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Final Report

PHYSIOLOGICAL STUDIES on MT. EVEREST CLIMBERS

William E. Siri

Donner Laboratory
University of California
Berkeley 4, California
June, 1965

American Mt. Everest Expedition

1963

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ABSTRACT

Studies of erythropoiesis and adrenal gland function were performed on members of the American Mt. Everest Expedition (chronic exposure to severe hypoxia) and on a member of the expedition during 4 days exposure to 17,000 ft in a chamber (acute hypoxia). Twenty-four hour urine collections obtained at altitudes from 17,800 ft to 28,000 ft showed no erythropoietin and normal excretion rates of 17-OHCS, 17-OS, aldosterone, catecholamines, and electrolytes. Adrenocortical response to ACTH was normal. Plasma iron turnover doubled at 17,800 ft and increased 2 1/2 times at 23,000 ft. A rapid fall in hemoglobin concentration, 0.4 g/Kg-d, accompanying descent from 17,800 ft suggests either a short red cell life span or active removal of cells from the circulation. The expedition member acutely exposed in the chamber developed high serum and urinary concentrations of erythropoietin that were maximal on the 2nd day and declined to low levels by the 4th day. Plasma iron turnover increased with erythropoietin concentration. Erythropoietin declined with improving acclimatization but hemoglobin synthesis remained elevated for some time after returning to sea level pressure. Urinary 17-OHCS were elevated 50% all four days and 17-OS were elevated 50% on 2nd day only. Serum and urine Na, K, Cl, remained unchanged in the chamber subject and expedition climbers.

INDEX WORDS

acclimatization
aldosterone
blood pressure
catecholamines
eosinophils
erythropoiesis
erythropoietin
heart rate
hemoglobin
hypoxia
leucocytes
plasma volume
plasma iron turnover
red cell volume
17-hydroxycorticosteroids
17-oxosteroids

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INTRODUCTION

Men engaged in climbing the highest Himalayan peaks are in some respects unique subjects for research on the body's regulatory mechanisms. Driven by intense motivation to reach high summits, climbers subject themselves for extended intervals to levels of hypoxia for which the human body cannot adequately acclimatize nor permanently endure. At great altitudes physiological responses evoked specifically by hypoxia may reasonably be expected to undergo the fullest possible development, making their associated regulatory systems more amenable to investigation. It is also reasonable to assume, a priori, that severe, prolonged hypoxia, combined with fatigue, insomnia, anorexia, cold, and psychogenic factors that are inevitable concomitants of high altitude climbing, would induce decisive evidence of nonspecific physiological "stress." These were the premises for physiological, psychological, and sociological studies conducted on members of the American Mt. Everest Expedition in the spring of 1963.

The psychological and sociological studies are reported elsewhere by their respective investigators, Dr. James T. Lester and Dr. Richard M. Emerson.

The physiological investigations, which are reported here,

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centered on erythropoiesis and adrenal gland function. Numerous studies of erythropoietic activity have been made at altitudes up to 14,900 ft, notably by Hurtado et al (7), Merino (14), Lawrence and his associates (6, 10) and Reynafarje et al (25). More recent, unpublished findings by the author in studies at 12,000 and 17,000 ft in the Andes are summarized in this report. These investigations, consisting principally of determinations of plasma iron turnover, urinary erythropoietin, and hematological values, were extended in the studies on Mt. Everest to altitudes of 17,800 21,500, and for erythropoietin, 23,000 ft.

The assessment of cortical and medullary activity of the adrenal glands during the course of the Expedition was based primarily on urinary excretion of cortical steroids and their metabolites, and total catecholamines. Twenty-four hour urine collections for these assays and other chemical measurements were obtained from climbers during prolonged stays at altitude and in the course of acute stressful episodes, such as the descents from the summit, 29,028 ft ($P^{O}2$ = 49.6 mm Hg), without oxygen. In most instances, a second urine collection was obtained following administration of ACTH. Collateral tests of adrenocortical function were necessarily limited to simple procedures that were practicable under the restrictive conditions imposed by the environment and expedition activities.

By the time the expedition reached its base camp at 17,800 ft on Mt. Everest, acclimatization was already well advanced as a result of the

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four-week long approach march and occasional stops for acclimatization at intermediate altitudes. Acute responses to hypoxia were by then largely attenuated or superseded by long-term acclimatization processes. To assist in differentiating these responses, a pre-expedition study was conducted in which a member of the Expedition was exposed for four days to a simulated altitude of 17,000 ft following rapid decompression in a low-pressure chamber (27). Measurements similar to those to be made later in the field were applied more intensively and supplemented with other tests to identify more clearly the transient responses that appear to take place in the early stage of acclimatization.

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MATERIALS AND METHODS

Subjects.

Subjects for the Mt. Everest studies were healthy, athletic, Caucasian members of the Expedition, 24 to 44 years in age. Ages, weights, and other particulars are given in Table 4. Eight of the 17 had previous climbing experience at altitudes greater than 20,000 ft.

Expedition member "A" served as subject in the low-pressure-chamber study on acute hypoxia. Base-line values of physiological and biochemical quantities were determined at Donner Laboratory, University of California, Berkeley (sea level) a month prior to the Expedition's departure.

The blood studies at 12,000 ft were made on four young male residents of La Paz, Bolivia, whereas the subjects at 17,000 ft were young indians who were long-time residents at this altitude. The latter were studied at the Laboratory for Cosmic Ray Physics, Chacaltaya (17,000 ft), Bolivia, through the courtesy of Professor Ismael Escobar, and with the assistance of members of the Faculty of the Medical School, Universidad Mayor de San Andres, La Paz.

Erythropoietin was assayed in 24-hr urine collections that were processed by the collodion absorption method for extracting urinary erythropoietin (35). Collodion filters were prepared in advance of the Expedition's departure, stored and transported in distilled water

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until used at the time of urine collection in the field. After processing a urine collection, the filter was dissolved in ether and centifuged. The supernatant was discarded and the solids dried and sealed under nitrogen. Samples were later assayed at Donner Laboratory by the method of DeGowin et al (1a) (red-cell incorporation of Fe^{59} in hypertransfused mice). In each assay, five mice were given 0.5 ml each of the urinary concentrate dissolved in 6.5 ml saline.

Plasma iron turnover was measured with Fe^{59}. The radioactivity in serial blood samples was determined with a Nuclear-Chicago Model 2800 portable scalar and Model DST5 probe equipped with a well-type Na(Th) I crystal that was to have doubled as an in vivo counter for cardiac output measurements. Serum iron concentration was determined in samples returned to Donner Laboratory. Earlier tests had demonstrated that prolonged storage at room temperature would not significantly affect the measurable Fe concentration. Plasma and red blood cell volumes were estimated from the radioiron disappearance curves. The common hemotological values were determined by generally accepted methods.

Urinary excretion rates of 17-hydroxycorticosteroids (17-OHCS), 17-ketosteroids (hereinafter called 17-oxosteroids and abbreviated 17-OS), aldosterone, catecholamines, and various chemistries were determined in 24-hr urine collections, usually started in the mornings between 7:00

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and 9:00 A.M. A second collection, immediately following the first, was preceded by intramuscular administration of 80 U.S.P. units of long-acting ACTH (Armour Lab., ACTHAR Gel). Two-hundred ml aliquots of the urine collections were returned to Donner Laboratory for all analyses. Routine tests for ketones, sugar, protein, density, and total volume were made at the time of collection.

Total urinary 17-OHCS were determined in 15 ml aliquots of 24-hr urine collections by the Few (2) method, modified by Thomas and Bulbrook (32). Urinary 17-OS from subject A in the low-pressure chamber experiment were fractionated by the method of Kellie and Wade (8) modified by Thomas and Bulbrook (32). Total 17-OS in urine collections from the Expedition were determined by the method used by the Biochemical Unit of the Imperial Cancer Research Fund, Royal College of Surgeons. Briefly, the method is as follows:

To a 10 ml aliquot of urine, 3 ml of concentrated HCl is added and the mixture heated for ten minutes in a boiling water bath. After cooling it is extracted with 10 ml of ethylene dichloride, and the extract washed with water, shaken with a solution of 3 N Na OH containing 10% sodium dithionite, and filtered. Aliquots of 1 ml to 3.5 ml, depending on the 24 hr urine volume, are taken to dryness. To the dry residue are added 1.5 ml of 1% in-dinitrobenzene and 0.75 ml of 2.5 N KOH (40) both reagents prepared in absolute ethanol. An hour in the dark at room temperature is allowed for the Zimmerman reaction, 3 ml of absolute ethanol added, and the color read in the Bechman Spectrophotometer at 440, 520 and 600 mu, the Allen correction applied and the data calculated in terms of the chromogenicity of dehydroepiandrosterone.

Catecholamines (epinephrine plus norepinephrine) were determined in 15 ml aliquots of 24-hr urine collections by the method of

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von Euler and Lishajko (39). Attempts to measure separately epinephrine and norepinephrine yielded results that were not sufficiently dependable to include in this report.

Aldosterone was assayed in 25 ml aliquots of urine by Dr. William Bigliari, San Francisco County Hospital, who employed the double-labelling technique.

Serum and urinary Na, K, Cl, and creatinine were determined by accepted methods in general practice.

Basal heart rates were self-determined on awakening in the morning. Blood pressures were read after a 10 min rest with the subject seated and on days when he was not engaged in substantial physical work.

Three-minute step tests were conducted at intervals during the course of the expedition, primarily to determine if recovery patterns of heart rate and blood pressure are significantly altered during acclimatization to severe hypoxia. Starting from the conclusion of the exercise, heart rate was recorded at 10 sec intervals by one observer while a second rapidly measured blood pressure and recorded systolic and diastolic separately when they were read. Qualitative changes in the response were sought rather than close comparison of the results from the several tests for each subject. A fixed work level could not be maintained because of the changes in body weight, variations in clothing, ambient temperature, and unavoidable differences in step height from time

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to time.

Breath holding times were taken after a normal expiration and following a maximal inhalation, with care being taken to avoid hyperventilation in advance of each test.

The same procedures were employed in the low-pressure chamber experiment except that no ACTH was given and the tests were conducted continually before, during, and after the four-day exposure. Erythropoietin CWC, RBC, hemoglobin, and hematocrit were determined every 6 hr, iron turnover every 12 hr, and adrenocortical steroids every 24 hr. Additional tests, omitted from the expedition studies, were made on the subject in the chamber study to assess his level of functional hypoxia. The subject received a complete physical examination every 12 hr and a partial examination at intervening 6-hr periods. Respiration, heart rate, and EKG were monitored continually on instruments outside the chamber. Oxygen consumption and pulmonary function tests were determined every 12 hr with a Jones Metabolator using air.

Total body water (TBW) was measured with tritiated water that was given by mouth and assayed in serial urine samples. The measured TBW was reduced by 1% to correct for hydrogen-tritium exchange. The initial values of total fat (depot triglycerides, not adipose tissue) were estimated from body density, determined by the helium-dilution method (28), and TBW using the formula proposed by Siri (29). In the field total fat was estimated from the widely-used formula fat % = 100 - (TBW%/0.73).

