LIPOPROTEIN CONTENT OF BLOOD IN MONKEYS OF VARIOUS SPECIES AND AGES

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Recently there has been a growing interest in experimental use of monkeys for the development of atherosclerosis [2,4]. In addition to a description of the morphological changes in the vessels, data has been published concerning changes in the cholesterol, phospholipid and lipoprotein content of the serum. Information is available on the α- and β-lipoprotein content and their ratio in various animals [5]. The ratio was found to be 1 (α = 250 mg %, β = 300 mg %) in monkeys (species not given) and this differs from the ratio of 2 in man (α = 250 mg %, β = 500 mg %). Using the method of paper electrophoresis in a pH 8.5 barbiturate buffer and staining with Oil Red O, it was found that, among the various animal species, the baboon blood serum lipoproteins contain a preponderance of the β-fraction. Information of this kind, though extremely important, is scanty and has been obtained on only a limited number of monkeys.

The present work is devoted to a study of the α- and β-lipoprotein content of the serum in monkeys of various ages and species (hamadryad baboons, rhesus, lapunder, and green monkeys).

METHODS

Lipoproteins were determined in the blood serum of 181 monkeys of several species and in 34 healthy human subjects (blood donors). The monkeys did not receive animal fats in their diet.

The lipoproteins were determined by paper electrophoresis in a medinal-veronal buffer (pH 8.6). The stain (Sudan black) was eluted and the optical density of the solution was determined spectrophotometrically.

RESULTS

In all cases, both human and monkey, a clear separation of fractions was observed (Fig. 1). Visual inspection showed a definite preponderance of the β-fraction over the α-fraction in humans, and the reverse held for hamadryad baboons, rhesus, and green marmosets. The lapunder macaque was exceptional in that it frequently was found to have the principal amount of its lipoproteins in the β-fraction (see Fig. 1).

The serum lipoproteins in adult (4-12 years) hamadryad baboon (males) were characteristically rich in the α-fraction, and in the baboon, Augar, this rose to as much as 83.4% of the total. However, in the adult females of the same species, the serum α-lipoprotein accounted for considerably less of the total (average 50.2%). The immature (up to 4 years of age) hamadryad baboon was characterized by a high α-lipoprotein content in the females and somewhat less in the males, although the difference is not statistically significant ($P > 0.05$). The old (over 19 years) females contrasted with the "adult" females showed a small relative increase in the α-fraction (see table).

The rhesus macaque,in contrast to the hamadryad baboon, was found to have an α-lipoprotein content which was somewhat higher in the female, but this difference also was not statistically significant ($P > 0.05$, Fig. 2). The level of α-lipoproteins in the male (immature) Macaca rhesus was approximately equal to that in the immature male hamadryad baboon. However, the immature female rhesus macaque had significantly less α-lipoprotein than did the immature female hamadryads ($P < 0.01$). The sex differences in the group of immature rhesus monkeys were statistically significant.

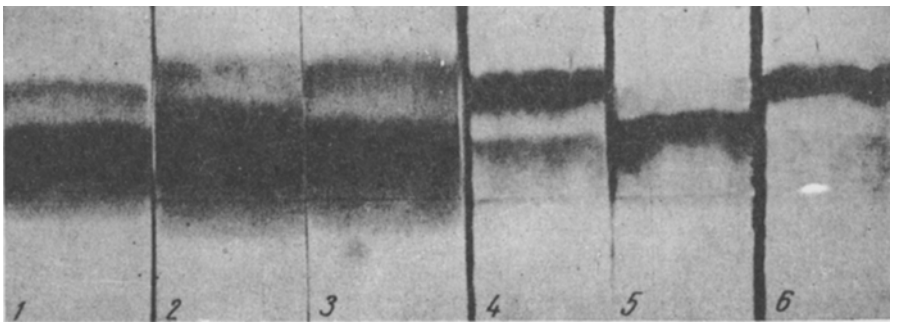

Fig. 1. Electrophoregrams of serum lipoproteins in man and monkeys: 1-3) human; 4) hamadryad baboon; 5) lapunder macaque; 6) rhesus macaque.

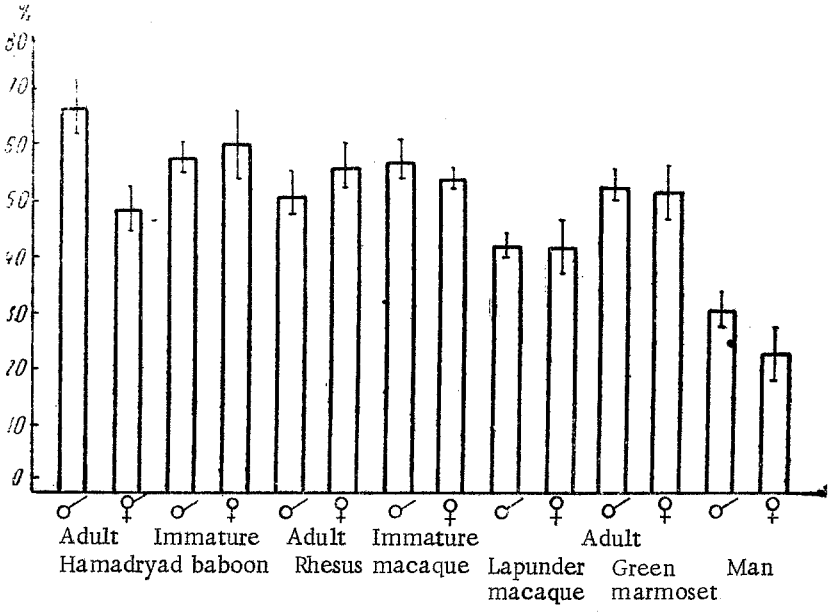

Fig. 2. Average levels and confidence limits of the serum α-lipoprotein content in various classes of monkeys and in man.

