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FOR INDUSTRI OG HÅNDVERK

NORSK POLARINSTITUTT

# SKRIFTER

Nr. 118

# NUTRITIONAL REQUIREMENTS UNDER ARCTIC CONDITIONS

BY
KÅRE RODAHL


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## Preface.

This publication contains the results of nutritional surveys which were carried out at the Arctic Aeromedical Laboratory, Ladd AFB, Alaska from 1950—1952 among two groups of Whites and four groups of Eskimos during the four seasons of the year. Further details regarding the Eskimo studies will be the subject of a later publication.

I am greatly indebted to Lt. Colonel A. 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.

## 1. Introduction.

When discussing the nutritional requirements of man in the Arctic, it is necessary to consider the wide range of conditions encountered in the different parts of the arctic regions, with regard to topography, climate, animal life, habitation, and the availability of natural food resources, since all these conditions directly or indirectly may influence nutrition.

The word "Arctic" is derived from the Greek word "arktos" which stands for the northern constellation the Great Bear, and applies to the area of land and sea nearest to the North Pole. The southern boundary of the arctic lands follows in a general way the northern limits of the tree line. According to the standard definition, the arctic regions include the areas where the mean temperature for the warmest month is below 50° F, and which have an average temperature below 32° F for the coldest month. On the basis of this definition the arctic regions include northern Alaska, a large part of the Canadian Archipelago, all of Greenland, Spitsbergen and other eastern arctic islands, the northern fringe of Norway, and northern Siberia.

The greater part of the arctic regions is taken up by the Polar Basin which covers almost 3 million square miles, with depths exceeding 15 000 feet. The central portion of the Basin is an almost lifeless desert of floating ice, moving with the wind and the current from the American and Asiatic continents north across the Pole and then to the south. Here there are no possibilities whatever for permanent human settlement. In the periphery of this area of drifting ice, however, there is considerable animal life, and in particular an abundance of seal.

As Fridtjof Nansen pointed out (Nansen, 1902), the oceanographical conditions of the North Polar Basin exert a great influence upon the climate of the area, and changes in the circulation of the ice and water would greatly affect the climate of the regions surrounding it. The warm currents flowing north are essential to the growth of the marine organisms on which animal life in the Polar Sea subsists. The cold south-bound currents and the ice they carry are the main obstacles to navigation in polar waters, and exert a decisive influence upon the climate of the arctic lands. The circulation of ice and water also explains the wide range of conditions encountered in the different parts of the arctic regions, where glaciation, climate, animal life, habitation and natural food resources vary greatly.

With regard to the arctic land, almost half of Norway lies north of the Arctic circle, but due to the Gulf Stream the conditions in the northern extremity of Norway are not essentially different from some of the more southerly parts of that country.

In Spitsbergen, conditions are far more severe, with an unfavorable climate, exceedingly difficult terrain, and a long period of winter darkness. On the other hand, both land and sea offer an abundant animal life, sufficient to support human beings in some numbers. The permanent inhabitants include several thousand coal miners.

Greenland represents practically all variations of arctic conditions. Its northern extremity, Pearyland, is the part of our earth closest to the North Pole, while the southern tip of Greenland, Cape Farewell, has the same latitude as Oslo, the capital of Norway. Four fifths of this largest island on earth are covered with eternal lifeless ice. Pearyland, though very nearly free of ice, supports only a humble vegetation. The climate is dry like that of a desert, and sand storms and extremely cold and violent gales, combined with four long months of winter darkness, make outdoor activities almost impossible. In the southernmost parts of Greenland, however, the climate is quite favorable, with fairly mild summers and dry cold winters. The fauna is very rich, and includes a large number of land mammals of great importance in the economy of Eskimos and Whites. In the fjords along the coast there is an abundance of seal and fish, and the rivers are rich in salmon. In other words, there are ample opportunities for man to obtain food from the natural resources.

The Canadian Arctic consists of a multitude of islands and a long arctic coast where conditions largely are similar to the corresponding areas of Greenland.

In Alaska there is the arctic coast in the north, with scattered isolated Eskimo settlements and a climate similar to that of the other arctic coastal regions. The arctic tundra stretches from the Polar Sea to the huge mountain range, the Brooks Range, beyond which there are immense forests rich in game, and finally, in the interior, cultivated land.

The remainder of the arctic regions consists of the arctic zone of Siberia, a closed land of islands and tundra. The eastern part of arctic Siberia is similar in climate to northern Alaska. Northern Siberia has a typically cold arctic summer; in winter the temperature decreases markedly as one goes inland from the coast.

When considering the most extreme conditions as judged by the mean temperature of the coldest month, Alaska is in a very favorable situation compared to the rest of the arctic areas, the mean temperature of the coldest month of northern Alaska being only —20° F, as against —30° F in the greater part of the Polar Basin, and —35° F in the northern Canadian Arctic.

From this summary it is evident that "arctic conditions" may mean conditions of entirely different nature, depending on the geographical area Considered. A would, therefore, be impossible in one report to cover the nutritional requirements under the great variety of arctic conditions. In this particular paper, conditions in Alaska and Greenland will form the main basis for the evaluations.

Not only may the nutritional requirements vary with the varying climatic conditions encountered in the different arctic areas, but the caloric need may be greatly affected by the difference in terrain, snow cover, and the conditions of the ground. For instance, walking across the level tundra will require considerably more energy than marching along a level road, and the energy required for walking on foot through snow will vary with the depth of the snow, its consistency, and whether or not there is a crust of wind-blown snow on top of it. Finally, training and experience will greatly affect the amount of energy used to perform certain tasks. Thus, a trained skier or snow-shoer will travel at a greater speed using less energy, than a person who does not fully master the technique of skiing or snowshoeing.

It is therefore obvious on the basis of these considerations that nutritional requirements under arctic conditions must vary within fairly wide limits.

The problem of nutrition in arctic regions have confronted us for many years, but until recently little scientific attention has been focused on this important subject. Consequently, lack of knowledge regarding the presence of vitamins in the flora and fauna of the arctic regions has prevented the trappers or arctic travelers from fully utilizing the natural resources, and many a trapper has died in his bunk from scurvy without knowing that just outside the cabin door there were sufficient sources of vitamin C to prevent and even cure his illness.

Through the ages many of the tragedies in the Arctic have been due to lack of information about proper feeding. In spite of the advanced knowledge of vitamins and of illnesses arising out of malnutrition it is a mistake to imagine that scurvy and beri-beri are things of the past. As late as in 1940 I had the opportunity of recording a mild case of beri-beri among European trappers in Greenland (Rodahl, 1945), and in the winter of 1937 mild cases of this disease and of hypovitaminosis C occurred among the trappers (Høygaard and Rasmussen, 1938).

In the Antarctic, according to Dr. G. H. Macklin (quoted by Hayes, 1928), Scott's South Pole party suffered from scurvy, and this was one of the factors responsible for the Scott disaster. Not only were Scott's trail rations poor in vitamins C and B, but the party had also lived on rations poor in these vitamins during the winter prior to the dash to the Pole.

It might be expected that the Eskimos who keep no milk-producing animals, and who for a great part of the year live almost exclusively on meat, may have a diet insufficient in carbohydrates, minerals and certain vitamins. If this were the case, however, they would not be likely to survive on their primitive diet.

It appears from Brøggers' description (1908) that the nutrition of the early Norwegians must have been very similar to that of the Eskimos, and even as late as 2000 years ago hunting and fishing must have been by far the most important means of subsistence of the ancient Norsemen. Since that time agriculture and industry have completely changed the dietary habits. Thus the study of the diet of the primitive hunters may offer the basis of an interesting comparison between the diet of the stone age man and the problems of modern nutrition.

It has repeatedly been demonstrated that the white man in his struggle to get along better in the hostile arctic environment may learn much from the Eskimos' way of living. In considering arctic nutritional problems it would therefore seem natural to turn our attention to the natives of the Arctic, who through generations have adapted their habits to suit the natural conditions of the country.

Fortunately man possesses great adaptability, and the wide extremes in diet that are compatible with health are surprising. Thus, man can live comfortably on a meat diet, a vegetable diet, or a combination of both. It has frequently been shown that arctic travelers normally accustomed to varied food may develop a liking for meat and blubber, when forced to live off the land, and may survive and maintain full working capacity on this food alone. On the basis of the generally accepted nutritional requirements in civilized conditions, this diet may appear highly inadequate.

The fact remains, nevertheless, that Nansen and Johansen (Nansen, 1897) maintained health and fitness on nothing but meat and blubber during nine months in a stone hut in Frans Josef Land. Here they slept on a shelf of stone, and cooked their meals by a blubber oil lamp.

They ate boiled bear flesh and soup in the morning, and fried steak in the evening. On this regime they not only remained perfectly healthy throughout the arctic winter, but they both gained considerable weight. Thus, Nansen gained 22 lbs., and Johansen 13 lbs. as a result of a winter's feeding on nothing but bear's meat and fat in the arctic climate. Nansen writes with regard to their appetites: «We consumed large quantities at every meal, and, strange to say, we never grew tired of this food, but always ate it with a ravenous appetite."

Sometimes they ate blubber with the meat, or dipped the pieces of meat in a little oil. A long time might often pass when they ate almost nothing but meat, and scarcely tasted fat. At other times they ate burned blubber which they picked from the lamp.

The fact that man can remain in good health on a diet of meat alone has further been convincingly proved by Stefansson (1935-1936, 1946). The evidence on which he clearly states this fact is ample and incontrovertible, both from his extensive field studies and from carefully controlled laboratory investigations, directed by Dr. E. F. DuBois, at the Russell Sage Institute of Pathology in New York, when Stefansson and Karsten Andersen lived on nothing but meat for a whole year (McClellan, 1930, McClellan et al. 1930a, 1930b, 1931). In this connection it was demonstrated that on this high protein diet there was a more efficient absorption of proteins than on a mixed diet. It was also shown that lean meat produced nausea and vomiting, which disappeared when additions of fat or fatter meats were given, which has also been experienced by the Eskimos.

It should be noted that the diet on which Nansen and Johansen, as well as Stefansson and Andersen, subsisted is not identical with the Eskimo diet, for the Eskimos, in addition to meat and fat, eat considerable quantities of entrails and plant food in the form of land plants and sea algae. During the summer 50% of their vitamin C supply is obtained from marine algae.

On the basis of the generally accepted view regarding the vitamin C requirements in man, both Nansen and Johansen, as well as Stefansson and his companions should have developed scurvy, since it would be impossible from meat alone to ingest the quantities of vitamin C usually recommended in textbooks as the daily requirement.

On the other hand, during the dark period of the year, November to February, the European trappers in Greenland, living on their usual diet of imported foodstuffs, generally show a lack of initiative, and complain of feeling lazy and show symptoms of debility (Rodahl, 1949 a, b). It has been suggested that this may be due to lack of vitamin C. Furthermore, examination of the crew of a Norwegian hunting vessel, who had spent the previous winter in Northeast Greenland, revealed that the whole crew of twelve men suffered from deficiency in vitamin A, ten of the twelve men suffered from deficiency in vitamin C, and the captain had manifest beri-beri (Høygaard and Rasmussen, 1938).

While deficiency diseases have been common among European trappers in the Arctic who mainly subsist on imported foodstuffs, they appear to be practically unknown among primitive native Eskimos who live entirely upon arctic animal organs and plants. It would therefore be of interest to compare the Eskimo diet and its vitamin content whith that of the white trappers.

We know that the Eskimo may eat practically all soft parts of the animals with the exception of the gall bladder, urinary bladder, rectum, and some foods which are considered poisonous. In times of famine even the skins of seals are eaten (Høygaard, 1941). While the Eskimo considers some of the internal organs as delicacies the white trapper seldom eats more than the liver, and often even this is discarded. We also know that the Eskimo eats large quantities of both sea and land plants, while the trapper seldom eats any of them.

It is interesting to note that all the internal organs and plants which have the highest vitamin contents are considered particular delicacies by the Eskimo, and that though he knows nothing about vitamins some of his methods of preparing stored foods offer the best possible preservation of the vitamins. Thus, plants stored in blubber bags made of seal skin ("imigarmit"), or in stomachs, together with dried meat, boiled seal flippers, boiled narwhale skin, blubber or fat, and dried marine algae, have been found to contain most of their vitamin C even after they have been kept in this way for months.

With a view to ascertaining to what extent vitamin deficiency might apply to the health of the arctic trappers, a comprehensive study of their diet during the four seasons of the year was made during an expedition to Northeast Greenland in 1939—40 (Rodahl, 1949 c). This dietary survey showed that the trappers maintained their body weight on an average gross consumption per man of 3000 calories per day, varying from 3300 in the summer to 2100 in the middle of the winter.

In this connection it may be mentioned that Abs (1929) calculated the food intake of miners in Spitsbergen who worked on an average $9^1/_2$ hours a day in summer, and $8^3/_4$ hours in the winter. He found an average consumption of 4580 calories per man per day, the values being slightly lower in the winter than in the summer. On this regime, most of the miners apparently gained weight.

It appears (Hayes, 1928) that the daily rations of the Scott Polar party had a calorie value of roughly 4800. In all probability the entire ration was not consumed every day. In the opinion of Dr. Thomson (quoted by Hayes, 1928), this ration, which was designed to meet the needs of men who were to live for five months constantly exposed to extreme cold, and for two months at altitudes above 5000 feet, including dragging sledge weights of almost 200 lbs. per man, was insufficient with regard to calories. However, there is no way of proving this statement on the basis of the available evidence, since there are no records of the body weights of Scott and his men.

When Høygaard and Mehren in 1931 crossed the inland ice of Greenland on skis they consumed 4465 calories daily and found this amount to be ample, even under the most strenuous conditions encountered during the expedition (Høygaard and Mehren, 1931).

In table 1 the caloric content of trail rations used by other polar expeditions are summarized.

As pointed out by Keys (1949—50), the calorie requirement must be related to the size of the individual, to his basal metabolism, to his relative obesity, age, climate, occupation, and general mode of life.

Of greatest importance is the question whether or not the food intake is maintaining the body weight constant, providing there is no changing state of hydration, or an altered ratio of fat to muscle. If the body weight is maintained constant, then the intake is the requirement in the sense of maintaining balance under the conditions of the study.

Another question which has to be considered is whether or not the body weight, regardless of being constant, is at a level which may be characterized as most desirable for the person. In field experiments we have found that the physical fitness as determined by standard tests, improved in sub-

Table 1.