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Altitude exposure and use of oxygen.

The first two weeks of the month-long trek from Kathmandu (5,000 ft) to Mt. Everest involves exposure to only moderate altitudes and terminates at the Sherpa village of Namche Bazar at 12,000 ft. The last two weeks of the march, although short in miles, brought exposure to progressively higher altitudes terminating on March 22nd at a base camp at 17,800 ft at the foot of Mt. Everest. Acclimatization stops of 4 and 5 days were made at elevations of 13,000 and approximately 16,000 ft.

Following the expedition's arrival at base camp (17,800 ft), 63 days were spent at this and higher altitudes. Approximately a month of this time was spent by each member at an altitude of 21,500 ft (camp 2) and higher altitudes. Excursions to 25,000 ft or higher, including the summit, usually lasted 4 to 10 days. Ten members climbed to elevations in excess of 26,000 ft, among them subjects B, C, D, E and R who climbed to the summit at 29,028 ft. The upper and lower altitudes at which climbers were located, day by day, are indicated in Fig. 1 and 2.

Supplemental oxygen was almost invariably used in climbing and for sleeping at altitudes greater than 23,000 ft. Oxygen was supplied by an open circuit apparatus utilizing an efficient and highly successful mask recently developed by Dr. Thomas F. Hornbein (5). For climbing, oxygen flow rates ranging from 2 l/min to 4 l/min were used depending upon the altitude and the needs of the climber. A flow rate of 1/2 to 1 l/min was used for sleeping beyond 25,000 ft.

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The length of exposure of the summit climbers to extreme altitude without oxygen was unprecedented. While this benefitted the physiological studies, it was regrettable for the serious frost bite injuries sustained as a consequence. Subject B exhausted his oxygen supply at the summit and spent 3 1/2 hr above 28,500 ft before reaching a reserve supply. Subjects C and D, climbing together, also exhausted their oxygen at the summit and were forced to bivouac over night at 28,000 ft, thus spending about 15 hr without oxygen between 28,000 and 29,000 ft. Subjects E and R who climbed together, and who pioneered a new route on Mt. Everest via its West Ridge, spent respectively 6 and 9 hr without oxygen at 28,000 ft and bivouacked with subjects D and C. Little food, no fluids, and, during the bivouac, no shelter, were available to the climbers for about 20 hr. Their descent the next day was aided with oxygen provided by a support team at 27,400 ft.

As a consequence of the use of oxygen above 23,000 ft it is difficult to assess the actual degree and duration of exposures to hypoxia. A reasonable estimate for the average exposure however, would be 30 days at 17,800 ft and 33 days at 21,500 ft and, for subjects E, J, K, M and R, about 8 days at 23,000 ft. The experiences of the summit climbers are considered here as acute exposures to the ambient oxygen pressures of 49.5 - 51.8 mm Hg between 28,000 and 29,000 ft.

Although the level of work performed by the climbers in ascending Mt. Everest is not directly relevant to the studies, it may have

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an indirect bearing on adrenocortical function and certainly on changes in body composition. Mt. Everest is climbed by stages through a series of successively higher camps, spaced at vertical distances of about 2,000 ft. A climb of 2,000 ft from one camp to the next, which required from 3 to 6 hr was generally considered a day's work. The ascent from the highest camp to the summit was the exception and for the two climbers who pioneered a new route, it required more than 12 hr. Loads carried above 22,000 ft ranged from 25 to 55 lbs in addition to 20 to 25 lbs of clothing. Out of the 63 days spent on the mountain, the most active member climbed on 31 days of which 19 were spent ascending and 12 descending. The total vertical ascent by the most active member of the team was therefore less than 40,000 ft in 63 days. The least active member climbed uphill 2 1/2 days, downhill 1 1/2 days during the same period. The average uphill climbing for the team was less than 15 days, or 30,000 ft, with an additional 10 days descending.

There can be no question about the intense subjective feelings of fatigue and, no doubt, physiological fatigue induced by hypoxia in working at high altitudes. Nevertheless the weekly average work level was exceedingly small compared to the sustained level of work climbers are accustomed to performing at lower elevations and to the level of work performed on the approach march. From the records of the movements of the team members it is difficult to escape the conclusion that climbing

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Mt. Everest was a relatively sedentary occupation compared to the activity of the same climbers at lower elevations.

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RESULTS

Erythropoietin.

The erythropoietin was assayed in urine collections obtained from climbers after they had spent 5 days or more at 21,500 ft and 23,000 ft. At the time of collection, subjects A, L, and F had been at the former altitude respectively 5, 20 and 29 days. Collections from subjects J and K were obtained after 5 days at 23,000 ft. Erythropoietin was also assayed in collections from three of the Bolivian Andean subjects who had lived at 17,000 ft 2 years or longer. None of the concentrates prepared from these collections contained detectable quantities of erythropoietin.

In contrast with the findings in subjects chronically exposed to high altitude, subject A developed a high transient elevation in serum and urinary erythropoietin during his acute exposure to simulated altitude in the low-pressure chamber as shown in Fig. 3. Erythropoietin became detectable in serum 12 hr after decompression, and continued to increase to an apparent maximum on the third day. On the fourth day the concentration was significantly lower but still clearly detectable. The erythropoietic activity in samples collected 1 1/2 and 2 days after the subject returned to sea level pressure was slightly greater

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than that of pre-exposure serum, but the difference may not be significant. From a dose-response curve of human urinary erythropoietin previously compared to a sample of standard "A" obtained from the Division of Biological Standards, Medical Research Council of Great Britain, the maximum serum erythropoietin concentration in the subject was estimated to be 1.4 "A" units/ml. The concentration in normal human serum has been estimated to be 0.003 "A" units/ml (34).

Erythropoietin could not be detected in unprocessed urine but it was definitely present in the concentrates of most urine samples collected after 24 hr exposure, with an apparent maximum in hormone excretion occurring at 48 hr. One sample collected two days after return to sea level pressure gave a result identical to the pre-exposure sample, neither being significantly higher than the saline-injected controls.

Plasma iron turnover and blood volume.

The results of these tests on Mt. Everest climbers and the Bolivian subjects are presented in Table I. Plasma iron turnover at sea level for the climbers averaged 34 mg/d. The rate doubled to 68 mg/d after a week or more at 17,800 ft and for the two subjects at 21,500 ft the rate was 81 mg/d. The large difference in average body weight between the Mt. Everest climbers and the Bolivian subjects is reflected in the lower average iron turnover rates of 29 mg/d for residents at 12,000 ft and 40 mg/d for residents at 17,000 ft. The effect of differences in

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weights are also evident in the plasma and red cell volumes. The plasma volumes of the climbers appear to be somewhat lower at altitude but the loss in body weight could more than account for the difference. The estimates of hemoglobin synthesis are based on the assumption that all of the plasma iron turnover is diverted to hemoglobin. It is well known that the fraction of iron turnover utilized for hemoglobin synthesis is highly variable and may depend to some extent on the plasma iron concentration. Hence, the estimates of rates of synthesis in Table I are intended only as indications of relative values. On this basis the average rates of hemoglobin synthesis for the climbers were 10, 20 and 25 g/d at sea level, 17,800 ft, and 21,500 ft. The averages for the Bolivian subjects were 9, and 12 g/d at 12,000 and 17,000 ft. It should be emphasized that the Bolivian subjects were lighter in weight. The responses of subject A to acute hypoxia in the low pressure chamber are shown in Fig. 3. An hour after decompression, plasma iron turnover was essentially unchanged at 1.04 mg/hr despite a decrease in plasma iron concentration from 112 μg/100 ml to 76 μg/100 ml. Eleven hours later plasma iron turnover was distinctly elevated and continued to increase to a maximum volume of 2.80 mg/hr 2 1/2 days after onset of hypoxia. During the last day and a half the subject was in the chamber, plasma iron concentration decreased to approximately 60 μg/100 ml, and by the end of the four days plasma iron turnover decreased to

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TABLE 1

Blood Volume, plasma iron turnover and estimated hemoglobin synthesis in Mt. Everest climbers and acclimatized Andean residents at various altitudes.

Subject	Altitude 1000 ft	Hct	Plasma Vol. l	R.C.V. l	Plasma Fe µg%	Plasma Fe Turnover mg/d	Estimated Hemoglobin g/d	Estimated Hemoglobin %/d
Mt. Everest Climbers								
A	0	48	2.56	2.36	112	25	7	.8
	17.8	57	2.53	3.37	100	75	22	1.9
A[1]	17.0				88	65	19	
B	0	46	3.41	2.91	88	39	11	1.1
	21.5	62	3.22	5.25	93	87	26	1.5
C	0	45	2.61	2.14	114	29	8	1.1
	17.8	50	2.55	2.55	68	49	14	1.6
	21.5	67	1.82	3.70	167	81	24	1.6
M	0	42	3.24	2.34	142	44	13	1.6
	17.8	62	3.00	4.88	82	79	23	1.4
Residents of La Paz, Bolivia								
Sa	12	50	2.60	2.54	62	29	9	1.0
Pc	12	51	2.14	2.04	117	30	9	1.3
Va	12	51	2.41	2.41	83	30	9	1.1
Mc	12	53	1.95	2.16	75	26	8	1.1
Indian Residents, Chacaltaya, Bolivia								
Th	17	62	1.98	3.19				
Ca	17	62	1.59	2.80	76	33	10	.8
Ch	17	59	1.54	3.18	96	37	11	1.0
To	17	62	1.70	3.58	94	49	14	1.1

[1]Values at time (2 1/2d) of maximum plasma iron turnover in subject A during exposure to simulated altitude in a low pressure chamber (pre-expedition, when subject was acclimatized to sea level).

[2]Estimate assumes complete utilization of plasma iron turnover for hemoglobin synthesis.

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2.03 mg/hr. Subsequently, plasma iron turnover decreased slightly during the first two days after return to sea level pressure, after which it declined more rapidly toward the initial base line value.

Hemoglobin synthesis, estimated on the same basis as for the climbers, was definitely elevated eleven hours after onset of hypoxia and continued to increase until the third day when it attained a maximum rate of 7.8 g/d. During the subsequent five days (last day in the chamber and four at sea level pressure) the rate dropped to about 5.5 g/d, after which a more gradual decrease toward the initial, pre-exposure rate continued during an additional eight days until measurements were terminated.

The pattern of change in hemoglobin concentration during the Expedition paralleled roughly the change in altitude, as shown in Fig. 1. However, changes in altitude were not reflected in hemoglobin concentration until 2 to 3 weeks later; hence, the hemoglobin curves are delayed by this span of time relative to the curve for altitude change. The maximum recorded hemoglobin concentration was in excess of 25 g/100 ml and a concentration of 21 g/100 ml was exceeded in all climbers sometime during the expedition, depending on their movements up and down the mountain.

