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Nr. 102

STUDIES ON THE BLOOD AND BLOOD PRESSURE IN THE ESKIMO AND THE SIGNIFICANCE OF KETOSIS UNDER ARCTIC CONDITIONS

I KOMMISJON HOS
BRØGGERS BOKTRYKKERIS FORLAG
OSLO 1954

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Nr. 102

STUDIES ON THE BLOOD AND BLOOD PRESSURE IN THE ESKIMO AND THE SIGNIFICANCE OF KETOSIS UNDER ARCTIC CONDITIONS

I. K. Rodahl: Seasonal Blood Changes in the Eskimo.
II. K. Rodahl: Blood Sedimentation Rates in Eskimos.
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I KOMMISJON HOS
BRØGGERS BOKTRYKKERIS FORLAG
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A. W. BRØGGERS BOKTRYKKERI A/S

Preface.

This publication contains some of the results from a study of the patho-physiology of the Eskimos, carried out at the Arctic Aeromedical Laboratory. Ladd A.F.B., Fairbanks, Alaska, from 1950 to 1952. The present paper, which is one of a series of publications, dealing with the effects of the cold environment on man, comprises the results of studies of blood changes and cardiovascular conditions in humans exposed to the Arctic environment. The computation of these data collected during the two year study in Alaska, has been carried out at the Institute of Physiology, Oslo University, with the aid of a grant from Norsk Polarinstitutt.

I am greatly indebted to Lt. Colonel A. I. Karstens, Commanding Officer, and Colonel J. Bollerud, formerly Commanding Officer of the Arctic Aeromedical Laboratory, as well as members of the staff of that Laboratory, for their interest and support in this study. I am also indebted to Professor Einar Langfeldt and Professor Fredrik Leegaard, Institute of Physiology, Oslo University, for their valuable support during the preparation of this paper.

Finally I wish to express my sincere gratitude to Norsk Polarinstitutt for granting the necessary funds to enable me to complete this work.

Institute of Physiology, Oslo, December 1953.

Kåre Rodahl.

Seasonal Blood Changes in the Eskimo.

BY

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1. Introduction.

Comparatively little information is available regarding the effects of cold environments on the blood in man. This problem is greatly complicated by the possible effects of race, sex, age, nutritional status, altitude and winter darkness, apart from temperature itself.

Mayer observed over 100 years ago that blood from a superficial vein was more red in the climate of Java than in Germany, and deduced on the basis of this observation that the production of heat and the process of oxidation must be less in torrid climates than in colder regions (Dill et al., 1940). Some of the fallacies in these interpretations have already been pointed out by Adolph (1926).

Petersen (quoted by Dill et al., 1940) has suggested that venous blood reflects changes in the weather, and he has presented a large body of data on the relation between the properties of blood and day-to-day variations in the weather.

Dill, Wilson, Hall and Robinson (1940) have examined the dependence of the properties of arterial blood on climate, weather and race in male adult whites and negroes at Boston, Nevada and Mississippi at various seasons of the year. They found that the properties of arterial blood do not show a clear cut dependence on climate or season. Blood from superficial veins, however, appeared to be more alkaline in hot weather. This they believed is partially dependent on increased blood flow through the skin. Negroes had about 8 per cent less hemoglobin than whites, and this difference they interpret as being a racial characteristic.

It is well established that change in environmental temperature alters blood volume (Conley and Nickerson, 1945, Spealman, Newton and Post, 1947, Bazett et al., 1940, Maxfield, Bazett and Chambers, 1941). During exposure to heat, blood volume increases at first by simple dilution and later by increase in the amount of circulating plasma protein. As a result, hemoglobin concentration declines by 5 to 10 per cent below values obtained at comfortable temperature. Opposite effects follow exposure to cold.

With regard to the influence of season on blood volume, the results are less clear. One might expect changes in blood volume associated with possible changes in hemoglobin concentration as a result of seasonal changes in environmental temperature. However, Post and Spealman (1948) found no clear cut seasonal variations in the total circulating hemoglobin determined by carbon monoxide in 4 men.

In the early arctic literature there are several references to the effect of the winter darkness on the blood, giving rise to what was commonly known as "Polar anemia" (Abs, 1932). Graffenberger found (according to Grimsgaard (1910)) reduced hemoglobin content of the blood during exposure to darkness. Blessing (1897), on the basis of monthly examinations, was unable to detect any cases of anemia among the crew during the drift of Fram, 1893—96, although they, for three consecutive years, endured winter darkness lasting 140—150 days.

Grimsgaard (1910), on the other hand, found a slight reduction in the hemoglobin values during the dark period of the year in 7 (4 adults and 3 children) persons in Northern Norway. In all his subjects the hemoglobin content was reduced during the dark period an average 4.10—5.05 per cent. He observed, as a rule, an increase of white blood cells during the winter, with a particular increase of lymphocytes.

Høygaard (1941) determined the hemoglobin values in Eskimos gathered on the hunting grounds in Southeast Greenland in the summer of 1937, when food conditions were unusually good. In addition, some winter observations were made on Eskimos settled in the Angmagssalik village. A few observations were also made during the period of food shortage in the winter at the trading post. He found that the mean hemoglobin values of 39 males and 58 females above 15 years of age living at the trading post were 110 per cent and 103 per cent respectively during the winter. In boys and girls below the age of 15 years, the values were around 101 per cent. When comparing the values for winter and summer, he found that the average winter values of primitive Eskimos were somewhat higher than the summer values. The difference was about 5 per cent in adults and 4 per cent in children, and he suggests that the higher winter values may possibly be due to slight degrees of hyperhemoglobinemia.

Below the age of 17 years Høygaard found lower hemoglobin values in boys than in girls. Above the age of 17 years the values are higher in males than in females. In males there was a rise in the hemoglobin concentration until it reached its maximum mean value about the age of 25 years. In females there was a slight decline in the hemoglobin values about the age of 17, and a rise towards the age of climacteric.

Isachsen (1911) and Odin (1937) found quite the opposite effects of the seasons in Europeans. Investigations by Lange (Lange and Palmer, 1948) indicate a slight increase in the number of erythrocytes from July to October.

In the Antarctic, several investigators have reported increased hemoglobin values during winter. Recently Wilson (1953) observed high hemoglobin values in members of the Norwegian—British—Swedish expedition 1949—1952. The hemoglobin content showed a marked decline during spring and summer. This drop he attributed to increased outdoor activity. The red cell counts remained unaltered, and the white cell counts were reduced by 25 per cent during their stay in the Antarctic.

In connection with studies on human acclimatization to cold in progress at the Arctic Aeromedical Laboratory, we had the occasion to examine the blood of 102 healthy Eskimos from four different localities in Alaska, representing different climatic conditions, living habits and diets. The first group at Barter Island on the north coast of Alaska live on a diet consisting of approximately 50 per cent sea mammals and fish and 50 per cent land mammals. The second group at Anaktuvuk Pass in the middle of the Brooks Range, 3000 feet above sea level, live almost exclusively on caribou meat. The third group at Kotzebue on the west coast of Alaska lives to a considerable extent on white man's food, and their living habits are very much affected by civilization. The fourth group at Gambell, St. Lawrence Island, live almost exclusively on sea mammals and especially on walrus meat. These four groups were examined both in the winter and in the summer. Thirty-six normal white men living in Alaska were examined during the four seasons of the year for comparison.

2. Methods.

a. *Collection of blood sample.* The blood was collected from the subject's finger with the use of an automatic blood lancet. The finger was cleaned with alcohol and then punctured with a firm quick stroke 4 mm deep, which was sufficient for the blood to flow immediately. The first drop was wiped off with dry gauze and a large drop was allowed to collect before touching a blood pipette.

b. *Hemoglobin content.* For the determination of the hemoglobin content the Sahli-hemoglobinometer was used. The calibrated tube was filled with N/10 hydrochloric acid to about the "20" mark. The pipette was then filled with blood to the 20 cubic mm mark. Any blood adhering to the outside of the pipette was carefully removed before the dilution was made. The pipette was carefully introduced into the calibrated tube and passed to the bottom into the acid. The blood was then slowly expelled, care being taken to form no bubbles. When all the blood had been expelled the pipette was rinsed twice with distilled water, the contents being expelled into the calibrated tube. After waiting for 5 minutes distilled water was added gradually until the shade agreed with that of the standard brown glass rod. The stirring rod was used for mixing the contents of the calibrated tube. The amount of hemoglobin was determined by the final volume in the calibrated tube and expressed in grams and in percentage, 14.5 grams equalling 100 per cent.

c. *Counting of blood cells.* For the counting of blood cells, the usual Thoma diluting pipettes were used, and the counting was made in the conventional manner, using the Buerker counting chamber without clamps.

d. *Differential count.* For the differential count blood smears were prepared in the usual manner. For differential white cell counts, Wright's stain was used.

e. *Volume of packed red cells.* For determining the volume of packed red cells the Wintrobe hematocrit tubes were used. Oxalated venous blood was placed in Wintrobe hematocrit tubes and centrifuged at 3000 revolutions per minute for half an hour.

3. Results.

From Table 1 it is observed that the hemoglobin content of the blood is about 10 per cent lower in Eskimo women than in Eskimo men. The erythrocyte counts are also lower in Eskimo women. The mean white cell counts are somewhat higher in Eskimo women. The differential counts show considerable individual variations, as is also the case with the hematocrit values. The mean hematocrit value, however, is higher in Eskimo men than in Eskimo women.

There appears to be no material difference between the hemoglobin values in Eskimo girls under 15 years of age and female Eskimos above the age of 15 years, while the hemoglobin values are higher in Eskimo men than in Eskimo boys under 15 years of age.

Table 3 shows the results of blood examinations of male Eskimos from the four different localities in Alaska. It is observed that there are no significant differences in the mean values for the four groups with respect to hemoglobin, red cell counts, white cell counts, differential counts or hematocrit.

When comparing the results in Eskimos with the results of blood examinations in 36 white men living in Alaska, examined during the different seasons of the year, summarized in Table 4, it is observed that the hemoglobin values are on an average approximately 7 per cent lower in Eskimo men than in white men of similar age. The hematocrit values are also lower in Eskimos. Very little difference was detected in the differential counts, while the total white counts were generally higher in white men than in Eskimo men.

As the result of a preliminary survey among 93 Eskimos from all four localities, it was found that the hemoglobin values appeared to be higher in the winter than in the summer. A more detailed study was

Table 1.

Hemoglobin, Blood Counts and Hematocrit in Male and in Female Eskimos, Separated into Two Age Groups.

	Number of subjects	Age, years	Hemoglobin		Red cell count, millions	White cell count	Total neutrophiles	Stabs	Metamyelocytes	Myelocytes	Lymphocytes	Monocytes	Eosinophiles	Basophiles	Hematocrit
			%	g											
Males															
Under 15 years of Age															
Mean:	4	8.0	77	11.2	4.005	6,140	41	1	-	-	50	3	2	1	45
Range:	-	(3—14)	(70—88)	(10.3—12.8)	(3.370—4.660)	(5,600—6,300)	(35—49)	(0—1)	-	-	(44—56)	(2—4)	(1—4)	(0—7)	(40—46)
Over 15 years of Age															
Mean:	63	28.7	84	12.3	4.680	6,900	50	1	-	-	42	4	2	1	49
Range:	-	(15—61)	(70—106)	(10.3—15.4)	(3.200—6.200)	(2,800—11,450)	(19—76)	(0—3)	-	-	(18—77)	(0—13)	(0—8)	(0—3)	(42—54)
Females															
Under 15 years of Age															
Mean:	5	8.8	77	11.2	3.860	6,600	45	1	-	-	42	8	2	1	45
Range:	-	(5—13)	(70—82)	(10.3—11.9)	(3.400—4.200)	(4,400—10,000)	(33—52)	(0—1)	-	-	(36—57)	(2—14)	(0—4)	(0—2)	(43—46)
Over 15 years of Age															
Mean:	30	28.9	76	11.0	4.198	7,760	48	1	-	-	46	3	1	1	44
Range:	-	(21—53)	(68—88)	(9.9—12.8)	(3.600—5.600)	(3,600—12,100)	(9—78)	(0—5)	-	-	(17—89)	(0—10)	(0—5)	(0—3)	(39—52)

T a b l e 2.

Seasonal Variations in Hemoglobin, Blood Counts and Hematocrit Values in Eskimos.

		Number of subjects	Age, years	Hemoglobin %	Hemoglobin g	Red cell count, millions	White cell count	Total neutrophiles	Stabs	Metamyelocytes	Myelocytes	Lymphocytes	Monocytes	Eosinophiles	Basophiles	Hematocrit
Eskimo Men																
W i n t e r	Mean:	10	24	86	12.5	4.648	6,540	54	2	-	-	38	5	1	1	49
	Range:		(15—36)	(80—104)	(11.5—15.0)	(3.200—6.200)	(4,100—7,400)	(27—74)	(0—4)	(0—1)	(0—0)	(18—64)	(0—8)	(0—4)	(0—4)	(46—54)
S u m m e r	Mean:	10	24	82	11.9	4.867	6,590	51	1	-	-	42	3	2	1	48
	Range:		(15—36)	(70—106)	(10.2—15.4)	(4.500—5.100)	(4,050—10,600)	(29—72)	(0—2)	(0—0)	(0—0)	(24—66)	(0—7)	(0—4)	(0—2)	(43—52)
Eskimo Women																
W i n t e r	Mean:	9	30	78	11.4	4.331	4,871	49	1	-	-	42	5	-	-	45
	Range:		(21—42)	(70—88)	(10.2—12.8)	(3.580—5.300)	(3,550—11,700)	(21—72)	(0—4)	(0—1)	(0—0)	(17—83)	(0—14)	(0—6)	(0—2)	(41—52)
S u m m e r	Mean:	9	30	73	10.7	4.266	7,094	45	1	-	-	53	1	1	-	45
	Range:		(21—53)	(68—80)	(10.0—11.6)	(3.690—4.900)	(3,650—9,250)	(26—62)	(0—4)	(0—0)	(0—4)	(33—70)	(0—3)	(0—6)	(0—2)	(39—51)

Table 3.

Mean Hemoglobin, Blood Counts, and Hematocrit in Male Eskimos at Four Different Localities in Alaska.

	Number of subjects	Age, years	Hemoglobin		Red cell count, millions	White cell count	Total neutrophiles	Stabs	Metamyelocytes	Myelocytes	Lymphocytes	Monocytes	Eosinophiles	Basophiles	Hematocrit
			%	g											
Barter Island															
Mean:	12	28.5	84	12.3	4.670	6,020	54	1	0	0	38	4	2	1	48
Range:		(15—61)	(80—106)	(11.7—15.4)	(3.200—6.200)	(4,050—7,350)	(29—76)	(0—4)	(0—1)	(0—1)	(18—66)	(1—9)	(0—3)	(0—4)	(45—52)
Anakutuvuk Pass															
Mean:	14	27.5	85	12.4	4.670	7,440	54	1	0	0	38	3	2	1	49
Range:		(20—47)	(70—104)	(10.3—15.2)	(4.200—5.700)	(4,400—11,300)	(43—70)	(0—2)	(0—0)	(0—0)	(24—58)	(0—7)	(0—3)	(0—4)	(46—54)
Kotzebue															
Mean:	14	31.0	83	12.2	4.570	7,830	52	1	0	0	38	5	2	1	50
Range:		(18—58)	(74—94)	(10.7—13.7)	(4.200—5.200)	(4,600—11,450)	(32—71)	(0—4)	(0—1)	(0—0)	(23—57)	(0—13)	(0—8)	(0—3)	(42—53)
Gambell															
Mean:	23	28.2	85	12.4	4.740	6,460	50	1	0	0	49	3	1	1	49
Range:		(19—59)	(74—95)	(10.7—13.8)	(4.100—5.900)	(2,800—11,300)	(19—72)	(0—4)	(0—0)	(0—0)	(22—77)	(0—4)	(0—4)	(0—3)	(43—54)

carried out in 10 Eskimo men and 9 Eskimo women, who were examined both during summer and winter (Table 2). It is observed that both in Eskimo men and women the hemoglobin values are somewhat higher in winter than in summer. This is in agreement with previous findings by Høygaard (1941). It should be noted, however, that the observed differences in hemoglobin values are small, 5 per cent for men and 6.5 per cent for women. Of all the 19 subjects examined both during winter and summer, the hemoglobin values were in 14 cases higher in the winter, in two cases there was no difference, and in three cases it was lower in the winter than in the summer.

The number of erythrocytes is no higher in winter than in summer. In Eskimo women there is a higher white cell count in the summer, and in both sexes there is an increased number of lymphocytes during the summer. Otherwise there are no material seasonal differences.

Similar seasonal differences are observed in white men living in Alaska (Table 4). Here the highest hemoglobin values were observed during midwinter (mean 13.8 g) and the lowest values in the middle of summer (mean 12.7 g). The mean hematocrit values were also highest in the winter.

4. Discussion.

Many of our subjects, both white and Eskimos, had hemoglobin and erythrocyte values which were considerably lower than the average figures accepted as standard values. The lower figures may be due to the method and the technique employed, or to physiological peculiarities. It should be noted, however, that the standard technique was employed and the working conditions were in all instances excellent. Well-equipped laboratories were established at each of the four Eskimo settlements. In addition, representative subjects of the Eskimos were examined for control purposes at our main laboratory at Ladd Field, where all white subjects were examined. Furthermore, examinations by different observers showed invariably similar results.