*Trail rations used by various polar expeditions.* *

| Expedition | Ration Wt. | Caloric Content | Ratio Protein: Fat: Carbohydrate |
|---|---|---|---|
| Courtauld, 1935 ........ | 27.7 oz. | 4.174 | 1 : 2.1 : 2.1 |
| Watkins, 1930 ......... | 39.4 oz. | 6.000 | 1 : 1.4 : 1.5 |
| Lindsay, 1934 ......... | 30.0 oz. | 4.300 | 1 : 1.0 : 1.3 |
| Glen, 1935—36 ........ | 32.0 oz. | 4.400 | 1 : 1.4 : 2.1 |
| Rymill, 1934—37 ...... | 25.9 oz. | 4.000 | 1 : 2.0 : 2.2 |
| BAE II 1933—35 .... | 37.5 oz. | 5.500 | 1 : 1.8 : 2.8 |

* Taken from «Report on Scientific Results of the United States Antarctic Service Expedition 1939—41.» Proceedings of the American Philosophical Society, 89, p. 237, 1945.

jects living on 1,000 calories per day for 10 days, performing considerable muscular work. This was interpreted as being the result of loss of weight in men who were slightly overweight, which made it easier for the subject to perform the physical fitness test. Because they had less "load" to carry, the subjects also stated that they felt better after this loss of weight (Rodahl, Shaw and Drury, 1952).

In Lusk's scale, the calorie requirements of an average adult male doing moderate work for 8 hours was assessed at 3,300 gross calories (3,000 net calories). The League of Nations scale recommended an allowance of 2,400 net calories per day for adult persons not doing manual work, and 3,000 net calories for adult males performing moderate work 8 hours a day.

Keys (1949) suggests that all the recommended calorie figures of the National Research Council Recommended Daily Allowances seem high. Similarly, an elaborate analysis of nutrition in Switzerland during World War II led to the conclusion that the calorie requirements established by the League of Nations are too high (Fleisch, 1947), 2,160 calories daily being sufficient for a man with no special manual work to maintain favorable health. Magee (1948) questions whether a significant number of hard workers anywhere require much more than 3,500 calories seven days a week.

Estimates based on calorie expenditures per hour for various types of hard manual work extrapolated to a yearly or monthly basis are apt to err, in assuming that the laborers in question are always active, and experience has shown that the results are invariably much less when actual food consumption is studied on a longer time basis (Keys, 1949).

In the revised scale of the National Research Council (1948) the recommended calorie allowance for a "physically active" man of 70 kg (154 lbs.) is set to 3,000 calories, 2,400 calories for sedentary men, and 4,500 calories for heavy work.

In the judgment of the Committee on Calorie Requirements (Food and Agriculture Organization of the United Nations, 1950), an average 25-year-old man needs on an average for the entire year 3,200 calories daily. The Committee defines this man as follows: "The reference man is 25 years of age. He is healthy, i. e., he is free from disease and exhibits a ,normal' degree of physical fitness. He weighs 65 kilograms and lives in the temperate zone at a mean external temperature of 10° C. He consumes an adequate, well-balanced diet; he neither gains nor loses weight. His activity is exemplified by the following average weekly schedule: on each working day, 8 hours of physical work of the type referred to below, 4 hours of ,sedentary' activity (e. g. reading, writing), a walk of 5 to 10 kilometers on the level, and at least 2 hours out of doors; on each non-working day, the active pursuit of exercise and sport not of the extremely strenuous variety. The degree of activity involved in occupation in light industry, driving a truck, dairy farming or market gardening, or general laboratory work would represent approximately his working activity."

The Committee on Calorie Requirements (1950) recommends the following adjustments for calorie requirements according to body size, age and environmental temperature:

1. Body size: E (i. e. calorie requirement) $= 152.0\ (W)^{0.73}$ for men. W = body weight in kilograms.
2. Age. A decrease in calorie requirement of 7.5 per cent for every 10 years beyond the age of 25 years.
3. Environmental temperature. Calories/man/day $= 4{,}660 - 15.9\ T_f$ where $T_f = 0.5$ (daily maximum plus minimum measured in degrees Fahrenheit), or an increase of 5 per cent of the requirements at the reference level of 10° C for each 10° of lowered temperature.

With regard to the effect of climate one may expect that it affects the calorie requirement through the influence on basal metabolism, and because of the energy cost of bodily movement in bulky clothing, through difficult terrain, snow etc.

Johnson and Kark (1947) compared the calorie intake of soldiers doing the same type of work under similar conditions except for climate, and found that as the environmental fell the calorie intake rose. They concluded that the difference could not be accounted for by differences in basal metabolism, but suggest that the increased intake was in part due to the binding and hobbling effect of the heavier clothing worn in the colder environment. Gray et al. (1951) found that the calorie output of a given amount of external work performed at a constant temperature increased about 5 per cent when the clothing was changed from temperate to arctic clothing, and that the calorie output for a given amount of external work performed in a given outfit of clothes decreased about 2 per cent as the temperature was raised from —15° to 60°F. In other words, the authors find that the change in metabolism due to the hobbling effect of clothing appears to be at least twice as great as the change due to ambient temperature, and they believe that it must be regarded as playing a major role in the increased calorie requirement as the temperature is lowered.

In animals the level of metabolism has been found to be inversely related to the environmental temperature. In man studies on the influence of climate on metabolism are conflicting and the problem is greatly complicated by the possible effect of race and diet.

It has been generally considered that the basal metabolism in white people is depressed in warm climates, and increased in cold climates. In the subtropical climate of New Orleans, Eaton (1939) reports the basal metabolism to average 90 per cent of the standards for more northern regions, and Hafkesbring and Borgstrom (1926—27) found even lower values. At San Paulo, Brazil, the basal metabolism has been reported to be 6.5 per cent lower than the standard for temperate North America. It should be noted, however, that the standards referred to are generally considered 6—8 per cent too high, and that if this is taken into consideration, the reported deviations from the standard are very small.

In cold climates, basal metabolic rates higher than the standards for Whites in temperate environments have been reported in Eskimos. In the case of Eskimos, figures from 13 to 33 per cent higher than the DuBois standards have been reported. In a recent study (Rodahl, 1952, 1954) it has been shown about 9 per cent of this higher metabolism in Eskimos is caused by apprehensiveness, and about 15 per cent is caused by the specific dynamic action of the high meat diet of the Eskimo. When these two factors were eliminated, the basal metabolism of the Eskimo was almost exactly the same as in White controls. Thus the difference is not caused by racial factors.

In Whites living in Alaska, the basal metabolism was 6 to 8 per cent below the DuBois standard, which is the same as the basal metabolism observed in white men living in temperate climates (Rodahl, 1954). In a recent study (Ames and Goldthwaite, 1948) eleven men were first tested in Massachusetts in the fall and then at intervals during the winter in Northern Canada. There were no significant changes, except in one man who had the greatest exposure to the outside cold while living in Canada. In his case a rise of about 20 per cent occurred.

Some reports suggest that increase in human metabolism may be present after several days' exposure to cold. Spealman et al. (1948) found, however, that energy metabolism was not affected greatly by environmental extremes: 16 to 21° C, as judged by the record of calorie intake, dietary composition, basal metabolism, and resting, fasting respiratory quotients.

It thus appears that an increase of basal metabolism in man due to climate may be questionable, although Keys (1949—50) writes: "On the basis of the present information, it would seem reasonable to suggest an adjustment to the climate of caloric requirements which might be put at about $\pm 10$ per cent because of basal metabolism alone."

Quenouille et al. (1951), on the basis of statistical analysis of the available data, have prepared prediction tables for metabolism in relation to height and weight for a mean annual temperature of 70° F and mean annual humidity of 75%. Starting from these points, metabolism for 24 hours changes inversely with temperature at a rate of 4 calories for 1° F in men, and changes directly with humidity by 3 calories for 1%. According to these calculations the basal metabolism of a man of 65 kg and 175 cm in New York would be in the order of 1638 calories, and in the Canadian subarctic about 1865.

Høygaard (1941) has assessed the energy requirements of the adult male Angmagssalik Eskimo (Southeast Greenland) to 2800 calories per day, assuming his outside work, like hunting and fishing, and exposure to cold, to require an additional 150 calories per hour. The total average daily output then amounts to:

| | |
|---|---|
| 8 hours' sleep at 76 less 10% calories per hour .................. | 537 |
| 12 hours' inactive stay at 76 plus 30% calories per hour ........... | 1185 |
| 4 hours' outside work at 76 plus 30% plus 150 calories per hour .. | 995 |
| | 2717 |

On the basis of the data of Krogh and Krogh (1913) from four male West Greenland Eskimos, Høygaard has calculated the total average energy expenditure for Eskimo men with a body weight of 65 kg to be 2920 calories.

As the result of various field trials Johnson and Kark (1946) conclude that 4500 calories per man per day were required to maintain bodyweight and efficiency at 90° F, and 4700 calories at —3° F.

Johnson and Kark (1946) estimate that during the Canadian Army Arctic Mobile Exercise "Musk Ox", February—May 1946, when a group of 48 soldiers covered about 3300 miles in tracked snowmobiles in mean temperatures ranging between 35 and —40° F, caloric balance, as judged by maintenance of bodyweight, was well maintained on a caloric intake of 4400 calories per man. Of the 4400 calories 11 per cent came from protein, 40 per cent from fat, and 49 per cent from carbohydrate. In comparison, they report the average daily consumption per man in U. S. training camps to be 3800 calories (13 per cent from protein, 43 per cent from fat, and 44 per cent from carbohydrate).

Johnson and Kark (1946) also report the results of tests at Ladd Field, Alaska, in 1943, where groups consisting of from 1 to 5 men consumed 1200—3200 calories per man per day from 4 to 10 days. An average loss of weight per day of 0.4 lbs. was reported for the group consuming 3200 calories, and 1.1 lbs. for the group consuming 1200 calories. Both groups marched 9 miles a day cross country.

On the basis of metabolic balance studies in a group of men flown directly from Florida to Canada where they were exposed to the cold for a period of 12 days, Bly et al. (1950) concluded that 3400 calories are required for men with adequate clothing, fuel and tentage, while doing no physical work other than necessary to keep themselves comfortable. For comparison, it may be mentioned that during the last years of the war the daily food ration in the messes of the Royal Canadian Air Force averaged 2,870 calories per man with an additional 200—400 calories being consumed outside the messes (Branton et al. 1947).

During the winter of 1948—49 Johnson et al. (1949) conducted three nutrition surveys on personnel of the Cold Weather Material Testing Unit at Ladd Air Force Base, Alaska. The subjects were young men, and were classified as "moderately active", spending 80—90 per cent of the day indoors at tasks involving moderate exercise. It was concluded that calorie balance was just maintained without depositing unnecessary fat on an average calorie intake totaling about 5900 calories per man per day. The authors conclude that this high calorie intake was no more than necessary to maintain balance and therefore represents the actual requirements for these men. They recommended that a daily average intake in the mess of around 4000 calories per man should be provided, and that provision should be made for the troops to obtain approximately 900 calories per man per day outside the mess.

Swain et al. (1949) have presented a series of surveys which they undertook at Fort Churchill, Manitoba, Canada, primarily to obtain information on the nutrient intake of garrison troops receiving unrestricted rations in a subarctic climate. The study was carried out in the winter of 1947—48 on garrison troops receiving an abundant and varied ration of fresh and frozen foods (5,500 calories issued per man per day), the men being under medical observation throughout the winter. Surveys were conducted during November 1947, February and April 1948. The average man was moderately active and spent about three hours daily in the open. The food consumption was estimated by inventories taken at the beginning and the end of each 10-day period, records were kept of food issued, plate waste and kitchen waste were weighed, and head counts were made at each meal. Computations were made with the aid of tables of food composition.

According to these calculations, the average total daily consumption per man in the three surveys was 5,620, 5590 and 5,690 calories. On this diet, an average weight gain of 3.4 lbs. per man from December to April was observed. They found the calorie intake to be inversely correlated with the mean temperatures prevailing at the time of the survey, and directly correlated with the mean windchill.

The percentages of calories furnished by protein, fat and carbohydrates remained almost constant in all three surveys, averaging 13, 41 and 46, respectively. They conclude that these values are not significantly different from those reported for United States troops eating a garrison ration in temperate climates, nor was the pattern of food habits different in the subarctic climate from that of the U. S. training camps in temperate climates. In particular, they found no evidence of an increased appetite for fats in the subarctic winter. This survey is in agreement with Johnson and Kark's generalization on the basis of observations durinȝ World Wars I and II, that the colder the weather, the more North American troops want to eat.

Schor and Swain (1948) report the results of simultaneous nutrition surveys carried out in 1945 at 44 military posts of the United States Army where Field Ration A was provided. They estimate the average calorie intake to be approximately 3,700 calories with an addition of 300 to 400 calories purchased at P. X. (protein 127 g, fat 181 g, carbohydrate 411 g, calcium 1.3 g, phosphorus 2.2 g, iron 23.3 mg, vitamin A 10.042 I. U., thiamine 1.6 mg, riboflavin 2.9 mg, niacin 23.0 mg, ascorbic acid 89.0 mg). No significant correlations were found between the consumption of any individual nutrient and local mean temperature, altitude or activity of the group.

During World War I, studies by Murlin (1918) indicated that the typical U. S. Army soldier consumed 129 g protein, 121 g fat, and 496 g carbohydrate, which supplied slightly less than 3,700 calories.

McCay et al. (1945) determined the nutrients actually consumed by the men during a series of studies at four large naval training stations. They conclude that the typical man in the U. S. Navy eats food that provides about 3400 calories or less per day, and that this amount of food permits some gain in weight. Of the 3400 calories served in the messhall but not necessarily consumed, carbohydrate represents 42 per cent (410 g), protein 14 per cent (103 g), fat 44 per cent (109 g).

The typical man in the Navy tends to discard part of his food, espcially fat (50 per cent), and in exchange for this he purchases food rich in sugar.

In the Greenland trappers (Rodahl, 1949 b), the average daily consumption of protein was 94 g (12.2 per cent of the calories), of fat 197 g (57.5 per cent), and of carbohydrate 234 g (30.3 per cent) (Table 2). For men of similar size and age engaged in work of similar magnitude in Scandinavia, the recommended figures are roughly: 100 g protein, 90 g fat and 400 g carbohydrate (Lundsgaard, 1953). Compared with the Canadian dietary standard, the trapper's consumption of protein is slightly higher, and of fat much higher. On the other hand, the consumption of carbohydrate is comparatively low. The trapper's diet, similarly to that of the Eskimo, is more a fat diet than a carbohydrate diet. When comparing these figures with the recommended daily allowances in the U.S.A., it is observed that the trapper's consumption of protein is higher than the recommended figures.