During the first twenty days exposure to altitude, March 20 to April 10, hemoglobin concentration increased approximately 0.25 g/100 ml-d. The average rate of rise during the succeeding 20 days,

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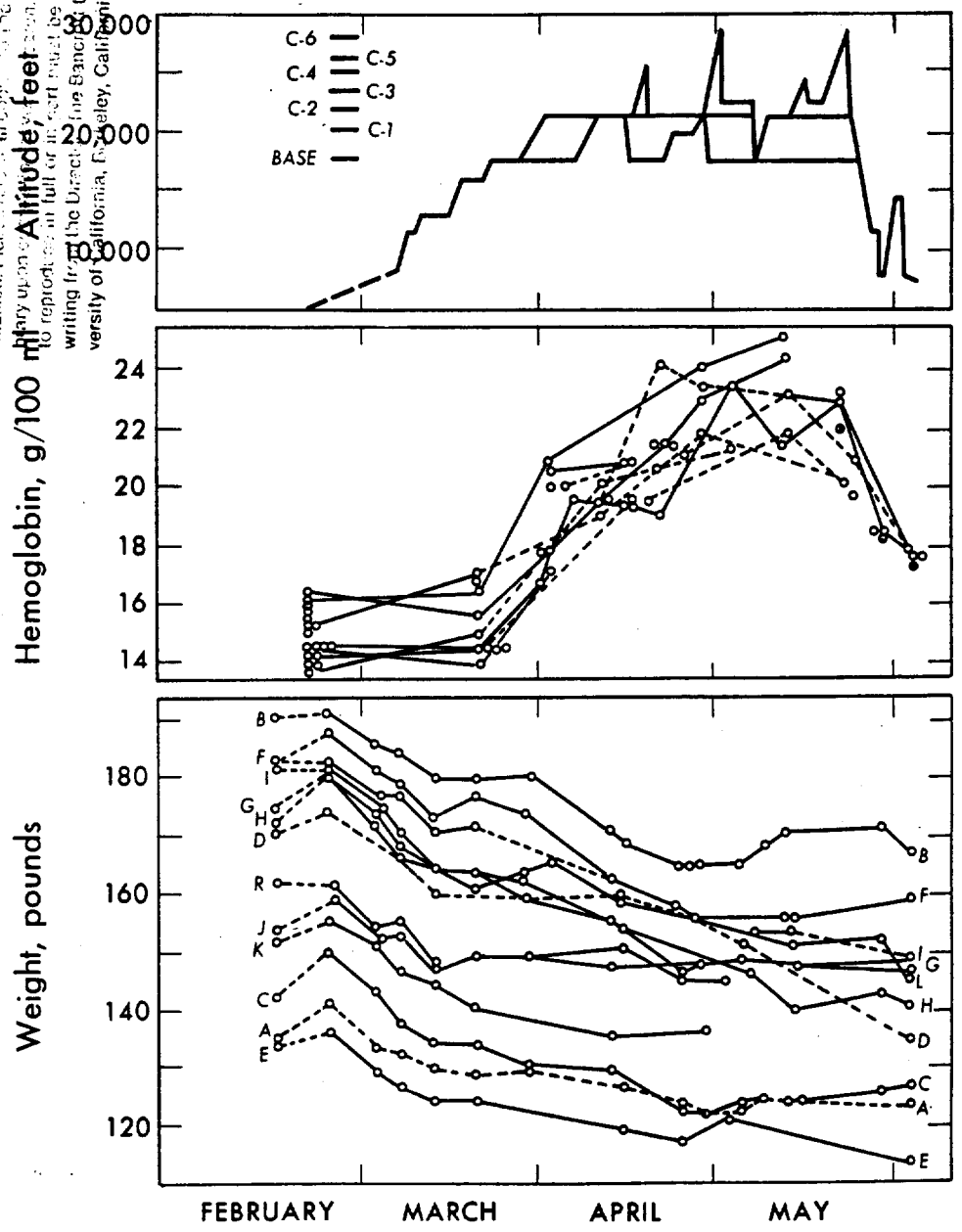

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Figure 1

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April 10 - April 30, was only 0.18 g/100 ml-d. During this period most of the climbers were stationed at 21,500 ft where their hemoglobin was also measured. When the expedition left base camp and descended to lower elevations on the return march, hemoglobin concentration responded immediately by decreasing at an average rate of 0.4 g/100 ml-d.

Erythrocyte counts showed increases comparable to those of hemoglobin concentration but the data are not reported here because rapid evaporation of blood samples in the counting chambers at high altitude made the precision of the counts doubtful.

No significant changes were observed in plasma or red blood cell volume, erythrocyte count, and hemoglobin concentration in subject A during the four-day low pressure chamber experiment.

Adrenocortical steroids.

The results of assays of 17-OHCS, 17-OS, and aldosterone are presented in Table 2. The altitude and the number of days the subject was exposed to the indicated altitude at the time urine was collected are shown in the right hand column. For altitudes of 17,800 ft and 21,500 ft urine collections were obtained 5 days or more after arrival at these altitudes to avoid acute responses in adrenal activity.

The daily excretion rate of 17-OHCS at sea level before departure of the expedition was 15.2 mg/d. The average value of 14.8 mg/d for all urine collections taken on Mt. Everest is not significantly

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different from the base line value. An average of 16.8 mg/d was obtained for the four summit climbers in the course of their descent following the high altitude bivouac without oxygen. This is only about 10% greater than the base line value and does not appear to be significant. With two exceptions the pre-expedition excretion rates of 17-OHCS lie within the range that is generally considered normal for adult males. Subjects B and D showed abnormally high excretion rates of both 17-OHCS and 17-OS. For the most part stimulation with ACTH brought on a normal response by increasing the excretion rate of 17-OHCA by factors ranging from 2 and 4 and 17-OS by a factor of two. Anomalous responses were observed in subjects A and F whose rate of excretion of cortocoids increased by more than the factor of 7.5 following ACTH administration. These high values were confirmed by repeated assays on the same urine collections. These anomalous responses were not seen in urine collections from the subjects during the expedition. The corticoid excretion rates during the course of the expedition were markedly elevated in only two uring collections. Both were in subjects immediately following exposure to extreme altitude. These were subject D, who also showed an anomalously high base line value, and subject H after exposure to 27,400 ft.

With two exceptions the excretion rates of 17-OS were within the normal range for adults. The exceptions were the base line values for

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TABLE 2. Urinary excretion rates of adrenal steroids and catecholamines

Subject	Age	17-OHCS mg/d		17-OS mg/d		Aldosterone µg/d		Total Catecholamines µg/d		Exposure conditions: Time and Altitude
		Pre-ACTH	With ACTH	Pre-ACTH	With ACTH	Pre-ACTH	With ACTH	Pre-ACTH	With ACTH	
A	44	11.3	82.6	9.7	20.2	11.0		26.8	29.9	Pre-expedition
				9.0	12.8			8.2	57.4	7 d at 17,800 ft
		14.3	55.8	10.1	17.4				37.3	8 d at 21,500 ft
		13.3	39.8	10.6	22.5	12.1	23.4	26.6	27.2	8 mo post expedition
B	33	21.7	66.1	29.1	34.5			54.0	67.0	Pre-expedition
		10.9	36.5					38.0	48.4	2 and 3 d after summit
				17.5				28.6		7 d at 17,800 ft
C	26	13.9	16.3	11.5	8.9	5.9		12.0	26.2	Pre-expedition
		12.2		17.3				21.9		1 d after 24,200 ft
		13.9	34.1	9.9	16.0			52.2	31.5	2 and 3 d after 26,000 ft
		15.7		11.8				83.7		1 and 2 d after summit
		10.8	33.7	17.3	29.5	5.4		18.6	9.6	8 mo post-expedition
D	31	27.6	48.3	24.8	18.0		13.4	48.5	20.2	Pre-expedition
		10.6	36.4	7.4	10.4		10.1	12.2	9.1	2 and 3 d after 26,000 ft
		24.0		9.3		16.4		40.7		1 and 2 d after summit
E	32	11.7	44.3	6.5	9.4			28.3	39.0	Pre-expedition
		16.8						18.6		1 d after summit

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TABLE 2. Continued

Subject	Age	17-OHCS mg/d		17-OS mg/d		Aldosterone µg/d		Total Catecholamines µg/d		Exposure conditions Time and Altitude
		Pre-ACTH	With ACTH	Pre-ACTH	With ACTH	Pre-ACTH	With ACTH	Pre-ACTH	With ACTH	
F	29	12.1	94.7	8.3	31.0			34.0	26.1	Pre-expedition
		12.8	46.7	5.6	23.6			75.6	45.8	27 d at 21,500 ft
		13.3		8.0				84.9		36 d at 21,500 ft
G	35	11.9	59.6	6.5	22.3			35.6	50.8	Pre-expedition
		14.6						7.0		9 d at 21,500 ft
		11.6	35.3	6.7	9.7			26.7	42.8	24 d at 21,500 ft
		15.7	29.3	6.9	6.0			49.3	3.9	3 d at 26,000 ft
H	26	18.4	46.6	12.1	19.1			37.1	29.9	Pre-expedition
		27.5						4.5		2 d at 27,400 ft
I	44	11.2	22.7	7.3	10.9	8.4	10.2	20.7	40.5	Pre-expedition
		15.5		3.5				7.4		3 d at 27,400 ft
J	26	10.5	23.1	8.6	5.4	13.9	14.2	40.1	17.0	Pre-expedition
		12.2		8.5				5.1		5 d at 21,500 ft

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TABLE 2: Continued

Subject	Age	17-OHCS mg/d		17-OS mg/d		Aldosterone µg/d		Total Catecholamines µg/d		Exposure conditions Time and Altitude
		Pre-ACTH	With ACTH	Pre-ACTH	With ACTH	Pre-ACTH	With ACTH	Pre-ACTH	With ACTH	
K	36	13.9	66.6	10.4	20.4			17.9	53.8	Pre-expedition
		13.9		9.2				51.4		5 d at 22,950 ft
L	35	18.8	69.1	10.0	20.5			28.5	32.4	Pre-expedition
		13.2		11.3				18.5		21 d at 21,500 ft
Average		15.2	53.3	12.1	18.4	9.8	12.6	32.0	36.1	Pre-expedition
		14.8	39.2	9.5	13.7			33.4	34.5	Total high altitude
		16.8	-	10.6				45.2		Four summit climbers

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subjects B and D who were the two subjects who also exhibited high base line excretion rates of 17-OHCS. The average base line excretion rate of 12.1 mg/d differs from the average of 9.5 mg/d for all values obtained in the field because of the weight of the two abnormally high base line values. There is no evidence of significant response in 17-OS to any of the conditions of exposure. The responses to ACTH are normal with the exception of base line value of subject C whose corticoids also did not respond, and probably is attributable to an inactive ACTH preparation.

