values, all measurements or samples were obtained in the environment described in Table I. Blood and gas samples were obtained at altitude, passed through a small air-lock and analyzed at ground level. Arterial blood samples were placed in an ice bath within 2-3 minutes after drawing and the blood gas tensions and pH were determined directly, using an Instrumentation Laboratory Model 113 pH and blood gas analyzer. Arterial samples were obtained by means of an indwelling arterial needle. Alveolar gas tensions were determined on gas samples collected by the Haldane and expiratory method[4] with subsequent analysis at ground level by the Scholander technique. Hematocrits were determined on peripheral venous blood samples by the micromethod.[5] Vital capacity was determined by using a Custom Engineering Servo-Spirometer with the amplifier and readout on a Sanborn recorder located outside the simulator. Duplicate forced vital capacity measures were made at each period indicated in Table IV and the results expressed as the average of the two, corrected to BTPS. Posterior-anterior chest x-ray films were made at altitude, using a 100 Kva machine, shooting through a 5 mm. thick aluminum port. Psychomotor performance was assessed by the operator system described previously.[6,7] Programming was accomplished by punched Mylar tapes, a tape reader and a decoding device. The signal rate was held constant at 500 per hour.

In order to have a daily assessment of the test subjects, electrocardiograms, pulse rates, body temperatures, blood pressures and respiratory rates were monitored as shown in Table IV. The techniques utilized have been described previously.[9]

Other variables that were determined during these studies were considered to be of secondary importance and were added to the experimental protocol to provide additional pertinent information. These included routine hematology, blood electrolytes, urinalyses, energy and water requirements, body weight, 24-hour urinary steroid and catecholamine excretion.[11] Routine hematology and blood electrolytes were performed according to the schedule in Table IV. Urinalyses were performed daily. Steroid and catecholamine excretion patterns were also followed daily, utilizing aliquots from each voiding to compose a 24-hour sample. Body weights were taken in the fasting state.

RESULTS AND DISCUSSION

The results of the arterial studies are shown in Table V, along with the alveolar oxygen and carbon dioxide partial pressures and calculated alveolar-arterial oxygen gradients (A-ao_2 gradient). The P_aO_2 values were obtained by adherence to the schedule shown in Table IV wherever possible. In test subjects 17 and 18, arterial studies were not possible on day one of the experiment due to the occurrence of bends in subject 18 which necessitated a very slow ascent to the experimental altitude. The arterial Po_2 values obtained during these two experiments all appear to be within normal physiologic limits for this environmental condition, although somewhat low. This is probably related to several factors, the predominant being a more pronounced effect of "normal" physiologic veno-arterial shunting while breathing a higher PO_2. Similar values were obtained in subjects 17 and 18 when pre-experimental samples were with-

TABLE IV. EXPERIMENTAL PROTOCOL

Test	Pre-Experiment	Day of Experiment 1	2	3	4	5	6	7	8	9	10	11	12	13	14
Vital capacity	A	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Alveolar $pO_2 + pCO_2$	A	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Arterial $pO_2 + pCO_2$	B	B						B							B
Chest x-ray	B	B						B							B
Blood pressure	A	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Pulse	A	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Body temperature	A	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Respiratory rate	A	C	C	C	C	C	C	C	C	C	C	C	C	C	C
Electrocardiogram	A	C	C	C	C	C	C	C	C	C	C	C	C	C	C

A—Six determinations made during 10-day pre-experiment period.
B—Single determination.
C—Determined once daily at 7:00 a.m. or 7:00 p.m. alternately.
X—Determined twice daily at 7:00 a.m. and 7:00 p.m.

drawn while the subjects were breathing an enriched oxygen-nitrogen mixture which provided P_AO_2 values (174 and 162 mm. Hg in subjects 17 and 18, respectively) equivalent to those found at the experimental altitude. Periodic comparison of calculated saturation versus determined saturation showed good agreement and in no instance was significant desaturation observed. The P_AO_2 levels observed were estimated to represent a venous-arterial shunt of approximately two per cent,[2] but cannot be considered clearly abnormal.

No evidence for pulmonary atelectasis was found on the chest x-rays. The radiographs were of good to excellent quality and no technical problems associated with the experimental arrangement were encountered.

Vital capacity reduction was apparent from the outset of experimental exposure and averaged 2.9 per cent less than pre-experiment levels (Table VI). The reduction was significant in three of the four test subjects, two at the 0.01 level and one at the 0.05 level. There was a prompt return of vital capacity to pre-experimental levels in all but subject #15 when the simulator pressure was returned to normal ambient laboratory pressure. This slight decrease in vital capacity following ascent to altitude has been noted during previous experiments[9, 12] conducted at reduced pressures and does not appear to be indicative of atelectasis.