In the miners in Spitsbergen (Abs, 1929), the average consumption of protein was 178 g, fat 166 g, and carbohydrate and alcohol 607 g.

Høygaard and Mehren (1931) consumed 118 g protein, 253 g fat, and 453 g carbohydrate daily during the crossing of the Greenland Ice Cap on skis in the summer of 1931.

Johnson and Kark (1946) report the calculated intake during exercise "Musk Ox" to be: 120 g protein, 190 g fat, 520 g carbohydrate.

According to Hayes (1928) the daily rations of the Scott Polar party consisted of approximately 220 g protein, 235 g fat, and 455 g carbohydrate.

In the Angmagssalik Eskimo the average daily consumption of protein was 299 g, of fat 169 g, and of carbohydrate 22 g. In the West-Greenlanders the figures were: protein 319 g, fat 154 g and carbohydrate 35 g (Høygaard, 1941).

The Eskimos apparently prefer a diet which nearly covers half of the

Table II

*Ingestion of protein, fat, carbohydrate, and minerals per man per day at different periods of the year in Norwegian trappers in Northeast Greenland.*

| Period | Food Intake per man per day, g | Calories | Protein, g | Fat, g | Carbohydrate, g | Ca, g | P, g | Fe, mg |
|---|---|---|---|---|---|---|---|---|
| I. (October 3, 1939—October 18, 1939) ... | 1191 | 3159 | 97 | 189 | 249 | 1.00 | 1.79 | 15.23 |
| II. (December 31, 1939—January 17, 1940).... | 851 | 2093 | 64 | 144 | 157 | 0.48 | 1.20 | 12.63 |
| III. (April 28, 1940—May 17, 1940) ...... | 1123 | 3312 | 91 | 212 | 227 | 0.86 | 1.60 | 18.77 |
| IV. (June 15, 1940—June 30, 1940) ...... | 1275 | 3311 | 123 | 242 | 303 | 0.92 | 1.76 | 18.07 |
| Mean | 1110 | 2969 | 94 | 197 | 234 | 0.82 | 1.59 | 16.17 |

Table III

*Vitamin intake per man per day at different periods of the year in Norwegian trappers in Northeast Greenland.*

| Period | Food Intake per man per day, g | Vitamin C, mg | Vitamin $B_1$, I. U. | Vitamin A, I. U. | Vitamin D, I. U. |
|---|---|---|---|---|---|
| I. (October 3, 1939—October 18, 1939)...... | 1911 | 12.0 | 362 | 5389 | 288 |
| II. (December 31, 1939—January 17, 1940)...... | 851 | 8.8 | 254 | 1348 | 260 |
| III. (April 28, 1940—May 17, 1940) ........ | 1123 | 23.0 | 273 | 2289 | 48 |
| IV. (June 15, 1940—June 30, 1940) ........ | 1275 | 11.2 | 294 | 3300 | 318 |
| Mean | 1110 | 13.8 | 296 | 3082 | 229 |

energy requirements by fat, and half by protein. They maintain that fat is necessary to keep themselves warm on cold journeys, and that they cannot stand cold when living on lean meat. In agreement with this, Stefansson (1945) describes how his Eskimo companions on an arctic journey suffered from a permanent sensation of hunger, fatigue and diarrhea after having lived upon lean reindeer meat for two or three weeks. An addition of half a cup of blubber oil daily was enough to make the symptoms disappear in three days.

Mitchell et al. (1946) have pointed out that dietary modifications may exert considerable and favorable effects upon the ability of man to withstand exposure to intense cold. According to these authors, high-carbohydrate, and particularly high-fat foods are to be preferred to high-protein foods, and a high-fat diet is probably superior to a high-carbohydrate diet in maintaining general psychomotor performance and visual efficiency as measured by flicker fusion frequency.

Dugal, Leblond and Therien (1945) have investigated the relative value of different diets in producing resistance to extremes of temperature in rats. These diets were equicaloric and equivitaminic and different only in the relative proportions of fats, proteins and carbohydrates. They found that a diet rich in fat is decidedly superior to one rich in carbohydrates for adaptation and resistance to cold and that a diet rich in carbohydrates and poor in fats is much more favorable than one rich in fats for conferring resistance to heat.

Keeton et al. (1946) on the other hand have claimed superiority for a high-carbohydrate diet over a high-protein diet in increasing the tolerance to cold of adult man under conditions in which the calorie requirements are just satisfied.

In the cold environment it would appear, however, that the heat of the specific dynamic action would contribute to the maintenance of body temperature (Keys, 1949—50, DuBois, 1928). The specific dynamic action of the high-protein Eskimo diet caused a 15 per cent higher heat production in the Eskimo (Rodahl, 1952). Glickman et al. (1948) found that the total specific dynamic action after meals containing about 1000 calories was about 169 calories for the high-protein meals (containing 37 per cent of protein calories) and 103 calories for the high-carbohydrate meals (containing 7 per cent of protein calories), or 17.0 and 9.6 per cent respectively of the total calories consumed. They conclude that high-protein meals as compared with low-protein meals exert an inappreciable effect in protecting men against a cold environment.

On the basis of the available evidence it appears that the carbohydrate may spare the N-needs of the mammalian organism at all levels of protein intake (Albanese, 1950). The protein-sparing action of fats is considerably less than that of carbohydrate (Lusk, 1928). It has been found that increasing the fat content of isocaloric diets results in an increase in the rate of weight gain, decrease in heat production and improved reproductive characteristics in rats (Pearson and Panzer, 1949). Rubner has demonstrated that the N-balance in a man fed 23 g of N and 220 g carbohydrates could be progressively improved by increasing the fat content of the diet from 99 to 350 g (Albanese, 1950).

In the Greenland trappers (Rodahl, 1949 c), the average consumption of calcium (0.82 g), phosphorus (1.59 g), and iron (16.17 mg), is higher than the Canadian standard (Table 2). When comparing these figures with the recommended daily allowances in the U.S.A., it is observed that the trappers' consumption of iron is slightly higher, but the intake of calcium is slightly lower than the recommended figures.

The primitive diet of the Angmagssalik Eskimo contained 0.5 g calcium, 2.0 g phosphorus and 2.8 g chlorides (Høygaard, 1941).

According to McCay et al. (1945) the typical man in the U. S. Navy at various training stations in the United States consumes 1.2 g calcium and 2.6 g phosphorus.

Available data indicate that requirements for a number of nutrients are markedly increased under conditions of low environmental temperature. According to Ershoff and Greenberg (1950), an increased requirement for thiamine (Ershoff 1950) and ascorbic acid has been demonstrated in animals following prolonged exposure to low environmental temperatures (Dugal, 1947). Therien and Dugal (1945) have observed an increase of over 50% in the ascorbic acid content of the tissues of rats exposed to cold temperatures. They interpret this phenomenon as being a normal physiological response to cold temperatures in animals able to synthesize ascorbic acid, indicating an increased need of this vitamin. They also observed, in support of this conclusion, that rats which died in the cold had a very low content of ascorbic acid. Some animal experiments have also indicated increased requirements for vitamin A (Ershoff, 1952 a). Adjustment to cold is significantly impaired in rats fed diets deficient in riboflavin (Ershoff, 1952 b).

In man, on the other hand, the available experimental data have failed to demonstrate clearly an increased vitamin requirement at low environmental temperatures, nor has a convincing beneficial effect of increased vitamin dosage in man against environmental stress been produced. Keys (1947) states with regard to this question: "The potential benefits of vitamin supercharging have been the subject of unwarranted claims . . . . Vitamin supercharging confers no benefit in terms of fitness, and fitness is not peculiarly sensitive to vitamin deficiencies."

Glickman et al. (1946) studied in twelve healthy men the effect of supplements of water soluble vitamins (to a diet containing per 3000 calories: 33 mg ascorbic acid, 1.22 mg thiamine, 1.77 mg riboflavin, and 8.5 mg nicotinic acid) on their ability to withstand repeated exposures of 8-hour duration to intense cold (—20° F). They conclude that this experiment indicated clearly that the ability of men to withstand the damaging effects of repeated exposures to cooling environments and to maintain normal neuromuscular and mental efficiency cannot be appreciably enhanced by giving excessive doses of ascorbic acid, thiamine, riboflavin and nicotinic acid above the amounts required for adequate nutrition. They also suggest that the requirements of some of these vitamins are considerably less than the recommended allowances for the Food and Nutrition Board of the National Research Council.

A carefully conducted field study with 2500 soldiers in Sweden indicated that three months of dosing with ascorbic acid produced large changes in blood and urine levels, but no changes in performance or any of the numerous aspects of health evaluated (Dahlberg et al., 1942).

Very little is known of the actual vitamin requirements of man under arctic conditions. In the case of vitamin C, the available data seem to indicate that man may remain free of deficiency symptoms on doses of vitamin C considerably below the figures usually considered as normal requirements in temperate climates.

According to Keys (1949), a number of different experimental studies on the relation between test dose intake and the level of ascorbic acid in blood and urine which have been interpreted as indicating high requirements, may be contrasted with some data on ascorbic acid intake. Thus, in Toronto in late winter, as many as 16—20 per cent of a surveyed group received less than 5 mg daily.

According to a report from the Committee of the Privy Council for Medical Research (1948) seven men at Sheffield, England, subsisted on a diet yielding 10 mg ascorbic acid daily, and ten men on only 1 mg. No sign of deficiency appeared in the former group in 14 months. In the latter group the first signs of deficiency appeared after 190 and 240 days, and frank scurvy was evident 1—2 months later. A daily dose of 10 mg ascorbic acid produced fairly rapid improvement.

In the case of the vitamin C requirements under arctic conditions, the observed evidence of a possible inter-relationship between vitamins C and A may prove to be of considerable importance. It has been demonstrated (Elvehjem and Krehl, 1947), that although cattle are able to synthesize vitamin C to meet their requirements, the amount of synthesis is greatly reduced in vitamin A deficiency. Mayer and Krehl (1948) found that one of the first symptoms of the vitamin A deficiency syndrome in rats was a depletion of the animal's vitamin C reserves, as evidenced by symptoms resembling scurvy and curable by ascorbic acid, as well as by decreases in ascorbic acid content of liver, blood and adrenals.

As pointed out by Straumfjord (1945) the range of the human requirement for vitamin A has not been satisfactorily established. The available information indicates clearly that the vitamin A levels in the blood may be influenced by many factors other than the dietary intake. Moore and Sharman (1951) have obtained indications in their experiments that the adverse effect of an unheated room on the growth of rats may sometimes be partially corrected by increasing the vitamin A allowance. The conditions necessary to demonstrate this possible beneficial action of the vitamin were, however, achieved in only two out of four experiments.

In an extensive study reported by Hume and Krebs (1949) when twenty men and three women received a diet deficient in vitamin A and carotene but complete in all other respects, for periods ranging from 6 to 25 months, they found that the majority of clinical examinations revealed no significant differences between the deprived and non-deprived group, or in the same person before and after deprivation of vitamin A (biomicroscopical appearance of the cornea and conjunctiva, the blood picture including platelet counts, gastrointestinal abnormalities, etc.). With daily doses of about 1300 I. U. vitamin A one depleted subject showed gradual restoration of capacity for dark adaption and showed rise in the plasma value for vitamin A. In prophylactic tests with a vitamin A concentrate, a daily dose of 2500 I. U. appeared to maintain two subjects for 14 to 17 months.

They came to the conclusion that about 1300 I. U. daily is a minimum protective dose of vitamin A. The figure of 2500 I. U. daily is recommended as an estimate of the requirement to cover individual variations and to leave a margin of safety. If all the vitamin is given in the form of carotene, they suggest that the daily requirement should be 7500 I. U. (three times the daily requirement of vitamin A).

Høygaard (1940) found very high night visual acuity in Eskimos living on 50,000 I. U. vitamin A and carotene a day, while it was reduced in seamen living on slightly more than 1000 I. U. daily (Høygaard, Holm and Rodahl, 1940). Høygaard and Rasmussen (1938) found reduced night vision in the crew of a sealing vessel at the end of a winter in Greenland. No hemeralopia was observed in Norwegian students living on more than 3,600 I. U. vitamin A daily (Høygaard, Holm and Rodahl, 1940).

During the fall the Greenland trappers' consumption of vitamin A is above the level usually considered as the normal requirement for temperate climates (Table 3). In this period most of the vitamin A is obtained through the ingestion of eggs, butter, cheese, milk and vitaminized margarine. During mid-winter, at which time there is practically no daylight, the intake falls much below normal requirements. In the spring and summer the vitamin A consumption still remains at a low level. The Greenland Eskimo, on the other hand, has very high vitamin A intake during all periods of the year, perhaps as much as 50,000 I. U. vitamin A daily, thanks to the ingestion of livers rich in vitamin A.

The Arctic trappers consume very little vitamin $B_1$, while the Eskimo diet is rich in this vitamin. Of the European foodstuffs usually brought up to the trappers in Northeast Greenland, eggs, sardines, potatoes, ham, peas, beans and dark bread are of most value from the standpoint of the vitamin $B_1$ supply.

When considering the vitamin $B_1$ requirement for the arctic trappers, it should be remembered that on account of the high consumption of fat and protein, and the relatively low consumption of carbohydrate by these people, the actual requirement of vitamin $B_1$ may be considerably lower than the amount usually recommended.

In the month of March 1940, our base at Revet, Northeast Greenland, was visited by a young trapper, 25 years old, who had spent the two previous winters alone trapping at Peters Bay, latitude 76° N. During the whole winter he had suffered from anorexia. His diet was very little varied, and consisted mainly of salted or fried meat, potatoes, white bread and coffee. Very little of the internal organs of newly slaughtered animals had been consumed, and no dark bread or eggs. During the last month prior to his arrival at our base, he had oedema and itching of the legs, calf muscle cramps and occasionally signs of heart trouble. For a fortnight he was given vitamin $B_1$ in the form of dried yeast, and he recovered quickly.

The consumption of vitamin C by the white trappers in Greenland throughout the whole year was less than the figures considered as normal human requirements. Thus, in the middle of the winter (December and January), the intake was less than 10 mg vitamin C per day per individual. No distinct symptoms of scurvy were observed among these trappers, but during the mentioned period they showed loss of appetite, and inertia and lack of initiative was observed. It has previously been found that Europeans in Greenland during sledging journeys of long duration subsisted on less than 15 mg vitamin C daily without any ill effect (Høygaard and Mehren, 1931). In the Greenland Eskimo the daily intake of vitamin C has been found to be 36 mg per individual, varying from 0 to 100 mg depending on the type of diet. Similar to the conditions found among the European trappers in Greenland, the daily average intake of vitamin C per person was influenced by the seasons (Høygaard, 1941). Thus, in the fall from September to November the daily intake averaged more than 50 mg per person, while it was only 8 mg during the latter half of December and the first part of January. The reason for this low intake of vitamin C was found to be the comparatively large consumption of dried foods and blubber, which contain no vitamin C. From January to June the consumption of vitamin C gradually increased.