Results of urinary 17-OHCS and 17-OS assays for subject A in the low-pressure chamber experiment are summarized in Table 3. The end products of the 17-OHCS are chiefly etiocholanolone and 11 - hydroxyetiocholanolone in approximately the ratio one to four in normal subjects. The data are reported as the sum of these two 17-OS in terms of the chromogenicity of dehydroepiandrosterone.

Total urinary 17-OS increased from a base line excretion rate of 8.3 mg/24 hr to a maximum of 13.1 mg/24 hr on the second day in the chamber. The excretion rates on the third and fourth days were the same as the pre-exposure value for the subject. The 11-oxy fraction of the total 17-OS more than doubled on the second day, whereas the 11-deoxy fraction increased about 50%. The urinary excretion rate of 17-OHCS, which was 11.3 mg/24 hr prior to exposure, increased about 45% the first day in the chamber and remained relatively constant at this higher rate during the four-day test period.

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TABLE 3. 17-OHCS and 17-OS excretion rates for subject "A" during acute exposure to 17,000 ft.

Time from decompression days	17-OHCS mg/24 hr	17-OS Total mg/24 hr	17-OS 11-oxy fraction % of total
	Subject at sea level pressure		
	11.3	8.3	9.5
	Subject at 17,000 ft		
0-1	16.2	10.5	9.7
1-2	15.5	13.1	16.0
2-3	16.2	8.6	11.6
3-4	16.9	8.6	11.8

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The relatively few values for daily aldosterone secretion rates presently available are well within the normal range for adult humans for the assay method that was used. The average of 9.8 μg/d for the samples is in the middle of the normal range.

Values for total catecholamines excretion seem notable for their wide fluctuation. The average of 34 μg/d for the expedition values is identical to the average for the base line values. The difference between these averages and the 45 μg/d for the four summit climbers is not statistically significant, nor is there a significant change in excretion rate after ACTH administration.

Serum and urinary electrolytes and creatinine.

The relatively few observations that could be made on serum Cl, Na, K and creatinine are presented in Table 4. Urinary excretion rates of these electrolytes and creatinine are given in Table 5.

Blood pressure and heart rate.

Systolic and diastolic pressure relative to pre-expedition values are charted in Fig. 2 along with average relative pulse pressures. The altitude positions of the members of the expedition are plotted on the same time scale. By the time an elevation of 13,000 ft had been attained on the approach march, blood pressure had increased significantly. Average systolic pressure for the group was elevated about 10% and remained elevated about this amount during the succeeding two months. The final

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TABLE 4. Plasma electrolytes and creatinine.

Subject	Cl^- mg/100ml	Na^+ mg/100ml	K^+ mg/100ml	Na^+/K^+	Creatinine mg/100ml	Exposure conditions Time and altitude
A	365	308	15.2	20.3	1.10	Pre-expedition
	402	345	17.8	19.4	1.24	10 d at 17,800 ft
	401					5 d at 21,500 ft
B	348	308	13.7	22.5	1.40	Pre-expedition
	409	342	17.1	20.0	1.68	15 d at 21,500 ft
C	337	306	16.0	19.1	0.70	Pre-expedition
	406	338	16.4	20.6	1.21	10 d at 17,800 ft
	404	378	19.6	19.3		20 d at 21,500 ft
F	386	337	15.2	22.2		39 d at 21,500 ft
M	355	322	15.6	20.6	0.92	Pre-expedition
	416	360	17.0	21.2	1.08	7 d at 17,800 ft

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TABLE 5. Urinary excretion rates of electrolytes and creatinine.

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Subject	Wt Kg	Cl^- meq/d	Na^+ meq/d	K^+ meq/d	Na^+/K^+	Creatinine gm/d	Exposure conditions Time and altitude	
A	68.6		89	150	0.59		Pre-expedition	*
	63.2	472	515	88	5.85	1.25	7 d at 17,800 ft	
	63.2	282	235	99	2.37	1.00	8 d at 17,800 ft	*
	61.8	384	399	90	4.43	1.08	5 d at 21,500 ft	
	61.1	106	57	108	0.53	1.01	9 d at 21,500 ft	*
		177				2.05	8 mo post expedition	
		146				2.19	8 mo post expedition	*
B	91.0	307	432	110	3.93	2.70	Pre-expedition	
	86.2	536	565	106	5.33	1.87	7 d at 17,800 ft	
	79.1	82	66	31	2.13	1.02	2 d after summit	
	79.0	387	318	121	2.63	1.35	3 d after summit	*
C	68.9	114	151	59	2.56	1.83	Pre-expedition	
	63.6	385	414	78	5.31	1.16	7 d at 17,800 ft	
	63.2	264	296	63	4.70	1.09	9 d at 21,500 ft	
	60.0	91	92	31	2.97	1.09	2 d after 26,000 ft	
	60.0	283	247	73	3.38	1.14	3 d after 26,000 ft	*
	60.7	48	47	30	1.57	0.88	1 d after summit	
		208				1.67	8 mo post expedition	
		83				1.32	8 mo post expedition	*

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TABLE 5. Continued

Subject	Wt Kg	Cl^- meq/d	Na^+ meq/d	K^+ meq/d	Na^+/K^+	Creatinine gm/d	Exposure conditions Time and altitude	
D	81.9	174	157	73	2.15	2.02	Pre-expedition	
	73.2	108	136	25	5.44	0.86	2 d after 26,000 ft	
	73.2	239	215	81	2.65	1.33	3 d after 26,000 ft	*
	65.4	51	46	47	0.98	1.08	1 d after summit	
F	87.6	117	139	24	5.79	1.16	Pre-expedition	
	75.7	315	357	73	4.89	1.38	27 d at 21,500 ft	
	75.9	231	149	124	1.20	1.61	28 d at 21,500 ft	*
	76.8	183	167	42	3.98	1.24	36 d at 21,500 ft	
G	83.5	45	143	46	3.11	1.10	Pre-expedition	
	75.0	379	428	70	6.11	1.20	9 d at 21,500 ft	
	71.6	205	213	52	4.10	0.90	24 d at 21,500 ft	
	71.6	168	149	75	1.99	0.79	25 d at 21,500 ft	*
	71.8	93	93	37	2.51	1.01	3 d at 26,000 ft	
	71.8	249	179	75	2.39	0.74	1 d after 26,000 ft	*
H	82.6	223	265	61	4.34	1.52	Pre-expedition	
	69.1	188	207	39	5.31	1.50	2 d at 27,400 ft	
I	87.5	247	221	69	3.20	1.79	Pre-expedition	
	74.1	69	67	24	2.79	1.10	3 d at 27,400 ft	

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TABLE 5. Continued

Subject	Wt Kg	Cl^- meq/d	Na^+ meq/d	K^+ meq/d	Na^+/K^+	Creatinine gm/d	Exposure conditions Time and altitude
J	79.5		164	84	1.95		Pre-expedition
	79.5	269	62	47	1.32	1.91	Pre-expedition *
	71.6	137	165	38	4.34	0.62	5 d at 21,500 ft
	71.6	36	46	16	2.88	0.49	5 d at 22,950 ft
K	72.7	184	168	73	2.30	1.59	Pre-expedition
	65.9	128	131	42	3.12	1.62	5 d at 22,950 ft
L	68.6	83	119	64	1.86	1.64	Pre-expedition
	74.1	223	259	56	4.62	1.14	21 d at 21,500 ft

* Urine collection made after I.M. administration of 80 U.S.P. units ACTH in gel.

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set of values taken on May 20th at 17,800 ft represents a selected group of subjects. They were climbers who had returned to base camp ten to fifteen days earlier, following a month-long exposure to higher altitudes.

Diastolic pressure for the entire group was almost uniformally higher than at sea level and on the average showed an increase of about 20% that persisted throughout the time the expedition was on Mt. Everest. It was about 25% higher in the selected group that exhibited low systolic pressure on May 20th. Pulse pressure on the average showed no significant change from sea level values until most of the expedition members reached an altitude of 21,500 ft. This was followed by a gradual reduction of about 20% in pulse pressure relative to the pre-expedition average. The five climbers measured at base camp on May 20th had an average pulse pressure that was only 60% of their pre-expedition values.

Subject A showed relatively little change in his normal systolic pressure of 120 mm Hg during his four days in the low-pressure chamber. His diastolic pressure, which was normally 75 mm Hg, increased to 90 mm Hg during the first forty hours but thereafter stabilized at 80 mm Hg for the remainder of the time he was in the chamber.

Basal heart rates of most of the expedition team fluctuated widely. In general however heart rates increased with altitude at the outset but after a month showed a decrease with time. Toward the end of May when the expedition left base camp the heart rates of most members

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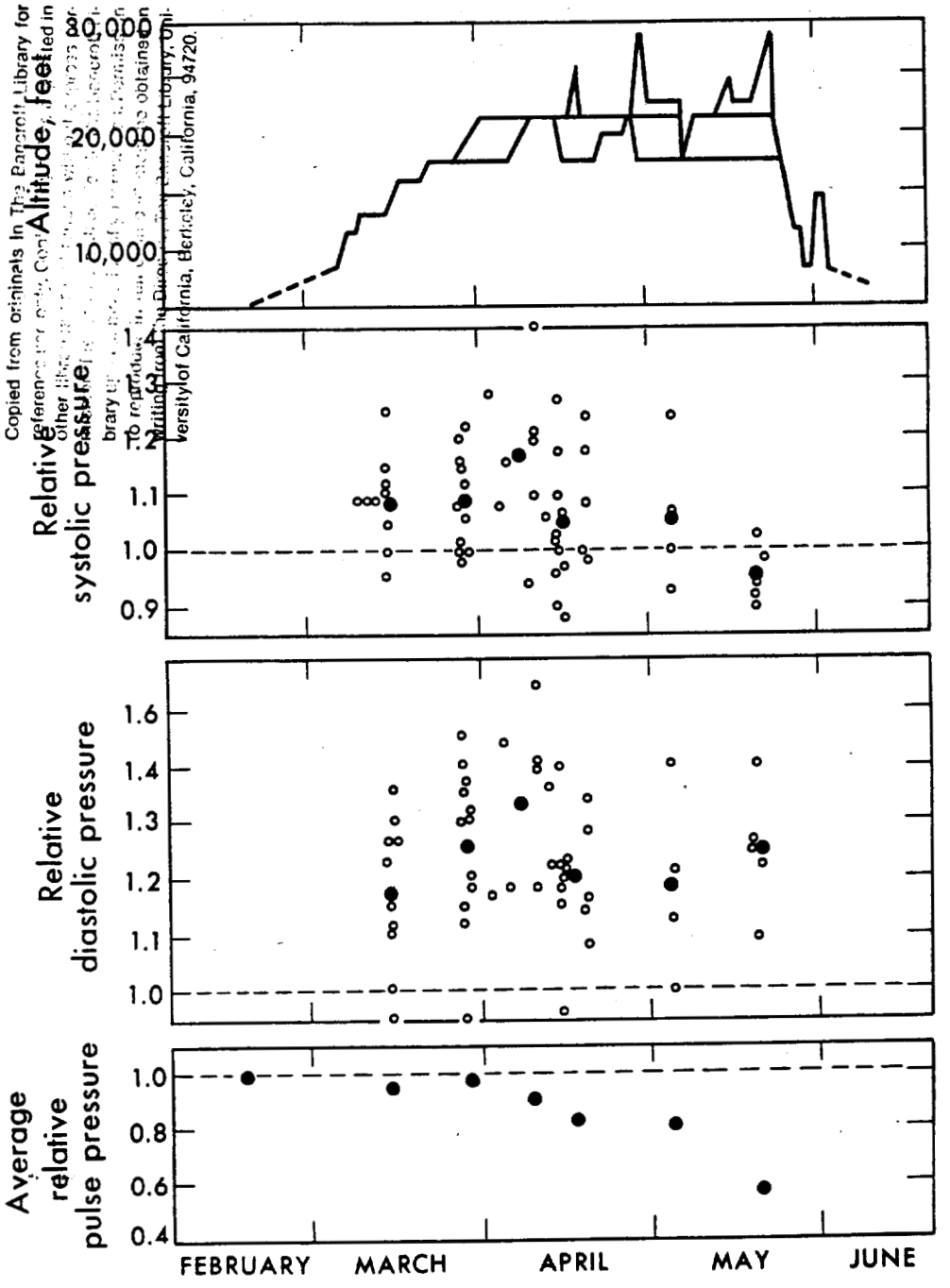