Lange and Palmer (1948) have pointed out that of the factors which may produce a change in the concentration of erythrocytes, the following points are of practical importance. For rapid change: copious intake of fluid, work and posture. For slow changes: pregnancy, season of year, and possibly altitude and age. In our subjects no large quantities of liquid were consumed prior to the examination, nor were the subjects engaged in any strenuous exercise. The same authors also maintain that the erythrocyte values are considerably less uniform when a scarificator is used for puncturing the skin than when a sharp knife is used. They also found that wiping off the first drop of blood that appears after the puncture leads to undesirable variations in the number of erythrocytes. These factors may possibly have influenced our results. On the other hand, according to the above-mentioned authors, finger blood comes close up

Table 4.

Hemoglobin, Blood Counts and Hematocrit in 36 White Men 18—27 Years Old Living in Alaska.

		Number of subjects	Hemoglobin		Red cell count, millions	White cell count	Total neutrophiles	Stabs	Lymphocytes	Monocytes	Eosinophiles	Basophiles	Hematocrit
			%	g									
Fall	Mean:	24	88	12.9	4.705	9,580	53	2	32	9	2	1	49
	Range:		(80—100)	(11.7—14.5)	(3.700—5.600)	(6,800—13,600)	(28—72)	(1—7)	(21—51)	(1—21)	(0—5)	(0—3)	(44—58)
Winter	Mean:	18	95	13.8	4.855	8,600	47	3	35	11	3	1	52
	Range:		(86—110)	(12.4—16.0)	(4.100—5.600)	(3,200—11,600)	(13—58)	(0—8)	(24—56)	(2—24)	(0—8)	(0—3)	(45—55)
Spring	Mean:	15	90	13.1	4.665	8,985	53	2	38	5	1	1	50
	Range:		(80—97)	(11.7—14.1)	(4.100—5.600)	(5,900—15,500)	(38—73)	(0—3)	(19—54)	(2—10)	(0—2)	(0—3)	(44—55)
Summer	Mean:	18	87	12 7	4.980	8,855	55	1	38	3	2	1	51
	Range:		(76—100)	(11.0—14.5)	(4.500—5.900)	(5,800—14,300)	(45—70)	(0—3)	(27—51)	(0—9)	(0—5)	(0—3)	(47—56)

Table 5.

Average Consumption in Male at Four Localities in Alaska.

	Calories	Protein, g	Fat, g	Carbohydrate, g	Calcium, mg	Phosphorus, mg	Iron, mg	Copper. mg	Vit. A, I. U.	Thiamine, mg	Riboflavin, mg	Nicotinic acid, mg	Vitamin C, mg
Barter Island													
Winter:	3800	160	164	418	980	1800	19	2.6	3445	1.2	1.6	23	22
Summer:	3700	157	176	380	930	2064	24	2.2	3388	2.0	2.0	34	34
Anaktuvuk Pass													
Summer:	4650	199	257	357	352	1912	46	3.9	289	2.0	3.0	39	3
Kotzebue													
Winter:	2780	140	114	297	860	1776	15	1.8	3686	0.9	1.6	19	54
Summer:	2600	138	92	285	815	1665	17	1.2	1125	4.0	2.0	25	36
Gambell													
Winter:	1970	128	75	200	500	1560	21	2.4	69576	1.0	3.0	31	23
Summer:	2200	113	98	214	254	1227	14	2.6	1786	1.0	2.0	20	26
Mean	3100	148	139	307	670	1715	22	2.4	11890	1.7	2.2	27	28

to the venous blood value, and does not show the great variations as is the case in ear blood.

In the present study, the counting of blood cells was performed in the usual manner. Lange and Palmer (1948) have shown that the unequal distribution of erythrocytes in the counting fields is systematic with increased concentration in the inner half of the field. They suggest that the counting should be made diagonally.

In our subjects we have observed a slight increase in hemoglobin during winter. Spealman et al. (1947) found increased concentration of hemoglobin during exposure to cold, and it is possible that this may, at least in part, explain the higher winter hemoglobin concentration in our subjects exposed to the arctic or subarctic environment in Alaska. During the period of the study, the highest temperature recorded during the summer was 90° F and the lowest —59° F during the winter. It should also be borne in mind that the observed differences may reflect changes associated with the process of acclimatization. It is well known that blood volume is increased in the warmth, decreased in the cold, and these changes are associated with changes in total circulating hemoglobin and total plasma protein. Bazett et al. (1940) have emphasized that during temperature changes, the changes in plasma volume develop more rapidly than those in the cells, and that, therefore, the initial changes in blood volume are consequently associated with temporary changes in the opposite direction in hemoglobin concentration and hematocrit.

Although it is well known that starvation may cause considerable changes in the composition of the blood, a restricted but sufficient diet, poor in fat and protein, seems to have only a slight effect upon the composition of the blood. In our Eskimos the diet was high in fat and protein, and there was no marked dietary difference between winter and summer, although the consumption of protein was higher during winter, but starvation never occurred during the entire period of the study.

It is not very likely that the observed differences in hemoglobin values are associated with iron deficiency, for in our subjects the iron intake was no higher in winter than in summer. The recommended daily dietary allowance for iron for a physically active man of 70 kg has been set to 12 mg by the National Research Council. In our white subjects the average daily iron intake was 15—28 mg, in Eskimos the average figures varied from 14 to 46, mean 22 mg (Table 5). These figures must be considered as minimum values, for Widdowson and McCance (1943) have pointed out that iron intakes often are a great deal higher than those calculated from food tables because of contamination from various cooking utensils.

Our values for the hemoglobin concentration as a whole are slightly less than the average hemoglobin concentrations reported for 20-year-old men in Great Britain (13.3 g as against 14.3 g, variations 11.8—16.8 g). On the other hand, the lower limits of the nineteen-twentieths of the distribution in a study of 3,029 persons in North Carolina was approximately 12 g for white men (Milan and Muench, quoted by Darby, 1951). According to these figures the hemoglobin values in our material are not likely to be associated with abnormality.

5. Summary and Conclusion.

Hemoglobin concentrations, blood counts and hematocrit values were recorded in 102 Eskimos and 36 whites during the different seasons in Alaska. The results were essentially the same in all four Eskimo groups examined.

The hemoglobin concentration of the blood was about 10 per cent lower in Eskimo women than in Eskimo men. The erythrocyte counts and hematocrit values were also lower in Eskimo women, while the white cell counts were higher.

The hemoglobin values were on an average approximately 7 per cent lower in Eskimo men than in white men of similar age. The hematocrit values were also lower in Eskimos.

Both in Eskimo men and women the hemoglobin values were somewhat higher in winter than in summer (5—6.5 per cent). Similar seasonal differences were observed in white men living in Alaska, where the highest hemoglobin values were observed during midwinter, and the lowest in the middle of summer.

6. Acknowledgments.

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Blood Sedimentation Rates in Eskimos.

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1. Introduction.

Sedimentation of red cells was known to physicians in ancient times (Ponder, 1951), but the modern concept of sedimentation as a physical phenomenon originated from the work of Fåhraeus (1921).

Generally speaking the factors influencing sedimentation rate include: the number of cells available for sinking, the tendency towards aggregation, and the physical or chemical composition of the plasma.

In considering the hydrodynamics of the sedimentation, Fåhraeus (1929) points out that the velocity of a spherical particle suspended in a fluid of less specific gravity than the particle itself is proportional to the difference between the specific gravity of that sphere and that of the fluid, inversely proportional to the viscosity of the fluid and directly proportional to the square of the radius of the sphere. Variation in the size of the red corpuscles has apparently no appreciable influence on the variations in the sinking velocity. On the other hand, the tendency to form aggregation of the red blood corpuscles is the predominant factor determining the sinking velocity. Experiments in which washed normal corpuscles have been suspended in pathological plasma and vice versa with measurements of the sinking velocity have shown that rapid sedimentation and strong aggregation are phenomena which in a very high degree are bound to the properties of the plasma rather than of blood corpuscles (Fåhraeus, 1929).

The settling rate is greater in plasma that has a greater viscosity. This introduces the factor of fibrinogen and globulin content of the plasma since these substances have a greater viscosity than serum albumin (Kracke, 1941).

When suspended in a pure fibrinogen solution the erythrocytes show a very marked tendency to aggregate and settle with extreme rapidity. When suspended in a pure serum globulin solution, aggregation and increased sedimentation are still very marked, but when suspended in a pure solution of serum albumin, on the other hand, no aggregation of the red corpuscles occurs and the sinking is very slow (Fåhraeus, 1929). Thus, Fåhraeus has found that there exists pronounced parallelism between the amount of fibrinogen or serum globulin and the sinking velocity of the red corpuscles.

It should also be noted that the lipids of the plasma as well as the proteins of the stroma of the erythrocytes have been considered to be of importance (Fåhraeus, 1929). Dilution of the cells with plasma increases the sinking velocity, oxygen increases and carbon dioxide decreases the sedimentation rate (Kracke, 1941). Best and Taylor (1950) state that the sedimentation rate is increased when the blood cholesterol concentration is increased.

In man the sedimentation rate varies according to age, sex, and in women it is altered during pregnancy. Fåhraeus (1929) found that the lowest figures are obtained in the new-born (average 0.5 mm). In adults, men generally show considerably lower figures than women, as a rule 1 to 3 mm as against 4 to 7 mm. Fåhraeus is of the opinion that figures such as 10 mm in men and 13 mm in women may be too high to be considered normal for perfectly healthy individuals. He states that a sinking velocity of 13 mm and above may be considered as a very marked reaction. In diseases such as sepsis and pneumonia the figures are regularly raised to about 100 mm or more. Ponder (1951) points out that a sedimentation rate of over 10 to 13 mm in one hour by the Westergren method is always to be regarded as abnormal except in pregnancy where the velocity increases from about 15 mm per hour in the second month to about 45 mm at term. He emphasizes that in the case of the infective state the sedimentation rate is best compared to temperature and leucocytosis, although it does not run parallel to either of them.

Abnormally high sedimentation rates have been found associated with chronic infectious diseases, such as tuberculosis and syphilis and acute infectious diseases: pneumonia, septicemia, endocarditis, exanthemata, and acute bronchitis; localized suppurations such as pelvic inflammatory disease, suppurative mastoditis and sinusitis, bronchiectasis and acute intoxications such as lead and arsenic poisoning. Apparently little or no increase in sedimentation rate has been found in simple catarrhal inflammations such as simple rhinitis, simple colitis, acute catarrhal appendicitis, chronic ulcerations such as gastric and duodenal ulcers. No increase in sedimentation rate has been observed in functional diseases; certain diseases of the nervous system, such as dementia praecox; focal infections such as abscess of teeth, diseased tonsils; metabolic diseases such as uncomplicated diabetes and essential hypertension; allergic diseases such as asthma and hay fever; most skin diseases, but is increased in skin tuberculosis, erythema nodosum, dermatis herpetiformis, and Hodgkin's disease with skin lesions (Ponder, 1951).

It is generally agreed that the sedimentation rate is a good index of the activity of a tubercular infection, and it is claimed that the sedimentation rate usually parallels the activity of the tubercular lesion.

Increases in the sedimentation rate have often been observed to run hand in hand with deflections of the polynuclear count and similar indicators of the presence of an infective state (Ponder, 1951).

Table 1.

Sedimentation Rates in Rats Given 10 γ Insulin Intraperitoneally.

Rat No.	Sex	Body weight, g	Prior to injection of insulin		1 hr. after injection		2 1/2 hrs. after injection	
			Blood sugar, mg %	Sed. rate, mm	Blood sugar, mg %	Sed. rate, mm	Blood sugar, mg %	Sed. rate, mm
1	♀	165	92	1.5	77	2.0	66	1.5
2	♀	210	95	2.0	57	1.5	75	2.0
3	♀	180	92	3.5	54	1.5	59	2.5
4	♀	175	90	1.5	52	1.5	74	2.0
5	♀	185	92	1.5	54	2.0	50	2.0
6	♀	200	95	1.5	47	1.0	74	1.5

Table 2.

Sedimentation Rates in Rabbits Given Varying Doses of Insulin.

Rabbit No.	Sex	Insulin dosage, mg	Prior to injection of insulin		1 hr. after injection		2 hrs. after injection	
			Blood sugar, mg %	Sed. rate, mm	Blood sugar, mg %	Sed. rate, mm	Blood sugar, mg %	Sed. rate, mm
1	♂	0.2	104	1.0	56	1.0	50*	1.0
2	♀	0.4	106	1.0	63	1.5	74	1.5
3	♀	0.6	101	1.5	48*	1.5	57	1.0
4	♂	0.6	110	1.0	68	1.0	72	1.5

* Convulsions.

Ponder (1951) quoting Kramer points out that an increase in the sedimentation rate so certainly indicates infection that the high incidence of rapid sedimentation in diabetes is attributed to latent infection. In hypoglycemia produced by insulin we have found no change in the sedimentation rate in rats and rabbits, as is evident from the experiments presented in Tables 1 and 2.

During a series of field studies in Alaska in 1950, it was observed that the blood sedimentation rates were markedly reduced in normal white men who were subject to strenuous field exercises while subsisting on restricted diets. No satisfactory explanation could be found for this phenomenon, and it was considered desirable to examine the effects of arctic environment on blood sedimentation rates in further detail in connection with extensive studies of the patho-physiology of the Alaskan Eskimos. The purpose of this paper is to report briefly some of the preliminary results of these studies.

2. Material and Method.

The data utilized comprise blood from 72 healthy Eskimos of both sexes, and 48 normal white men who had spent about a year in arctic or subarctic Alaska at the time of the commencement of the study. The Eskimos came from four different settlements in Alaska (Rodahl, 1952). These four Eskimo groups were examined both during winter and summer, and 36 of the white subjects were examined during the four seasons of the year.

The subjects, mostly between 20 and 40 years old, were carefully selected on the basis of complete and thorough medical examination, including medical histories, physical examination with x-ray examination of the chest and long bones, as well as routine urine and blood examination, in order to rule out any pathological conditions. Whenever possible, previous medical records were also examined. In addition, every subject with elevated body temperature at the time of the study was excluded, regardless of the cause. All the subjects included in this paper may therefore be considered as "normal" or "healthy" subjects.

For the determination of the sedimentation rates, venous blood was collected in small bottles containing the anticoagulant solution. An hematocrit tube was filled with blood and set in a vertical position in a specially constructed rack at room temperature of about 22° C. The results were measured in millimeters at the end of one hour.

3. Results.

The mean sedimentation rate in 51 adult male Eskimos (73 observations) was 15 mm, and 26 mm in 21 adult female Eskimos (30 observations). In males the majority of subjects had sedimentation rates between 5 and 20 mm, while in females the majority fell into the group 20—35 mm (figure 1).

From Table 3 it is observed that there is no material difference in the mean sedimentation rates in male or female Eskimos during winter and summer, the figure being slightly higher during winter than during summer. Eleven male and nine female Eskimos were examined during both seasons, and the results are given in Table 4. Again no seasonal difference is detected.

When considering the sedimentation rates in male Eskimos from the four different Eskimo settlements (Table 5), it is observed that the sedimentation rates were lowest in the primitive and isolated inland Eskimos at Anaktuvuk Pass, where the general health conditions were very good, and highest among the Bering Sea Eskimos at Gambell where there was a high incidence of infectious diseases, although none of the subjects examined were found to suffer from any complaints.

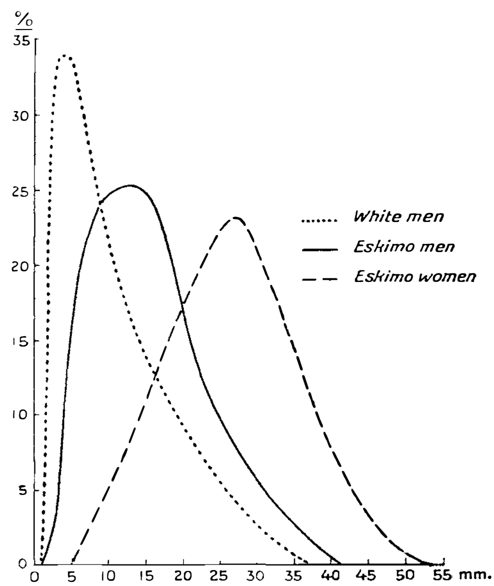

Fig. 1.

Table 3.

Showing Sedimentation Rates in Eskimos.

	Winter		Summer	
	No. of subj.	Sed. rate, mm	No. of subj.	Sed. rate, mm
Adult Male Eskimos	27	17	24	13
Adult Female Eskimos	19	27	11	24

Table 4.

Showing Sedimentation Rates in 11 Male and 9 Female Eskimos, Examined Both during Winter and Summer.

		Winter	Summer
Men	Mean:	11	11
	Range:	(4—20)	(3—32)
Women	Mean:	28	24
	Range:	(11—50)	(14—36)

Table 5.

Showing Sedimentation Rate in Male Eskimos from Four Different Settlements.

Barter Island	14 mm
Anaktuvuk Pass	9 „
Kotzebue	16 „
Gambell	20 „

Table 6.

Sedimentation Rates in 36 Adult White Men during the Four Seasons of the Year.

Fall	16 mm
Winter	8 "
Spring	7 "
Summer	6 "

Table 7.

Mean Sedimentation Rates in Normal White Men, Subsisting on 1000 Calories Daily during Strenuous Field Exercises.