Johnson and Kark (1946) report the calculated intake during exercise "Musk Ox" to be: 4,900 I. U. vitamin A, 2.2 mg thiamine, 2.8 mg riboflavin, 26 mg niacin and 50 mg ascorbic acid.

According to McCay et al. (1945) the typical man in the U. S. Navy at various training stations in the U.S.A. consumes 1.7 mg thiamine, 3.4 mg riboflavin, 27 mg niacin and 39—119 mg ascorbic acid.

## 2. Plan.

From the survey of the available literature it is evident that very little exact information is at hand regarding the nutritional requirements under arctic conditions. In the case of calorie requirements a number of different figures have been quoted, many of which are based on guesswork, and the data are often conflicting. Furthermore, the values for calorie expenditure in a great many different activities, under a variety of arctic conditions, are unknown. In the case of the different nutrients, the available information often seems confusing, and with regard to the vitamin requirements our knowledge is extremely sparse.

In view of the importance of the question of nutritional requirements of troops on arctic or subarctic duties, it seemed desirable to subject this problem to further analysis on a broad basis. As this vast task can only be approached during long-range studies, it was decided to initiate these investigations with a survey of the nutritional status of troops stationed in Alaska, which might yield sufficient data to allow a discussion of some of the aspects of the problems of arctic nutritional requirements.

The plans for this study involved individual food weighings among a group of 12 normal infantry soldiers and a group of 12 airmen engaged in their normal duties, stationed at Ladd AFB, Alaska, during weekly periods at the four seasons of the year. Simultaneously similar data were to be obtained from various groups of Eskimos for comparison. In addition to the weighing of food consumed, an attempt was to be made to estimate the calorie expenditure on the basis of time-activity data. As an indication of calorie balance the body weight at the beginning and end of each period was to be used. Careful clinical examinations and some limited laboratory tests were to be made in order to detect possible deficiency symptoms.

## 3. Material.

*a. Subjects.* A total of 36 young men (infantry soldiers and airmen) of an average age of $20^1/_2$ years, with an average weight of 70.0 kg and an average height of 69 inches were used for the study, representing two different groups: the Infantry group and the Air Force group (Table IV).

The Infantry group consisted of regular infantry personnel from one company of the 4th Infantry Regiment, engaged in the usual infantry activities. The average age was 20.4 years, the average weight was 151.9 lbs. (69.0 kg), and the average height was 68 inches.

The Air Force group consisted of regular airmen on ordinary Air Force duty in Alaska, from the Arctic Aeromedical Laboratory and the Cold Weather Testing Detachment: clerks, laboratory technicians, drivers, maintenance personnel, etc. Their average age was 20.6 years, the average weight was 155.6 lbs.(71 kg), and the average height was 70 inches.

Table IV.

*Subjects.*

| Subjects | Age, years | Height, inches | Weight, lbs. |
|---|---|---|---|
| Infantry Group | | | |
| Subj. No. 1 .... | 22 | 66.75 | 203.75 |
| 2 .... | 19 | 72.75 | 187.75 |
| 3 .... | 20 | 69.0 | 144.0 |
| 4 .... | 19 | 65.0 | 126.75 |
| 5 .... | 19 | 66.75 | 127.0 |
| 6 .... | 20 | 65.5 | 128.5 |
| 7 .... | 20 | 66.75 | 155.5 |
| 8 .... | 21 | 66.0 | 123.75 |
| 9 .... | 19 | 69.0 | 145.5 |
| 10 .... | 20 | 72.0 | 176.0 |
| 11 .... | 27 | 71.0 | 180.25 |
| 12 .... | 19 | 67.5 | 129.0 |
| 13 .... | 21 | 67.25 | 133.75 |
| 14 .... | 20 | 68.0 | 164.75 |
| Mean | 20.4 | 68.09 | 151.88 |
| Air Force Group | | | |
| Subj. No. 1 .... | 23 | 66.0 | 110.0 |
| 2 .... | 22 | 72.75 | 168.75 |
| 3 .... | 20 | 67.25 | 171.5 |
| 4 .... | 20 | 68.25 | 131.0 |
| 5 .... | 20 | 67.25 | 155.0 |
| 6 .... | 20 | 69.25 | 146.25 |
| 7 .... | 21 | 71.25 | 159.75 |
| 8 .... | 21 | 70.25 | 156.75 |
| 9 .... | 23 | 66.25 | 181.75 |
| 10 .... | 18 | 70.0 | 157.25 |
| 11 .... | 21 | 74.75 | 147.75 |
| 12 .... | 19 | 72.25 | 166.0 |
| 13 .... | 21 | 74.5 | 141.75 |
| 14 .... | 23 | 74.0 | 199.5 |
| 15 .... | 20 | 78.0 | 190.0 |
| 16 .... | 20 | 72.5 | 156.0 |
| 17 .... | 20 | 63.0 | 120.0 |
| 18 .... | 19 | 67.75 | 149.0 |
| 19 .... | 19 | 70.5 | 137.0 |
| 20 .... | 21 | 68.25 | 182.0 |
| 21 .... | 20 | 66.5 | 151.0 |
| 22 .... | 21 | 69.25 | 146.0 |
| Mean | 20.6 | 69.99 | 155.63 |

The subjects in the Infantry group had lived in Alaska during a period of 17 months at the time of the commencement of the study. The Air Force group had spent approximately one year in Alaska prior to the study. They were selected on the basis of detailed medical and laboratory examinations in order to exclude any pathological conditions which might influence the results of the study.

Of the original 24 subjects, six infantry soldiers and one airman remained in Alaska and continued the studies throughout the entire year. The rest of the original subjects continued for the greater part of the year, and were eventually replaced by other subjects of similar age, weight and occupation in order to maintain the number of subjects in each group.

During each period of the study the men were again subject to extensive medical examinations, including medical histories, clinical examinations including x-ray examinations of the chest and the long bones, oral temperature, pulse rate, blood pressure, night vision, capillary fragility tests, examination of the teeth and the gingiva, in addition to blood and urine examinations. In many cases the basal metabolism was also determined.

The medical histories revealed nothing abnormal of significance to this study, with the exception of subject No. 1 in the Infantry group, who stated that he had gained approximately 10 lbs. during the last few months prior to the commencement of the study. He was included in the study nevertheless, and the recording of his body weight at intervals showed that it remained quite level throughout the entire year, with small changes of about 1 lb. from one period to another: October 1950: 202 lbs., January 1951: 202 lbs., May 1951: 201 lbs.

Table V.

*Basal metabolic rates, infantry group, examined by single test.*

| Subj. No. | Sex | Age | Date | Fast. Hours | Oral Temp. | Pulse Rate | Blood Pressure | Height in. | Weight lbs. | BMR Cal/m²/hr | BMR Deviation from Du Bois Standard |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | M | 22 | 27 Oct. '50 | 16 | 97.2 | 56 | 124/70 | 66.5 | 205.0 | 41.6 | + 1 |
| 2 | M | 19 | 27 Oct. '50 | 22 | 97.0 | 60 | 114/78 | 72.5 | 185.7 | 36.5 | —13 |
| 4 | M | 20 | 29 Jan. '51 | 16 | 97.2 | 72 | 112/80 | 67.7 | 126.5 | 39.8 | — 5 |
| 5 | M | 20 | 2 Feb. '51 | 17 | 97.5 | 56 | 118/74 | 66.7 | 131.0 | 35.7 | —14 |
| 6 | M | 20 | 30 Jan. '51 | 16 | 98.4 | 57 | 116/64 | 64.7 | 134.0 | 47.5 | +14 |
| 7 | M | 20 | 30 Jan. '51 | 17 | 97.8 | 73 | 100/64 | 66.7 | 154.0 | 41.3 | — 1 |
| 8 | M | 22 | 3 Nov.'50 | 16 | 98.0 | 60 | 112/72 | 66.2 | 123.5 | 38.2 | — 5 |
| 9 | M | 19 | 2 Nov.'50 | 17 | 98.5 | 72 | 114/74 | 68.5 | 145.7 | 48.0 | +13 |
| 10 | M | 20 | 3 Nov.'50 | 18 | 98.1 | 52 | 118/87 | 72.2 | 179.5 | 44.8 | + 8 |
| 11 | M | 27 | 4 Nov.'50 | 15 | 98.2 | 68 | 122/80 | 70.7 | 178.2 | 39.6 | — 3 |
| 12 | M | 21 | 2 Nov.'50 | 18 | 98.4 | 64 | 111/62 | 67.5 | 132.0 | 43.5 | + 4 |
| Man. | — | 21 | — | 17 | 97.8 | 63 | 115/73 | 68.1 | 154.1 | 41.5 | ± 0.0 |

Medical examination revealed no significant pathological findings, and the subjects had no complaints at the time of the study. In the Infantry group mild gingivitis was observed in one subject (No. 8) and ulcerative gingivitis in one (No. 12).*

Routine urine and blood examination showed no significant pathological findings. There was an increased sedimentation rate in several cases, especially during the fall and early winter, which was also observed in other white personnel in Alaska, without it being possible to find any explanation for this phenomenon. In a few cases the monocyte counts were high.

The basal metabolism was within the normal range (Table V.).

*b. Activity.* During October (Period I) the daily activity of the Infantry group consisted of the usual infantry training and field maneuvers, including infantry drill, marching, physical training, map reading, camp work, cleaning of rifles and equipment, digging trenches, building bivouac, cutting trees, etc., in addition to details such as loading trucks, kitchen police etc. During Period II (January), the outdoor activity also included snowshoeing, skiing, and shoveling snow. During Periods III (April) and IV (August), the activity was quite similar to that of Period I (October).

The activities of the Air Force group were largely the same at all four periods. During Periods I (October), II (January), and IV (July), most of the subjects were engaged in indoor duties, mostly clerical work, to some extent manual work such as carpentry, cleaning up of the camp area, and other camp work. A few of the subjects had guard duty, and occasionally took part in the loading of trucks, etc., driving cars or trucks, kitchen police. During Period III (April), the subjects, in addition to the above mentioned regular duties also took part in a field maneuver which lasted only a few hours.

Table VI.

*Showing caloric expenditure in the infantry group estimated on the basis of time-activity data.*

| Activity | Cal. per hour | Period I | | Period II | | Period III | | Period IV | |
|---|---|---|---|---|---|---|---|---|---|
| | | Hours | Caloric Exp. | Hours | Caloric Exp. | Hours | Caloric Exp. | Hours | Caloric Exp. |
| Sleeping | 70 | 9.1 | 637 | 7.4 | 518 | 8.9 | 623 | 8.3 | 581 |
| Dressing | 110 | 0.6 | 66 | 0.6 | 66 | 0.5 | 55 | 0.2 | 22 |
| Lying | 80 | 1.1 | 88 | 0.9 | 72 | 0.8 | 64 | 1.9 | 152 |
| Sitting | 100 | 3.4 | 340 | 3.9 | 390 | 3.8 | 380 | 4.4 | 440 |
| Standing | 110 | 1.1 | 121 | 1.1 | 121 | 1.3 | 143 | 1.5 | 165 |
| Walking | 200 | 1.9 | 380 | 0.6 | 120 | 2.5 | 500 | 2.5 | 500 |
| Conversation | 110 | 0.4 | 44 | 0.3 | 33 | 0.4 | 44 | 1.1 | 121 |
| Writing | 140 | 0.3 | 42 | 0.3 | 42 | 0.1 | 14 | 0.05 | 7 |
| Drill | 400 | 0.5 | 200 | — | — | — | — | — | — |
| Exercises | 400 | 0.8 | 320 | — | — | — | — | — | — |
| Loading | 350 | 0.1 | 35 | — | — | — | — | — | — |
| Map Reading | 140 | 0.2 | 28 | — | — | — | — | — | — |
| Camp Work | 200 | 0.9 | 180 | 1.0 | 200 | 1.1 | 220 | — | — |
| Eating | 110 | 1.5 | 165 | 2.3 | 253 | 1.5 | 165 | 1.5 | 165 |
| Physical Exam. | 150 | 0.2 | 30 | 1.0 | 150 | 0.3 | 45 | — | — |
| Reading | 110 | 0.2 | 22 | 0.02 | 2.2 | — | — | — | — |
| Classes | 140 | 0.2 | 28 | 0.8 | 112 | 0.5 | 70 | — | — |
| Showering | 110 | 0.01 | 1.1 | — | — | — | — | — | — |
| K. P. | 200 | 0.6 | 120 | 0.7 | 140 | 0.2 | 40 | 0.9 | 180 |
| Dancing | 250 | 0.02 | 5 | 0.1 | 25 | — | — | — | — |
| Cutting trees | 450 | 0.1 | 45 | — | — | — | — | — | — |
| Digging holes | 410 | 0.5 | 205 | — | — | — | — | — | — |
| Bivouac | 100 | 0.08 | 8 | — | — | — | — | — | — |
| Cleaning of equimt. | 170 | 0.06 | 10.2 | — | — | — | — | — | — |
| Climbing | 600 | 0.01 | 6 | — | — | — | — | — | — |
| Snow-shoeing | 300 | — | — | 0.4 | 120 | — | — | — | — |
| Skiing | 300 | — | — | 1.0 | 300 | — | — | — | — |
| Guard duty | 140 | — | — | 0.8 | 112 | — | — | — | — |
| Lecture | 140 | — | — | 0.5 | 70 | — | — | — | — |
| Inspection | 150 | — | — | 0.06 | 9 | — | — | — | — |
| Riding in car | 100 | — | — | 0.05 | 5 | — | — | — | — |
| Fixing skis | 200 | — | — | 0.01 | 2 | — | — | — | — |
| Movie | 100 | — | — | 0.3 | 30 | — | — | — | — |
| Cleaning rifles | 170 | — | — | 0.05 | 8.5 | 0.02 | 3.4 | — | — |
| Cleaning area | 150 | — | — | — | — | 0.1 | 15 | — | — |
| Night vision test | 110 | — | — | — | — | 0.01 | 1.1 | — | — |
| Went to town | 140 | — | — | — | — | 0.3 | 42 | — | — |
| Detail | 200 | — | — | — | — | 1.1 | 220 | — | — |
| Physical training | 300 | — | — | — | — | 0.1 | 30 | 0.2 | 60 |
| Closed order drill | 240 | — | — | — | — | 0.2 | 48 | — | — |
| Reading lying | 100 | — | — | — | — | 0.02 | 2 | — | — |
| Painting | 210 | — | — | — | — | 0.03 | 6.3 | 0.1 | 21 |
| Prep. for inspection | 110 | — | — | — | — | 0.1 | 11 | — | — |
| Fatigue detail | 110 | — | — | — | — | 0.2 | 22 | — | — |
| Cleaning barracks | 150 | — | — | — | — | — | — | 0.4 | 60 |
| Physical in lab. | 140 | — | — | — | — | — | — | 0.2 | 28 |
| Guard mount | 200 | — | — | — | — | — | — | 0.03 | 6 |
| Carpentry | 230 | — | — | — | — | — | — | 0.4 | 72 |
| Watching baseball | 110 | — | — | — | — | — | — | 0.1 | 11 |

Table VII.