Figure 2

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of the team were still somewhat elevated. These trends however were not shared by all members of the team; subjects A, B, C, D, and E did not change significantly during the entire expedition. The heart rates of subjects F and N, which increased 50 and 35% respectively, were the highest and most persistent responses that were observed. Subject A, whose heart rate did not change significantly during the expedition, showed an increase of about 30% after the first day of his exposure in the low-pressure chamber.

Body composition and weight loss.

Table 6, which summarizes measurements of total body water, depot fat and other particulars of the climbers reveals that the group as a whole is less lean than one might expect of active athletes. Depot fat ranged from a low of 13 to a high of 29% of body weight before the expedition's departure. The average fat content of the entire team was 20% of body weight. The total body water measured in 7 climbers a week after they returned to base camp from protracted sojourns to higher altitudes on Mt. Everest, showed an increase in percentage of water but a loss in volume. Total depot fat estimated from TBW in the subjects was then 10% of body weight compared to 20% for the same subjects before the expedition. It is apparent from these data that the fat loss does not wholly account for the weight loss sustained by these subjects. Assuming hydration was normal at the time total body water was measured, part of

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TABLE 6. Body composition[1]

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Subject	Age	Ht cm	Wt Kg	Density gm/cc	TBW %	Fat %	Fat Kg	Wt. loss Kg	Lean tissue loss Kg
A	44	171.0	65.82	1.067	63	14	9.2		
			60.0		67	8	4.8	5.8	1.4
B	33	190.0	91.00	1.066	58	18	16.4		
			79.1		68	6	4.7	12.9	1.2
C	26	167.5	68.9	1.053	56	22	15.2		
			60.0		67	8	4.8	8.9	+1.5
D	31	167.5	81.9	1.055	60	18	14.7		
			73.2		67	8	5.8	8.7	+0.2
E	32	167.5	65.5	1.065	61	16	10.5	13.6	
F	29	186.5	87.6	1.042	51	27	23.6	12.6	
G	35	179.0	83.5	1.059	57	20	16.7		
			71.2		65	11	7.8	13.0	4.1
H	26	179.0	82.6	1.050	59	20	16.5		
			70.9		61	14	9.9	11.7	5.1
I	44	179.0	87.5	1.034	54	26	22.7		
			74.1		62	15	11.1	13.4	1.8

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TABLE 6. Continued

Subject	Age	Ht cm	Wt Kg	Density gm/cc	TBW %	Fat %	Fat Kg	Wt loss Kg	Lean tissue loss Kg
J	26	181.5	79.5	1.066	61	16	12.7	7.4	
K	36	174.5	72.7	1.067	59	17	12.3	6.8	
L	35		86.7	1.056	55	22	19.1	15.9	
M	38	183.5	93.2	1.031	53	29	27.0	21.7	
N	29	186.5	85.7	1.071	64	13	11.1	12.5	
O	24	181.0	97.7	1.044	61	20	19.5	12.7	
P	41	180.5	77.7	1.062	59	18	14.0	9.4	
Averages	33	178.3	81.7 69.8	1.056	58 65	20 10	16.3 7.0	12.2	

[1] First line for each subject consists of pre-expedition values, with fat estimated from TBW and density. Second line consists of values obtained on May 6, 1963, with fat estimated from TBW.

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the loss appears to have been lean tissue. This evidence for lean tissue loss is only suggestive however because estimates of fat from TBW are not more reliable than several kilograms.

The trends in body weight of the climbers during the course of the expedition, shown in Fig. 1, are remarkable for their uniformity. With few exceptions weights increased measurably during the three weeks of somewhat over-indulgent living from the time the team left Berkeley until it started the approach march to Mt. Everest. During the first 17 days of the march, the climbers, without exception, sustained weight losses of 5 to 10%. Weights then stabilized, remaining essentially constant, until members of the team ascended to 21,500 ft. As long as members stayed at this or higher altitudes they lost weight steadily and without exception until they returned to base camp at 17,800 ft. At base camp weights again tended to stabilize until the return march when further weight loss was sustained.

Peripheral blood leucocytes.

Once the expedition reached the relative isolation of Mt. Everest and respiratory infections that flourished during the approach march had run their course, leucocyte counts remained within the range 5,000 to 11,500 cells /mm^3. No trends in concentration were evident in either individual subjects or the group. Differential counts, shown in Table 6, taken before, during, and after the expedition are essentially identical.

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The apparent reduction in eosinophil percentage is not significant in view of the poor counting statistics. Platelet counts remained in the normal range during the time the expedition was on Mt. Everest, and the average did not differ significantly from the pre-expedition value.

Definite responses in leucocyte and platelet counts occurred in subject A during his acute exposure to hypoxia in the chamber. (See Fig. 3). An abrupt doubling in leucocyte count was seen soon after onset of hypoxia, followed by an irregular return to the pre-exposure level during the following two weeks. The proportions of granulocytes and lymphocytes remained unchanged (40% lymphocytes). Eosinaphils (4% before exposure) fell to 1% by 6 hr and remained at this level for the following 10 days before returning to the pre-exposure level. The platelet count rose gradually during the 4-day exposure and remained elevated for approximately three weeks.

Step Test.

In general the pattern of recovery in blood pressure and heart rate that was characteristic for each subject following the three-minute step test remained much the same at the four altitudes, sea level, 13,000, 17,800, and 21,500 ft, where the test was conducted. The magnitude of the responses varied, however, with changes in weight, amount of clothing worn, and height of the step, and perhaps altitude and length of exposure to it. The response in pulse pressure to exercise may be more

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TABLE 7. Leucocyte differential cell counts

Cell	Pre-Expedition	Expedition	Post-Expedition
Segmented	58	60	56
Band cell	< 1	2	2
Eosinophil	3	2	4
Basophil	< 1	< 1	1
Lymphocyte	34	32	32
Monocyte	5	4	6

TABLE 8. Average breath holding times at altitude

Altitude Altitude ft ft	After normal expiration sec sec	After maximal inspiration sec sec
6,400	27.5 ± 4.7	86.2 ± 10.2
17,800	13.2 ± 3.4	31.3 ± 9.3
21,500	8.7 ± 1.6	27.2 ± 6.2

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meaningful than systolic and diastolic pressure changes because resting blood pressure was elevated at altitude, as noted earlier. A few days after arrival at 13,000 ft, the average elevation in pulse pressure stimulated by the step exercise, and the rate of recovery, were comprable to those measured at sea level, despite an average reduction in body weight of 5% and a step that was 2 in lower. Values comparable to those at sea level were also observed at 21,500 ft with a still lower step (12 in compared to 18 in at sea level) and a further reduction in weight. The smallest response in both pulse pressure and heart rate (with a 15 in step) was seen in tests at 17,800 ft near the conclusion of the expedition when climbers returned from high camps and were well acclimatized. At this time two subjects, A and C, had no measurable elevations in heart rate at the end of the exercise.

Five Sherpas tested at 21,500 ft with the 12 in step displayed heart rate responses comparable to the American team members, but their systolic pressure responses were widely divergent. At one extreme, Sherpa Ghotari (120/87 resting) showed no change in systolic pressure and a depression of only 6 mm Hg in diastolic pressure. At the other extreme, Sherpa Tashi, whose resting blood pressure was 177/110, had a systolic pressure of 235 mm Hg, 30 sec after the test, and 210 mm Hg at one minute.

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DISCUSSION

Erythropoieses.

Erythropoietin, assuming it is normally present, is not generally detectable in the blood and urine of healthy persons at sea level and moderate altitude with bioassays currently available. It is readily detectable, however, in crude extracts of blood and urine from bled and from phenylhydrazine-treated animals, and animals acutely exposed to severe hypoxia. In humans, elevated levels of erythropoietin are sometimes found in association with anemia when hemoglobin concentration drops below 4 g/100 ml; in exceedingly rare instances unaccountably high concentrations have been found.

Exposure to low oxygen pressure evokes in rats and rabbits an abrupt rise in erythropoietin concentration in blood and urine followed by a rapid fall to low or undetectable levels with continued exposure (15, 23, 30, 31). The magnitude of the response depends upon the severity of the hypoxic stimulus (31) whereas the time after onset of hypoxia when the maximum concentration occurred in these studies seemed to depend upon the size of the animal. For the rat, peak concentration occurred in 12 to 24 hr (15) and for the rabbit, 24 to 48 hr (23). In 9 human subjects taken from sea level to an altitude of 3990 m (13,100 ft)

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in the Andes, Scaro (26) found a progressive increase in erythropoietic stimulating activity in the pooled urine from the second day at altitude through the sixth, and last, day of the study.

Our study on subject A in the low pressure chamber clearly confirmed that a transient response in erythropoietin occurs in the human on acute exposure to severe hypoxia. Moreover, the response was in keeping with that observed in small animals subjected to low pressure under comparable conditions. Serum erythropoietin rose at an increasing rate to a maximum on the third day of hypoxia, then fell to low levels on the fourth day (see Fig. 3). Judging from comparable findings in small animals, body size would not appear to have an important influence on the time in which maximum serum concentration occurs. The manner in which the erythropoietin concentration responded in the first three days suggests that the rate of increase may be limited by the rapidity with which the source of the hormone can augment synthesis in response to acute hypoxic stimulation, and beyond that, the rate may be governed by the prevailing level of "functional hypoxia." The fall in serum and urinary erythropoietin concentration with continued exposure to low pressure, we believe, is associated with attenuation of erythropoietin synthesis brought on by reduction in functional hypoxia as acclimatization progresses. Suggestive evidence for this appears in the physiological and clinical changes that accompanied changes in erythropoietin.