	Before the experiment	During exp.	After exp.
Group 1. 5 men subsisting on a high meat diet	7	6	5
Group 2. 5 men subsisting on an all carbohydrate diet	9	5	4
Group 3. 2 men subsisting on a high meat diet with addition of carbohydrate	15	12	14

In the 36 normal white men the lowest sedimentation rates were observed during summer and the highest values during fall (Table 6).

In a separate experiment 12 normal white men were examined before and after a 10-day strenuous field exercise, while subsisting on 1000 calories daily, living in tents at temperatures ranging between —36° F and 12° F, and covering a distance of 10 miles per day on foot in snow through difficult terrain. The results are given in Table 7. It is evident that the marked reduction in the sedimentation rate which was observed in the preliminary experiment under similar conditions was not reproduced in this experiment although there is a tendency towards a slight reduction in the sedimentation rates in both the meat group and the carbohydrate group at the end of the field experiment.

4. Discussion.

Within the last 20 years the measurements of the sedimentation rate of red cells have been subject to many modifications. At present about 40 different methods or modifications are in use, or have been suggested. The situation with regard to the significance of the test has been summed up by Hambleton and Christianson as follows (quoted by Ponder, 1951): "The sedimentation test remains today essentially what it was when Fåhraeus introduced it in 1918, and all significant clinical data can be obtained by a single one-hour reading by the Westergren technique. Alleged improvements on the Westergren sedimentation method have been suggested and these appear theoretically correct, that is, correction for cell volume, use of heparin instead of citrate, and graphic methods for recording the results. Instead of making the test more valuable, these changes have had the reverse effect, and either lead to results of less clinical value, or make the test more tedious to perform or less easy to interpret without increasing its clinical value."

It is generally agreed that certain precautions should be observed in the performance of the test (Kracke, 1941, Ponder, 1951). It is important that the test is carried out immediately after withdrawal of the blood, for if the test is done some time after the sample is taken, this will, as a rule, result in reduced sedimentation rate. The sedimentation test should be carried out at room temperature, about 22° C; with increasing temperature there is an increase in sedimentation rate. The size of the sedimentation tube may be important, for the longer the tube, the greater is the sedimentation rate. All observers agree that precaution should be taken that the sedimentation tube is vertical, for the more inclined, the faster is the rate, and corrections should be made for cell volume since increased dilution means increased sedimentation rate.

In the present study the hematocrit tubes were used for the sedimentation test both in Eskimos and Whites. Since these tubes are smaller than the regular sedimentation tubes, the results would be expected to be lower than those obtained with the regular sedimentation tubes. The test was performed immediately after the withdrawal of the blood sample, and the temperature was maintained at 18—22° C, not in excess of 22° C. It thus appears that the observed difference in sedimentation rates between Eskimos and Whites is not due to factors pertaining to the technique, especially since the same technique was applied to both Eskimos and Whites.

On the basis of thorough medical examinations all subjects reported in this study were classified as normal individuals since no evidence of acute or chronic infections or any other conditions known to influence the sedimentation rate were detected. None of the females included in this study were pregnant.

None of the Eskimo subjects had elevated body temperatures at the time of the sedimentation test. In the majority of the Eskimos there was some reduction in the number of erythrocytes, which might possibly in part account for the observed increase in sedimentation rates, although corrections were made for cell volume in this study.

Increased cholesterol concentrations in the blood may give increased sedimentation rates. The blood cholesterol concentration was determined in some of the Eskimo subjects and found to be within the normal range

Table 8.

Oral Temperature, Blood Cholesterol, and Blood Counts in Eskimos and Whites during Winter and Summer.

		Oral temperature	Cholesterol mg %	Erythrocytes, millions	Total leucocytes	Neutrophiles	Lymphocytes	Monocytes	Eosinophiles	Basophiles
Eskimos										
Men	Winter:	97.6	197.3 (122—254)	4.680	6,900	50	42	4	2	1
	Summer:	97.6	„ „	4.867	6,590	51	42	3	2	1
Women	Winter:	98.4	211.0 (163—291)	4.331	4,871	49	42	5	1	0
	Summer:	98.4	„ „	4.266	7,094	45	53	1	1	0
Whites										
Men	Winter:	97.6		4.855	8,600	47	35	11	3	1
	Summer:	97.9		4.980	8,855	55	38	3	2	1

Table 9.

Serum Proteins in 16 Normal Adult Eskimos, 8 Males and 8 Females.

	Mean values	Range
Total serum proteins	7.12 g/100 ml	(6.37—8.25)
Albumin	3.48 g/100 ml	(2.68—4.35)
Globulin	3.55 g/100 ml	(3.34—4.97)
α_1 globulin	7.2 %	(2—13)
α_2 „	9.1 %	(1—15)
β „	14.9 %	(11—21)
γ „	19.5 %	(11—36)
Albumin/globulin ratio	0.89	(0.7—1.3)

(Table 8) so that this factor may be excluded as being of any significance. Nor was there any marked leucocytosis in the subjects studied which might be correlated with the increased sedimentation rates.

It is possible that changes in the serum proteins may at least in part account for the observed difference. In 16 of the Eskimo subjects the total serum proteins, as well as the albumin and globulin fractions were determined (Table 9). While the total serum proteins were within the normal range (average 7.12 g/100 ml), the mean albumin value was 3.48 g/100 ml (49.5 %) which is lower than the figures considered normal in Whites. The globulin values were 3.55 g per 100 ml (59.5 %) as against an average of about 2.5 g/100 ml in normal Whites. (Albritton, 1951.)

Fåhraeus (1929) has shown that there exists a pronounced parallelism between the amount of fibrinogen or serum globulin and sinking velocity of the red corpuscles. In 5 per cent solutions of the different proteins the serum albumin suspension of erythrocytes gave a sinking value of 1 mm after one hour, the serum globulin suspension: 50 mm in the same time, while corpuscles in the fibrinogen solution sank 110 mm in ten minutes (Fåhraeus, 1929).

In view of the ability of the increased serum globulin to cause a higher sinking velocity of the erythrocytes it would seem probable that the indicated increased serum globulin may explain the higher sedimentation rates observed in the Eskimos.

5. Summary and Conclusion.

Blood sedimentation rates were determined in 72 healthy Alaskan Eskimos of both sexes and in 48 normal white men during different seasons in Alaska. The mean sedimentation rates in adult male Eskimos was 15 mm at the end of one hour, and 26 mm in adult female Eskimos, as against approximately 9 mm in normal white men. No significant seasonal variation in the sedimentation rates was detected in the Eskimos. In the male Eskimos the sedimentation rates were lowest in the most primitive and isolated inland Eskimos at Anaktuvuk Pass, and highest in the Bering Sea Eskimos. In Whites the sedimentation rate was highest in the fall, and a tendency towards slight reduction in the sedimentation rates during strenuous field exercises on restricted diets was observed in some cases.

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Prothrombin Content of the Blood in Man Exposed to Cold Environments.

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1. Introduction.

Svihla et al. (1952) have shown that there is a reduction in the amount of prothrombin in the blood of squirrels during hibernation. This change has been interpreted as a protective mechanism to prevent the formation of blood clots in the dormant state.

In view of this seasonal change in prothrombin levels in animals, it would be of interest to examine prothrombin levels in man exposed to the arctic environments. During a twelve-month period, 1950—51, prothrombin levels were estimated in Eskimos from various settlements in Alaska, as well as in normal Whites living in the same area during the different seasons of the year. The purpose of this paper is to report briefly the main results from this study.

2. Material and Methods.

A total of 50 healthy Eskimo men and 27 Eskimo women were examined, and of these, 13 were studied both during winter and summer. For comparison 36 normal white men were examined during the four seasons of the year. The subjects were carefully selected on the basis of complete medical and laboratory examinations in order to rule out any pathological conditions. The subjects reported here may therefore be considered as normal, healthy individuals.

For the estimation of prothrombin, the one-stage method of Owren (Owren & Aas, 1951) was used, which determines the combined effects of prothrombin and proconvertin. The blood sample was collected with one part (0.5 ml) 2 % potassium oxalate monohydrate solution to 9 parts blood (4.5 ml). After centrifugation a dilution of 1 part oxalate plasma (0.2 ml) and 9 part veronal buffer (1.8 ml) was made (Owren, 1949). 0.20 ml prothrombin-free and proconvertin-free oxplasma was mixed in a small test tube together with 0.20 ml plasma dilution and 0.20 ml thromboplastin solution. The mixture was placed in a water bath at 37° C for 5 minutes, after which 0.20 ml calcium chloride solution was added for optimal recalcification, and the clotting time was determined by stop watch. In each case duplicate samples were examined. The prothrombin-free ox-plasma and the thromboplastin were prepared in Professor Owren's laboratory and flown to Alaska. Both the ox-plasma and the thromboplastin were stored in a deep-freeze in small bottles containing a quantity sufficient for a series of determinations. In this way repeated thawing and refreezing was avoided.

3. Results and Comments.

In adult male Eskimos (50 subjects) the mean prothrombin value was 58 %, and in adult female Eskimos (27 subjects) it was 62 %. From Table 1 it is observed that both in Eskimo men and women the mean values were considerably higher in the winter than in the summer. Thirteen of the Eskimo subjects were examined both during winter and summer. In these subjects the mean value was 68 % in winter and 47 % in summer.

Table 2 shows the results from normal white men. No marked seasonal variation in the prothrombin content of the blood was observed, although the mean figures for spring and summer are lower than those for fall and winter. When comparing these figures with the corresponding figures for male Eskimos, it is observed that while the winter values are only slightly lower in Eskimos than in Whites, the summer values are considerably lower in the Eskimos.

The normal correlation graph used to determine the prothrombin percentage was prepared in Owren's laboratory for the batch of reagents prior to shipment to Alaska. The possibility of changes occurring during transport and subsequent storage cannot be excluded, which might explain the low prothrombin values obtained in Alaska. This, however, would not influence the relative prothrombin values in Eskimos and Whites obtained simultaneously in Alaska by the same investigator, using the same reagents and identical technique.

In this connection it may be of interest to note that the prothrombin time was determined by Quick's method in some of our subjects: In a total of 28 Eskimos the mean prothrombin time was 33 seconds, as

Table 1.

Mean Prothrombin Blood Levels of Eskimos in Alaska.

		Winter		Summer	
		No. of observations	% Prothrombin	No. of observations	% Prothrombin
Eskimo Men					
	Mean:	39	64 %	15	45 %
	Range:	-	(39—100)	-	(34—68)
Eskimo Women					
	Mean:	19	70 %	8	51 %
	Range:	-	(46—105)	-	(34—71)

Table 2.

Mean Prothrombin Content of Plasma from 36 Normal White Men, Examined during the Four Seasons in Alaska.

Season	% Prothrombin	Range
Fall	76	44—106
Winter	76	55— 92
Spring	60	45—101
Summer	68	50— 95

against 19 seconds in 23 Whites. However, these determinations were made by various investigators during different seasons of the year.

These preliminary investigations emphasize the need for further detailed studies of the prothrombin and proconvertin contents of the blood in man exposed to cold environments.

4. Summary.

During a 12-month period, 1950—51, prothrombin levels were estimated in 77 Eskimos from various settlements in Alaska, as well as in 36 normal Whites living in the same area, during the different seasons of the year, by Owren's one-stage method. In adult Eskimos the mean prothrombin content of the blood was 58—62 %. In adult white males, the mean value was about 70 %. Both in Eskimo men and women the mean values were considerably higher in the winter than in the summer, while in the Whites men no marked seasonal variations were observed, although the mean figures for spring and summer were somewhat lower than those for fall and winter.

5. Acknowledgments.

The author is greatly indebted to Professor P. A. Owren and Dr. K. Aas, Department of Medicine, the University Clinic, Oslo, who have kindly furnished prothrombin-free ox-plasma and thromboplastin for these investigations, and have greatly aided this study by offering valuable advice and criticism.

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Preliminary Survey of Dietary Intakes and Blood Levels of Cholesterol and the Occurrence of Cardiovascular Disease in the Eskimo.

BY

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1. Introduction.

Since the role of certain lipids, especially cholesterol, in the genesis of atherosclerosis, was first recognized (Aschoff, 1907) considerable efforts have been made to relate total cholesterol, cholesterol/phospholipid ratio, beta lipoproteins, and the fraction of cholesterol in the beta lipoproteins, and a number of other variables, to the development of atherosclerosis (Lewis and Page, 1950; Morrison et al., 1950; Katz and Stamler, 1953; Keys, 1953-a).

It is generally considered that the concentration of total cholesterol in blood serum bears an important relationship to the development of atherosclerosis and its sequela (Keys, 1953-a). It also appears to be well established that the total cholesterol concentration in the serum of men is substantially independent of the dietary cholesterol intake over the whole range of possible human diets (Keys, 1953-b). In an extensive review of the subject Keys (1953-a) concludes that the total cholesterol concentration in serum changes directly with changes in the total fat content of the diet, and that both vegetable and animal fats are effective in evoking the serum response. Keys (1953-b) observed no important influence of dietary fat levels on serum cholesterol in men from the age of 18 to the early thirties, but there was an increasingly marked effect from the early thirties through middle age. Fifty-year old men on high fat diet have a mean serum cholesterol concentration some 50 mg per 100 ml higher than men of the same age on diets where the dietary fats provide 20 to 25 per cent of the total calories.

Gofman et al. (1950) have recently proposed a technique involving ultra-centrifugal flotation of giant lipoprotein molecules of cholesterol-protein conjugate of the so-called S_f 10—20 class,[1] as correlating positively with the extent of atherosclerosis. Later on, Jones et al. (1951) have reported even better results with the S_f 12—20 measurement.

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[1] Gofman and collaborators speak of flotation instead of using the term negative sedimentation in referring to molecules that move against a centrifugal field. A molecule described as having a flotation rate of 20 S units (S = Svedberg unit; 1 S = 10^{-13} cm/sec/dyne/g) is referred to as a molecule of the S_f 20 class, etc.

In his critical review of the available evidence, Keys (1953-a) concludes that an important relationship exists between the concentrations of the "giant molecules" (S_f 10—20, S_f 12—20) and the development of atherosclerosis, similar to that already observed for the concentration of total cholesterol in the blood. Measurements of total cholesterol and of S_f 12—20 particles in the serum afford highly significant differentiation between groups of men who are clinically healthy, and groups of men who have or are likely to develop coronary heart disease. In this regard there is, according to Keys, no important difference between the cholesterol and the S_f 12—20 measurements, particularly with men before old age. Keys states, however, that these measurements of total cholesterol or of S_f 12—20 concentrations in the serum, have very little practical value for individual diagnosis or prognosis, the index of forecasting efficiency being in the order of 20 per cent.

Atherosclerosis is generally considered to be one of the major diseases of this era and its consequences are responsible for more deaths and disability than any other single disease (Katz and Stamler, 1953). In spite of intensive research there is still no agreement regarding the sequence of pathogenetic events, etiology or treatment of atherosclerosis. As Katz and Stamler (1953) have emphasized, the key task of research in this field is to deepen our knowledge of the interrelationship between altered lipid metabolism and atherogenesis, "for atherogenesis is consequent upon an alteration in lipid metabolism".

Katz and Stamler (1953) point out that the differences which exist among peoples in incidence and severity of atherosclerosis tend to correlate with culturally-conditioned variations in nutrition and diet, rather than with racial, climatic or other factors. Rosenthal (1934) states, on the basis of the analysis of 28 reports up to 1934, that: "where a high protein diet is consumed, which naturally contains small quantities of cholesterol, but where the neutral fat intake is low, atherosclerosis is not prevalent".

The Eskimo race is generally believed to have a low incidence of cardiovascular disease (Wilber and Levine, 1950), although their diet is apparently high in fat and cholesterol. In view of this it would be of considerable interest to make these conditions in the Eskimo subject to a systematical study, since it is thus conceivable that the Eskimo may serve to throw light on this complex problem.

In accordance with this, systematic studies of this nature were initiated in connection with extensive studies of the patho-physiology of the Eskimo during a two-year period in Alaska 1950—1952.

The purpose of this paper is to present the preliminary results of an initial survey of cholesterol in some common Eskimo foods, and the results of blood studies in a consecutive series of 16 healthy Eskimo subjects, in connection with a discussion of our present knowledge regarding the occurrence of atherosclerosis in the Eskimo. Further extended studies are in progress, including comparative studies among different groups of Eskimos representing different racial purities, different diets, living habits and showing varying degrees of the effects of civilization. These studies will be subject to later publications.

2. Material and Methods.

The mean age of the 16 Eskimos was 35 years. Forty milliliters of blood were drawn from each subject who was in a post-absorptive state. The blood was allowed to clot at room temperature and then centrifuged. The serum was decanted and stored in the refrigerator at 4° C until the analysis could take place.

The serum cholesterol was determined by the method of Bloor (1916) as recorded in Hepler's manual (Hepler, 1950), and the S_f 12—20 serum lipoproteins (CPC) were estimated by the ultracentrifugal procedure by the cardiovascular research group under the direction of L. J. Milch at the USAF School of Aviation Medicine, as described by Redmond, et al. (1952).

The total cholesterol contents of the Eskimo foods were determined by the method of Schoenheimer and Sperry (Schoenheimer and Sperry, 1934; Sperry and Brand, 1943).

For the purpose of another investigation the water content and the contents of fat and protein were determined in the same samples by the standard technique. Since the majority of these native foods have not been examined previously, the mentioned data are included in this paper.