The effect of exposure to the 5 psi, oxygen atmosphere on hematocrit is shown in Table VII. There appears to be a slight drop in hematocrit during the first seven days of exposure, followed by a return to pre-flight levels during the last seven days of exposure and post-flight. The meaning of this initial decline is not clear at this time and is undoubtedly complicated by blood samples obtained during the physical examination period and the experimental period (total volume about 700 cc.). A comparison of the average experimental values versus the control values shows a statistically significant drop in hematocrit in three of the four subjects (Subject #15, $p<0.1$; subject #16, $p<0.01$; subject #17, $p<0.05$; and subject

TABLE VI. EFFECT OF 258 MM. TOTAL PRESSURE, 243 MM. P_{O_2} ON FORCED VITAL CAPACITY (BTPS)

Subject Number	Pre-Experiment liters	Experiment liters	Post-Experiment liters	Per Cent * Change
15	5.44 ± 0.08	5.28 ± 0.14	5.24 ± 0.08	− 2.9 [1]
16	5.60 ± 0.13	5.41 ± 0.17	5.75 ± 0.10	− 2.5 [2]
17	6.15 ± 0.07	6.17 ± 0.07	6.38 ± 0.07	+ 0.3 [3]
18	4.77 ± 0.16	4.46 ± 0.15	4.75 ± 0.11	− 6.5 [1]
Average	5.49	5.34	5.53	− 2.9

* Pre-experiment vs. experiment.
[1] Significant at the 0.01 level.
[2] Significant at the 0.05 level.
[3] Not significant.

TABLE VII. SUMMARY OF HEMATOCRIT DATA

Phase	Day of Test	Subject Number 15	16	17	18
Pre-Experiment		44(4) *	46(3)	47(3)	46(3)
Range		42-48	45-46	47-48	46-47
	3	38	42	45	44
	7	38	35 ?	40	40
Experiment					
	10	41	43	44	43
	14	41	44	47	44
		—	—	—	—
	Mean	40	43	44	43
	P	<0.1	<0.01	<0.05	<0.05
Post-Experiment		40(5)	45(1)	45(1)	44(1)
Range		38-41			
Follow-Up **		44(2)	48(2)	46(2)	47(2)

* Number in parentheses indicate number of samples.
** 3 months later for subjects 15 & 16, 2 months for subjects 17 & 18.

TABLE V. RESULTS OF ARTERIAL AND ALVEOLAR STUDIES

Subject Number	Ambient Gas	P_B mm. Hg	P_AO_2 mm. Hg	P_ACO_2 * mm. Hg	P_aO_2 mm. Hg	P_ACO_2 mm. Hg	pH	Saturation * Per Cent	A-a_{O_2}
				Pre-Experiment					
15	Room air	750	107	34	84	35	7.415	96	23
16	Room air	750	105	35	92	38	7.370	97	13
17	Room air	747	107	34	90	34	7.425	97	17
17	29.9 per cent O_2 in N_2	747	174	34	136	34	7.420	100	38
18	Room air	747	103	37	84	36	7.440	96	19
18	29.9 per cent O_2 in N_2	747	162	33	134	33	7.440	100	28
				Day #1					
15	241 mm. P_{O_2}	258	173	32	127	33	7.440	100	46
16	241 mm. P_{O_2}	258	177	34	154	36	7.420	100	23
17	245 mm. P_{O_2}	258	174	35	—	—	—	—	—
18	245 mm. P_{O_2}	258	166	40	—	—	—	—	—
				Day #7					
15	242 mm. P_{O_2}	259	177	35	133	37	7.450	100	44
16	242 mm. P_{O_2}	259	173	36	124	43	7.415	100	49
17	238 mm. P_{O_2}	258	167	37	126	43	—	100	41
18	238 mm. P_{O_2}	258	164	40	136	44	7.420	100	28
				Day #14					
15	243 mm. P_{O_2}	258	—	—	131	39	7.450	100	—
16	235 mm. P_{O_2}	258	169	34	129	32	7.460	100	40
17	238 mm. P_{O_2}	258	170	35	126	38	7.415	100	44
18	240 mm. P_{O_2}	258	165	37	136	41	7.450	100	29

* Per cent saturation obtained from nomogram of Dill, et al. (5).
— No data available.
P_B = barometric pressure; P_AO_2 = alveolar P_{O_2}; P_ACO_2 = alveolar P_{CO_2}; P_aO_2 = arterial P_{O_2}; P_aCO_2 = arterial P_{CO_2}; A-a_{O_2} = alveolar-arterial P_{O_2} gradient.