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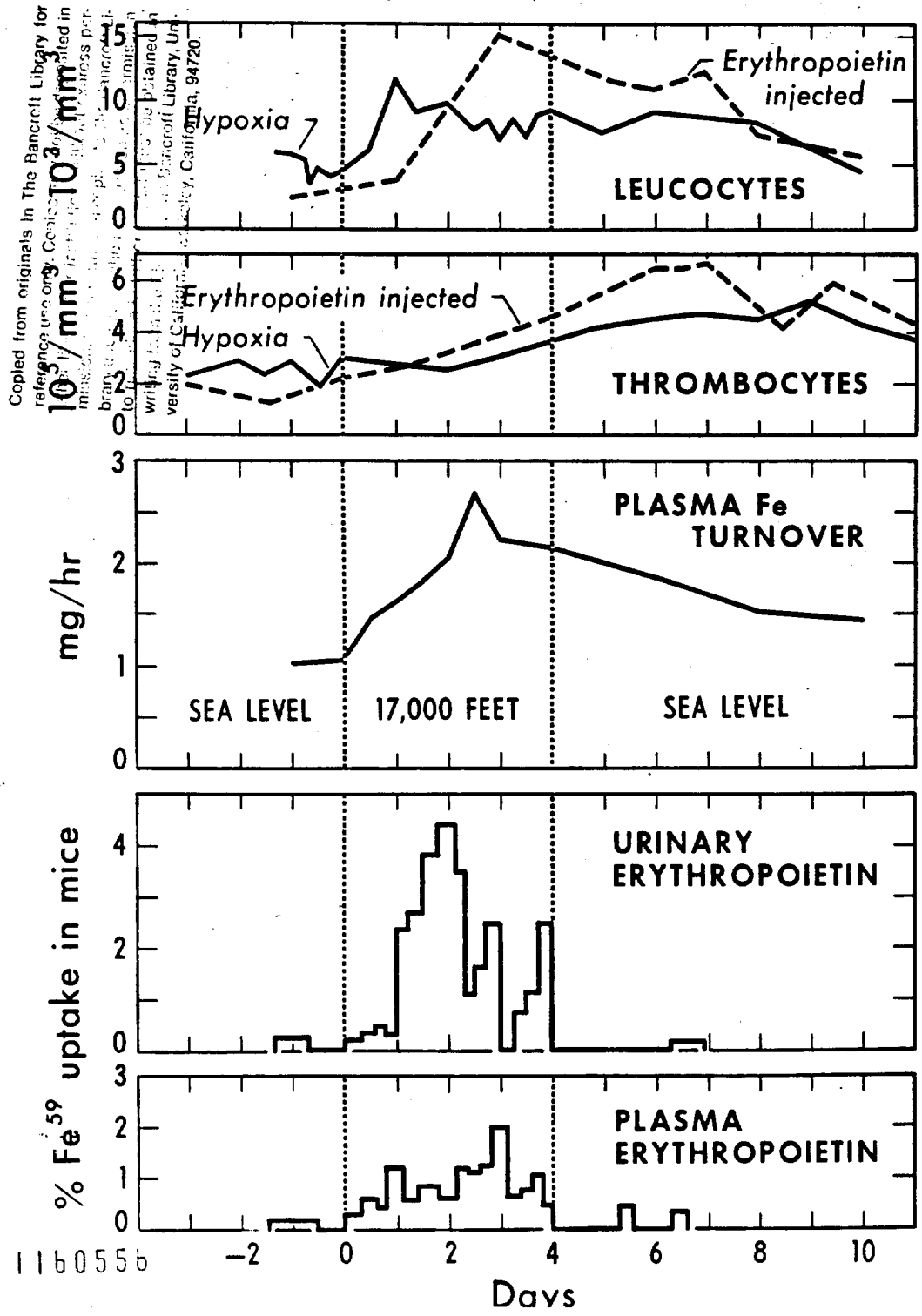

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Twenty-four hours after the start of exposure, the subject first showed subjective signs of acclimatization. In varying degrees and rates, nausea subsided, appetite and capacity for physical activity improved, and headache and insomnia diminished in severity. On the fourth day, recovery from symptoms was almost complete.

After 24 hr the respiratory rate returned nearly to normal from the doubled rate observed earlier. Minute volume (BTPS) followed a similar pattern, but when reduced to STPS it showed a drop at 24 hr to about one-half the pre-exposure value despite the 15% increase in oxygen consumption. These changes clearly indicate a marked increase in the subject's ability to extract oxygen from the inspired air and from blood. The increase in heart rate from a normal value of 72 beats/min to 97 beats/min at 36 hr, together with the return in pulse pressure to the subject's normal 45 mm Hg, suggests an increase in cardiac output consistent with the respiratory changes.

Among the hormonal changes that were observed, serum PBI doubled by the second day; urinary 17-OHCS excretion was elevated 50% throughout the four days. Urinary 17-OS increased by 50% on the second day and then returned to pre-exposure values on the third day.

During the period 48 - 72 hr, evidence of progressive myocardial hypoxia became apparent from the decreasing amplitude of the T waves in the left lateral precordial leads and AVL. This effect could not be

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attributed to changes in serum electrolytes because none were observed during the four-day test period. The greatest attenuation of the T waves occurred coincidentally with the maximum elevation in serum ervthropoietin. The subsequent reversion to the normal EKG pattern on the fourth day correlates well with the preceding evidence of acclimatization.

Collectively, these cardiac, respiratory, and symptomatic changes characterize in part an early stage of acclimatization in which the body learns to function effectively on greatly reduced arterial oxygen tension long before secondary polycythemia is present to augment the oxygen carrying capacity of blood. The changes all occurred shortly before or coincidentally with the maximum elevation in serum erythropoietin. The fall in erythropoietin, therefore, appears to reflect the reduction in functional hypoxia taking place during the initial acclimatization process. Improved tissue oxygenation, or whatever underlying process influences functional hypoxia, may also be responsible for reducing erythropoietin production following its initial stimulation by hypoxia.

The absence of measurable quantities of erythropoietin in the urine of Bolivian natives living at 17,000 ft, and failure to detect the hormone in acclimatized climbers at 23,000 ft, is in agreement with more recent observations by Van Dyke (personal communication) on Human subjects at 13,000 ft. These findings, particularly for high

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altitudes where erythropoieses is two to three times more active than at sea level, strongly suggest that elevated levels of erythropoietin are not necessary for maintaining a hyperactive marrow in the acclimatized subject. The initial outpouring of the hormone observed in the early stage of acclimatization seems to be needed primarily to accelerate erythropoietic activity but may not in itself regulate normal activity nor maintain an elevated level of activity in chronic hypoxia. The continued maintenance of elevated erythropoietin concentration is sometimes observed in severely hyposic animals that are moribund or nearly so. This has led some investigators to suggest that erythropoietin may be a "panic hormone" evoked only in crisis and that another, as yet unknown, mechanism normally regulates erythropoiesis. The observations reported here seem to support this contention.

A final observation on erythropoiesis, which is an outcome of the study on subject A in the low-pressure chamber, seems significant. It is well established that a temporary shut-down in erythropoiesis immediately takes place when a human who is acclimatized to high altitude descends to sea level (6, 25). In contrast to this, subject A's high rate of plasma iron turnover and hemoglobin synthesis persisted after he was restored to sea level pressure, then gradually decreased toward normal values over an extended interval of time (more than two weeks). This striking difference in response may depend upon the presence or absence

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of polycythemia at the time the subject changed altitude. The subject in the chamber experiment, although apparently acclimatized in most other respects, was not polycythemic when restored to sea level pressure. The level of erythropoietic activity may be governed more by the difference between the actual red cell volume and what it ought to be for a given altitude than by the level of hypoxia itself.

The most extensive studies of hemotological changes brought on by hypoxia have been those conducted by various investigators working at Morococha (14,900 ft, 430.6 mm Hg), Peru (6, 7, 10, 14, 25). At this altitude plasma iron turnover in acclimatized residents is about 25% greater than in sea level residents (approximately 0.55 compared to 0.45 mg/Kg-d). In contrast, rates of iron turnover nearly twice the sea level value were generally observed in unacclimatized subjects for the first few weeks after arriving at altitude from sea level (6, 25). Rates of 0.52 and 0.72 mg/Kg-d measured in Bolivian residents at 12,000 and 17,000 ft are in good agreement with the value for Peruvian residents at the intermediate altitude. The Expedition subjects' base line average of 0.43 mg/Kg-d is also in agreement with the mean value for Peruvian residents at sea level. The rates of 0.98 and 1.40 mg/Kg-d for Expedition climbers at 17,800 and 21,500 ft are consistent with what one would expect for subjects who are not fully acclimatized, or more correctly, subjects whose red blood cell volume has not yet stabilized. In April, when these measurements were made, the expedition had been

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exposed to altitudes greater than 15,000 ft for more than a month. However, Fig. 1 shows hemoglobin concentration and, presumably, circulating red blood cell volume still increasing rapidly.

Plasma iron turnover in subject A during his exposure to low pressure in a chamber increased from an initial value of 0.37 mg/Kg-d to a maximum of 0.95 mg/Kg-d after 2.5 days (Fig. 3). This is noteworthy for its close correspondence with the rise in serum erythropoietin concentration. If a correspondence exists after the third day, it is not clear. Although plasma iron turnover rate declined slowly for nearly two weeks after the subject was restored to sea level pressure, urinary erythropoietin was no longer detectable after the subject left the chamber and the presence of serum erythropoietin was doubtful.

Although iron turnover is obviously related to hemoglobin synthesis, there is disagreement among authorities on iron kinetics about how it is related and on what fraction of the observed plasma iron turnover is used for hemoglobin synthesis in the healthy human. The uncertainties stem partly from biological variability but perhaps more from varied interpretations of iron kinetics. From a comprehensive study of iron kinetics in 13 normal subjects, Pollycove (22) concludes that when serum iron concentration exceeds 92 μg/100 ml only 65% of the iron turnover is diverted to hemoglobin synthesis but when the concentration is less than 54 μg/100 ml, 95% of the iron turnover is so utilized. Since

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the grounds for selecting any one proposal in preference to another for estimated hemoglobin synthesis are in dispute, we have assumed, for the sake of estimating relative rates of hemoglobin production, that iron turnover is completely utilized for this purpose. On this basis, the rate of hemoglobin synthesis for the four expedition subjects at sea level was 0.13 g/Kg-d at 17,800; and at 21,500 ft the rates were 0.28 and 0.35 g/Kg-d. At 12,000 and 17,000 ft, the acclimatized Bolivian subjects produced 0.16 and 0.22 g/Kg-d.