*Showing caloric expenditure in the Air Force group estimated on the basis of time-activity data.*

| Activity | Cal. per hour | Period I | | Period II | | Period III | | Period IV | |
|---|---|---|---|---|---|---|---|---|---|
| | | Hours | Caloric Exp. | Hours | Caloric Exp. | Hours | Caloric Exp. | Hours | Caloric Exp. |
| Sleeping | 70 | 8.4 | 588 | 8.4 | 588 | 7.7 | 539 | 8.3 | 581 |
| Dressing | 110 | 0.7 | 77 | 0.6 | 66 | 0.6 | 66 | 0.5 | 55 |
| Lying | 80 | 1.3 | 104 | 1.5 | 120 | 0.7 | 56 | 1.3 | 104 |
| Sitting | 100 | 2.2 | 220 | 3.2 | 320 | 3.8 | 380 | 3.4 | 340 |
| Standing | 110 | 1.3 | 143 | 1.5 | 165 | 2.6 | 286 | 2.1 | 231 |
| Walking | 200 | 1.3 | 260 | 1.9 | 380 | 2.2 | 440 | 1.9 | 380 |
| Conversation | 110 | 1.1 | 121 | 0.3 | 33 | 1.3 | 143 | 1.3 | 143 |
| Writing | 140 | 0.7 | 98 | 0.8 | 112 | 0.4 | 56 | 0.4 | 56 |
| Exercise | 300 | 0.03 | 9 | 0.01 | 3 | — | — | — | — |
| Loading | 350 | 0.1 | 35 | 0.2 | 70 | 0.2 | 70 | — | — |
| Map-reading | 140 | 0.06 | 8.4 | — | — | — | — | — | — |
| Camp work | 200 | 2.3 | 460 | — | — | — | — | 0.5 | 100 |
| Eating | 110 | 1.6 | 176 | 1.2 | 132 | 1.3 | 143 | 1.4 | 154 |
| Dancing | 250 | 0.1 | 25 | — | — | 0.05 | 12.5 | — | — |
| Carpentry | 230 | 0.5 | 115 | — | — | — | — | 0.4 | 92 |
| Reading | 110 | 0.6 | 66 | 0.7 | 77 | 0.05 | 5.5 | 0.08 | 8.8 |
| Painting | 210 | 0.3 | 63 | — | — | — | — | — | — |
| Dental clinic | 140 | 0.02 | 2.8 | — | — | — | — | — | — |
| Night vision | 110 | 0.08 | 8.8 | — | — | 0.05 | 5.5 | — | — |
| K. P. | 200 | 0.2 | 40 | 0.5 | 100 | 0.3 | 60 | 0.3 | 60 |
| Guard duty | 140 | 0.4 | 56 | 0.1 | 14 | — | — | — | — |
| Cleaning lab. | 150 | 0.2 | 30 | — | — | 0.2 | 30 | 0.3 | 45 |
| Showering | 110 | 0.05 | 5.5 | 0.1 | 11 | 0.03 | 3.3 | 0.09 | 9.9 |
| Social meeting | 140 | 0.05 | 7 | — | — | — | — | — | — |
| Riding in bus | 100 | — | — | 0.04 | 4 | 0.1 | 10 | — | — |
| Before Prom. Brd. | 150 | — | — | 0.04 | 6 | — | — | — | — |
| Bowling | 240 | — | — | 0.2 | 48 | — | — | — | — |
| Cleaning area | 150 | — | — | 0.2 | 30 | 0.4 | 60 | — | — |
| Driving | 140 | — | — | 0.5 | 70 | 0.6 | 84 | 0.1 | 14 |
| Physical Exam. | 110 | — | — | 0.4 | 44 | — | — | 0.05 | 5.5 |
| Movie | 100 | — | — | 0.04 | 4 | — | — | 0.1 | 10 |
| Cleaning store | 210 | — | — | 0.2 | 42 | — | — | — | — |
| Operating Herm. Nilsen heater | 140 | — | — | 0.9 | 126 | — | — | — | — |
| Trash detail | 350 | — | — | 0.1 | 35 | — | — | — | — |
| Carrying oil | 200 | — | — | 0.02 | 4 | — | — | — | — |
| Playing piano | 140 | — | — | — | — | 0.1 | 14 | — | — |
| Alert | 150 | — | — | — | — | 0.3 | 45 | — | — |
| Desk work | 140 | — | — | — | — | 0.8 | 112 | 1.3 | 182 |
| Physical work | 200 | — | — | — | — | 0.01 | 2 | — | — |
| Repairing truck | 250 | — | — | — | — | 0.1 | 25 | — | — |
| Cleaning room | 200 | — | — | — | — | — | — | 0.06 | 12 |
| Weighing food | 140 | — | — | — | — | — | — | 0.02 | 2.8 |
| Typing | 140 | — | — | — | — | — | — | 0.2 | 28 |

The activities of the subjects during the different periods of the study are listed in Tables VI and VII.

*c. Environment.* Mitchell (1950) has stressed the importance of physical environmental control in nutrition studies, pointing out that the factors of climate, temperature, humidity, air motion etc., do modify the nutritional processes by modifying appetite, body temperature, heat economy, water

Table VIII

*Meteorological data for Ladd AFB, Alaska, for the periods of the study*

| | Temperature of | | | | | Precipitation | | | Wind | | Sky Condition (% of time) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Averages | | | Extremes | | | | | | | | | |
| | Daily Max. | Daily Minimum | Monthly | Highest | Lowest | Total inches | Snow fall, inches | Average hourly speed, m. p. h. | Prevailing direction | Greatest speed m. p. h. | Clear or scattered | Broken, overcast or obscure | Average depth of snow on ground, inches |
| October 1950 . . | 34 | 18 | 26 | 62 | -11 | 0.66 | 8.5 | 5 | ENE | 12 | 13.4 | 88.6 | 3 |
| January 1951 . . | -17 | -30 | -24 | 10 | -57 | 0.77 | 8.2 | 0 | ESE | 6 | 22.5 | 77.5 | 21 |
| April 1951 . . . . | 45 | 25 | 35 | 58 | 12 | 0.07 | 0.0 | 3 | E | 18 | 32.6 | 67.4 | 4 |
| May 1951 . . . . . | 63 | 38 | 51 | 75 | 31 | 0.26 | 0.0 | 4 | SSE | 26 | 40.9 | 59.1 | 0 |
| July 1951 . . . . . | 71 | 52 | 62 | 90 | 43 | 1.34 | 1.0 | 3 | SW | 32 | 24.8 | 75.2 | 0 |
| August 1951 . . | 69 | 49 | 59 | 85 | 41 | 1.31 | 0.0 | 3 | WSW | 18 | 18.4 | 81.6 | 0 |

balance, endocrine activity, and probably in many other ways. Lee (1953) has emphasizedthe importance of physiological climatology as a field of study.

The temperature in the living and sleeping quarters during the four periods of this study was maintained at the same level as was customary for the subjects. As a rule, both the infantry soldiers and the airmen maintained a very high room temperature in their sleeping quarters. Measurements by thermographs and hydrographs at various periods revealed that both during the winter and summer, the mean temperature in the sleeping quarters was about 75° F in the Infantry as well as in the Air Force barracks, — as a rule 70° F or higher during the day. On a few occasions temperatures as high as 100° F were recorded.

The mean relative humidity was about 20 per cent (15—30%) in the winter and varied from 5 per cent to 35 per cent in the summer.

The meteorological data for the different periods of the study for Ladd AFB are given in Table 8. In general, the climate here is characterized by a dry cold winter with very little wind, and a fairly warm summer. Thus, the factor of windchill is comparatively small. The highest temperature recorded during this study was 90° F in July, and the coldest was —57° F in January. The precipitation was small, and the greatest snow cover on the ground was 21 inches in January. A great proportion of the time the sky was clear, with long periods of sunny days.

From the viewpoint of outdoor activities, comparatively small difficulties were encountered with temperatures down to —30° F. In the case of man one may say that the limit for efficient outdoor operations under exposed conditions is in the vicinity of —30° F. At —40° F even animal activity is markedly reduced, and with increasing cold it ceases almost completely. At times the persistent frost fog during periods of extremely low temperatures hindered many phases of extensive field operations.

### 4. Methods.

*a. Food Intake.* During all examination periods a complete nutritional survey was carried out with individual food weighing at each meal. The subjects were allowed to select the food as usual in unlimited quantities. Each food item was collected on separate paper plates and in paper cups, and accurately weighed. At the end of the meal each plate or cup together with the remaining unconsumed food was again weighed and the food consumption recorded.

The periods of the study were selected in such a way that the recording of food consumption took place before pay day, to avoid abnormalities such as unusually large consumption outside the mess, and irregularities caused by liquor consumption etc.

For the computation of the results, the values were taken from the standard tables, or calculated on the basis of the recipes. The figures for the composition of foods have been obtained from the following sources:

(1) "Composition of Foods, Raw, Processed, Prepared", by Bernice K. Watt & Anabel L. Merrill. U. S. Department of Agriculture, Handbook No. 8, June 1950.
(2) "Hospital Diets". War Department Technical Manual, TM8-500, March 1945.
(3) "Nutritional Data", by H. A. Wooster, Jr. and F. C. Blanck. Heinz Nutritional Research Division, Mellon Institute, Pittsburgh, Pa., 1949.
(4) "Bridge's Food and Beverage Analysis", by M. R. Mattice. Lea & Febiger, Philadelphia 1950.
(5) "The Chemical Composition of Foods", by R. A. McCance and E. M. Widdowson, Chemical Publishing Co. Inc., Brooklyn, N. Y. 1947.

Numerous investigations have been carried out by different workers in which the values obtained by computation from food composition tables have been compared with those given by direct chemical analysis. These have in general shown that the results are sufficiently close to warrant the use of food composition tables in dietary surveys of families or groups of individuals (Food and Agriculture Organization of the United Nations, 1949). In the case of calories, there is no longer any doubt as to the general validity of estimating the calorie value of a diet from tables of food composition, provided complete and accurate data pertaining to the quantities of all foods consumed are obtained.

On comparing analytical and computed values for the different constituents, Hunter et al. (1948) found a fairly good measure of concordance. Widdowson and McCance (1943) compared the chemical composition of individual mixed diets as determined by the direct analysis of duplicate portions, with the values obtained by calculation from food tables, and found that the results were sufficiently close to warrant the use of food tables in dietary surveys.

One drawback in many nutritional surveys is the fact that though the family examined is urged to eat as usual, the diet may be altered because of the survey. There may be an increase in the purchase of the more expensive foods to impress the investigator, or a reduction when it is thought that relief may be the result of the study. In addition, the surveys as a rule place a heavy burden on the housewife, resulting in poor cooperation (Food and Agriculture Organization of the United Nations, 1949). None of these factors influenced our surveys which concerned military personnel eating in messhalls.

The dietary data were collected over a period of about a week. It was found that the diets varied little from one week to another. Thus, the week's information might be regarded as roughly valid for a season.

For the computation of the nutritional composition of the meals, the services of the I. B. M. Service Bureau in New York were used on a contract basis. The raw data were recorded on specially prepared cards, which enabled the I. B. M. to enter the data directly into the punch cards, thus eliminating lengthy transcription and reorganization of the data.

*b. Body Weight.* The body weight was recorded in each subject, nude and fasting in the morning, before and after each survey.

*c. Clinical Examinations.* A thorough clinical examination was made at each period in order to detect any changes which might result from food deficiency (Aykroyd et al., 1949): dry, coarse, lack-lustre hair, perifolliculosis, blepharitis, suborbital pigmentation and telangiectasis of the skin of the face, xerosis, follicular keratosis, angular stomatitis, cheilosis, changes in the gum (red hyperemia, blue, congested, swollen, loss of interdental papillae, recession, retraction and presence of pus), changes of the teeth and tongue (reddened, swollen, hypertrophic papillae, atrophic, papillae fissuring), signs of rickets by x-ray examination of the bones, muscular development (winged scapulae) and neurological signs such as: absent knee and ankle jerks, and tender calf muscle.

In this study the following physical signs of vitamin deficiency (Goldsmith, 1949) were methodically looked for:

Vitamin A deficiency: Dryness and scaling of the skin, follicular hyperkeratosis, xerophthalmia, Bitot's spots and night blindness or lesser degrees of abnormal dark adaptation.

B-complex deficiency: Early signs of vitamin B-complex deficiency include non-specific complaints such as decreased appetite, easy fatiguability, lack of ambition, and nervousness, as well as personality disturbances: irritability, moodiness, depression etc.

(a) thiamine deficiency: polyneuritis, cardiovascular disturbances and oedema, — anorexia, neurasthenic symptoms, digestive disturbances, constipation, have been reported as early manifestations.

(b) riboflavin deficiency: corneal vascularization, seborrheic dermatitis, glossitis, cheilosis, angular stomatitis, and lesions of the scrotum.

(c) niacin deficiency: glossitis, diarrhea, and certain mild psychic disturbances may appear prior to the development of frank pellagra.

Vitamin C deficiency: perifollicular hyperkeratotic papillae, perifollicular hemorrhages, petechiae. Poor wound-healing, measurable decrease in output. In protracted depletion: changes in the gums and atrophy of the alveolar bone with loosening of the teeth.

In addition, Goethlin's capillary fragility test was made in each subject at each period. The test was carried out according to Goethlin's original description (Goethlin, 1931). If a pressure of 50 mm Hg for 15 minutes produces not more than 4 petechiae within a circle with a diameter of 6 cm, the test is negative, i. e. one may, according to Goethlin, conclude that the vitamin C standard is normal.

The use for capillary fragility tests in the diagnosis of vitamin deficiency has been criticized by several writers. According to Murno et al. (1947 )a large minority of scurvy cases do not show positive capillary strength changes, and most studies fail to show a relation between capillary fragility, blood ascorbic acid, and the results of tolerance tests. According to Goldsmith (1949), the capillary fragility test is of no value in diagnosing vitamin C deficiency.