#18, $p<0.05$). As a result of a pronounced drop in hematocrit from a pre-experiment high of 48 per cent to 38 per cent in the early phase of the experiment, subject #15 was given a more complete hematological examination at the termination of the study. Findings included a slight anisocytosis and hypochromia, a 0.5 to 0.9 per cent reticulocyte count, normal serum iron and bilirubin, mild erythroid hyperplasia of the bone marrow, and no fecal occult blood. Barium enema was also normal. The diagnostic conclusion was that a self-limited anemia was present which was not secondary to a disease process. The possibility of depression of erythropoietic activity as a consequence of exposure to this environment cannot be ruled out at this time, but, as mentioned above, the effect of repeated blood sampling has undoubtedly altered the meaning of these results. We have noted, for example, a significant ($p<0.05$) decline in the hematocrit of a subject maintained at ground level (ambient atmospheric conditions). Also, in the experiment[14] subsequent to the two being reported here in which atmospheric conditions were very similar to the studies under discussion, no significant alteration in hematocrit was observed. In that particular study, blood loss was approximately one-half (320 to 360 cc.) of the blood loss in the present experiments.

Performance was evaluated in terms of mean response times in each hour at each task. Individual task means were pooled into a smaller number of similar task groups and handled in terms of a two-day (odd and even day) "package." The datt for subjects 15 and 16 were quite satisfactory. For analysis, three two-day packages were selected from the early, middle, and late portions of the flight. A double classification analysis of variance with portions of the flight and five task groups as variables shows a significant difference (.01 level) for both variables with no significant interaction.

Subjects 17 and 18 presented many problems in terms of analysis due to lack of data or data falling within no systematic pattern. Much of the lack of performance data was due to technical difficulties related to the chamber or to biomedical measurements. The unsystematic data were largely due to the subjects who failed to follow the operator schedule even when this was possible. In spite of these limitations, it was possible to secure comparable data for early and late periods for three representative tasks for both experiments. The average response times for each subject on each of the three tasks for the two flights is shown in Table VIII.

The tasks represented in Table VIII are those involving complex discrimination (I), simple monitoring (II), and encoding-arithmetic (III). It is quite apparent that even with this limited data, one cannot find performance decrement as measured by these tasks from early in the flight to its termination. On the contrary, the decrease in reaction time as an index of performance is significantly different, showing that task improvement occurred. While a portion of this improvement in performance undoubtedly is due to the learning effect, in our opinion this effect would not serve to mask a significant decrement in performance ability.

TABLE VIII. RESPONSE TIME IN SECONDS FOR THREE REPRESENTATIVE TASKS

Subject Number	Period	Task I (sec.)	Task II (sec.)	Task III (sec.)
15	Early	7.48	2.31	4.58
	Late	4.54	1.22	2.11
16	Early	5.17	1.86	3.51
	Late	5.06	2.15	2.85
17	Early	7.19	1.90	5.80
	Late	5.36	1.79	3.30
18	Early	6.59	3.22	6.37
	Late	5.21	2.54	4.05

TEST SUBJECT MONITORING

At a partial pressure of oxygen of 243 mm. Hg (altitude 27,000 feet), symptoms similar to those of oxygen toxicity[1] were encountered more often and were generally more severe than previously noted[10] at an ambient Po_2 of 174 mm. Hg (altitude 33,500 feet). For example, substernal pain was seen in three of four test subjects (Table IX). In one case, the pain was located beneath the sternum and was of the quality previously reported to be typical of oxygen toxicity.[1] In the other two cases, fleeting, sharp substernal pain which increased on deep inspiration and radiated slightly over the precordium to the left was encountered. These were not considered typical of oxygen toxicity. In all three instances, however, the pain occurred within the first four days of exposure and decreased markedly within 48 hours after onset. Ear discomfort and eye irritation were encountered in all cases.

TABLE IX. SYMPTOMS OF OXYGEN TOXICITY

Symptom	Occurrence
Substernal pain	3
Lower respiratory tract:	
Reduced vital capacity *	4
Upper respiratory tract:	
Cough	2
Nasal congestion	2
Sore throat	1
Ear discomfort (aural atelectasis)	4
Fatigue	–
Eye irritation	4
Other:	
Paresthesiae	2
Dizziness	–
Aching teeth *	–
Joint or muscle pain *	1

* Probably related to reduced barometric pressure. See Discussion.