From the initial rate of rise in hemoglobin concentration of 0.25 mg/100 ml-d, during the first 20 days when the expedition first ascended to significant altitude and the initial mean red cell volume of 2.44 liters, it is apparent that about 14 g were being produced per day in addition to that necessary for replacement. A crude estimate of 7 g/d for the latter is obtained from the red cell volume and a mean red cell life span of 120 days; hence, the rate of synthesis, at least at the outset of the 20-day period, was about three times normal for the group. Since plasma volume does not appear to change at altitude nor with the development of polycythemia, one can, at some risk, project the red cell volume to the start of the next 20-day period when hemoglobin concentration increased at the rate of 0.18 g/100 ml-d. This interpolation yields a mean red cell volume of 3.25 liters, a total blood volume of 6.20 liters, and an excess hemoglobin production rate of 13 g/d with a

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maintenance production of 12 g/d. The sum, 25 g/d, agrees, perhaps too well, with the estimate of 25 g/d derived from plasma iron turnover measured during this period at 21,500 ft. In view of the assumptions implicit in this estimate, the agreement may only be accidental.

It is well known that when high altitude residents descend to sea level, erythropoiesis is depressed until the red blood cell volume is reduced by red call attrition to values normal for sea level (6, 25). Reynafarje (25) observed a rate of decrease in volume that was consistent with what one would expect for a normal red-cell life span, and in a later study (24), showed by more direct methods a normal life span for cells formed immediately after arrival at 14,900 ft.

The abrupt and extremely rapid drop in hemoglobin concentration, 0.4 g/100 ml-d, that occurred when the climbers left base camp (17,800 ft) and descended to lower altitudes on the return march, is not consistent with earlier reports and raises doubts about the life span of red cells formed at high altitude. At the start of the descent, hemoglobin concentration averaged about 21 g/100 ml. Assuming that plasma volume had not changed greatly, the red cell and total blood volumes would have been 4.8 and 7.8 liters. The initial rate of loss of circulating hemoglobin would therefore have been approximately 2.5%/d. At that point in time, after 63 days at altitude, all but a small fraction of the circulating red blood cells would have been produced at high altitude as a result of the

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expiration of the life span of pre-existing cells and the greatly accelerated production of new cells during the preceding 2 months. As a further consequence of rapid cell production during this short period of time, the ages of a large fraction of the cells would be relatively young and not distributed uniformly over the age span as they are normally. Under these circumstances there could be a complete cessation in erythropoiesis with no substantial drop in red cell volume (or hemoglobin concentration) until the bulk of the cells had lived out their life spans. This should have happened about 30 days after the Expedition left Mt. Everest, but in fact occurred the moment the Expedition descended to lower elevations. It should be borne in mind that this situation differs from that for which Reynafarje (25) describes an expected loss in red cell volume on descent from altitude. He used in his study a long-term high altitude resident in whom cell ages were distributed normally, and doubtless the average cell life span was normal. In their earlier study, Reynafarje et al (24) measured cell life spans with radiocarbon - labeled glycine and found normal values. However, the glycine was given only 10 hr after the subjects arrived at 14,900 ft and consequently would have labeled only cells produced before the bone marrow was fully stimulated.

There appears to be no direct evidence that the life spans are normal for cells produced during the first month or two of severe hypoxia when erythropoiesis is most intensely stimulated.

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Studies on animals show a marked reduction in red cell life span when the cells are formed during times of intense erythropoietic activity. Neuberger and Niven (18a) found a reduction of 30 - 50% for red cells formed in the rabbit after bleeding. Berlin and Lotz (I) also found that acute hemorrhage produces in the rat abnormal cells with short life spans. A similar effect was observed by Fryers and Berlin (2a) in hypoxic rats, provided the labelled glycine used for tagging the cells was given in the initial stage of acclimatization to hypoxia. No change in life span was apparent in red cells formed in acclimatized animals.

The sudden, rapid drop in hemoglobin concentration observed in the Mt. Everest climbers can only be accounted for by either a significantly shorter life span for cells formed during the first 60 days at high altitude, or by active, random removal of red cells from the circulation.

Adrenal gland activity.

There is general agreement that secretion of 17-OHCS and 17-OS is stimulated in the initial stage of acclimatization by hypoxia but not after acclimatization is well advanced. Koller and his associates (9) reported an increased urinary excretion of both cortical steroid groups, along with a fall in eosinophils at 3450 m (11,300 ft). An elevated excretion rate of 17-OHCS and 17-OS was observed by Timiras

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et al (3) for 5 days or more after subjects arrived at 4100 m (13,450 ft) from sea level. Mackinnon et al (13) found a significant increase in adrenocortical activity, based on urinary 17-OHCS and other indices during the first five days in subjects taken to 4330 m (14,200 ft) in the Alps. However, they also report a slight depression in 17-OS excretion on the fifth day. Even at the relatively low altitude of 2000 m (6560 ft) Halhuber and Goble (3) found in newly arrived subjects an elevation in urinary 17-OHCS excretion and a depression of eosinophils that persisted for several weeks.

In studies on acclimatized subjects, Moncloa et al (16, 17) found no significant differences between urinary excretion rates of steroids in native residents at 14,900 ft and sea level. The adrenocortical responses to ACTH and Methopyrapone were also much the same in the two groups of subjects. A similar result for adrenal urinary steroids is reported by Mackinnon (13) for his subjects at 4330 m, and by Hornbein (4) for 17-OHCS excretion in climbers exposed to altitudes over 21,000 ft for two to three weeks.

For the most part the adrenocortical responses observed in the Mt. Everest climbers, and in subject A during acute hypoxia in the chamber, are in accord with the findings of others for the effect of less severe hypoxia. Only 4 values of 17-OHCS, and 2 for 17-OS, are clearly and abnormally elevated. Two of these were pre-expedition when

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anxieties and strains of last-minute preparations are greatest. One of the high values occurred the day following the climber's ascent to the summit and his bivouac at 28,000 ft without oxygen for 14 hr. However the adrenocortical activities of other summit climbers were not altered and the average for the four men is not significantly different from their pre-expedition value. The same conclusion applies to the 17-OS excretion rates and the responses of both 17-OHCS and 17-OS to ACTH.

The adrenocortical activity of subject A showed no changes during the expedition that were statistically significant. His adrenocortical response to acute hypoxia in the chamber, however, appeared to be more definite. The increase of about 50% in both 17-OHCS and 17-OS we believe is significant evidence of an adrenocortical response in this subject, based on measurements made occasionally over a period of several years. Two aspects of the response are noteworthy. First, the changes in excretion rate of 17-OS did not parallel those of 17-OHCS. The excretion rate of 17-OS attained a maximum on the second day but returned to the normal, pre-exposure rate on the third and fourth days. The 17-OHCS were uniformly elevated on all four days of the test. Second, the 11-oxy fraction of the 17-OS increased about twice as much as the 11-deoxy fraction.

The depression in subject A's eosinophil count from his normal level of 4% to 1% during his four days in the chamber is consistent with

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his moderate increase in adrenocortical activity. No consistent changes in eosinophil concentration were noted in subject A or other members of the expedition while on Mt. Everest.

Catecholamine response to hypoxia has not been extensively investigated. Pace et al (19) observed no increase in epinephrine excretion in six men taken from sea level to 3,800 m (12,500 ft) during the 14 days the subjects were observed. In contrast, norepinephrine increased two-fold during the two week period, starting on the second day at altitude. If it is assumed that adrenocortical activity in these subjects was also increased, Pace's findings would seem to conflict, at least on superficial examination, with Luft and von Euler's (12) observations that administration of ACTH, Cortisone, and desoxycorticosterone acetate greatly reduce norepinephrine excretion. Our findings do not appear to be in accord with either of these observations. The Mt. Everest climbers showed no change in catecholamine excretion with altitude or ACTH administration.

It should be noted that our values for daily excretion rates are about one half the values generally found in the literature, but we believe this to be due to a systematic difference in the assay that would not have affected the relative values.

Miscellaneous observations.

Leucocytes. Healthy persons acclimatized to moderate altitudes (less

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than 21,500 ft), in whom erythrocytosis is invariably present, do not in general exhibit leucocytosis and thrombocytosis (6, 7). Temporary leucocytosis, however, has been observed in the early stage of acclimatization (7, 38). The findings from the Expedition and the chamber study bear out these observations. No meaningful changes in either total or differential leucocyte counts were seen during extended stays at 21,500 ft nor in climbers who made excursions of several days to much higher altitudes. In contrast, subject A on acute exposure to severe hypoxia developed moderate but significant leucocytosis and thrombocytosis, with a marked depression in eosinophil concentration.

Van Dyke et al (36) demonstrated that concentrated but impurified urinary erythropoietin from a human donor (one of only several known to excrete large quantities of the hormone) produced in normal subjects a leucocytosis and thrombocytosis in addition to the expected reticulocytosis. The similarity between the pattern of the responses in the subjects given large doses of erythropoietin and that observed in subject A (See Fig. 3) raises the possibility that high concentrations of erythropoietin may act as a generalized hematopoietic stimulant. The absence of leucocytosis and thrombocytosis in chronic exposure to hypoxia may mean only that production of these cell forms is insensitive to erythropoietin at the relatively low concentrations (and possible absence) that prevails after acclimatization is well advanced.

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stimulating factors other than erythropoietin are postulated, they seem singularly insensitive to hypoxia except in the initial stress of acclimatization.

Heart rate and blood pressure. Disagreement exists in the literature on the changes in heart rate and blood pressure that occur during sojourns to high altitude. To a large extent this would seem to be inevitable because of the varied conditions under which such observations are made. A wide range in response was seen in the Mt. Everest climbers, but several distinct patterns seem to emerge. In general, basal heart rates were elevated during the 60 days at or above 17,800 ft. Although the rates were highest during the first month and decreased thereafter, there was no clear tendency to return to sea level values. No heart rate was consistently less than at sea level, but five climbers exhibited no change from base-line values during the course of the expedition.

Resting diastolic pressures were uniformly and chronically elevated. Systolic pressure was also elevated, but more labile and showed a tendency to diminish after a month of acclimatization. The heart rate of subject A showed no consistent change during the first 24 hr in the low-pressure chamber, but thereafter it increased about 20%. After a day and a half his systolic and distolic pressures increased slightly. He also maintained a somewhat higher than normal blood pressure during the expedition. These observations are somewhat at

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variance with those of Leuthold (11) who reports no change in blood pressure in climbers at altitudes up to 6400 M (21,000 ft), and no change in heart rate for altitudes up to 5400 m (17,750 ft), although a marked increase at 6400 m.

The general character of the recovery pattern for heart rate and blood pressure following light exercise (3-min step test) did not change appreciably with altitude and acclimatization. The rise in heart rate and pulse pressure produced by the exercise seemed to diminish progressively with acclimatization. In the first week, when symptoms of hypoxia were most pronounced, the responses were greater than at sea level, if weight changes and step height are taken into account. During the two months that followed, pulse pressure and rate responses to the exercise at 17,800 ft seemed to decrease steadily.

Weight loss. The weight loss of 5 - 8 Kg sustained by all members of the Expedition team during the 4-week approach march is not surprising in view of the daily high work level, high ambient temperatures, and initial average fat burden of 20%. It indicates, however, that pre-expedition physical training was less than wholly adequate for the task, but it should be added that this was one of the purposes served by the approach march.