3. Results.

The results of analyses of Eskimo foods are presented in Table 1. On the basis of nutritional surveys with individual food weighings in different families from four Eskimo settlements in Alaska and the above-mentioned results of cholesterol determinations in Eskimo foods, supplemented by figures available for the cholesterol content of non-Eskimo foods (Okey, 1945; Pihl, 1952), the cholesterol intake of Eskimos has been estimated (Tables 2, 3). From these calculations it is observed that the mean caloric consumption of the 45 adult male and female Eskimos was about 2,700 calories, the fat consumption was 105 g and the mean cholesterol intake was roughly 340 mg daily, varying from 150 mg to 700 mg per day. It should be noted that these cholesterol figures may be considered as minimum values because several of the food items ingested could not be included in the calculation since the cholesterol content was unknown. It may also be noted that the cholesterol intake varies greatly from one Eskimo group to another, depending on the different dietary habits. Thus, it was observed that among the

Table 1.

Showing the Results of Analyses of Eskimo Foods.

Organ	Location	Date	Water %	Fat %	Protein %	Cholesterol mg 100 g
Ringed Seal						
Meat, raw	Kotzebue	Oct. 1951	45.4	0.9	65.1	104
„ „	Barter Isl.	„ „	69.5	3.5	21.3	79
„ boiled	Gambell	Feb. 1952	57.3	7.6	21.2	140
Blubber, raw	Kotzebue	July 1951	4.1	86.8	3.1	56
Blubber oil	„	Oct. 1951	0.1	99.7	5.7	9
Liver...............	„	„ „	64.4	2.5	12.1	186
Heart	„	„ „	74.1	1.0	17.5	117
Bearded Seal						
Meat, raw	Kotzebue	„ „	68.2	0.8	25.4	152
„	Barter Isl.	„ „	74.8	1.1	23.0	44
„ dried, raw	Kotzebue	July 1951	23.9	15.0	59.2	43
„ salted, raw						
a) fat	Gambell	Sept. 1951	9.1	90.5	0.0	} 49
b) muscle ...	„	„ „	61.7	5.2	25.0	
Blubber, raw	Kotzebue	July 1951	5.3	86.2	0 0	27
Liver, raw	Gambell	Feb. 1952	68.8	4.6	10.9	152
„ „	„	Sept. 1951	68.2	2.4	16.5	410
Walrus						
Skin w fat, raw						
a) hide	Gambell	Sept. 1951	47.6	7.5	26.6	} 121
b) fat	„	„ „	12.4	72.3	2.7	
Skin boiled w/blubber	„	Feb. 1952	12.6	78.8	17.5	84
Meat, boiled	„	„ „	59.6	18.9	20.8	96
Liver, raw	„	March 1951	65.5	2.5	13.0	182
White Whale						
Muktuk in oil						
a) skin	Kotzebue	July 1951	59.9	9.9	23.3	} 127
b) subc. fat ..	„	„ „	7.5	83.5	0.0	
Muktuk, raw						
a) skin	Nome	Oct. 1951	54.7	4.9	17.3	} 145
b) subc. fat ..	„	„ „	9.6	87.7	0.0	
Whale oil...........	Gambell	Sept. 1951	0.2	98.1	0.0	10
Polar Bear						
Meat	Barter Isl.	Oct. 1951	63.7	15.9	22.0	55
Mountain Sheep						
Liver, raw	Anakt. Pass	July 1951	16.6	8.7	57.0	415
Reindeer						
Meat, lean	Kotzebue	Oct. 1951	76.9	0.8	19.0	83
Caribou						
Meat, ...	Barter Isl.	Oct. 1951	73.7	1.9	20.2	75
„ frozen	Anakt. Pass	Nov. 1952	66.4	3.0	37.9	171
„ brisket	„	March 1952	65.7	5.1	29.8	159
„ head, boiled	„	„ „	66.3	4.3	40.4	139
„ jawbone, boiled	„	„ „	61.0	7.5	36.3	63
„ ribs, roast						
a) muscle ...	„	„ „	52.6	5.0	33.7	} 92
b) fat	„	„ „	12.1	77.8	0 0	
„ ribs, boiled	„	„ „	67.5	5.1	26.8	77
„ backbone, boiled	„	„ „	69.3	3.6	37.2	91

Table 1 (cont.)

Organ	Location	Date	Water %	Fat %	Protein %	Cholesterol mg/100 g
Caribou (cont.)						
Tongue, boiled	Anakt. Pass	March 1952	22.9	45.5	20.9	123
Brain, boiled	"	" "	27.2	25.5	54.6	836
Soup (meat+rice)	"	" "	38.9	5.3	51.2	46
" w. bones	"	" "	90.5	8.4	0.0	40
Gravy (flour+fat+meat)	"	" "	59.4	31.1	0.0	74
Fat, from boiled meat .	"	" "	3.2	95.5	0.0	118
" fried w meat	"	" "	7.3	88.4	26.8	114
" from intestines. .	"	" "	7.8	88.9	0.0	86
" raw	"	" "	9.4	87.5	0.0	66
" marrow, boiled . .	"	" "	0.3	94.6	0.0	67
" " raw	"	" "	19.3	74.4	0.0	102
Ptarmigan						
Meat, raw	Barter Isl.	Oct. 1951	70.4	1.2	28.5	218
" frozen	Kotzebue	" "	72.0	0.8	21.3	70
Goose						
Meat, salted	Gambell	Sept. 1951	57.1	21.5	19.7	72
Duck						
Meat	Barter Isl.	Oct. 1951	69.9	4.0	17.8	72
Cormorant						
Meat	Gambell	Sept. 1951	71.8	1.0	33.7	141
Seagull						
Meat	Gambell	Sept. 1951	62.0	11.7	22.6	118
Salmon						
Muscle, dried	Kotzebue	Oct. 1951	16.1	13.6	69.0	141
Trout						
Muscle, stored	Barter Isl.	Oct. 1951	69.8	4.1	19.4	48
Rainbow, muscle, raw	Gambell	Sept. 1951	73.0	2.1	13.7	105
White Fish						
Cross section	Kotzebue	Oct. 1951	76.6	1.2	23.8	47
Muscle, stored	Barter Isl.	" "	71.1	6.0	16.8	60
" dried	Kotzebue	" "	19.2	2.8	74.2	131
Tom Cod						
Cross section, fresh . .	Kotzebue	Oct. 1951	78.0	0.6	22.3	59
Sheefish						
w/o skin, frozen	Kotzebue	Oct. 1951	78.9	3.1	10.8	39
Pike (Pickerel)						
Dried	Kotzebue	Oct. 1951	18.8	1.5	70.5	178
Greens						
Native Greens, fresh, 1.	Gambell	Sept. 1951	92.8	0.4	0.0	20
" " " 2.	"	" "	79.0	1.0	7.1	7
" " " 3.	"	March 1951	90.5	0.8	5.0	21
" " " 4.	"	" "	90.9	0.8	6.1	24
" " " 5.	"	" "	90.3	0.9	4.5	17
" " " 6.	Kotzebue	Dec. 1950	85.3	0.6	4.8	56

Table 2.

Estimated Cholesterol Consumption in Mg per Day per Person from Different Foods in 45 Eskimo Subjects.

Food item	Cholesterol intake, mg per day	Food item	Cholesterol intake, mg per day
Meat and Meat Products:			
Muktuk	24.5	Ground squirrel meat	3.3
Frankfurters, boiled	0.3	Seal blubber	0.6
Meat patty	1.1	Corned beef	1.8
Ptarmigan soup	2.4	Spam	0.8
Ptarmigan meat	6.2	Oogruk in oil	1.5
Beef, roast	1.4	Whale heart	1.0
Caribou meat	23.0	Flippers, Narwhale	3.7
Gravy	5.6		
Bacon	0.8	*Fish and Fish Products:*	
Hamburger steak	2.4	Salmon, boiled	8.9
Caribou soup	29.0	Sheefish	4.1
Chicken	0.9	Tuna fish	2.6
Meat hash	1.6	White fish, boiled	10.1
Muktuk soup	0.6	White fish, frozen	24.2
Seal soup	0.6	Fish scalp, boiled	1.8
Seal liver	12.2	Salmon, dried	0.2
Seal meat, uncooked	1.5	Tom cod, frozen	1.1
Walrus meat, boiled	14.3	Trout	0.8
Walrus blubber	2.1	Grayling, boiled	0.8
Lard	0.4	Fish oil	2.9
Seal oil	0.9	Fish soup	0.5
Ham, fried	0.8		
Soup, Scotch broth	19.3	*Milk and Milk Products:*	
Ducks, boiled	0.6	Milk, evaporated	3.4
Seal meat, boiled	34.4	Butter	20.5
Walrus liver	3.2	Cheese, American	3.9
Whale oil	0.5		
Bird meat, boiled	6.2	*Miscellaneous:*	
Turkey	0.6	Margarine	5.1
Sheep meat, boiled	24.0	Eggs	9.0
Bone fat	1.8	Hot cakes, sourdough	2.2
Fat from intestines	1.6	Raisin pie	0.9
Sheep kidney, boiled	2.7	Apple pie	0.2
		Total cholesterol consumption (mg per day)	343.4

inland Eskimos, the Nunamiuts at Anaktuvuk Pass, some of the men consumed as much as 70 grams or more of boiled brain from mountain sheep in a single evening meal yielding almost 600 mg cholesterol from this food item alone.

It is thus evident that some Eskimos have fairly high cholesterol intakes compared with healthy American white men, although the mean intake for the 45 Eskimos studied is in the order of 2.5 g per week (varying from 1 to 5 g).This corresponds to the group of moderate habitual cholesterol intakes reported for normal American men (Keys, 1949) while in the Inland Eskimos the mean figure is in the order of 4 g chol-

Table 3.

Estimated Consumption of Calories, Fat and Cholesterol per Day per Individual in 45 Eskimo Subjects.

Subjects	Calories per day	Fat g per day	Cholesterol mg per day
Charley Slwooko (1950)	2 217	98.3	552
Charley Slwooko (1951)	2 660	65.5	538
Amy Slwooko	2 458	87.4	373
Joseph Slwooko	2 650	83.9	469
Ellen Slwooko	2 679	172.9	381
Lilly Gregory	2 426	129.8	415
George Akootchook	3 842	53.2	553
Maggi Akootchook	1 841	179.1	152
Rhoda Nageak	2 890	167.1	432
Mary Akootchook	2 587	130.2	490
Harry Mitchell	2 753	12.5	317
Delbert Mitchell	3 115	85.6	259
Vivian Iyakitan	2 848	20.1	233
Daniel Iyakitan	2 875	22.1	308
Belle Sours (1950)	2 597	80.5	600
Belle Sours (1951)	2 461	91.3	253
Mary Goodwin (1950)	2 699	72.6	282
Mary Goodwin (1951)	2 847	109.2	286
Elisabeth Driggs	2 334	63.5	168
Evelyn Barr	3 312	175.3	240
Lydia Norton	2 170	119.4	316
Bessie Barr	2 484	108.6	364
Homer Mekiana	4 658	259.8	650
Doris Mekiana	3 432	170.9	363
Alyne Slwooko (1950)	1 145	38.1	226
Alyne Slwooko (1951)	2 541	53.5	225
Andrew Akootchook	2 711	115.5	301
Elisabeth Akootchook	2 272	138.3	485
Perry Akootchook	3 585	153.5	388
Vincent Nageak	2 383	160.3	422
Isaac Akootchook	3 114	176.3	699
Mabel Mitchell	2 661	77.5	186
Vera Skin	2 494	79.1	160
Lewis Iyakitan	2 939	22.1	268
Lane Iyakitan	2 907	22.1	267
Clara Iyakitan	2 464	19.6	265
Willie Goodwin (1950)	2 431	106.1	408
Willie Goodwin (1951)	2 709	109.6	360
Terence Driggs	2 929	96.5	168
Marion Sours	2 472	107.0	281
Ronald Barr	2 346	129.9	231
Charley Norton	2 831	143.1	281
Charley Barr	2 851	97.7	172
Mabel Analoak	2 926	134.7	239
Rebecca Mekiana	4 087	214.7	530
Mean	2 747	105.6	343

esterol per week, which corresponds to the group of highest habitual cholesterol intakes for normal American men, reported by Keys (1949).

Keys (1950) has estimated that the American diet varies with regard to cholesterol content from a low of 200—300 mg daily to 700—800 mg,

Table 4.

S_f 12—20 Lipoproteins and Total Cholesterol in the Sera of Alaskan Eskimos.

Subject	Sf 12—20 lipoproteins mg/100 ml	Serum cholesterol mg/100 ml
L. Nelson	0	291
W. Goodwin	12	122
M. Goodwin	24	203
C. Jones	14	152
B. Sours	24	224
Z. Hugo	20	192
B. Ahgook	32	203
A. Morry....	50	264
I. Hugo	4	186
M. Maptegak	36	254
J. Slwooko	42	195
V. Iyakitan	0	208
H. Silook	0	162
D. Harry	16	208
B. Slwooko	0	225
G. Slwooko............	50	163
Mean	20	203

depending on the food consumed. Gubner and Ungerleider (1949) have given the figure 200—360 mg for daily cholesterol intake on a mixed diet.

It thus appears that the estimated mean figures for cholesterol intakes in Eskimos may be comparable to those of Whites on a mixed diet.

The average figure for the daily fat consumption in the 45 Eskimo subjects reported here was only about 105 g (37 % of the calories), while in a larger survey the average daily fat consumption in Alaskan Eskimos was 139 g (40 % of the calories). In normal white men living in Alaska the fat consumed represented 37.5 % of the calories ingested.

In the Eskimo subjects the mean serum cholesterol concentration was 203 mg per 100 ml (Table 4) which is about the same as is found in normal Whites. Thus L. J. Milch (personal communications) found an average level of 207 mg cholesterol per 100 ml serum in Whites 30—35 years old.

On the other hand, the Eskimo serum concentration of S_f 12—20 lipoproteins was 20 mg/100 ml as against 28 mg/100 ml in Whites of similar age, observed by Milch (personal communications). For Whites under 25 years of age Milch found 24 mg/100 ml, and for Whites 40—45 years of age 38 mg/100 ml.

4. Discussion.

Since hypertension in man has been stated to be typically associated with increased incidence and severity of atherosclerosis (Katz and Stamler, 1953), it would be of interest to compare the incidence of hypertension in Eskimos with that of Whites although the interrelationship between hypertension and atherosclerosis is by no means clear. In a survey of 104 Alaskan Eskimos the author found that both the systolic and diastolic blood pressures were lower in Eskimos than in Whites of corresponding age. Eighty per cent of the recorded systolic blood pressures were below 116 mm Hg. and no systolic blood pressure higher than 162 mm was ever recorded in our "normal" Eskimo subjects. In a series of 117 Eskimo patients, only one of the patients had systolic blood pressure above 145 mm (a 60-year old woman having a blood pressure of 200/80 mm) (Rodahl, 1954). It may be noted in this connection that Alexander (1949) found hypertension to be practically non-existent among Aleuts, and his electrocardiographic and clinical examination of 296 Aleuts, including 23 above the age of 60, revealed almost no cardiovascular disease.

Gofman et al. (1950) have found that some hypertensives show elevated plasma concentrations of S_f 10—20 lipoproteins even if the blood cholesterol concentration is normal, although these changes in the "giant molecule" levels are not correlated with the degree of hypertension.

Very little is known regarding the plasma lipids in Eskimos, and the plasma lipid studies in Eskimos so far reported have yielded inconsistent data. This may not be surprising when considering the wide range of conditions, dietary and otherwise, encountered in the different groups of Eskimos. Corcoran and Rabinowitch (1937) who studied two groups of Canadian Eskimos, one group subsisting on a meat diet and one group subsisting on a mixed diet, found in both groups lower concentrations of plasma lipids and of cholesterol than the normal values for Whites, and the meat group had slightly higher plasma lipid levels than the group on a mixed diet. In this connection it may be noted that serum cholesterol in Whites is decreased in severe caloric undernutrition (Keys, 1953-b). Periods of semi-starvation may occur among the Eskimos, which thus may affect the blood lipid levels. Sinclair et al. (1949) have reported plasma lipid findings in the Canadian Eskimos that are similar to the figures considered normal in Americans. Wilber and Levine (1950) found moderately elevated plasma lipid levels of Alaskan Eskimos. It may also be noted that Alexander (1949) found mean plasma cholesterol levels of 176—197 mg/100 ml in two groups of Aleuts.

In view of the small number of Eskimos examined in the present study no definite conclusion can be drawn from this limited material.

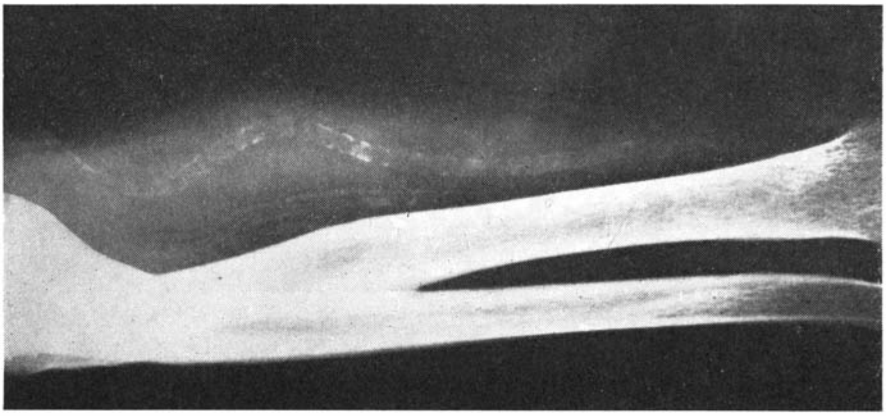

Fig. 1. Arteriosclerosis of arteria ulnaris in 61 year old male Barter Island Eskimo (A. Akootchook).