The lapunder macaque was unique in showing a preponderance of β-lipoproteins, a fact which differentiates these from all the other species of monkey studied. The α-lipoprotein in the lapunder macaque was identical in male and female and was lower than in the other monkey species. Despite the difference of the mean α-lipoprotein content in the male lapunder macaque from that in the male hamadryad baboon, the difference is not statistically significant ($P > 0.05$). The α-lipoprotein levels in 2 immature lapunder monkeys was almost the same as that in the adults of the same species.

The distribution of lipoprotein fractions in the green marmosets was similar to that in the rhesus monkey. The α-lipoprotein predominated in both males and females and the sex differences were not marked (see Fig. 2).

The study of lipoproteins in human subjects revealed a substantial preponderance of the β-lipoprotein fraction and sex differences consisting of a relatively higher level of α-lipoprotein in men (see table and Fig. 2). The difference is statistically significant ($P < 0.01$). The sex differences in man with respect to serum lipoprotein levels have been observed also by others [3]. The lipoprotein levels we have found in the human subjects agree with those published in the literature [1,6].

The distribution of lipoproteins in the serum electrophoretic fractions in monkeys has evident peculiarities: in the green marmoset, the macaque rhesus (females) and the hamodryad baboons (males), there is a clear preponderance of the α-fraction ($P < 0.001$). In the hamadryad baboons (female), the α- and β-lipoprotein fractions are

α- and β-Lipoprotein Concentrations in the Lower Monkeys and in Man (%)

	Value	Adult				Immature					Value	Aged			
		Male		Female		Male	Female					Male		Female	
		Lipoproteins					Lipoproteins					Lipoproteins			
		α	β	α	β	α	β	α	β			α	β	α	β
Hamadryad baboons	$M \pm m$	68,4±2,42	31,6±2,33	50,2±2,0	49,8±2,87	58,8±1,46	41,2±1,75	62,5±1,79	37,5±3,24	*M*	—	—	54,4	45,6
	σ	11,4	10,9	8,0	11,5	5,66	6,8	5,92	10,79	Limits of variation	—	—	49,5—58,9	41,1—50,5
Macaca rhesus	$M \pm m$	52,8±1,83	47,2±2,06	58,0±2,1	42,1±2,3	59,6±1,37	40,4±2,53	56,5±0,97	43,5±2,07	*M*	—	—	36,5	63,5
	σ	7,07	7,99	7,85	8,61	5,48	10,1	3,62	7,78	Limits of variation	—	—	22,7—46,8	53,2—77,3
Macaca lapunder	$M \pm m$	44,5±0,90	55,2±3,96	44±2,54	56,0±2,02	46,9	53,1	—	—	*M*	51,9	48,1	42,2	57,8
	σ	2,54	11,2	8,8	6,97	—	—	—	—	Limits of variation	—	—	14,4—71,0	—
Green marmoset	$M \pm m$	54,9±1,29	45,1±1,34	54,4±2,15	45,6±2,59	—	—	—	—	—	—	—	—	—
	σ	4,09	4,25	7,45	8,95	—	—	—	—	—	—	—	—	—
		Men		Women											
Human (20-40 years)	$M \pm m$	33,0±1,65	67,0±1,79	25,5±2,08	74,5±2,19	—	—	—	—	—	—	—	—	—
	σ	6,6	7,17	8,85	9,33	—	—	—	—	—	—	—	—	—

approximately equal, and in the rhesus macaque (males), despite a difference in the mean levels, the difference between α- and β-fractions is not significant ($P > 0.05$). The lapunder macaque, like man, shows a significant excess of β-lipoprotein ($P < 0.02$). Thus, with the exception of the lapunder species, all classes of monkeys studied differ from man in the high level of the α-fraction. However, there is a published report to the effect that the β-fraction is preponderant in the baboons. This finding is in disagreement with our data and the discrepancy may be based on the fact that the other worker apparently studied anubis baboons rather than hamadryads and used a different dye in staining the electrophoregrams.

The adult hamadryad baboons have definite and statistically significant sex differences in lipoprotein content as does man; in this monkey, the male has the higher α-fraction and,in humans, the same is true. The other classes of monkeys under study did not evidence sex differences.

Age differences were noted in the hamadryad baboons (males and females) and in the rhesus monkeys (males). The immature hamadryad baboons (males) had substantially lower α-lipoproteins than did the adults ($P < 0.001$), but the immature rhesus monkey (male) had less α-lipoprotein than the adults ($P < 0.01$). With regard to the females, those among the immature hamadryad baboons had higher α-lipoproteins than did the comparable female adults ($P < 0.001$), but in the immature rhesus macaque no such significant difference was found.

According to certain authors, the most convenient species of animals for producing atherosclerosis are those having a high β/α ratio. Among the species having this characteristic are the rabbit, chicken, and the monkey (species not specified); in these, the ratio of β/α is respectively 1.1, 6, and 1. The β/α ratio in human subjects is about 2 [5]. Inasmuch as the β-fraction had been observed to predominate in the baboons (probably the anubis), these animals are considered to be the most suitable for experimental atherosclerosis. We may add that, according to our data, the lapunder macaque would also be a suitable subject for such work since its β/α ratio was 2.25. However, among the hamadryad baboons and the rhesus macaques, the β/α ratio is less than 1 (according to our findings the values for these species are 0.7 and 0.8, respectively), and there are reports in the literature on the successful production of atherosclerosis in these types of monkeys [4].

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