The persistent loss of weight in climbers at 21,500 ft and higher elevations cannot be attributed to a calorie imbalance caused by work.

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The cause must be sought elsewhere because the average daily work level during the 30 days or more most climbers spent at and above 21,500 ft was rather low. It is generally assumed that weight loss at high altitude is an inevitable consequence of depressed appetites, the ever-present difficulties of preparing food and occasional food shortages. These factors were present and, combined with the additional calorie demands imposed by the low ambient temperatures at 21,500 ft (0 to -20 C), could adequately explain the loss in weight. Nevertheless, two additional factors may have more significance than heretofore suspected. The exclusive, but necessary, use of highly concentrated, processed foods led to a monotony of diet that seemed to have more impact on appetite than did hypoxia. In contrast, fresh foods of any description, including tough goat meat that would have been rejected as inedible under normal conditions, were eagerly consumed at all altitudes. There was no evidence that fats were less acceptable than at sea level. Bacon and butter always remained in demand. If the diet shifted more toward carbohydrates at higher altitudes, it was because they were more accessible, required no preparation and were in familiar forms that are part of the ordinary diet at sea level. Sherpas, who subsisted on their normal diets, supplemented with expedition food, showed little evidence of weight loss at high altitude.

A possible second factor in weight loss relates to digestion and

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and absorption in the intestine of food consumed at high altitude. Little work appears to have been done on the effects of hypoxia on hydrolysis of fat and protein and absorption of digestive products in the gastroin gastrointestinal tract. Evidence for this effect of hypoxia is still dubious. Aside from persistent weight loss at times when caloric intake seems adequate, it consists of the observation on a number of expeditions, including this one, that a sprue-like syndrome occurred with large volumes of flatus and bulky, steatorrheic stools. Whatever the cause of weight loss, it seems likely from the losses in TBW that members of the expedition were subjected to malnutrition as well as under-nutrition. Evidence for lean-tissue wasting admittedly is meager, but it is worth noting that if lean tissue were lost, it occurred while substantial depot fat still remained. It is clear from the work of Picon-Reategui et al (20, 21) and Nevison et al (18) that no change in body compisition occurs during prolonged exposure to 14,000 ft (permanent residence) and 19,000 ft (9 months). At both altitudes, body weight and TBW remained nearly constant. It appears probable from these observations that the highest altitude at which body weight can be maintained lies between 19,000 and 21,500 ft.

Electrolytes. Much has been said about physiological reaction to hypoxia brought on by excessive renal excretion of potassium ion as a result of respiratory alkalosis and a potassium shift from intracellular space.

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Occurred in the Mt. Everest climbers, it was not evident after they reached base camp (17,800 ft) when measurements began; sodium and potassium excretion appeared to be normal even after ascents to very high altitude. Serum levels of both ions were also normal in the subjects tested at 17,800 and 21,500 ft. In the acute exposure of subject A to hypoxia in the chamber, no significant changes occurred in either serum or urinary Na, K, and Cl. It must be concluded from these observations that potassium was not a factor in acclimatization, at least in these subjects and under the conditions of the studies.

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REFERENCES

1. Berlin, N. I., and C. Lotz. Life span of the red blood cell of the rat following acute hemorrhage. Proc. Soc. Exper. Biol. Med. 78:788-790, 1952.

1a. DeGowin, R. L., D. Hofstra, and C. W. Gurney. A comparison of erythropoietin bioassays. Proc. Soc. Exptl. Bio. Med. 110:148-51, 1962.

2. Few, J. D. A method for the analysis of urinary hydroxycorticosteroids. J. Endocrin. 22:31-46, 1961.

2a. Fryers, G. R., and N. I. Berlin. Mean red cell life of rats exposed to reduced barometric pressure. Am. J. Physiol. 171:465-470, 1952.

3. Halhuber, M. J., and F. Gabl. 17-OHCS excretion and blood eosinophils at an altitude of 2000 m. (See Ref. 41)

4. Hornbein, T. F. Adrenal cortical response to chronic hypoxia. J. Appl. Physiol. 17:246-248, 1962.

5. Hornbein, T. F. Oxygen in Americans on Everest. New York, J. B. Lippincott Company, 1964.

6. Huff, R. L., J. H. Lawrence, W. E. Siri, L. R. Wasserman, and T. G. Hennessy. Effects of changes in altitude on hematopoietic activity. Medicine 30:197-217, 1951.

7. Hurtado, A., C. Merino, and E. Delgado. Influence of anoxia on the hematopoietic activity. Arch. Int. Med. 75:284-323, 1945.

8. Kellie, A. E., and A. P. Wade. The analysis of urinary 17-oxosteroids by gradient elution. Biochem. J. 66:196-206, 1957.

9. Koller, F., E. Schwarz, and M. Marti. Ueber die reaktion der nebennierenrinde beim aufstieg ins hochgebirge. Acta Endocr. 16: 118-140, 1954.

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10. Lawrence, J. H., R. B. Huff, W. E. Siri, L. R. Wasserman and T. G. Hennessy. A physiological study in the Peruvian Andes. Acta Med. Scand. 142:117-131, 1952.

11. Leuthold, E. H. Das verhalten von puls und blutdruck wahrend und nach langfristigen aufenthalt in grossen hohen. Hel. Physiol. Pharm. Acta, 17:109-130, 1959.

12. Luft, R. and U. S. von Euler. Excretion of catechol amines during administration of ACTH, cortisone and desoxycorticosterone acetate.

13. MacKinnon, P. C. B., M. E. Monk-Jones, and K. Fotherby. A study of various indices of adrenocortical activity during 23 days at high altitude. J. Endocrin. 26:555-566, 1963.

14. Merino, C. F. Studies on blood formation and destruction in the polycythemia of high altitude. J. Hematology 5:1-31, 1950.

15. Mirand, E. A., and T. C. Prentice. Presence of plasma erythropoietin in hypoxic rats with or without kidney (s) and/or spleen. Proc. Soc. Exptl. Biol. Med. 96:49-51, 1957.

16. Moncloa, F., E. Pretell, and J. Correa. Studies on urinary steroids of men born and living at high altitude. Proc. Soc. Exptl. Bio. Med. 108:336-337, 1961.

17. Moncloa, F., and E. Pretell. Cortisol secretion rate, ACTH and Methopyrapone tests in high altitude native residents. J. Clin. Endocr. Metal. XXIV: 915-918, 1964.

18. Nevison, T. O., J. E. Roberts, W. W. Lackey, R. G. Scherman, and K. H. Averill. 1960-61 Himalayan Scientific and Mountaineering expidition. I. USAF High Altitude Physiological studies. Lovelace Foundation, Albuquerque, New Mexico.

18a. Neuberger, A., and Niven, J. S. F. Haemoglobin formation in rabbits. J. Physiol. 112:292-310, 1951.

19. Pace, N., R. L. Griswold, and B. W. Grunbaum. Increase in urinary norepinephrine excretion during 14 days sojourn at 3,800 meters elevation. Fed. Proc. April, 1964.

20. Picon - Reategui, E. Basal metabolic rate and body composition at high altitudes. J. Appl. Physiol. 16:431-435, 1961.

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21. Picon-Riategui, E., R. Lozano, and J. Valdivieso. Body composition at sea level and high altitudes. J. Appl. Physiol. 16:586-592, 1961.

22. Pollycove, M., and R. Mortimer. The quantitative determination of iron kinetics and hemoglobin synthesis in human subjects. J. Clin. Invest. 40:753-782, 1961.

23. Prentice, T., and E. A. Mirand. Effects of hypoxia on plasma erythropoietin in the rabbit. Proc. Soc. Exptl. Biol. Med. 106:501-502, 1961.

24. Reynafarje, C., N. I. Berlin, and J. H. Lawrence. Red cell life span in acclimatization to altitude. Soc. Exptl. Biol. Med. 87: 101-102, 1954.

25. Reynafarje, C., R. Lozano, and J. Valdivieso. The polycythemia of high altitudes: Iron metabolism and related aspects. Blood 14:433-455, 1959.

26. Scaro, J. Actividad eritropoyetica del extracto urinairo de sujetos residentes en la altura. Rev. Soc. Arg. Bio. 31:1-8, 1960.

27. Siri, W. E., D. C. VanDyke, H. S. Winchell, M. Pollycove, H. G. Parker, and A. S. Cleveland. Early erythropoietin, blood, and physiological responses to severe hypoxia in man. Donner Laboratory Semi-Annual Report, Fall, 1962. (UCRL-10683) J. Appl. Physiol. (submitted).

28. Siri, W. E. Apparatus for measuring human body volume. Rev. Sci. Inst. 27:729-738, 1956.

29. Siri, W. E. The gross composition of the body. in Advances in Biological and Medical Physics. ed. J. H. Lawrence and C. A. Tobias, Vol. IV, Academic Press, New York, 1956.

30. Stohlman, Jr., F., and G. Brecher. Humoral regulation of erythropoiesis V. Relationship of plasma erythropoietin level to bone marrow activity. Proc. Soc. Exptl. Biol. Med. 100:40-43, 1959.

31. Stohlman, Jr., F., and G. Brecher. Humoral regulation of erythropoiesis III. Effect of exposure to simulated altitude. J. Lab. Clin. Med. 49:890-895, 1957.

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32. Thomas, B. S., and R. D. Bulbrook. A rapid method for the estimation of total 11-deoxy-17-oxosteroids in urine. J. Chromatog. 14:28-36, 1964.

33. Timiras, P. S., N. Pace, and C. A. Hwang. Plasma and urine 17-hydroxycorticoid and 17-ketosteroid levels in man during acclimatization to high altitude. Fed. Proc. 16:340, 1957.

34. VanDyke, D. C., and M. Pollycove. In Erythropoiesis. New York and London: Grune and Stratton, 1962.

35. VanDyke, D. C. in Haemopoiesis, London: J. and A. Churchill, Ltd., 1960.

36. VanDyke, D. C., J. H. Lawrence, M. Pollycove, and P. Lowy. In Proc. Conf. on Hormones and the Kidney, Cambridge, England, 1962. In press.

37. VanDyke, D. C., J. H. Lawrence, W. E. Siri. Erythropoietin as an etiologic factor in blood dyscrasias. Acta Isotopica 3:217-225, 1961.

38. Van Liere, E. J., and J. C. Stickney. Hypoxia. Chicago: The University of Chicago Press, 1963.

39. von Euler and F. Lishajko. Improved technique for the fluorimetric estimation of catecholamines. Acta Physiol. Scand. 51:348-356, 1961.

40. Wilson, H. and P. Carter. Stabilization of the alcoholic potassium hydroxide in colorimetric 17-retosteroid determinations. Endocrinology. 41:417, 1947.

41. Physiological Effects of High Altitude, ed. by W. H. Weihe, New York: The MacMillan Company, 1964.

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