THE EFFECT OF HIGH ALTITUDE ON THE PROTEIN COMPOSITION OF HUMAN BLOOD

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There are as yet no data on the effect of the complex of high altitude factors on the protein composition of the blood in humans and animals.

In cats, severe oxygen deprivation does not cause a change in blood protein composition [5]. Prolonged action of atmospheric pressure reduced to 310.8 mm Hg (4 hours daily for 21 days) in rats causes decrease in the albumin-globulin coefficient in the serum as a result of lowered albumin concentration and a considerable rise in the concentration of α_2-globulin, with decreased occurrence of a raised content of other globulin fractions in the serum [9]. "Elevation" in a pressure chamber to a "height" of 8500 meters and keeping there for three hours a day for 15 days caused in dogs a lowered content of blood γ-globulin [7]. Examination of healthy humans in mountain regions has not shown any change in blood protein composition [8] but under the same conditions physical stress causes a lowered albumin concentration and a rise in the globulin concentration [6].

The present study was designed for the purpose of explaining the effect on protein composition of blood serum of a move of people from their usual atmospheric conditions to conditions of a high altitude climate.

METHODS

We determined the protein composition of the blood in 12 young individuals of both sexes, completely healthy clinically, at Stalinabad (850 m) and under mountain conditions in Eastern Pamir at an elevation of 4200 m above sea level (during the period of the high altitude scientific expedition of the Stalinabad Medical Institute from May to October, 1958).

Blood for the study was taken in the morning, directly after sleep, on an empty stomach, from the finger into a centrifuge tube, which was at once stoppered with a tightly fitting stopper (to prevent the blood from drying, which would be particularly important at lower barometric pressures). After the blood had coagulated it was centrifuged and the total concentration of protein was determined in the serum with an RF-1 refractometer. Fractionation of the serum proteins was carried out by paper electrophoresis according to the accepted laboratory method [3]. Statistical treatment of the materials of the investigation gave the significance of the variations by a differential method [1] according to the index t.

TABLE 1. Change in Protein Concentration in Human Blood Serum (in g-percent) Before and After a Rise in Elevation.

Conditions of study / Statistical index	Before rise (850m)	After rise (4200m)		A month after descent
		First month	Fourth month	
M	7.3	8.2	7.7	7.8
$\sigma \pm$	0.58	0.51	0.47	0.20
P	—	<0.01	<0.05	<0.05

Note: In Tables 1 and 2 the significant difference (P) is calculated from the ratio to the initial data in Stalinabad before the ascent.

RESULTS

In Table 1 we give the statistical treatment of the results of the study of total protein concentration in blood serum.

Table 1 shows that during the first month of stay in Pamir the concentration of protein was raised significantly ($P < 0.01$). After four months at this altitude the concentration of protein in the blood fell somewhat, but remained above the starting level ($P < 0.05$). In the first month after the descent the concentration of protein in the serum continued to remain high ($P < 0.05$).

The results of the electrophoretic study of serum protein concentration are given in Table 2.

Analysis of the results of Table 2 shows that the concentration (relative and absolute) of albumin in human blood serum falls immediately after their ascent to the altitude and continues to remain truly low ($P < 0.05$) for at least a month after the descent. The concentration of α_1-and γ-globulins in humans increases immediately af-

TABLE 2. Change in Protein Composition of Human Blood Serum (in relative percent before and after ascent to altitude)

Protein fraction	Conditions of study / Statistical indexes	Before ascent (850 m)	After ascent (4200m)		A month after descent
			first month	fourth month	
Albumin	M	66.2	55.7	57.3	54.8
	$\sigma \pm$	3.5	2.8	5.3	3.9
	P	—	<0.001	<0.001	<0.05
Globulins					
α_1	M	2.9	5.5	5.2	5.1
	$\sigma \pm$	0.9	1.2	2.2	1.6
	P	—	<0.001	<0.02	<0.001
α_2	M	2,9	3.9	3.8	5.3
	$\sigma \pm$	0,9	1.5	1.3	2.1
	P	—	<0,2	<0.1	<0.01
β	M	13,2	16.4	14.6	17.4
	$\sigma \pm$	1,9	2.6	1.9	4.7
	P	—	<0.01	<0.1	<0.01
γ	M	14,8	18.5	19.1	17.4
	$\sigma \pm$	2,6	3.6	4.9	3.2
	P	—	<0.01	<0.01	<0.05

ter the ascent and remains high after the descent. The concentration of β-globulin rises immediately after the ascent; four months later it has fallen somewhat (the difference compared to the initial value is statistically insignificant, $P < 0.1$), and after the descent it actually again rises above the initial value. The concentration of α_2-globulin is not changed by ascent to the altitude and during the period of stay, but after the descent it increases ($P < 0.01$).

The regularities of change in composition of human blood proteins which we have observed in the move from Stalinabad (850 m) to the high altitude region of Eastern Pamir (4200 m) are characterized by a decreased concentration of albumin and an increased concentration of the globulin fraction (chiefly the γ-, α_1-, and β-globulins) with increased concentration of total protein in the serum.