The night visual acuity of each subject was measured at each period with the Kodak Night Vision Tester Model II, following 30 minutes dark adaptation. A detailed description of the procedure has been published in a report by Drury and Rodahl (1952).

*d. Laboratory Methods.* For the routine blood and urine examination the standard methods were used.

The basal metabolic rate was determined by the Benedict-Roth apparatus. The technique has been described in detail in a previous report (Rodahl, 1954).

For the determination of urinary nitrogen elimination, twenty-four hour urine samples were collected in individual, labeled canteens. After thorough mixing and determination of the volume, nitrogen determinations were made as follows: Following appropriate dilation and thorough digestion with sulphuric acid and potassium persulphate, the nitrogen content was determined by the Nessler reaction. Readings were made at 540 mu with the Klett photoelectric colorimeter and corrected to mg/ml with the aid of a calibration factor.

## 5. Results.

In the Infantry messhall three meals were taken daily: breakfast, dinner and supper. A hot dish was served at each of the meals. When engaged in field maneuvers, the dinner was brought out in vans and served in the field, while breakfast and supper were taken in the messhall as usual. In-between-meals consumption was recorded on separate sheets by the subjects. These records were examined and checked by the observer and added to the food consumption for that day.

The breakfast usually consisted of fresh fruit or fruit juice, dry or cooked cereal; hot cakes with syrup and bacon, or eggs (scrambled or fried), or sausages, ham, creamed beef etc.; toast, occasionally hot buns; butter, peanut butter or jam; milk for drinking was occasionally made from powdered milk diluted with water, but as a rule fresh frozen milk was served, and evaporated milk used for the coffee.

For dinner various kinds of soup were usually served, and a meat course such as steak, fried chicken or sausages etc., and potatoes (french fried, mashed or boiled) in addition to salads or tomatoes; bread and butter, occasionally hot biscuits, cookies, doughnuts or cakes, and coffee with evaporated milk. Usually pickles, ketchup, and various sauces were available. The dessert usually consisted of canned fruit or pies.

At supper a hot dish was always served, consisting of various kinds of meat (spareribs, sausages, chicken, meat loaf, pork chops), occasionally fried fish or spaghetti, together with potatoes and vegetables such as various kinds of salads, sauerkraut, corn, beets, or onions. In addition there was bread and butter, occasionally hot biscuits and jam. Canned fruit was served as dessert, occasionally ice cream.

In-between-meals consumption generally consisted of fruit, beer, coca-cola or other beverages, cakes, ice cream or milk shakes, and occasionally snacks such as hamburgers etc.

There was very little variation between the food served in the different periods of the study, and the food in the Infantry mess was very similar to the food served in the Air Force messhall. Generally speaking, therefore, the type of food consumed by the Air Force group was about the same as listed above.

In Table 9 the food consumed in the two groups at the different periods is listed.

In the Infantry group the gross consumption of calories (Table XI) varied between 3100 and 3400 calories per man per day (mean 3200), the highest figures observed during the winter months when also the calorie expenditure was highest (Table 16). When deducting approximately 5 per cent from the figures for the gross calories intake as unabsorbed wastage, the average net consumption is approximately 3000 calories per man per day (Table 16). The average calorie expenditure for all four periods was estimated to about 2800 calories on the basis of the time-activity data (Table 16). Under these conditions no appreciable weight change occurred; there was an average weight gain of 0.4 lbs. throughout the whole year of all subjects (Table 16).

In the Air Force group the average gross consumption varied between 2400 and 3500 calories per man per day, mean 2950 (Table 10).

If 5 per cent is deducted from the gross intake as unabsorbed wastage, the figure for the average net calorie consumption throughout the year is approximately 2800 calories per man per day (Table 15), and the estimated mean calorie expenditure is 2700 calories (Tables 13, 15). On this regime the body weight of all Air Force subjects, for all four periods of the year, remained unaltered (Table 15).

The body weight of individual subjects remained about the same at the different periods of the study. In the six Infantry soldiers who were examined throughout the entire year there was an average change of +0.2 lbs. from October 1950 to August 1951:

The average consumption of fat was 126 g in the Air Force group, and 128 g in the Infantry group. In the Air Force group the highest figure for the fat consumption was observed during winter, when it was approximately 40 per cent higher than during spring and summer. In the Infantry group the fat consumption was about 18 per cent higher in the winter than in the summer (Tables 10, 11).

When considering the percentage of calories supplied from fat at the different seasons, however, it is observed that in the Infantry group 37.0 per cent of the calories were supplied from fat both during the winter and the summer, while in the Air Force group 44.7 per cent of the calories came from fat in the winter as against only 35.7 per cent in the summer (Table 12). The average figures for all subjects were as follows: In the Air Force group the average consumption of protein was 92 g (76—111 g), and 109 g (102—122 g) in the Infantry group. The average consumption of carbohydrate was 350 g in the Air Force group and 408 g in the Infantry group (Tables 10, 11).

The airmen consumed an average of 0.9 g calcium, 1.4 g phosphorus, and 15 mg iron 6300 (5500—7000) I. U. vitamin A, about 2 mg thiamine, 2 mg riboflavin, 15 mg nicotinic acid, and 74 mg ascorbic acid (32—113 mg). In the infantrymen the consumption of these nutrients were: 2.3 g calcium, 1.6 g phosphorus, 28 mg iron, 4200 I. U. vitamin A (1484—6270), 2 mg thiamine, 2 mg riboflavin, 20 mg nicotinic acid, and 102 mg ascorbic acid (88—128 mg).

Clinical examinations at each of the four periods revealed no signi-

Table 9.

*Average food consumption in grams per man per day of soldiers at Ladd AFB during the four seasons of the year. Calculated by food groups.*

| Food groups | Period I Fall | | Period II Winter | | Period III Spring | | Period IV Summer | |
|---|---|---|---|---|---|---|---|---|
| | Air-men | Inf. men | Air-men | Inf. men | Air-men | Inf. men | Air-men | Inf. men |
| *Breakfast, Lunch, Dinner:* | | | | | | | | |
| Meat, fish and poultry . . . | 219 | 241 | 206 | 213 | 198 | 163 | 197 | 230 |
| Eggs . . . . . . . . . . . . . . . . . . | 41 | 30 | 19 | 41 | 26 | 74 | 21 | 51 |
| Milk and milk products . . | 324 | 156 | 291 | 343 | 208 | 361 | 468 | 305 |
| Butter . . . . . . . . . . . . . . . . | 25 | 18 | 37 | 18 | 20 | 13 | 31 | 4 |
| Cheese . . . . . . . . . . . . . . . . | 11 | – | – | – | 9 | 6 | 1 | 18 |
| Bread . . . . . . . . . . . . . . . . . | 186 | 204 | 170 | 235 | 121 | 221 | 152 | 172 |
| Cereals and grain products | 258 | 203 | 134 | 196 | 188 | 237 | 145 | 93 |
| Potatoes . . . . . . . . . . . . . . . | 124 | 244 | 93 | 166 | 86 | 254 | 229 | 194 |
| Other roots and tubers . . . | 5 | 12 | 5 | 24 | 4 | 10 | 5 | 3 |
| Leaf and stem vegetables . | 20 | 9 | 6 | 24 | 9 | 32 | 6 | 43 |
| Flower, fruit and seed vegetables . . . . . . . . . . . . | 52 | 99 | 67 | 63 | 63 | 78 | 98 | 137 |
| Salads . . . . . . . . . . . . . . . . | 27 | 15 | 42 | 14 | 42 | 12 | 12 | – |
| Fruit, fresh . . . . . . . . . . . . | 14 | 82 | 16 | 13 | 15 | 2 | 116 | 155 |
| Fruit, canned . . . . . . . . . . | 76 | 68 | 74 | 40 | 25 | 53 | 63 | 39 |
| Juices . . . . . . . . . . . . . . . . . | – | 90 | 41 | 80 | 86 | 88 | 260 | 228 |
| Sugar, syrup, honey, jams & jellies . . . . . . . . . . | 156 | 112 | 51 | 107 | 49 | 60 | 39 | 33 |
| Dressings . . . . . . . . . . . . . | 17 | 15 | 21 | 16 | 34 | 12 | 8 | 8 |
| Gravy . . . . . . . . . . . . . . . . | 64 | 26 | 53 | 9 | 25 | 13 | 17 | 9 |
| Sauce . . . . . . . . . . . . . . . . . | 2 | 12 | 2 | 4 | 38 | 8 | 1 | 20 |
| Soups . . . . . . . . . . . . . . . . | 110 | 9 | 52 | 8 | – | 37 | – | – |
| *Consumption between meals:* | | | | | | | | |
| Beverages (coca-cola, beer etc.) . . . . . . . . . . . . . . . . . . | 232 | 112 | 133 | 55 | 90 | 168 | 191 | 293 |
| Milk shakes . . . . . . . . . . . . | 12 | 10 | – | 15 | – | 5 | – | 23 |
| Chocolate milk . . . . . . . . . . | 20 | 4 | 31 | 16 | – | 11 | 8 | 12 |
| Ice cream and sundaes . . . | 4 | 3 | – | 32 | – | 26 | – | 3 |
| Sandwiches . . . . . . . . . . . . . | 24 | 6 | 11 | 1 | – | – | 2 | 7 |
| Snacks (hamburgers, eggs, etc.) . . . . . . . . . . . . . . . . . | 13 | – | 9 | 10 | 2 | – | – | 5 |
| Candy . . . . . . . . . . . . . . . . | 15 | 15 | 24 | 19 | 27 | 0 | 1 | 2 |
| Sugar . . . . . . . . . . . . . . . . . | 4 | – | 8 | 4 | 7 | – | 8 | – |
| Fruit . . . . . . . . . . . . . . . . . | 56 | 14 | 20 | 33 | – | 7 | – | – |
| Pies, cookies, bread, cereal | 9 | 4 | 7 | 19 | 2 | – | 17 | 5 |
| Greens . . . . . . . . . . . . . . . . | 2 | – | – | – | – | – | 4 | – |
| Nuts, popcorn . . . . . . . . . . | – | – | 9 | – | 2 | – | 7 | 1 |

ficant pathological findings, and no evidence of deficiency symptoms were detected. The Goethlin's test was negative in all subjects at all four periods of the study, and no abnormalities were detected in night visual acuity. The data concerning night vision will be subject to a special report. Examination of the urine showed negative findings, with the exception of traces of acetone (in 15 out of 36 subjects), especially during winter and spring, which apparently is of no significance (Rodahl et al., 1952). The blood findings were

Table 10.

*Air Force group: average consumption.*

| Period | Calories | Water, g | Protein, g | Fat, g | Total Carbohydrates, g | Calcium, mg | Phosphorus, mg | Iron, mg | Copper, mg | Vit. A, I. U. | Vit. $B_1$, mg | Riboflavin, mg | Nicotinic Acid, mg | Vit. C, mg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I. October .... | 3500 | 1309 | 111 | 147 | 432 | 1115 | 1374 | 17.6 | 2.3 | 6748 | 1.8 | 2.3 | 20.0 | 32 |
| II. January .... | 3000 | 1066 | 90 | 149 | 325 | 809 | 1330 | 13.8 | 3.3 | 5958 | 1.4 | 1.7 | 19.5 | 70 |
| III. April ...... | 2400 | 874 | 76 | 101 | 299 | 570 | 1135 | 14.0 | 3.1 | 7069 | 2.7 | 2.5 | 18.2 | 80 |
| IV. July ....... | 2900 | 1491 | 91 | 107 | 342 | 1191 | 1626 | 15.0 | 1.7 | 5530 | 2.8 | 2.6 | 19.6 | 113 |
| Mean | 2950 | 1185 | 92 | 126 | 350 | 921 | 1366 | 15.1 | 2.6 | 6326 | 2.2 | 2.3 | 19.3 | 74 |

Table 11.

*Infantry group: Average consumption.*

| Period | Calories | Water, g | Protein, g | Fat, g | Total carbohydrates, g | Calcium, mg | Phosphorus, mg | Iron, mg | Copper, mg | Vit. A, I. U. | Vit. $B_1$, mg | Riboflavin, mg | Nicotinic Acid, mg | Vit. C, mg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I. October (Fall) ....... | 3300 | 1070 | 102 | 129 | 442 | 789 | 1416 | 18.6 | 2.5 | 4296 | 2.0 | 1.8 | 19.3 | 99 |
| II. January (Winter) ..... | 3400 | 1123 | 103 | 139 | 432 | 1156 | 1751 | 19.5 | 3.3 | 9280 | 2.1 | 3.0 | 20.7 | 88 |
| III. May (Spring) ....... | 3200 | 1309 | 122 | 126 | 412 | 1246 | 1735 | 16.8 | 2.3 | 4937 | 2.4 | 2.6 | 18.4 | 91 |
| IV. August (Summer) .... | 3100 | 1365 | 108 | 118 | 345 | 1004 | 1598 | 18.0 | 1.7 | 6270 | 2.0 | 2.2 | 21.4 | 128 |
| Mean | 3200 | 1217 | 109 | 128 | 408 | 1048 | 1625 | 18.2 | 2.5 | 6195 | 2.2 | 2.4 | 20.0 | 102 |

*Body weight in pounds*

| Infantry Subj. No. | October | January | May | August |
|---|---|---|---|---|
| 2 | 187.75 | 184.25 | 187.0 | 178.0 |
| 4 | 126.75 | 128.75 | 132.0 | 131.0 |
| 7 | 155.5 | 156.5 | 160.0 | 161.25 |
| 10 | 176.0 | 179.75 | 181.5 | 179.75 |
| 11 | 180.25 | – – | 170.25 | 171.5 |
| 12 | 129.0 | 130.75 | 135.0 | 134.75 |
| Mean | 159.2 | 156.0 | 160.9 | 159.4 |

| Period | Protein | Fat | Carbo-hydrate |
|---|---|---|---|
| Fall...... | 12.4 % | 36.3 % | 51.3 % |
| Winter ... | 12.1 % | 40.9 % | 47.0 % |
| Spring ... | 13.7 % | 36.3 % | 50.0 % |
| Summer.. | 14.3 % | 36.3 % | 49.4 % |
| Mean | 13.1 % | 37.5 % | 49.4 % |

normal with the exception of increased sedimentation rates in some cases. In general, the hemoglobin values were possibly slightly lower than the figures usually considered normal for young men, the mean hemoglobin value being 13.3 g (90 per cent).