Physical examination on days 7 and 14 of the experiment revealed the previously noted[10] erythema of the posterior pharynx with mildly increased pharyngeal lymphoid tissue. Chest ausculation of three subjects (numbers 15, 16 and 17) on day 7 disclosed a

TABLE X. TEST SUBJECT MONITORING

Subject	Pre-Experiment			Experiment		
	Blood Pressure mm. Hg	Pulse Beats/Min.	Temperature ° F.	Blood Pressure mm. Hg	Pulse Beats/Min.	Temperature ° F.
15	113/67	66	98.4	107/66	56	97.7
16	102/60	69	98.3	106/64	52	97.9
17	116/65	69	98.2	110/68	59	98.7
18	104/70	65	98.2	100/68	58	98.3

TABLE XI. SUMMARY OF ENERGY REQUIREMENTS

Subject Number	Initial Body Wt. (kg.)	Caloric Intake (Kcal./day)	Caloric Intake (Kcal./kg. body wt.)	Wt. change (kg.)	Caloric Requirement * (Kcal./day)	Caloric Requirement * (Kcal./kg. body wt.)
15	70.2	1975	28.1	0	1975	28.1
16	72.5	2183	30.1	− 1.36	2636	36.4
17	66.8	2534	37.9	+ 0.45	2370	35.5
18	61.8	2054	33.2	− 0.45	2234	36.1
Mean	67.8	2186	32.3	− 0.34	2304	34.0

* Cabin intake data corrected for any observed weight change, using as a correction factor, 4 Kcal./gm. of weight change.

few scattered, fine basilar inspiratory rales which cleared with deep breathing. These were present in subject 15 on day 14 as well.

Electrocardiograms remained essentially unchanged throughout the experiment except that marked sinus arrhythmias occurred in two subjects. In one of these subjects, the arrhythmia was so marked that the subject at rest complained of forceful palpitations of the heart on normal inspiration. There was no change in blood pressure and a slight drop in pulse rate (Table X). Body temperatures remained unchanged during the experimental period (Table X).

SECONDARY STUDIES

The routine hematological analyses were essentially negative throughout the experiments, there being no alteration in the white blood count, differential count, eosinophils or sedimentation rate. Serum electrolytes were also constant, sodium averaging 147 mEq./l; chloride, 104 mEq./l; potassium, 47 mEq./l; phosphate, 3.66 mEq./l; and calcium, 4.7 mEq./l. Blood urea nitrogen levels were also within normal limits, averaging 14.3 mg. per cent.

Urinalysis data were negative, with red blood cells ranging from 0-2, no hyaline casts and no indications of protein in the urine. Post-flight followups 3-4 months later showed the same results. One subject (#16) showed a significant ($p<0.05$) increase in urinary specific gravity (from 1.013 to 1.024) during the study.

Body weight data as well as a summary of energy requirements are presented in Table XI. The precooked, dehydrated foods used in this experiment were very acceptable to the test subjects and, in general, the amount consumed was adequate to maintain the body weight of the men. The energy intake is expressed both on a kilocalorie/day and kilocalorie/kilogram body weight basis. Energy requirements are based on caloric intake corrected for observed weight change, using a factor of 4 Kcal./gm. of weight change. The average caloric requirement of 34.0 Kcal./kg. body weight is slightly higher than we have observed in previous experiments,[12] which averaged 30-31 Kcal./kg. body weight. The distribution of the caloric intake was 54.2 per cent carbohydrate, 26.8 per cent fat, and 19 per cent protein.

Water requirements and water use data are summarized in Table XII. In calculating the water lost by evaporative cooling, the assumption is made that the test subjects were in water balance, permitting the evaporative loss to be calculated by subtracting the water excreted from that water available to the body. The water available to the body averaged 2265 ml./man/day and included not only the liquid water used but also preformed water in the food and that water formed by the oxidation of foodstuffs in the body. The water lost via the kidneys and in the feces averaged 1436 ml./man/day. The average water lost by evapora-

TABLE XII. SUMMARY OF WATER REQUIREMENTS

	Subject Number				
	15	16	17	18	Mean
Water used (ml./day)	1526	1822	2516	2425	2072
Liquids	848	1021	1714	1502	1271
Food rehydration	552	724	752	694	681
Personal hygiene	126	77	50	229	120
Available to body (ml./day)	1682	2065	2836	2478	2265
Liquids	848	1021	1714	1502	1271
Food rehydration	552	724	752	694	681
Content in food	35	48	62	45	47
Water of oxidation	247	272	308	237	266
Excreted by body (ml./day)	1127	1133	1853	1631	1436
Urine	1068	1044	1812	1556	1370
Feces	59	89	41	75	66
Evaporative water loss (ml./day)	555	932	983	847	829