The disturbance in blood protein composition is found during the four month stay of the individuals under high altitude conditions and is kept after the descent (a period of one month observation). The length of the disturbance does not permit explaining it only by a concentration of the blood or a redistribution of proteins between blood and extravascular intercellular tissue fluids. It is possible that these factors have some effect only at the beginning of the change in protein composition of the blood. The observed disturbance in protein composition of the blood has a nonspecific character. The organism reacts to any extreme and unusual stimulus by lowering the albumin content and increasing the content of globulins in the serum [2, 10]. Such a reaction of the protein composition of the blood is considered as a humoral effect in the first phase of the Selye adaptation syndrome [10]. Actually, the move of humans from ordinary atmospheric pressure (680 mm) to conditions of decreased atmospheric pressure (450 mm) and the return have been considered a stress which causes an internal functional reorganization of the whole physiological system of the organism. Evidently, under these conditions, as usual there is a weakening of albumin synthesis and a compensatory strengthening of synthesis of the globulins.

One of the most important functions of the plasma proteins is the maintainance of a constant oncotic pressure of the blood, and hence an equal distribution of the water between the vessels and the extravascular spaces. In this connection it is of interest to explain the change in oncotic pressure of the blood under high altitude conditions. In Table 3 we give values for the oncotic pressure of the blood calculated on the basis of determination of the concentration of total protein, albumin, and globulins.

Table 3 shows that only in the first month after ascent to the altitude was the oncotic pressure of the blood above the initial value. With further stay at the altitude it became equal to the original and did not change with descent. In the first month of stay at the altitude the total protein concentration in human serum rose on the average by 0.9% (albumin concentration decreased by 0.2%, but the globulins increased by 1.1%). At the end of the stay at the altitude the concentration of total protein in the serum fell somewhat (increase above the initial value of 0.4%). However, with this there was a change in ratio between concentration of albumin and total globulins (albumin concentration 0.4% below initial level, and globulins 0.8% above initial level). As a

TABLE 3. Change in Oncotic Pressure of Human Blood Serum (in cm of water)

Index	Before ascent (850 m)	After ascent (4200 m) first month	After ascent (4200 m) fourth month	4 month after descent
Albumin (g%)	4.8	4.6	4.4	4.2
Globulins (g%)	2.5	3.6	3.3	3.6
ΔA (g%)	—	— 0.2	— 0.4	— 0.6
$\Delta \Gamma$ (g%)	—	+ 1.1	+ 0.8	+ 1.1
Albumin-globulin coefficient	1.9	1.3	1.3	1.2
Oncotic pressure				
I	34.8	39.8	36.5	36.0
II	33.6	36.9	33.9	33.5
III	32.2	32.8	31 2	30.5
M	33.5	36.5	33.8	33.3

Note: 1. ΔA and $\Delta \Gamma$ are values for variation of albumin and globulin concentrations from the initial values before the ascent. 2. Oncotic pressure of the blood (OBP) in mm water is calculated from formulas of [4]: I. OBP=C(21.4 + 5.9A); II. OBP=C(21.1 + 5.2A); III. OBP= (3.56 + Γ)/0.06, where C, A, and Γ are the concentrations in gram-percent of total protein, albumin, and globulins. 3. M is the arithmetical average of oncotic pressure from calculation by the three equations.

result there is a normalization of the value for oncotic pressure. Almost the same ratio is maintained in the month after descent. Hence, in the initial period of stay at the altitude the increased oncotic pressure of the blood can be explained by the hypercompensatory reaction of the organism to lessened albumin concentration, consisting in excess accumulation of globulins in the blood ($\Delta\Gamma/\Delta A$=5.5). With further increase in globulin concentration the albumin concentration begins to correspond ($\Delta\Gamma/\Delta A \simeq 2$) and the oncotic pressure is normalized.

Thus, we can present a mechanism for the normalization of oncotic pressure in the adaptation of individuals to high altitude conditions in spite of maintenance of a disturbed protein composition of the blood.*

SUMMARY

Twelve healthy young individuals had the protein composition of their blood determined in Stalinabad (850 m) and during their sojourn in the mountain of East Pamir between the months of May and October, 1958, at the altitude of 4200 m.

During the first month of sojourn at high altitude, the total concentration of protein went up, while towards the end of the 4 month period it dropped somewhat, but still remained above the initial level. The relative and the absolute albumin content in the blood serum dropped immediately after the ascent and remained low for a month after descent from 4200 m to 850 m. The figures for α_1-, β- and γ-globulins rose immediately after ascent. During the 4 month stay at high altitude, the α_1- and γ-globulins went back to normal. During the first month after descent, figures for α_1-, β- and γ-globulins were higher than the initial levels; α_2-globulin went up only after descent. Oncotic pressure of blood rose during the first month after ascent, then returned to normal at the expense of increased concentration of the globulin fraction, which compensates for the decreased albumin content in blood serum.

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