From Table 9 it is observed that the average basal metabolic rate in the Infantry subjects showed no deviation from the DuBois standard during the first test. In four of the subjects, repeated tests on different occasions, under strictly controlled conditions, were carried out until the BMR had established itself on a constant level on the third or fourth test, when the average BMR was 8 per cent lower than the DuBois standard. It should be noted that the so-called DuBois standards are generally considered as being 6—8 per cent too high, and that the original level, published in 1916, included factors of tension in patients undergoing their first or second test. Satisfactory BMR tracings were also obtained in two of the Air Force subjects. The deviation from the DuBois standard was $\pm 0.0$ per cent in one case and in the second case $+2$ per cent in the first test.

On the basis of these examinations, then, it appears that the basal metabolism of the subjects conformed with the normal standards.

In a separate experiment 12 normal Infantry soldiers lived on the regular Air Force mess ration for a period of five days. They were allowed to consume unlimited quantities of this ration. Their average daily intake of calories was 3000, varying between 2000 and 4000 calories. Approximately 12 per cent of the calories were derived from protein, 42 per cent from fat, and 46 per cent from carbohydrate, with an estimated calorie

Table 12.

*Showing percentage of calories supplied from protein, fat and carbohydrate.*

| Period | Protein | Fat | Carbohydrate |
|---|---|---|---|
| *Infantry group* | | | |
| Fall ........ | 12.2 % | 34.8 % | 53.0 % |
| Winter...... | 12.1 % | 37.0 % | 50.9 % |
| Spring...... | 14.9 % | 34.7 % | 50.4 % |
| Summer .... | 15.0 % | 37.0 % | 48.0 % |
| *Air Force group* | | | |
| Fall ........ | 12.7 % | 37.9 % | 49.4 % |
| Winter...... | 12.0 % | 44.7 % | 43.3 % |
| Spring...... | 12.7 % | 37.9 % | 49.8 % |
| Summer .... | 13.5 % | 35.7 % | 50.7 % |

expenditure of approximately 2400 calories per day. A slight weight gain was observed during the period. During this experiment the subjects remained in a positive nitrogen balance (Table 17).

Four of the Infantry subjects were examined under carefully controlled conditions, while living on the regular messhall diet served at the Infantry messhall. Their urinary nitrogen elimination was 0.4—0.5 g per hour 14—18 hours after the last meal.

Similar findings were made in another group of 12 white men living on the diet served in the Air Force messhall. It may be added that normal white controls (students) examined by Dr. E. F. DuBois in New York (personal communication) excreted about 0.5 urinary nitrogen per hour 14—18 hours after the last meal.

## 6. Discussion.

Although it is generally recognized that proper feeding is an essential factor in maintaining normal health in arctic conditions, the actual nutritional requirements under these special conditions are by no means firmly established.

It has been suggested by several authors that the arctic calorie requirements would be in the order of 600 calories per man per day. A dietary survey during the four seasons of the year among Norwegian trappers in Northeast Greenland, however, showed that the average gross consumption per man was in the order of 3000 calories per day, varying from 3311 in the summer to 2093 in the middle of the winter. These findings are of considerable practical consequence, for the rations constitute a significant proportion of the load, and on arctic journeys every pound of weight is important because weight is nearly always a critical factor.

T a b l e 13. Air Force group.

*Caloric intake, energy expenditure, and weight change at the four periods.*

| Subj. No. | I. October 1950 | | | II. January 1951 | | | III. April 1951 | | | IV. July 1951 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Caloric Intake | Caloric Expen-diture | Weight Change | Caloric Intake | Caloric Expen-diture | Weight Change | Caloric Intake | Caloric Expen-diture | Weight Change | Caloric Intake | Caloric Expen-diture | Weight Change |
| 1 | 2210 | 2290 | +1.12 | 2220 | 2490 | —1.25 | — | — | — | — | — | — |
| 2 | 3930 | 2480 | —2.00 | — | — | — | — | — | — | — | — | — |
| 3 | 2750 | 3060 | +0.75 | — | — | — | — | — | — | — | — | — |
| 4 | 3240 | 3050 | +0.25 | — | — | — | — | — | — | — | — | — |
| 5 | 3920 | 2910 | —0.75 | 3520 | 2830 | —1.50 | 2580 | 3070 | —0.50 | — | — | — |
| 6 | 3600 | 3050 | —2.25 | — | — | — | — | — | — | — | — | — |
| 7 | 3670 | 2880 | —4.00 | 3450 | 2580 | —1.00 | 2470 | 2650 | —0.25 | — | — | — |
| 8 | 3870 | 2830 | —3.25 | 3220 | 2770 | —2.50 | 2420 | 2630 | +3.00 | — | — | — |
| 9 | 5300 | 2470 | —0.50 | — | — | — | — | — | — | — | — | — |
| 10 | 3510 | 2870 | —1.25 | 2850 | 2350 | —0.75 | 2200 | 2660 | +2.0 | 2280 | 2740 | +1.50 |
| 11 | 3300 | 2670 | +2.25 | 3160 | 2740 | +1.50 | — | — | — | — | — | — |
| 12 | 3800 | 2720 | —1.00 | 2560 | 2660 | ±0 | — | — | — | — | — | — |
| 13 | — | — | — | 3110 | 2640 | +0.75 | 2320 | 3020 | +4.00 | — | — | — |
| 14 | — | — | — | — | — | — | 1810 | 2660 | +6.00 | 3510 | 2590 | +0.75 |
| 15 | — | — | — | — | — | — | 2450 | 2420 | +2.50 | 2520 | 2260 | — |
| 16 | — | — | — | — | — | — | 2410 | 2400 | +0.50 | 2790 | 2510 | +1.25 |
| 17 | — | — | — | — | — | — | — | — | — | 2050 | 2560 | +2.00 |
| 18 | — | — | — | — | — | — | — | — | — | 3260 | 2730 | +0.75 |
| 19 | — | — | — | — | — | — | — | — | — | 3030 | 2550 | +0.25 |
| 20 | — | — | — | — | — | — | — | — | — | 3500 | 2500 | +0 |
| 21 | — | — | — | — | — | — | — | — | — | 2950 | 2450 | +0.75 |
| 22 | — | — | — | — | — | — | — | — | — | 3080 | 3000 | +1.5 |
| Mean | 3490 | 2770 | +0.7 | 3010 | 2630 | +0.8 | 2430 | 2690 | +1.50 | 2900 | 2600 | ±0.0 |

The facts cited regarding the arctic trappers may be surprising since it has been generally assumed that almost the double amount of calories would be necessary under arctic conditions. However, real hard work is only done occasionally by the arctic trapper, — for instance during traveling on foot under difficult conditions. During the dark period of the year, when the food intake and caloric consumption is at a very l w level, the weather conditions usually prevent any exercise taking place. At times, the trappers are confined indoors for several weeks, during which periods they rest in their sleeping bags for the greater part of the day. They are adequately pro-

Table 14. Infantry group.

*Caloric intake, energy expenditure, and weight change at the four periods.*

| Subj. No. | I. October 1950 | | | II. January 1951 | | | III. May 1951 | | | IV. August 1951 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Caloric Intake | Caloric Expen-diture | Weight Change | Caloric Intake | Caloric Expen-diture | Weight Change | Caloric Intake | Caloric Expen-diture | Weight Change | Caloric Intake | Caloric Expen-diture | Weight Change |
| 1 | 3240 | 2860 | —2.75 | 3620 | 2410 | +0.75 | 3560 | 2500 | —3.0 | — | — | — |
| 2 | 3130 | 3460 | +2.0 | 3840 | 3110 | +0.75 | 2660 | 2500 | +3.5 | 2460 | 2560 | —1.5 |
| 3 | 3350 | 3100 | +2.5 | — | — | — | — | — | — | — | — | — |
| 4 | 3100 | 3440 | +0.25 | 3110 | 2810 | —0.25 | 2490 | 2900 | +1.25 | 3280 | 2540 | —0.5 |
| 5 | 2810 | 3100 | —1.0 | 2840 | 2840 | —0.5 | 1990 | 2830 | ±0 | — | — | — |
| 6 | 3200 | 2500 | —1.0 | 3230 | 2980 | +2.0 | — | — | — | — | — | — |
| 7 | 3360 | 2550 | —0.25 | 3670 | 3370 | +0.75 | 3880 | 2900 | —1.0 | 3010 | 2980 | —2.5 |
| 8 | 3400 | 2870 | —0.25 | 4140 | 2800 | +3.25 | 3200 | 2400 | +0.5 | — | — | — |
| 9 | 3650 | 2820 | —0.25 | 3440 | 2600 | ±0 | — | — | — | — | — | — |
| 10 | 4010 | 3150 | +2.0 | 3050 | 3080 | ±0 | 3530 | 2960 | —0.5 | 3090 | 2400 | +0.25 |
| 11 | 3690 | 3130 | —1.5 | — | — | — | 3960 | 2790 | +1.0 | 3780 | 2900 | —1.5 |
| 12 | 2950 | 3740 | +0.5 | 3240 | 3100 | +1.5 | 3750 | 2860 | —1.0 | 3380 | 2650 | —3.0 |
| 13 | — | — | — | — | — | — | — | — | — | 3350 | 2540 | +0.25 |
| 14 | — | — | — | — | — | — | — | — | — | 2690 | 2470 | —0.75 |
| Mean | 3300 | 3000 | ±0 | 3400 | 2900 | +0.8 | 3200 | 2700 | ±0 | 3100 | 2600 | +1.1 |

tected against loss of heat by well-heated cabins. In the fall and early spring the trappers travel by sledge and dogs along the fjord ice, and as the going is usually good, they are able to sit in the sledge during the journey, well protected by warm fur clothing. During the late spring when the fjord ice is breaking up and the snow is melting on the land, the trappers are again confined to the cabin. In the summer, they usually travel by motor boat, which does not entail hard work. These circumstances may well explain the surprisingly low calorie consumption of the European trappers in Greenland.

In this connection it should be noted that the total average energy

Table 15.

*Showing average caloric consumption, estimated average caloric expenditure and average weight change in the Air Force group at the four periods.*

| Period | Gross consumption, calories | Net consumption, calories | Estimated caloric expenditure | Weight gain or loss, lbs. |
|---|---|---|---|---|
| Period I, October .... | 3500 | 3300 | 2800 | + 0.7 |
| Period II, January .... | 3000 | 2850 | 2600 | + 0.8 |
| Period III, April ..... | 2400 | 2300 | 2700 | + 1.5 |
| Period IV, July ...... | 2900 | 2750 | 2600 | ± 0.0 |
| Mean | 2950 | 2800 | 2700 | ± 0.0 |

Table 16.

*Showing average caloric consumption, estimated average caloric expenditure and average weight change in the Infantry group at the four periods.*

| Period | Gross consumption, calories | Net consumption, calories | Estimated caloric expenditure | Weight gain or loss, lbs. |
|---|---|---|---|---|
| Period I, October .... | 3300 | 3100 | 3000 | ± 0.0 |
| Period II, January.... | 3400 | 3200 | 2900 | + 0.8 |
| Period III, May...... | 3200 | 3000 | 2700 | ± 0.0 |
| Period IV, August .... | 3100 | 2950 | 2600 | + 1.1 |
| Mean | 3200 | 3050 | 2800 | + 0.4 |

Approximately 5 % deducted from gross consumption as inedible wastage.

expenditure of an adult Greenland Eskimo is estimated to be slightly less than 3000 calories daily, and similar figures were obtained for Eskimos examined by us in Alaska (2700 calories). At the same time we determined the Eskimo's average gross calorie intake to be about 3100 calories a day, the net consumption of calories being roughly 2900. On this regime there was an average weight loss of 0.4 lbs. during the period of the study.

This may be explained by the fact that the Eskimo does not normally go out in his kayak when the weather is bad, and he avoids traveling when the snow conditions are such that he must walk on foot instead of sitting comfortably on the sledge being pulled by his dogs. This is especially true in Greenland. Although enormous amounts of work may occasionally be carried out during a short period, at times when the possibilities of hunting are exceptionally good, most of the time is spent in waiting for the game to appear or for the fish to bite. Furthermore, the Eskimos' clothing offers an excellent protection against loss of heat.

Table 17.

*Nitrogen balance in 14 Infantry soldiers consuming unlimited quantities of Air Force rations.*

| Subject | Nitrogen, Intake, g | Foecal Nitrogen (approximately), g | Urinary Nitrogen, g | Total Nitrogen Elimination, g | Nitrogen Balance |
|---|---|---|---|---|---|
| Subj. F. L. O. . . . | 15.4 | 1.5 | 12.7 | 14.2 | +1.2 |
| » E. E. K. . . . | 14.7 | 1.5 | 12.5 | 14.0 | +0.7 |
| » B. R. L. . . . | 11.7 | 1.5 | 11.4 | 12.9 | —1.2 |
| » C. L. S. . . . | 8.7 | 1.5 | 11.1 | 12.6 | —3.9 |
| » L. N. W. . . | 16.4 | 1.5 | 16.4 | 17.9 | —1.5 |
| » L. A. G. . . . | 16.0 | 1.5 | 12.0 | 13.5 | +2.5 |
| » P. M. . . . . . | 16.6 | 1.5 | 15.1 | 16.6 | 0.0 |
| » R. B. V. . . . | 13.1 | 1.5 | 19.7 | 21.2 | —8.7 |
| » J. D. . . . . . . | 13.8 | 1.5 | 10.3 | 11.8 | +2.0 |
| » L. C. L. . . . | 21.6 | 1.5 | 13.3 | 14.8 | +6.8 |
| » E. C. R. . . . | 17.9 | 1.5 | 12.0 | 13.5 | +4.4 |
| » H. W. . . . . . | 14.4 | 1.5 | 10.2 | 11.7 | +2.7 |
| Mean | 15.0 | 1.5 | 13.1 | 14.6 | +0.4 |

The results of the present study are in agreement with our findings from Greenland.

On the basis of the popular assumption that the calorie requirement for troops on arctic duty is in the order of 5000—6000 calories per man per day, any young soldier stationed in the Arctic should be calorically undernourished, and even emaciated, if his mean calorie intake were considerably less than 5000 calories daily over a prolonged period.

Our results indicate clearly that this is not the case. Our subjects had spent about a year in Alaska prior to the commencement of the study, and many of them remained in Alaska throughout the year in which the study was carried out. The available evidence indicates that their diet had been roughly the same during the year prior to the study as during the period of the actual survey. They remained in excellent health and good physical condition, and their height and weight agreed favorably with the usual standards for height and weight in relation to age.