These preliminary investigations indicate, however, that while some Eskimos, such as the Nunamiuts, may have very high cholesterol intakes, the average figures for dietary cholesterol and fat for the four Eskimo groups examined are comparable to those of the average American man; their blood cholesterol levels are the same, while the S_f 12—20 lipoproteins (Gofman fraction) were lower in concentration than Whites of corresponding age. If it were convincingly demonstrated that the Eskimos in reality have a lower incidence of cardiovascular disease than Whites, it would appear that these findings support Gofman's postulates that the high concentration of the cholesterol-bearing protein molecules are associated with atheroclerosis.

It should be noted, however, that very little exact information is available regarding the occurrence of arteriosclerosis in Eskimos. None of the 16 Eskimos analyzed here showed any evidence of arteriosclerosis by clinical or roentgenological examination, and cardiovascular disease was extremely rare among the large number of Eskimo patients examined by the author during a two-year period in Alaska. Similarly, Dr. Paul Haggland, who has operated on a large number of Eskimos in Alaska during the last 15 years, has never seen arteriosclerosis or atherosclerosis in Eskimos (personal communications). He had the occasion to perform autopsy on one female and two male Eskimos, aged 60—65 years, and found no arteriosclerosis. Dr. Earl Albrecht, Territory Commissioner of Health, states that arteriosclerosis is rare in Eskimos, based on clinical evidence (personal communications).

Bertelsen (1940) is, on the other hand, of the opinion that arteriosclerosis is fairly common in Greenland, particularly if one considers the average span of life for the Greenland Eskimos. Høygaard (1941) writes

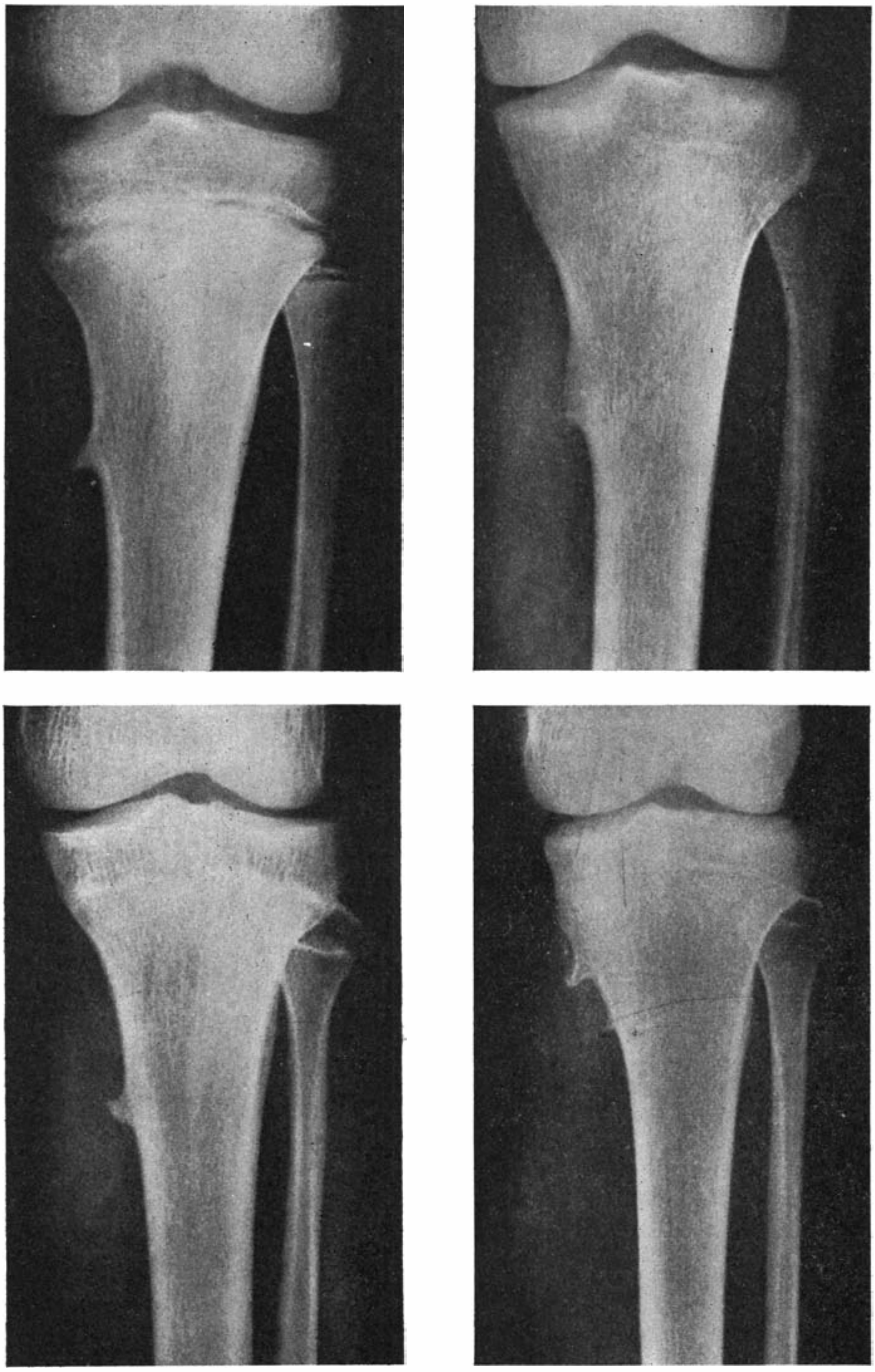

Fig. 2. Cartilaginous exostoses of the tibia in four Eskimos at Barter Island, Alaska, who are all related to one another. (John Apayaok, Leah Apayaok, Daniel Akootchook, Lily Gregory.)

with regard to the Angmagssalik Eskimos, Southeast Greenland, that "arteriosclerosis was frequently found even in persons below 40".

Brown (1951) states with regard to the Southampton Island Eskimos and the Igloolik Eskimos: "We have found well-marked general arteriosclerosis and also coronary heart disease proved by electrocardiogram and, in one case, by post mortem. Some of the cases of coronary heart disease were in congestive failure."

During our study of the patho-physiology of the Alaskan Eskimos from 1950 to 1952, x-rays were taken of the chest and extremities of 84 Eskimos, using a portable x-ray apparatus. All chest x-rays were taken at a distance of 180 cm; all x-rays of the limbs (left arm and left leg) were taken at a distance of 90 cm. Professor Johan Torgersen, Institute of Anatomy, Oslo University, has very kindly examined all these roentgenograms, with a particular reference to possible roentgenological evidence of arteriosclerosis and other cardiovascular abnormalities. He finds, as a typical feature of all roentgenograms examined, that the bone structure in the Eskimo is unusually massive with sharply defined, well-calcified bone lamellae. The muscle attachments are as a rule very large. The occurrence of arthritis deformans is no less frequent in these Eskimos than in Whites of similar age (5 cases in 84 Eskimos, 51 males and 33 females, with an average age of 28 years). Four Eskimo subjects at Barter Island had cartilaginous exostoses on the tibia (fig. 2).

From this material (see Table 5) it appears that the occurrence of roentgenological evidence of arteriosclerosis in these Eskimos is neither more nor less than what one would expect to find in Whites of similar age groups. Out of 9 Eskimos over 47 years of age, roentgenological evidence of atherosclerosis of the arch of the aorta was detected in 3 cases, 2 males and 1 female. Of the entire material one Eskimo showed calcium deposits in the arteries (see fig. 1). In one 60-year old Eskimo woman with a blood pressure of 200/80, there was slight enlargement of the left ventricle of the heart.

It is thus evident that further studies are necessary in order to settle the question of arteriosclerosis in the Eskimo and the relation between dietary cholesterol, serum cholesterol levels and cardiovascular disease in these people.

Table 5.

Results of X-Ray Examination of the Chest and Limbs of 84 Eskimos from Five Different Settlements in Alaska.[1]

Name	Sex	Age, years	Max. int. diam. of thorax max. transv. diam. of heart, cm	Lungs	Heart	Aortic arch	Calcification of costal cartilage	Upper and lower limbs
Anaktuvuk Pass								
Mekiana, Homer	♂	47	31/14	Negative findings	Normal	Somewhat widened aorta, no calcium deposits, probably atherosclerosis	0	Left arm: Systic rarefication in os lunatum and os triquetrum, otherwise no pathological conditions. Left leg: Normal findings. There is no roentgenological evidence of arteriosclerosis; the bone structure is unusually massive with clearly defined contours and rich calcium content of all bones.
Mekiana, Justus	♂	22	32/13	Negative	Normal	Normal	0	Left arm: Normal findings. Left leg: Marked growth-lines in proximal end of tibia.
Rullund, Johnny	♂	22	32/15 5	Negative	No enlargement	Normal	0	Left arm: Distal epiphyseal lines of radius and ulna still open. Left leg: Tibia, fibula, epiphyseal lines open.
Hugo, Zacharias	♂	20	29/13	Negative	Normal	Normal	0	No pathological findings.

[1] All roentgenograms were examined and interpreted by Professor dr. med. Johan Torgersen, Institute of Anatomy, Oslo University.

Table 5 (cont.)

Name	Sex	Age, years	Max. int. diam. of thorax/max. transv. diam. of heart, cm	Lungs	Heart	Aortic arch	Calcification of costal cartilage	Upper and lower limbs
Barter Island								
Akootchook, Andrew	♂	61	31/15	Calcification right lung, old pleural-affection left side	Negative	Negative	0	Arteriosclerosis of arteria ulnaris, otherwise no pathological findings.
Putugook, Alice	♀	75	28/13	Calcification in the apex of right lung	Negative	Slightly looping, probably atherosclerosis	0	No pathological findings.
Akootchook, Isaac	♂	28	30/15	Pleural adhesions both sides, calcification left lung	Negative	Negative	0	No pathological findings.
Rexford, Herman	♂	36	32/13	Negative findings	Negative	Negative	0	No pathological findings.
Akootchook, Daniel	♂	17	30/14	Calcified primary complex right lung	Negative	Negative	0	Exostosis tibiae; the epiphyseal lines of the radius, ulna, tibia and femur are still open.
Nageak, James	♂	10	24/12	Negative findings	Negative	Negative	0	No pathological findings.
Akootchook, Mary	♀	29	28/12.5	Negative findings	Negative	Negative	0	No pathological findings.
Putugook, Donald.............	♂	21	27/14	Negative findings	Not enlarged[2]	Negative	0	No pathological findings.
Nageak, Vincent..............	♂	47	30/16	Negative findings	Not enlarged[2]	Negative	0	No pathological findings.
Akootchook, George	♂	18	29/13	Pleural sequelae left lung	Negative	Negative	0	Distal epiphyseal lines of radius not closed.
Akootchook, Perry	♂	31	31/15	Negative findings	Negative	Negative	0	Following epiphyseal lines not closed: Distal radius, ulna; proximal end of all proximal phalanges; of 2nd middle phalanx and tibia. Long eunukoid fingers.
Rexford, Mildred	♀	34	32/15	Negative findings	Negative	Negative	0	No pathological findings.
Nageak, Rhoda	♀	36	31/13	Calcification left lung	Negative	Negative	0	No pathological findings.

Nageak, Lloyd	♂	5	20/10	Negative findings	Negative	Negative	0	No pathological findings.
Apayaok, John	♂	15	25/10	Negative findings	Negative	Negative	0	Irregular calcification of distal radius epiphyses (cartilaginous deformity). Small cartilaginous exostoses on tibia similar to subject's sister (Leah Apayaok); dominant inher.
Rexford, Mary Ann	♀	8	24/11	Negative findings	Negative	Negative	0	No pathological findings.
Nageak, Priscilla	♀	6	20/10	Negative findings	Not enlarged [2]	Negative	0	No pathological findings.
Apayaok, Leah	♀	24	27/14	Active tb lesion in apex of both lungs	Negative	Negative	0	Exostoses right tibia, otherwise normal findings.
Putugook, Annie	♀	32	30/14	Negative findings	Negative	Negative	0	No pathological findings.
Akootchook, Maggie	♀	22	26/13	Pleural adhesions right side	Negative	Negative	0	No pathological findings.
Akootchook, Elizabeth	♀	21	29/13	Negative findings	Negative	Negative	0	No pathological findings.
Nageak, Edith	♀	3	-	Negative findings	Negative	Negative	0	Normal findings.
Akootchook, Bennie	♂	3	-	Negative findings	Negative	Negative	0	Normal findings.
Akootchook, Ida	♀	5	-	Negative findings	Negative	Negative	0	No pathological findings.
Gregory, Lily	♀	17	29/13	Negative findings	Negative	Negative	0	Cartilaginous exostosis at growth line in tibia (relative of subj. J. A. and L. A.); the distal epiphyseal lines of radius and ulna still open.
Kotzebue								
Smith, Irvin	♂	58	31/15	Old pleural lesion left side, calcification left apex	Negative	Wide and winding without deposits of calcium. Probably atherosclerosis	0	Old healed fracture of patella; arthritis deformans in knee joint
Barr, Bessie	♀	60	30/16	Negative findings	Left ventricle enlarged, typical hypertension heart of slight degree	No pathological findings	0	Arthritis deformans in knee joint, otherwise no pathological findings.

[2] X-ray taken during inadequate inspiration, or during expirium.

Table 5 (cont.)

Name	Sex	Age, years	Max. int. diam of thorax/max. transv. diam. of heart, cm	Lungs	Heart	Aortic arch	Calcification of costal cartilage	Upper and lower limbs
Kotzebue (cont.)								
Kagoona, Janet	♀	23	31/14	Negative findings	Negative	Negative	0	No pathological findings.
Smith, Netty	♀	9	24/11	Healed tb lesion left lung	Negative	Negative	0	No pathological findings.
Smith, Grace	♀	50	28/13	Healed tb lesion left lung	Negative	Negative	0	Normal findings.
Karmun, Victor Ray	♂	13	-	-	-	-	-	No pathological findings.
Otton, Irene	♀	30	-	-	-	-	-	No pathological findings.
Sours, Ruth	♀	12	-	-	-	-	-	Normal findings.
Sours, Lena	♀	9	-	-	-	-	-	Normal findings.
Sours, Aurora	♀	6	-	-	-	-	-	Normal findings.
Curtis, Dick	♂	31	31/13	Negative findings	Negative	Negative	0	One finger amputated, otherwise normal findings.
Jones, Charley	♂	27	32/14	Negative findings	Negative	Negative	0	No pathological findings.
Curtis, John	♂	35	32/14	Plural adhesions right lung	Negative	Negative	0	No pathological findings. Large muscle attachments for interosseus muscles.
Sours, Eugene	♂	40	30/13	Negative findings	Negative	Negative	0	No pathological findings.
Ticket, Herman	♂	49	28/13	Negative findings	Negative	Negative	0	No pathological findings.
Goodwin, Willie	♂	36	32/14	Negative findings	Negative	Negative	0	No pathological findings.
Sours, Belle	♀	38	33/13	Calcification right apex	Negative	Negative	0	No pathological findings.
Sours, Marion	♂	36	30/13	Negative findings	Negative	Negative	0	No pathological findings.
Barr, Charlie	♂	18	32/12	Negative findings	Negative	Negative	0	Lower epiphyseal lines of radius and ulna still open.
Analoak, Mabel	♀	23	27/13	Negative findings	Negative	Negative	0	No pathological findings.
Vestal, Dolly	♀	52	31/14	Negative findings	Negative	Negative	+	Arthritis deformans in knee joint, otherwise normal findings.

Vestal, May	♀	21	30/14	Calcification right lung	Negative	Negative	0	No pathological findings.
Tikik, Magdaline	♀	31	27/12	Calcification right lung	Negative	Negative	0	No pathological findings.
Barr, Ronald	♂	25	33/14	Healed tb lesion right lung	Negative	Negative	0	No pathological findings.
Norton, Lydia	♀	30	32/14	Negative findings	Negative	Negative	0	No pathological findings.
Barr, Evelyn	♀	22	30/12	Negative findings	Negative	Negative	0	No pathological findings.
Gambell								
Iyakitan, Daniel	♂	30	31.5/14.5	Negative findings	Negative	Negative	0	Left arm: No pathological findings. Left leg: Small marginal exostoses in the knee joint (arthritis deformans?).
Appassingok, Herbert	♂	24	29/15	Calcification in apex of right lung and pleuro-pericardial adhesions.	Not enlarged[3]	Normal	0	No pathological findings.
Kulukhon, Willa	♀	21	-	-	-	-	-	No pathological findings; large muscle attachments.
Ungwalok, Ber.ha	♀	54	-	-	-	-	-	Old fracture of processus styloideus right side.
Slwooko, Helen	♀	23	-	-	-	-	-	Thin, osteoporotic bones, inactivity atrophy (infantile paralysis).
Gologergen, Tim	♂	35	-	-	-	-	-	Exostosis anterior aspect of talus on both extremities.
Konahok, Howard	♂	38	28/12	Increased density of parenchym in infra-clavicular region right lung, tb	Negative	Negative	0	No pathological findings.
Kulowiyi, Albert	♂	50	-	-	-	-	-	Deformity of middle phalanx of 5th finger, klino-daktyli, small area of rarefication the size of a pea in capitulum ulnae of unknown nature.