TABLE XIII. STEROID AND CATECHOLAMINE VALUES OBTAINED FROM URINE ANALYSIS

Subject Number		Epinephrine gamma/24 hrs.	P-Values	Norepinephrine gamma/24 hrs.	P-Values	17-OHCS mg./24 hrs.	P-Values	Corticosterone-like Hormones mg./24 hrs.	P-Values
15	Pre	1.1 ± 0.3	0.2 **	49.3 ± 3.2	0.2	8.7 ± 1.4	0.7	31.7 ± 7.2	0.5
	Exp	1.7 ± 1.6		54.3 ± 10.5		9.3 ± 2.6		35.7 ± 3.8	
	Post	0.9 ± 0.1	0.1	49.7 ± 5.2	0.4	11.6 ± 0.4	—	29.2 ± 2.9	—
16	Pre	10.6 ± 3.1	0.02	132.2 ± 23.7	0.02	10.4 ± 1.9	0.4	88.1 ± 10.4	0.01
	Exp	5.1 ± 3.5		79.1 ± 26.7		11.6 ± 2.2		48.1 ± 6.9	
	Post	7.6 ± 1.9	0.2	66.7 ± 8.7	0.3	10.0 ± 2.1	0.4	47.1 ± 2.0	0.7
17	Pre	2.5 ± 0.2	0.01	65.7 ± 10.0	—	15.1 ± 1.0	0.01	50.0 ± 9.9	0.2
	Exp	7.4 ± 3.2		65.6 ± 19.5		11.7 ± 2.8		62.7 ± 15.8	
	Post	4.8 ± 0.0	0.01	55.8 ± 20.7	0.5	11.5 ± 1.1	—	53.6 ± 10.5	0.4
18	Pre	3.1 ± 0.3	0.6	49.2 ± 24.3	0.7	6.6 ± 0.4	0.01	32.4 ± 9.0	0.3
	Exp	3.6 ± 1.7		58.0 ± 16.9		8.2 ± 2.1		41.5 ± 10.3	
	Post	2.5 ± 1.3	0.4	58.6 ± 22.7	—	12.4 ± 3.1	0.2	42.3 ± 10.8	—

There are three samples in each of pre- and post-experiment groups; total number of control samples is six. The experimental group has fourteen samples.

* Standard Error from the Mean.

** These values show the degree of significance between Pre and Exp values and between Post and Exp values. Only P-Values less than 0.05 are considered significant.

tive cooling (assuming water balance) was 829 ml./man/day and is in the range normally accepted for such losses.

The results of the steroid and catecholamine studies are shown in Table XIII. The data reflect the general pattern that has been observed in previous studies [11] and is characterized by higher than normal control values pre- and post-experiment with a general trend to increase during the course of the experiment. The higher than normal control values are undoubtedly related to the unfamiliar surroundings and rather extensive physical examination that each man received pre- and post-experiment. The fact that there are no overall large increments in these hormones during the experimental period is, at the present time, interpreted to mean that the exposure to the experimental environment did not constitute a particularly stressful situation. Extraordinary occurrences in the simulator during the course of the experiment (i.e., illness, anger, equipment malfunction) are, of course, correlated with increased steroid and catecholamine excretion.

SUMMARY

The effects of a 14-day exposure to a total pressure of 258 mm. Hg and Po_2 of 243 mm. Hg have been studied in four men. No distinct evidence of atelectasis was noted based on the following data: arterial Po_2, alveolar Po_2 estimated A-V shunt, chest x-ray, vital capacity and performance. No hematological disorders were noted that were directly attributable to the oxygen-rich environment. One subject did develop a self-limiting non-specific anemia possibly complicated by repeated blood sampling during the course of the experiment.

Symptoms similar to those of oxygen toxicity were encountered in all subjects. These symptoms did not, in themselves, cause undue concern and were restricted to eye irritation, aural atelectasis, and erythema of the posterior pharynx. Substernal pain was noted in three of the four test subjects. In only one case, however, was this of the quality previously reported to be typical of oxygen toxicity.

The data obtained indicate that this atmosphere (242 mm. Hg Po_2) can be well-tolerated for a 14-day period. Exposure for time periods much in excess of this duration should be approached with a certain degree of caution.

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