[3] X-ray taken at abnormal angle.

Table 5 (cont.)

Name	Sex	Age, years	Max. int. diam. of thorax/max. transv. diam. of heart, cm	Lungs	Heart	Aortic arch	Calcification of costal cartilage	Upper and lower limbs
Gambell (cont.)								
Malegoohtik, Florence	♀	44	28/13	Negative findings	Negative	Negative	0	No pathological findings.
Oyaghok, Marcella	♀	21	-	-	-	-	-	No pathological findings.
Nawpokuhok, Gail	♀	23	26/12	Pleural adhesions right side	Negative	Negative	0	No pathological findings, large attachment for m. pronator.
Slwooko, Beda	♀	32	-	-	-	-	-	Normal findings.
Iknokinok, Clifford	♂	24	32/15	Negative findings	Negative	Negative	0	Normal findings.
Walunga, Willis	♂	24	31/14	Negative findings	Negative	Negative	0	Normal findings.
Aningayou, Norman	♂	39	-	Negative findings	Negative	Negative	0	Arthritis deformans in knee joint, fractura fibulae, ideal healing with normal callus.
Nawpokuhok, Leonard	♂	19	30/13	Negative findings	Negative	Negative	0	Normal findings.
Iyakitan, Lewis	♂	24	30/13	Increased density of parenchym right side	Negative	Negative	0	Normal findings, large muscle attachments.
Iyakitan, Lane	♂	21	29/13	Negative findings	Negative	Negative	0	Radius epiphyseal lines not quite closed
Antgahme, Jack	♂	39	29/14	Pleural adhesions left side	Negative	Negative	0	No pathological findings, very large muscle attachment.
Chauncy, Woodrow	♂	19	-	-	-	-	-	No pathological findings.
James, Winfred	♂	27	32/14	Negative (healed fracture of clavicula)	Negative	Negative	0	No abnormal findings.
Silook, Roger	♂	27	31/13	Negative findings	Negative	Negative	0	No pathological findings. Exceedingly well developed muscle attachments.

Silook, Nolan	♂	35	32/16	Negative findings	Norm. shape, poss. slight. enlarged	Negative	0	No pathological findings.
Oozevoseuk, Conrad	♂	25	32/16	Negative findings	Appears not to be enlarged	Normal	0	No pathological findings.
Harry, Don	♂	30	31/14	Negative findings	Negative	Negative	0	No pathological findings.
Slwooko, Howard	♂	31	-	-	-	-	-	No pathological findings, muscular attachments exceptionally well developed.
Slwooko, Roger	♂	18	-	-	-	-	-	Normal findings; the epiphyseal line of capit. ulnae is almost closed.
Slwooko, Joseph	♂	24	32/14	Negative findings	Negative	Negative	0	Left arm: Radius abnormally long (probably Madelung's deformity) Left leg: No pathological findings.
Slwooko, Vernon	♂	33	33/14	Negative findings	Negative	Negative	+	No pathological findings.

5. Summary and Conclusions.

The cholesterol content of some common Eskimo foods has been determined and the serum cholesterol level as well as the serum concentration of S_f 12—20 lipoproteins in 16 healthy Alaskan Eskimos are reported. On the basis of these preliminary data it appears that some Eskimos have high cholesterol intakes compared with healthy American men, but that their blood cholesterol levels are the same. On the other hand, the S_f 12—20 lipoproteins in Eskimos are lower in concentration than in Whites of corresponding age. From the available evidence it appears that the incidence of cardiovascular disease among the Alaskan Eskimos may be lower than in Whites. A more complete analysis of this problem is in progress.

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Observations on Blood Pressure in Eskimos.

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1. Introduction.

It appears to be the impression of most physicians who have had occasion to examine large numbers of Eskimos, that the blood pressure in Eskimos is lower than in normal Whites of corresponding age (P. B. Haggland, M. D., E. S. Rabeau, M. D., and E. Albrecht, M. D., personal communications). Abnormally elevated blood pressures (systolic blood pressure in the order of 170 mm or higher) are apparently quite rare. Thus, in the 213 Eskimo patients who were subject to medical examination by the author during a two-year period in Alaska, the blood pressure was measured in 117 cases, and only one of the patients had systolic blood pressure above 145 mm.

In contrast to this, Saxtorph (quoted by A. Bertelsen, 1940) reported in 1926 that he had seen a considerable number of cases of hypertensio arterialis, both in old and middle-aged Greenland Eskimos. In 12 cases he measured blood pressures between 200 and 240 mm.

Thomas (1927) on the other hand examined 142 Greenland Eskimos, 40—60 years of age, and found the average blood pressure to be 129/76 mm, with a single case of 170/100. He concluded that hypertension with associated complications is extremely rare among Eskimos.

Holbeck (quoted by Bertelsen, 1940) has reported that the average systolic blood pressure in Greenland Eskimos, between 40 and 55 years of age, was 141 in men and 131 in women. According to Bertelsen (1940) Svendsen examined, in 1930, the blood pressure of 106 Eskimos taken at random, some of whom had active pulmonary tuberculosis. He made the following findings: 15—30 years of age: 120/70 mm; 30—50 years of age: 137/77 mm; 50 years of age or over: 167/82 mm. Bertelsen (1940) concludes, on the basis of his experiences in Greenland, that the average blood pressure does not appear to deviate from that of Whites of corresponding age.

Probably the most extensive study of Eskimo blood pressure has been reported by Høygaard (1941). He measured the blood pressure systematically of 283 Angmagssalik Eskimos, South East Greenland, of both sexes, living on their primitive diet, using the standard technique in a lying or sitting position at least one hour after exercise. He found no material difference between males and females. Twelve persons out of

Table 1.

Blood Pressure of Angmagssalik Eskimos (according to Høygaard (1941)).

Number of Individuals	Age groups	Blood pressure			
		Systolic		Diastolic	
		Average	Range	Average	Range
45	5—9	104	82—128	74	62— 98
47	10—19	126	96—148	82	64—108
162	20—49	130	94—162	85	68—116
23	50—59	139	106—168	88	64—118
6	60 and over	147	134—168	88	74—116

283 (4 %) had a systolic blood pressure of 150 or higher; only two subjects had as much as 168 mm Hg. (Table 1). He concludes that hypertonia is not common.

According to MacMillan (1951) Dr. E. Morse found no instance of high blood pressure among the Thule Eskimos during the Bowdoin's voyage to Greenland in 1950.

In the case of Canadian Eskimos, Brown (1951) states with regard to the Southampton Island and the Igloolik Eskimos: "Arterial hypertension has also been found both in the group at Southampton Island and in the group at Igloolik." However, in the 63 Eskimos living in the vicinity of Chesterfield Inlet (30 males and 33 females) examined by Crile and Quiring (1939) the average blood pressure in the males (average age 38 years) was: systolic pressure 119 mm, diastolic pressure 75. In the females (average age 31 years) the figures were 112 and 72 respectively. The average pulse rate was 62—69 in the males and 79—82 in the females. These authors conclude that "the blood pressure for both the males and the females is lower than that of Whites of corresponding age, the pulse rate corresponds rather closely to that of White individuals".

Heinbecker (1931) reports an average pulse rate of 64 in 5 Eskimos (4 females and 1 male, 15—50 years of age) from Baffin Island. Bollerud, et al. (1950) report an average pulse rate of 58 in their 23 male St. Lawrence Island Eskimos, 17—41 years old.

In connection with extensive studies on the patho-physiology of Eskimos which were in progress at the Arctic Aeromedical Laboratory as part of a survey of human adaptation to cold, we had an opportunity of recording various physical and physiological measurements during a two-year period 1950—1952. In this paper we are only concerned with blood pressure, pulse rate and age.

2. Material.

The data utilized consist of 735 blood pressure measurements in a consecutive series of 104 Eskimos (75 males and 29 females) from four different Eskimo settlements in Alaska, representing different climatic conditions, living habits and diets. The first group at Barter Island, which is located on the north coast of Alaska, live on a diet consisting of approximately 50 % sea mammals and fish, and 50 % land mammals. The second group at Anaktuvuk Pass, located in the middle of the Brooks Range 3,000 feet above sea level, live almost exclusively on land mammals, and especially caribou meat. The third group at Kotzebue, situated on the west coast of Alaska, live to a considerable extent on White man's food, and their living habits are more affected by civilization than any of the other groups. The fourth group at Gambell, St. Lawrence Island, live almost exclusively on sea mammals, and especially walrus meat.

These four groups were examined both in the winter and in the summer. In addition to field studies, representative subjects of each group were studied under carefully controlled conditions in our laboratory at Ladd Field while living on the White man's diet. All these Eskimos were subject to complete medical examination, including medical histories, physical examination with x-rays of the chest and long bones, as well as urine and blood examinations. A total of 40 normal white men were used as controls.

3. Method.

The systolic and diastolic blood pressures were determined by the auscultatory method, and the standard technique was applied. A mercurial manometer with armlet of standard width was used. The subjects were examined both in the sitting and lying position. Great care was taken to insure as complete relaxation as possible during the examination. At each examination at least two readings were made, and only the final readings were recorded. As a rule each subject was examined on 5—10 different occasions.

The cuff was applied to the arm in the usual manner; the arm was allowed to rest on a table. The manometer was placed at the level of the heart. After inflating the armlet, the pressure was slowly released, and the reading, at which the first clear sound was audible, was taken as indicating the systolic blood pressure. The point at which the short, sharp, clear tone suddenly became muffled was taken as indicating the diastolic blood pressure.

4. Results and Discussion.

The results from all 104 Eskimo subjects of both sexes are presented in Table 2. The average age is just over 29 years, but the ages vary widely from 3 to 75. However, of the 104 subjects, 73 were between 15 and 40 years old and only 13 were below 15 years.

Table 2.

Age, Heart Rate and Blood Pressure of all Eskimo Subjects of Both Sexes.

	Mean	Standard deviation	Coefficient of variation	Range
Age (years)	29.3	14.10	13.6	3— 75
Heart rate (mean of all observations)	71	14.50	19.92	49—120
Heart rate (final observation)	67	16.50	24.62	44—120
Systolic blood pressure (mean of all observations)	110	9.84	8.95	92—137
Systolic blood pressure (final observation)	107	11.04	10.61	84—140
Diastolic blood pressure (mean of all observations)	71	6.74	9.49	58— 91
Diastolic blood pressure (final observation)	69	8.10	11.74	56—100

From this table it is observed that the pulse rate at rest, when considering the mean figure for all observations in each subject, is 71 beats per minute, but the figures show considerable individual variations. If only the final reading is considered, the mean value is 67 beats per minute, ranging from 44 to 120.

The average systolic and diastolic blood pressures in Eskimos of both sexes, when considering the mean values of all readings in each subject, were 110 and 71 respectively. The mean values of the final blood pressure readings obtained when the lower level was established after several repeated examinations, were slightly less, the systolic pressure being 107 and the diastolic pressure 69. The range of these measurements is considerable. Thus the resting systolic blood pressure varies from a minimum value of 84 to a maximum value of 140; the diastolic blood pressure varies from 56 to 100. Only one subject, a 14-year old boy, showed as high an average value for the systolic blood pressure as 140. No systolic blood pressure higher than 162 mm was recorded in this series. 80.76 % of the recorded systolic blood pressures were below 116 mm.

Table 3 shows the results of similar measurements in 40 normal white men examined in Alaska by the same investigator. In this material the average age is 23 years. It appears that the figures for pulse rate are very similar to the corresponding figures for Eskimos. The mean figures for blood pressure are higher than in the Eskimos, both in the case of systolic and diastolic pressure, and in the case of both the mean values of all observations as well as in the case of the final values, recorded when the lower level had been established as the result of repeated examinations. It is observed that the figures, both for pulse rate and blood pressure in these White subjects, are lower than the figures published by McKinlay and Walker (1935) for 566 normal white men with

Table 3.

Age, Heart Rate and Blood Pressure in 40 Normal White Men.

	Mean	Standard deviation	Coefficient of variation	Range
Age (years)	23.0	8.48	36.90	17— 68
Heart rate (mean of all observations) .	69	8.69	12.59	55—102
Heart rate (final observation ..	65	12.05	18.54	44—120
Systolic blood pressure (mean of all observations) .	116	10.96	9.44	91—144
Systolic blood pressure (final observation)........	114	11.72	10.28	92—144
Diastolic blood pressure (mean of all observations)..	74	6.03	8.14	61— 84
Diastolic blood pressure (final observation)........	73	7.57	10.36	56— 90

a mean age of 23.2 years. The difference is over 5 times the standard error, both in the case of pulse rate and blood pressure.

The wide range of "normal" variations in blood pressure in Whites, has been emphasized by McKinlay and Walker (1935). According to American sources the average values for systolic pressure in healthy males, as measured in the brachial artery with the individual at rest, vary from 100 to 120 in early manhood, from 125 to 136 in the middle years of adult life, and from 145 to 150 above the age of sixty years.

The range of individual measurements, however, may show much wider variations. Alvarez, quoted by McKinlay and Walker (1935), found that the systolic blood pressure in 6,000 University students and graduates between the ages of 16 and 40 years, may be as low as 85 mm or as high as 190 mm. He concludes that 22 per cent of men have a systolic blood pressure exceeding 140 mm and that one man in every forty has a systolic blood pressure higher than 160 mm. According to Diehl and Sutherland (1925), nine per cent of male students, 16—40 years of age, at the University of Minnesota had blood pressures over 140 mm. None of our Eskimo men, 15—40 years old, had mean blood pressures over 140 mm.

As a rule, the lowest blood pressure readings were obtained at the fourth examination in Whites, but not until the fifth examination in Eskimos.

McKinlay and Walker (1935) have examined the variability and interrelationship of heart rate, systolic and diastolic blood pressure, pulse pressure and age in healthy men of ages ranging from 16 to 40. They conclude that within the period of life studied, age is not of great importance in determining the level of any of these factors. They find definitely significant, positive relationship between age and both systolic and diastolic blood pressure, but not of such a degree as to form anything like a reasonably accurate basis for prediction. They find positive, but not very intimate, association between heart rate and blood pressure.

In Tables 4, 5 and 6 our data are separated into three age groups: 15—25 years, 26—40 years, and over 40 years old.

Twenty-five of the male Eskimos were between 15 and 25 years old, the average age being slightly over 21 years in this group. The same number of male Eskimos fell in the second age group: 26—40 years, the average age in this group being 33 years. Only twelve of the male Eskimo subjects were over 40 years old.

There is no difference in the mean value of all readings in each subject for the 15—25-year-old group as compared with the 26—40-year-old group, but the mean value for the group over 40 years old is higher than the first two groups. The difference is 4 times the standard error, and is therefore probably statistically significant.

The data for the 29 Eskimo women, divided into the three age groups: 15—25 years old (12 subjects), 26—40 years old (11 subjects), and over 40 years old (6 subjects), are given in Table 5. On the basis of this limited material it appears that the average blood pressure in Eskimo women is somewhat higher than in Eskimo men, but this difference is not statistically significant. There is also a tendency towards increased blood pressure with increasing age in Eskimo women.

Of the 40 white men, 34 fell into the first age group (15—25 years) and 5 in the second age group (26—40 years) while only one subject was over 40 years old. If we compare these white men with Eskimo men of corresponding age, it is observed that the average blood pressure is slightly higher in Whites than in Eskimos but the difference is too small to be significant statistically (less than 3 times the standard error). The mean of the lowest measured blood pressure in each subject in the first age group is considerably lower in Eskimos than in Whites, however. The difference is about 4 times the standard error, and may be statistically significant. The number of subjects is too small, nevertheless, to allow any definite conclusion to be drawn from this material.

It should also be noted that a larger proportion of the blood pressure measurements were recorded in the lying position in the Eskimos (70 %) than is the case in the Whites (25 %) and since the blood pressure tends to be lower in the lying position (Tables 7 and 8), this may partly account for the difference, although the difference between sitting and lying blood pressure in Whites in this material is not significant statistically. Thus, in Whites 15—25 years old, the difference between the means for sitting and lying systolic blood pressure is 5 mm, which is less than twice the standard error, as is also the case when comparing the diastolic blood pressure in the sitting and lying position. However, out of the 24 lowest measured blood pressures in Whites 15—25 years old, 76.47 per cent

Table 4.

Mean Blood Pressure in 62 Male Eskimos, Divided into Three Age Groups.

	15—25 years old (25 subj.)				26—40 years old (25 subj.)				Over 40 years old (12 subj.)			
	Mean	Standard deviation	Coefficient of variation	Range	Mean	Standard deviation	Coefficient of variation	Range	Mean	Standard deviation	Coefficient of variation	Range
Age (years)	21.3	2.77	13.20	15—25	33.0	4.28	12.97	26—39	53.2	8.88	16.75	41—71
Mean of all observations												
1. Systolic blood pressure	108	8.95	8.29	95—134	107	9.42	8.80	92—127	119	8.36	7.03	108—135
2. Diastolic blood pressure	69	6.53	9.46	58—91	69	6.06	8.78	62—83	77	4.93	6.40	71—85
Mean of highest measured blood pressure												
1. Systolic blood pressure	122	13.05	10.70	102—162	122	12.94	10.60	105—164	125	11.03	8.82	110—148
2. Diastolic blood pressure	73	11.41	15.63	50—92	72	9.48	13.17	50—88	79	6.17	7.81	70—86
Mean of lowest measured blood pressure												
1. Systolic blood pressure	90	8.88	8.97	88—128	97	8.09	8.34	84—112	113	11.02	8.48	94—135
2. Diastolic blood pressure	64	5.77	9.01	56—80	63	6.54	10.38	56—78	74	6.00	8.11	65—85

Table 5.

Blood Pressure in 29 Eskimo Women Divided into Three Age Groups.

	15—25 years old (12 subj.)				26—40 years old (11 subj.)				Over 40 years old (6 subj.)			
	Mean	Standard deviation	Coefficient of variation	Range	Mean	Standard deviation	Coefficient of variation	Range	Mean	Standard deviation	Coefficient of variation	Range
Age (years)	22	1.94	1.82	17—25	32	3.34	10.12	26—38	51	11.55	22.65	41—75
Mean of all observations												
1. Systolic blood pressure	111	8.30	7.47	95—128	111	7.10	6.40	98—121	122	9.79	8.02	112—137
2. Diastolic blood pressure	72	5.98	8.31	61—86	70	4.47	6.40	63—76	74	7.49	10.12	61—86
Mean of highest measured blood pressure												
1. Systolic blood pressure	121	7.44	6.15	110—134	122	3.45	2.83	100—136	126	9.46	7.51	114—140
2. Diastolic blood pressure	79	9.62	12.18	65—98	74	5.21	7.04	65—82	75	8.89	11.85	62—85
Mean of lowest measured blood pressure												
1. Systolic blood pressure	104	10.78	10.37	84—124	102	8.84	8.67	94—112	118	11.75	9.96	108—132
2. Diastolic blood pressure	69	7.30	10.58	56—86	67	5.05	7.53	60—76	73	7.62	10.44	60—85

Table 6.

Mean Blood Pressure in 39 Normal White Men, Divided into Two Age Groups.

	15—25 years old (34 subj.)				26—40 years old (5 subj.)			
	Mean	Standard deviation	Coefficient of variation	Range	Mean	Standard deviation	Coefficient of variation	Range
Age (years)	20 2	1.37	6 85	17—23	33.0	4.24	12.85	27—39
Mean of all observations								
1. Systolic blood pressure	116	11.28	9.72	91—139	112	8.50	7.59	100—122
2. Diastolic blood pressure	73	5.87	5 06	61—84	80	2.97	3.71	76—83
Mean of highest measured blood pressure								
1. Systolic blood pressure	122	12.73	10.43	92—152	118	11.94	10.12	100—134
2. Diastolic blood pressure	76	10.95	14.41	59—112	86	5.06	5.88	78—94
Mean of lowest measured blood pressure								
1. Systolic blood pressure	111	11.61	10.46	90—144	108	6.40	5 93	100—114
2. Diastolic blood pressure	71	8.16	11.49	56—94	75	4.14	5.52	70 80

Table 7.

Mean Blood Pressure and Heart Rate in Sitting and Lying Position in 24 Male Eskimos 15—25 Years Old.

	Mean	Standard deviation	Coefficient of variation	Range
Age (years)	21.3	2.83	13.40	15—25
Sitting				
Heart rate	76	10.14	13.34	60—92
Systolic blood pressure	116	11.61	10.06	101—154
Diastolic blood pressure	71	8.14	11.46	60—98
Lying				
Heart rate	59	5.59	9.47	47—73
Systolic blood pressure	107	9.37	8.76	92—132
Diastolic blood pressure	68	5.89	8.66	57—87

were measured in the lying position, and of the highest measured blood pressures in the same subjects, 97.06 per cent were measured in the sitting position. It may be noted however that in Eskimos the difference between sitting and lying blood pressure is about 3 times the standard error.

In Whites 15—25 years old, the mean pulse rate is 72 measured sitting, and only 58 when measured lying. The difference is 4 times the standard error, and may therefore be considered significant in a statistical sense, although the number of observations is very small. The range of the pulse rate measured sitting is 68—86, against 51—67 measured lying.

Table 8.

Mean Blood Pressure and Heart Rate in Sitting and Lying Position in 9 White Men, 15—25 Years Old.

	Mean	Standard deviation	Coefficient of variation	Range
Age (years)	19.8	1.05	5.03	19—22
Sitting				
Heart rate	72	9.12	12.67	63—86
Systolic blood pressure	116	11.38	9.81	103—143
Diastolic blood pressure	73	6.81	9.32	62—84
Lying				
Heart rate	58	5.25	9.05	51—67
Systolic blood pressure	111	7.07	6.37	104—126
Diastolic blood pressure	70	3.86	5.50	62—76

From Table 10 it appears that the Kotzebue and Gambell Eskimos in the age group 26—40 years have a lower mean blood pressure than the corresponding age groups from Anaktuvuk Pass and Barter Island. The difference between the Gambell and the Anaktuvuk Pass groups (the groups showing the most pronounced difference), as regards the means of the lowest measured blood pressures, is 12 mm, and the standard error is 3.20. Thus, the difference is over three times the standard error. However, the material is too small to allow any conclusion. No significant difference was detected in the blood pressure in Eskimos 15—25 years old from the 4 different settlements (Table 9).

5. Summary and Conclusion.

735 blood pressure and pulse rate measurements were made in a consecutive series of 104 Eskimos (75 males and 29 females) from 4 different Eskimo settlements in Alaska. Similar measurements were made in 40 normal white men for comparison. In Eskimos the mean resting systolic blood pressure varied from a minimum value of 84 to a maximum value of 140. No systolic blood pressure higher than 162 mm was ever recorded in our Eskimo subjects. 80 % of the recorded systolic blood pressures were below 116 mm. The mean diastolic blood pressures varied from 56 to 100.

In Eskimos the mean blood pressure is somewhat higher in women than in men of corresponding age although the difference is not statistically significant, and there is a tendency towards increased blood pressure with increasing age.

In Eskimo men the mean blood pressure was 108/69 at ages 15—40 years, and 119/77 above 40 years of age. In Eskimo women the figures were 111/71 and 122/74 respectively. When comparing the Eskimo men

Table 9.

Mean Blood Pressure in Male Eskimos, 15—25 Years Old, from Four Different Settlements in Alaska.

	Kotzebue (7 subj.)				Gambell (9 subj.)				Anaktuvuk Pass (5 subj.)				Barter Island (4 subj.)			
	Mean	Standard deviation	Coefficient of variation	Range	Mean	Standard deviation	Coefficient of variation	Range	Mean	Standard deviation	Coefficient of variation	Range	Mean	Standard deviation	Coefficient of variation	Range
Age (years)	22	2.45	11.14	18—25	22	2.59	11.77	18—55	22	1.41	6.41	20—23	18	2.14	11.88	15—21
Mean of all observations																
1. Systolic blood pressure	110	10.03	9.12	95—130	103	4.24	4.12	96—110	115	3.15	2.73	105—134	108	3.34	3.09	103 113
2. Diastolic blood pressure	66	5.49	8.32	58—74	66	1.90	2.88	63—70	76	7.94	10.45	70—91	71	5.92	1.99	66 81
Mean of lowest measured blood pressure																
1. Systolic blood pressure	103	13.04	12.66	90—128	95	5.82	6.13	88—108	100	7.28	7.28	92—112	99	1.73	1.75	98—102
2. Diastolic blood pressure	62	6.64	10.71	56—74	63	3.74	5.94	58—70	66	7.80	11.82	58—80	65	2.69	4.08	62—68

T a b l e 10.

Mean Blood Pressure in Male Eskimos, 26—40 Years from Four Different Settlements in Alaska.

	Kotzebue (5 subj.)				Gambell (12 subj.)				Anak uvuk Pass (5 subj.)				Barter Island (3 subj.)			
	Mean	Standard deviation	Coefficient of variation	Range	Mean	Standard deviation	Coefficient of variation	Range	Mean	Standard deviation	Coefficient of variation	Range	Mean	Standard deviation	Coefficient of variation	Range
Age (years)	31	4.20	12.35	27—39	33	7.49	22.70	26—39	33	3.18	9.64	29—37	32	3.30	10.31	28—36
Mean of all observations																
1. Systolic blood pressure	108	5.52	5.11	102—118	102	8.93	8.75	92—122	117	5.76	4.92	110—127	112	2.24	2.00	109—114
2. Diastolic blood pressure	68	2.93	4.30	63—71	66	3.18	4.82	62—72	76	5.50	7.24	68—83	76	2.24	2.95	73—78
Mean of lowest measured blood pressure																
1. Systolic blood pressure	95	4.67	4.91	92—100	93	7.80	8.38	84—108	105	5.16	4.91	100—112	103	3.78	3.67	100—108
2. Diastolic blood pressure	59	6.90	11.69	48—64	61	4.36	7.14	51—68	71	4.62	6.51	67—78	69	1.00	1.45	68—70

with white men of corresponding age, it is observed that both the systolic and diastolic blood pressures are lower in Eskimos than in Whites. This difference appears to be statistically significant in the case of the lowest measured blood pressure in each subject in the two groups.

The mean pulse rates in Eskimos at rest were not materially different from the corresponding figures for Whites.

6. Acknowledgments.

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The Significance of Ketosis Produced by a High Meat-Fat Ration under Arctic Conditions.

BY

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1. Introduction.

With the increasing human activities in circumpolar areas in recent years, the problem of an adequate and physiologically suitable ration with high caloric density has been the subject for much dispute among physiologists and nutritionists. Although a high protein diet has been successfully used by Eskimos and arctic travellers for generations, both as trail diet and emergency rations, there has been a tendency in recent years to emphasize the desirability of an all-carbohydrate ration (Mellinger, 1948, Roth, 1948, Dyme, 1950). One of the main arguments in favor of the carbohydrate ration has been its antiketogenic effect, assuming harmful effect of slight ketosis even during the short periods of survival in question under arctic conditions.

With reference to these questions a study was designed, the purpose of which was to consider a high-carbohydrate versus a high-protein diet, with reference to physiological adequacy and an evaluation of the physiological and clinical significance of ketosis under strenuous arctic field conditions during midwinter in Alaska.

2. Material, Methods and Procedures.

A total of 12 normal men, 19 to 23 years old, were used for this study. They were all thoroughly indoctrinated and well-trained in arctic survival and accustomed to arctic field activities. Eleven of the subjects had spent 17½ months in Alaska and one of the subjects, who was an Eskimo, had lived in the territory all his life. Medical examination including medical histories and complete physical examination, revealed no pathological condition in any of the 12 subjects selected from a group of 14 men. Routine blood and urine examinations showed normal findings.

The subjects were divided into two groups: One group of 5 men was given the carbohydrate ration, a second group of 5 men was given the meat ration. A third group of two men was, for the purpose of another study, given the meat diet during the control studies, while during the field study they received a combination of both rations.

As a carbohydrate ration, a starch-jelly bar was used, containing 355 calories per 100 g. Boiled ground round steak was used as a high protein ration. It was minced, thoroughly mixed, boiled, skimmed, strained and carefully weighed prior to consumption. Analyses of five different random samples of the prepared meat ration gave the following average results: Water 60.4 %, fat 12.5 %, protein 27.3 % and carbohydrate 0.0 %. The meat-carbohydrate group received 270 g of the meat ration and 116 g of the carbohydrate ration daily.

The camp for the field study was located on a hill, accessible by road, and the surrounding terrain was suitable for travel on foot. The camp consisted of 4 tents for the subjects and one tent for the observers. No heat was allowed in the tents. During the field study the temperature at the camp site ranged between —36° F and 12° F, the mean temperature being — 15° F.

During a control period of 4 days all subjects were subject to comprehensive clinical and laboratory examinations while subsisting on unlimited quantities of the normal varied diet with a certain caloric expenditure. The examinations included complete physicals, x-rays, routine blood and urine examinations, quantitative determination of total acetone bodies in the urine and determinations of fasting blood sugar. The studies included careful estimations of the caloric, water and nitrogen balance and turnover rates for each subject. These were calculated on the basis of complete individual food weighings and fluid consumption records, hourly time-activity data, repeated basal metabolic rate determinations, measurements of urine volume and nitrogen content and daily body weight determinations. Observations were made regarding physical fitness and a psychological evaluation of each subject was prepared by a psychiatrist.

An experimental period of 6 days followed the standardization phase. During this phase the same investigations were made in the same subjects while subsisting on the experimental ration (1000 calories daily), the conditions otherwise being unchanged.

During a third period following a suitable recuperation period, the experiment was repeated with the same rations on the same subjects under field conditions which involved similar caloric expenditure. The investigations carried out during this period were essentially the same as during the previous period. The field study lasted 10 days and the subjects were made to walk on foot 10 miles daily.

The subjects were observed during a period of three days during recovery after the field phase. During this period, the subjects were allowed to consume food and water in unlimited quantities.

For the routine blood and urine examinations the standard methods were used.

The composition of the meat ration was determined in the usual way; the water content was determined by drying to constant weight at 104° C, the fat content by extraction in the Soxhlets apparatus, the protein content by the Kjeldahl method.

During the standardization phase the food consumption was determined by careful individual weighing of the food consumed at each meal, using paper plates and cups. During the experimental and field phase the rations were weighed and issued at each meal and totally consumed. The caloric expenditure was estimated by using time-activity sheets which were filled out with the assistance of observers.

For assessing the physical fitness of the subjects at the various stages of the experiment, the treadmill test of physical fitness for hard muscular work, described by Johnson et al. (1942), was used. Repeated tests were performed, considering the possible factor of learning. In addition, the performance of each subject was evaluated by personal observations by the observers.

The basal metabolic rate was determined both by the Benedict-Roth and by the Sanborn Waterless apparatus. The technique has been described in detail in a previous report (Rodahl, 1952).

The subjects were allowed to consume water ad libitum, but the water consumption was measured.

Twenty-four-hour urine samples were collected in individual, labeled canteens which were kept at ambient temperature. This meant that each increment was frozen almost as soon as collected. Each morning the canteens were collected and replaced with empty ones. The urine was thawed and analyzed immediately after being brought in from the field. After thorough mixing and determination of the volume, nitrogen and ketone body determinations were made as follows:

1. Nitrogen. Following appropriate dilution and thorough digestion with sulfuric acid and potassium persulfate, the nitrogen content was determined by the Nessler reaction. Readings were made at 500 η with the Klett Photoelectric colorimeter and corrected to mg/ml with the aid of a calibration factor (straight line relationship).

2. Ketone bodies. Each 24-hour sample of urine was tested qualitatively for the presence of acetone and acetoacetic acid with the aid of prepared nitroprusside powder (Denco). In every case in which a trace or more of acetone was indicated, the acetone and acetoacetate were determined quantitatively by titration of the distillate from an acidified sample with standard iodine and thiosulfate solutions. Unfortunately, limitations of time, trained personnel, and available facilities did not permit determination of β-hydroxybutyric acid. However, in view of the mildness of the ketosis revealed by the acetone and acetoacetate assays, the β-hydroxybutyrate content and the total ketone body excretion may be assumed to have been too low to warrant more intensive study.

Attempts to collect carmine-dyed feces for the purpose of nitrogen determination were only partially successful because of the small quantities of feces produced and the delayed excretion during the experimental phase and the field phase. From the incomplete data obtained, it appears that the nitrogen loss through feces was not in excess of 10 per cent of the total nitrogen intake. There appeared to be a decrease in fecal nitrogen during the field phase.

On the basis of our incomplete data, which agreed with the generally accepted figures for nitrogen elimination (DuBois, 1928), the following figures for fecal nitrogen have been used in this study.

Standardization phase		1.5 g
Experimental phase:	Meat group	1.0 g
	Carbohydrate group	0.5 g
Field phase:	Meat group	1.0 g
	Carbohydrate group	0.5 g
	Meat-carbohydrate group	1.0 g

3. Results.

During the standardization phase when the subjects were living on their normal diet and were allowed to consume unlimited quantities, the average daily consumption of calories was about 3000 calories per day, varying between 2000 and 4000. Approximately 12 per cent of the calories were derived from protein, 42 per cent from fat and 46 per cent from carbohydrate.

During the experimental phase and the field phase, the average caloric consumption was as close as possible to 1000 calories per day in all groups. In the carbohydrate group all calories were derived from carbohydrate, while in the meat group approximately 50 per cent of the calories came from protein and the remaining 50 per cent from fat. The meat-carbohydrate group obtained 30 per cent of the calories from protein, 30 per cent from fat and 40 per cent from carbohydrate.

The average daily caloric expenditure for all 12 subjects during the standardization phase was estimated to 2400 calories, on the basis of time activity data. During this period a slight weight gain was observed while there appeared to be no water retention.

During the experimental phase the average daily caloric expenditure was estimated to 2300 calories and approximately 2700 during the field phase. The average daily caloric expenditure appeared to be quite uniform in all three groups.

During the entire field study, which lasted 10 days, a total distance of 100 miles was covered, varying between 9 and 12 miles daily.

No significant difference in the physical performance could be detected by personal observations during the field phase. When comparing the so-called physical fitness scores obtained by the treadmill test at the various stages of the experiment, it is observed that by the standards established by Johnson et al. (1942) all subjects came within the category "good scores" during all periods. During the standardization phase two subjects were superior (16 %). The physical fitness scores at the end of the experimental phase remained unchanged or were higher than during the standardization phase in all cases but one. The average score for the meat group was slightly higher at the end of the experimental phase than during the standardization phase. In the carbohydrate group this improvement of the scores was considerably greater. When comparing the scores at the end of the field phase with the scores during the standardization phase, an improvement is observed in every case. This improvement is greater in the carbohydrate group. At the end of the field phase the scores were 10 % higher in the meat group, 30 % higher in the carbohydrate group and 7 % higher in the meat-carbohydrate group than during the standardization phase. According to the Johnson standard, all scores except one were superior at the end of the field phase.

No significant difference between the different groups could be detected on the basis of psychiatric evaluation (Reidy, 1953.)

The average basal metabolic rate in all the 12 subjects on the second test during the standardization phase was 6 % lower than DuBois standard. In the meat group there was an increase of 13 % at the end of the experimental phase, while a reduction of 7 % in the BMR occurred in the carbohydrate group. When comparing the BMR at the end of the field phase with BMR during the standardization phase we found an increase of 9 % in the meat group, an increase of 7 % in the group receiving the meat-carbohydrate ration and a reduction of 7 % in the carbohydrate group. The average oral temperature and the pulse rate were almost the same at the end of the experimental phase as during the standardization phase. The blood pressure was slightly lower at the end of the experimental phase than during the standardization phase.

During the experimental phase an average total weight loss of 2.5 lbs occurred in the meat group while the subjects on the carbohydrate ration lost 4.6 lbs on an average. At the end of the field phase the average total weight loss in the meat group was 10.8 lbs (7 %), 12.1 lbs (7.5 %) in the carbohydrate group and 8.8 lbs (6 %) in the group receiving both meat and carbohydrates.

During the experimental phase the meat group consumed approximately 1500 ml free fluid while the carbohydrate group consumed approximately 1200 ml. During the field phase the consumption in the meat group was approximately 1500 ml, 850 ml in the carbohydrate group and about 1200 ml in the meat-carbohydrate group. The average urine volume during the experimental phase approximately 1500 ml in the meat group and 1250 ml in the carbohydrate group. During the field phase the urine volume was approximately 1100 ml in the meat group, 600 ml in the carbohydrate group and 1000 ml in the meat-carbohydrate group.

During the experimental phase all subjects in the meat group were in a positive nitrogen balance, while the subjects in the carbohydrate group showed a negative balance of 6.3 g on an average. During the field phase all 3 groups showed a negative nitrogen balance which was most pronounced in the carbohydrate group, followed by the meat-carbohydrate group, the meat group being the lowest with a negative balance of 2.2 g including the estimated fecal nitrogen of 1.5 g.

The results of routine urine examination at various stages of the experiment showed that apart from the acetone no abnormalities were detected during the experimental phase. During the field phase, small traces of albumin occurred in members of all three groups together with the occurrence of white blood cells.

The incidence and severity of ketosis during the experimental and field phases are indicated in Tables 1 and 2, respectively. As would be expected, carbohydrate afforded considerable protection against the ketogenic effects of low caloric intake and exercise, although under the more rigorous field conditions, the quantity administered was not sufficient to suppress ketonuria completely. It is interesting to note that while conditions evidently were more conducive to the development of ketosis during the field phase than during the experimental phase, as shown by the increased ketone body excretion of the subjects on carbohydrate, there was no further significant increase in the ketonuria of the subjects on the meat diet during the field phase.

The primary concern of this study was with the short-term effects of possible components of survival rations which would be intended for use over limited periods only. Considering this fact, the mildly ketogenic effect of the meat diet is of no practical importance. The highest value obtained was 866 mg per 24 hours (meat diet, fifth day of experimental phase). It is true that this value does not include the β-hydroxybutyrate. However, it is evident from Friedmann's data and graphs (Friedmann, 1942) that the ratio of β-hydroxybutyrate to the other ketone bodies would be less than one at this low level of ketonuria. If we assume a ratio of one, the total ketone body excretion of this subject was 1.8 g or 0.40 m M/kg/24 hr. This rate, which represents a maximum for one individual and which was not maintained on succeeding days, is still much lower than is often encountered during complete fasting. Other than ketonuria, no objective symptoms of ketosis developed in any of the subjects during any of the phases.

No significant changes were detected in the blood picture. The mean values for the fasting blood sugar were slightly lower during the experimental and field phase than during the standardization phase in the meat group while they remained almost unchanged in the carbohydrate group and in the group receiving both meat and carbohydrate. The lowest

Table 1.

Incidence and Severity of Ketosis during the Experimental Phase.

Day of phase	Carbohydrate diet (5 subjects)		Meat diet (7 subjects)	
	No. of positive reactions	Range [1]	No. of positive reactions	Range [1]
1	2	0—64	0	-
2	0	-	6	0—117
3	0	-	6	0—421
4	1	57	6	0—227
5	0	-	7	70—866
6	0	-	7	98—503

[1] Range = acetone — acetoacetic acid expressed as mg. of acetone 24 hr.

Table 2.

Incidence of Ketonuria during Field and Recovery Phases.

Day of phase	Carbohydrate diet (6 subjec.s)		Meat diet (6 subjects)	
	No. of positive reactions	Range [1]	No. of positive reactions	Range [1]
Field phase				
1	0	-	0	-
2	0	-	3	0—226
3	3	51—79	2	111—271
4	4	0—167	5	102—300
5	3	0—246	5	128—849
6	3	0—133	5	75—526
7	5	0—163	5	31—757
8	2	0—383	5	106—482
9	2	0—170	5	124—625
10	2	0—181	5	125—568
Recovery phase				
11	1	23	1	49
12	0	-	0	-

[1] Range = acetone — acetoacetic acid expressed as mg. of acetone 24 hr.

figure observed in the meat group was 66 mg per hundred ml. Molnar et al. (1942) records fasting blood sugar values of the same order (60—80 mg per 100 ml) in 7 men on a mixed diet of 3600 calories in an Arctic bivouac at Fort Churchill.

4. Discussion.

It is clearly realized that the determination of ketone bodies is subject to considerable inaccuracy. However, the reported data indicate that under the conditions of the test the excretion of urinary acetone in the meat group never exceeded 1 g per day. The highest figure recorded was 866 mg which is a very small amount.

Table 3.
Fasting Blood Sugar.

	Standard phase	Experimental phase	Field phase		
	Last day	Last day	1st day	5th day	11th day
Meat group					
Subj. No. 1	116	84	91	95	66
„ „ 5	84	79	103	100	89
„ „ 6	104	66	96	108	86
„ „ 10	118	65	88	81	86
„ „ 12	97	106	88	95	96
„ „ 4	92	83	-	-	-
„ „ 8	114	108	-	-	-
Mean:	103	84	93	96	85
Carbohydrate group					
Subj. No. 2	114	111	104	100	106
„ „ 3	93	88	94	107	92
„ „ 7	97	111	98	128	87
„ „ 9	115	109	88	116	102
„ „ 11	95	96	-	-	-
Mean:	103	103	96	113	97
Meat-carbohydrate group					
Subj. No. 4	92	-	83	93	92
„ „ 8	114	-	100	112	110
Mean:	103	-	92	103	101

According to Peters and Van Slyke (1946), ketones are regularly found in the urine of healthy persons leading a normal life. Van Slyke found as much as 280 mg ketones per 1000 ml urine. Others have reported figures between 7 and 125 mg daily.

Under conditions such as total starvation when all energy is derived from protein and fat, the production of ketone bodies by the liver is accelerated and the excretion of ketones in the urine increases. In normal adults the appearance of gross ketonuria, according to Peters and Van Slyke (1946), does not reach its height until 3 to 5 days of the fast have elapsed. As starvation proceeds ketosis gradually diminishes. He states that in the normal male, ketosis of starvation does not reach serious proportions because sufficient carbohydrate is derived from protein and oxidized, and the levels of blood ketones are not high enough to tax severely the mechanism for the preservation of acid-base equilibrium. In one subject about 6 g of β-hydroxybutyric acid were excreted daily in the urine for the last two weeks of a 31-day fast. In diabetic acidosis ketonuria may reach values 10 times higher than this.

Compared with these figures the amounts of acetones excreted in the urine in our subjects on the meat ration are insignificant, and it appears that this slight ketonuria observed under these conditions for

Table 4.

Nitrogen Balance.

	Standardization phase					Experimental phase					Field phase				
	Nitrogen intake	Faecal nitrogen (approximately)	Urinary nitrogen	Total nitrogen elimination	Nitrogen balance	Nitrogen intake	Faecal nitrogen (approximately)	Urinary nitrogen	Total nitrogen elimination	Nitrogen balance	Nitrogen intake	Faecal nitrogen (approximately)	Urinary nitrogen	Total nitrogen elimination	Nitrogen balance
Meat group															
Subj. No. 1	15.4	1.5	12.7	14.2	+1.2	19.9	1.0	16.8	17.8	+2.1	19.8	1.0	21.8	22.8	— 3.0
„ „ 5	14.7	1.5	12.5	14.0	+0.7	19.9	1.0	15.6	16.6	+3.3	19.8	1.0	24.7	25.7	— 5.9
„ „ 6	11.7	1.5	11.4	12.9	—12	19.9	1.0	12.9	13.9	+6.0	19.8	1.0	21.9	22 9	— 3.1
„ „ 10	8 7	1.5	11.1	12.6	—3.9	19.9	1.0	13.4	14.4	+5.5	19.8	1.0	14.5	15.5	+ 4.3
„ „ 12	16.4	1.5	16.4	17.9	—1.5	19.9	1.0	14.9	15.9	+4.0	19.8	1.0	22.3	23.3	— 3.5
„ „ 4	16.0	1.5	12.0	13.5	+2.5	19.9	1.0	11.7	12.7	+7.2	-	-	-	-	-
„ „ 8	16.6	1.5	15.1	16.6	0.0	19.9	1.0	14.5	15.5	+4.4	-	-	-	-	-
Mean:	14.2	1.5	13.0	14.5	—0.3	19.9	1.0	14.3	15.3	+4.6	19.8	1.0	21.0	23.0	— 2.2
Carbohydrate group															
Subj. No. 2	13.1	1.5	19.7	21.2	—8.7	0.0	0.5	5.9	6.4	—6.4	0.0	0.5	7.7	8.2	— 8.2
„ „ 3	13.8	1.5	10.3	11.8	+2.0	0.0	0.5	5.2	5.7	—5.7	0.0	0.5	8.8	9.3	— 9.3
„ „ 7	21.6	1.5	13.3	14.8	+6.8	0.0	0.5	8.3	8.8	—8.8	0.0	0.5	9.6	10.1	—10.1
„ „ 9	17.9	1.5	12.0	13.5	+4.4	0.0	0.5	5.7	6.2	—6.2	0.0	0.5	7.0	7 5	— 7.5
„ „ 11	14.4	1.5	10.2	11.7	+2.7	0.0	0.5	4.1	4.6	—4.6	0.0	0.5	-	0.5	— 0 5
Mean:	16.2	1.5	13.1	14.6	+1.4	0.0	0.5	5.8	6.3	—6.3	0.0	0.5	6.6	7.1	— 7.1
Meat-carbohydrate group															
Subj. No. 4	16.0	1.5	12.0	13.5	+2.5	-	-	-	-	-	11.8	1.0	15.6	16.6	— 4.8
„ „ 8	16 6	1.5	15.1	16.6	0.0	-	-	-	-	-	11.8	1.0	17.1	18.1	— 6.3
Mean:	16.3	1.5	13.6	15.1	+1.2	-	-	-	-	-	11.8	1.0	16.4	17.4	5.6

the periods considered likely as the duration of a survival situation would have no appreciably harmful effect.

Exercise greatly increases the ketosis, and a 10-mile walk in the morning without breakfast will produce distinct ketonuria in a healthy person who otherwise is living on a normal diet (Courtice and Douglas, 1936).

A number of evidences indicate a mechanism of adaptation to ketosis. In our Eskimo studies it is observed that the degree of ketonuria is less than what is normally observed in Whites on a similar diet. On the other hand, an Eskimo soldier who had lived for several months on the normal Army mess rations excreted the same amounts of acetone as the normal white soldiers when given a "ketogenic" diet. In the subjects studied by McClellan and DuBois (1930) the ketonuria diminished after several months on a carbohydrate-free diet.

Deuel and Gulick (1932) have demonstrated that ketosis develops more rapidly and attains greater intensity in women than in men.

It has been repeatedly observed that ketosis frequently occurs under strenuous field conditions regardless of the diet, and Sargent and Consolazio (1951) showed that the ketosis is reduced when the same subject undergoes repeated field tests, indicating some evidence of adaptation.

In an Arctic bivouac at Fort Churchill the approximate caloric expenditure was 4000 calories per day. The caloric intake was about 3600. Under these conditions all the men showed trace quantities of urinary ketones almost every day, starting on the third day in the bivouac (Molnar et al., 1942).

Of the great variety of physical fitness tests (Cureton, 1947), the Treadmill Test was selected for practical reasons. It should be emphasized, however, that physical fitness is exceedingly difficult to evaluate, not only because the meaning of physical fitness is far from clear, but also because the result of the test is greatly dependent upon a number of factors beyond the control of the observer.

In all cases we observed an improvement at the end of the field phase, most marked in the carbohydrate group, associated with approximately 10-pound weight loss (7.5 %).

It should be noted that the subjects had been living on a caloric deficit of the order of 2000 calories a day, and performing daily route marches of 10 miles.

In the case of untrained personnel in poor physical condition, one would expect an improvement in physical fitness during the field phase. Our subjects, however, were all well trained and in excellent physical condition at the onset of the experiment. The factor of physical training therefore can hardly explain the difference in the physical fitness scores.

On the other hand, it appears that the weight loss may be the most important factor in explaining the observed difference. The subjects started off probably slightly overweight and the loss of 7 per cent of their body weight would tend to increase their physical performance, since there is less weight to carry during the exercise. This is in conformity with general experience under similar conditions. It is observed that the carbohydrate group, which had the greatest weight loss, also showed the greatest improvement of physical fitness scores.

The purpose of the experimental phase was to study the effect of the experimental diet on various physiological functions as compared with the levels during the normal conditions in the standardization phase. The results indicate the following effect: Both in the carbohydrate group and in the meat group, there was an increase of the physical fitness scores, most pronounced in the carbohydrate group. The basal heat production was 13 per cent higher at the end of the experimental phase than during the standardization phase in the meat group, while a reduction of 7 per cent occurred in the carbohydrate group. This difference is probably due to the specific dynamic action of protein. During the experimental phase the meat group consumed 300 ml more fluid per day than the carbohydrate group. While all subjects in the meat group were in a positive nitrogen balance, the subjects in the carbohydrate group showed a negative balance of 6.3 g on an average. Ketonuria occurred in all meat subjects and in three of the carbohydrate subjects.

During the field phase the factor of climatic stress was added to the experimental conditions, and the following results were obtained:

No significant difference was observed in the physical performance of the subject on the meat ration, the carbohydrate ration, or on the meat-and-carbohydrate ration during the actual field phase. The physical fitness scores were improved in all three groups at the end of the field phase, and this improvement was greatest in the carbohydrate group which also had the greatest weight loss. The psychiatric evaluation revealed no distinct differences between the three groups. There was no significant deterioration in morale, but an increase in carelessness, irritability and desire to sleep which occurred in all three groups. The weight loss was 7.0 per cent in the meat group, 7.5 per cent in the carbohydrate group, and 6 per cent in the group receiving both meat and carbohydrate. There was an increase in the basal heat production of 9 per cent in the meat group and 7 per cent in the meat-carbohydrate group, while the carbohydrate group showed a reduction of 7 per cent in the BMR. The water consumption was 1500 ml in the meat group, 850 ml in the carbohydrate group, and 1200 ml in the meat-carbohydrate group. All three groups showed negative nitrogen balance, which was most pronounced in the carbohydrate group, where it was approximately 7 g, as against approximately 2 g in the meat group. Ketonuria occurred in all three groups, most pronounced in the meat group.

On the basis of these findings, and in view of the fact that water supply, as a rule, does not present any problem in the Arctic, it may be concluded that the carbohydrate ration offered no significant advantage under conditions of arctic survival as stimulated in the present study. In terms of heat production and nitrogen balance, the high meat ration is preferable. It is evident from this study that under survival conditions, which necessitate caloric expenditure, between 2500 and 3000 calories per man per day, including travel of approximately 10 miles a day, 1000 calories per man per day is sufficient for a period of at least 10 days.

It would therefore seem logical that survival rations developed for arctic use should consist of protein, fat, and carbohydrate in proportions which would serve to utilize the specific dynamic action of a high protein diet, the high caloric density of fat, and the physiological advantages of carbohydrates.

Protein-fat rations with high caloric density such as various types of pemmican, have already been successfully used for more than half a century by arctic travellers. It would appear advisable to base future arctic survival rations on the principle of a high meat-fat ration as the main meal of the day prepared in the evening, and an all-carbohydrate component of the ration to be consumed in the middle of the day while on the trail.

5. Summary and Conclusions.

In a series of laboratory experiments followed by field experiments under strenuous arctic conditions, the physiological adequacy of low caloric arctic rations have been studied in groups of normal men under conditions which necessitate travel under various arctic conditions. The rations studied contained approximately 1000 calories per man per day and consisted of an all-carbohydrate ration and a high protein-fat ration. On the basis of the presented data it may be concluded that from a physiological standpoint the all-carbohydrate ration offered no significant advantage over the high meat ration under the conditions of the study.

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MAPS AND CHARTS

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