Keys (1949—50) has shown that in general a change in body weight of 1 kg represents a change in stored energy of about 5000 calories. He states that if the body weight does not change by more than 1 kg or so in a few months, then the calorie intake in that period must have been within 1 per cent of the requirements necessary to maintain balance. He points out that the measurement of body weight and food intake is a sensitive and accurate way of estimating requirements for persons who are not changing body weight.

As is evident from Table 15, the body weights remained almost constant throughout the entire period of the study so that the calorie intake during this period may fairly closely represent the requirements necessary to maintain calorie balance under these conditions.

Table 18.

*Caloric consumption and ratio of protein, fat and carbohydrate consumed in different environments.*

| Authors | Location and Subjects | Environment | Calories Consumed: | Percentage of Calories Provided by: | | |
|---|---|---|---|---|---|---|
| | | | Cal/man/day | Protein | Fat | Carbohydrate |
| Høygaard, 1941 | Southeast Greenland: Eskimos | Arctic | 2.800 | 43 | 54 | 3 |
| Høygaard, 1941 | Southwest Greenland: Eskimos | » | 2.800 | 46 | 50 | 4 |
| Rodahl, (unpubl. data) | Alaska: Eskimos | » | 3.100 | 19 | 41 | 40 |
| Rodahl, 1949 | Northeast Greenland: European Trappers | » | 3.000 | 12 | 58 | 30 |
| Abs, 1929 | Spitsbergen: Miners | » | 4.580 | 16 | 33 | 51 |
| Høygaard and Mehren, 1931 | Greenland: Arctic Travellers | » | 4.465 | 10 | 50 | 40 |
| Quoted by Johnson & Kark, 1946 | Canada: Soldiers on «Musk Ox» | » | 4.400 | 11 | 40 | 49 |
| Hayes, 1928 | Antarctic Scott Polar Party | Antarctic | 4.800 | 18 | 44 | 38 |
| Swain et al., 1949 | Fort Churchill: Soldiers | Subarctic | 5.600 | 13 | 41 | 46 |
| Rodahl, 1953 | Alaska: U. S. Soldiers and Airmen | » | 3.100 | 13 | 38 | 49 |
| Quoted by Johnson & Kark, 1946 | U. S. Training Camps: Soldiers | Temperate | 3.800 | 13 | 43 | 44 |
| Schor & Swain 1948 | Continental U. S.: Army | » | 4.000 | 13 | 43 | 44 |
| Murlin, 1918 | Continental U. S.: Army | » | 3.700 | 14 | 31 | 55 |
| McCay, 1945 | U. S.: Navy | » | 3.400 | 14 | 44 | 42 |
| Quoted by Johnson & Kark, 1946 | Colorado Rockies: Soldiers | Mountain | 3.900 | 13 | 34 | 53 |
| Quoted by Johnson & Kark, 1946 | 38th Inf. Div. Soldiers | Wet Tropic | 3.200 | 12 | 34 | 54 |
| Quoted by Johnson & Kark, 1946 | Pacific Isl. | » » | 3.400 | 13 | 33 | 54 |

Table 19.

*Showing average consumption in male Eskimos at four localities in Alaska.*

| | Calories | Protein, g | Fat, g | Carbohydrate, g | Calcium, mg | Phosphorus, mg | Iron, mg | Copper, mg | Vitamin 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 |

From Table 14 it appears that an average gross consumption of approximately 2950 calories was sufficient to maintain the body weight in the Air Force group, and in the Infantry group a gross consumption of 3200 calories caused a very slight weight gain (Table 15). It would therefore seem justifiable to conclude that the calorie requirements under these conditions would be in the order of approximately 3000 calories or slightly higher.

It is true that the number of subjects in our study is small, and that the period of each survey only extended over a period of five days. On the other hand, the subjects were typical representatives of the group in question, and the smaller number allowed a very detailed, thorough and individual examination, and made it possible for the investigator to maintain a personal check on each subject. In view of the uniformity of the diet throughout the year, the short periods used in this study may be taken as fairly representative of the season.

There is no doubt that there has been a tendency in the past to put the calorie requirements too high, as has been emphasized by Keys (1949—50).

The National Research Council (1948) states (p. 16): "The proper calorie allowance is that which over an extended period will maintain body weight or growth at the level most conducive to well-being." The Council suggests that the recommended calorie allowance be regarded as subject to modifications of plus or minus 15 to 20 per cent according to conditions.

When using the scale recommended by the Committee on Calorie Requirements (Food and Agriculture Organization of the United Nations, 1950, p. 35) the calorie requirement of a man weighing 70 kg, living in an environment where the average annual temperature is 33° F (approximately 0° C), is 3.379+170=3.450 calories, which is in fair agreement with the figures arrived at in this survey. When using the equation (p. 14) calories/man/day=4.660—15.9 $T_f$ where $T_f$ is mean temperature in degrees F, the figure should be 4.135 calories per man per day.

In the past a large number of calculations have been made to determine the amount of nutrients which are supposed to be consumed per man in the Armed Forces. Most of these calculations are based upon the amount of food served, with corrections for wastage and losses during cooking. Many of these studies are based on large-scale food inventories, which may be subject to numerous errors through failure to record all unconsumed food, wastage, the number of persons consuming the food, or other inaccuracies.

In the case of field trials, records of food consumption of men engaged in field exercises of short duration cannot directly be taken as evidence of actual requirements, because it is generally experienced that the appetite and food consumption is often temporarily increased during the first few days in the field, particularly in untrained or unaccustomed men, after which it has a tendency to fall and eventually level off.

It also appears probable that in the past figures for calorie expenditure in troops under arctic or subarctic conditions are somewhat overestimated. This depends, particularly in the case of energy required for surface travel, to a great extent on the training and experience of the individual soldier, for an experienced arctic traveler may cover the same ground with much less effort than a person who does not possess the know-how and the technique of arctic travel.

In our material, the Infantry soldiers were all well-trained and thoroughly indoctrinated in arctic living and operations. In the case of the airmen, their exposure to environmental stress was probably not very much more than that of men in similar occupations in the more temperate zone. Furthermore, they all lived in well-heated billets, and wore adequate clothing which offered an excellent protection against loss of heat. The exposed areas of the body during outdoor activity were very small.

During a separate study (Rodahl et al., 1952), twelve normal Infantry soldiers lived in the field during a 10-day period, in the middle of the winter, covering a total distance of 100 miles, varying between 9 and 12 miles a day on foot, skis or snowshoes. The average daily calorie expenditure was estimated to 2700 calories per man per day on the basis of time activity data.

In carefully controlled animal experiments, on the other hand, the calorie requirements have been found to increase markedly during exposure to low environmental temperatures, but Keys (1946) has emphasized that "animal experiments provide few data applicable to man." This statement may be particularly true in the case of the effect of exposure to cold environment.

The average consumption of protein was 92 g in the Air Force group and 109 g in the Infantry group. In a separate group of 14 infantrymen consuming 15.0 nitrogen (138 g protein), there was a positive nitrogen balance, and it would appear that the dietary protein intake under these conditions is adequate. These figures are no higher than those reported for soldiers at various military posts in the U.S.A., but above the figures recommended as standard allowance in temperate climates (1 g per kg body weight). Our data do not allow any conclusion to be drawn regarding the optimal protein requirements for soldiers on arctic duty, but it appears that the dietary nitrogen should be higher than 1 g per kg body weight. The consumption of fat and carbohydrate was similar or slightly less than the figures reported for soldiers in the continental U.S.A.

In Table 14 the ratios of protein, fat and carbohydrate consumed in different environments have been compiled on the basis of the available data. In agreement with Johnson and Kark (1946) and Swain et al. (1949), the values for the percentages of calories by protein, fat and carbohydrate in American troops living in arctic or subarctic climates are not significantly different from those reported for United States troops eating a garrison ration in temperate or tropical climates. Europeans living in the arctic environment, however, obtain a greater proportion of calories from fat.

In the temperate environment, studies have shown that a healthy man receiving a diet adequate in all known essentials, is in calcium equilibrium when the calcium intake is 10 mg per kg of body weight. In our subjects this would correspond to 0.7 g daily. Our airmen received 0.9 g, and the infantrymen 2.3 g. It also appears that the phosphorus intake was ample (ratio of calcium to phosphorus 0.7—1.5).

It is probable that the calcium intake actually is higher than the above mentioned figures, for Widdowson and McCance (1943) have shown that up to 200 mg of calcium a day may be obtained from the drinking water in districts where the water is hard. This is as much as there was in the adult milk ration in the winter in England during the war.

There is evidence that the adult male needs relatively little iron. The recommended daily dietary allowances for iron for a physically active man of 70 kg has been set at 12 mg by the National Research Council. In our subjects the average daily iron was 15—28 mg. In our survey there was no clinical evidence of iron deficiency, although the values for the hemoglobin concentration are slightly less than the average hemoglobin concentrations reported for 20 year old men in Great Britain (13.3 g, as against 14.3, variations 11.8—16.8 g).

The lower limits of the hemoglobin concentration of nineteen-twentieths of the distribution in a study of 3029 persons in North Carolina was approximately 12 g for white men (Milam and Muench, quoted by Darby, 1951). According to these figures the hemoglobin values in our material are not likely to be associated with abnormality, particularly since the finding of a low hemoglobin level is not alone sufficient for the diagnosis of iron deficiencies. Widdowson and McCance (1943) have pointed out that iron intakes as calculated from food tables should be regarded as minimum values, for the actual intakes must sometimes be a great deal higher because of contamination from various cooking utensils.

We know very little about the human vitamin requirements under arctic conditions. Some animal experiments have indicated increased requirements for certain vitamins in the cold, but these results cannot directly be taken as evidence of increased human requirements.

Recent studies (Hume and Krebs, 1949) have indicated that the requirement of vitamin A for adult men in temperate climates is approximately 2500 I. U. vitamin A. In Greenland the European trappers subsisted on 3000 I. U. daily without showing clinical evidence of vitamin A deficiency. The present survey shows that in young soldiers on duty in Alaska 4000—6000 I. U. vitamin A daily was adequate in the sense that no deficiency could be detected. Most of the vitamin A was consumed as vitamin A, less than half of the consumption being taken as carotene.

It is interesting to note that the Greenland Eskimos' consumption of vitamin A is almost ten times higher than that of the trapper in Greenland. The Alaskan Eskimos consumed about 12,000 I. U. vitamin A daily. Since lack of vitamin A reduces the power of night vision, upon which the soldier or the arctic hunter must depend during the dark period of the year, the importance of a sufficient supply of vitamin A is evident.

On the basis of the available evidence it appears that when most of the vitamin A is consumed in the form of vitamin A, and not as carotene, the daily requirements for troops stationed in Alaska would not be in excess of 4000—6000 I. U. vitamin A.

It appears from our investigations that the vitamin A content of the arctic animals, both sea and land mammals and birds, is generally higher than that of those living in more temperate zones.

The main sources of vitamin A in the arctic regions are the livers of sea and land mammals and fish. Of these the livers of polar bear, 50 grams of which may supply the normal requirement of one man during a whole year, and of certain seals, particularly bearded seal, which may be as rich in vitamin A as the polar bear liver, are the richest sources of this vitamin. The vitamin A concentration is naturally an expression of the vitamin A richness of the food which these animals eat. The seals eat a large amount of herring, cod, etc., and seal liver in turn constitutes an important part of the food of the polar bear. Thus, an increasing accumulation of vitamin A takes place in the livers as one moves up in the animal kingdom, from the fish to the polar bear.

It is quite remarkable that while the usual laboratory animals avoid sources very rich in vitamin A, some of the arctic animals select by their own choices source rich in vitamin A. In fact, the polar bear may consume such large quantities of vitamin A that it may give rise to hypervitaminosis A in the bear (Rodahl, 1950). In this connection it may be mentioned that in animals it appears that the requirements of vitamin A are increased in the cold (Ershoff, 1952, Moore and Sharman, 1951).

The thiamine intake was slightly more than 2 mg daily both in our airmen and infantrymen (2.2 mg or 733 I. U.). The League of Nations standard requirement for thiamine is 300 I. U. per day, which some investigators consider to be the "physiological minimum", regarding the "desirable intake" as about 600 I. U., and relatively more should be needed by those doing severe physical exercise. The National Council recommends 1.5 mg (500 I. U.) for physically active men.

In Greenland less than 300 I. U. thiamine gave rise to vitamin $B_1$ deficiency symptoms, and one trapper developed beri-beri. It appears from the present survey that the requirement for soldiers in Alaska is not in excess of 700 I. U.

The consumption of vitamin C by the European trappers in Greenland throughout the whole year was less than the figures considered as minimum human requirements. Thus, in the middle of the winter the intake was less than 10 mg vitamin C per day per individual although no distinct symptoms of scurvy were observed among these trappers. It has previously been found that Europeans in Greenland during sledging journeys of long duration subsisted on less than 15 mg vitamin C daily without any ill effect. In the Greenland Eskimo the daily average intake of vitamin C has been found to be 36 mg per individual, varying from 0 to 100 mg depending on the type of diet. In the Alaskan Eskimos the average daily intake of vitamin C was 28 mg per person, varying from 3 to 54 mg. No clinical evidence of vitamin C deficiency was detected.

In the European trappers in Greenland there was a marked decrease in the consumption of vitamin C during the dark period, December and January, attributed to a reduced food intake. During this period the trappers showed loss of appetite, and inertia and lack of initiative was observed. In this connection it is interesting to note that Dr. H. U. Sverdrup relates (personal communication) that during the Maud expedition they endeavored to maintain normal appetite during the dark period of the year by regular and sufficient physical exercise. He also relates that in the spring of 1924 he had symptoms which he himself interpreted as slight scurvy, — but by consuming one or two tins of condensed, unsweetened milk daily, the symptoms disappeared.

In the present survey the average daily consumption of vitamin C was 74 mg in the airmen, and 102 in the infantrymen. The lowest figures were observed in the fall in the Air Force group when 32 mg vitamin C were consumed daily. Under these conditions no evidence of vitamin C deficiency was detected.

It is still an open question whether or not additional supplies of vitamin C may increase man's ability to withstand cold. Animal experiments have clearly indicated an increased requirement for vitamin C in the cold (Dugal, 1947), while studies in humans (Dahlberg et al., 1942) have failed to demonstrate any beneficial effect of additional vitamin C in troops exposed to cold environment. It should be emphasized, however, that it is exceedingly difficult to study such a relationship in man, because of the unsatisfactory criteria available for the study of human response to cold stress.

However, the consumption of vitamin C in our soldiers is considerably higher than the figures recommended for an average man in temperate environments.

As pointed out in the introduction, man has been known to remain in excellent health in the Arctic for long periods on 15 mg ascorbic acid or less daily. It has also been proved beyond doubt that man may prevent, and even cure, scurvy on a diet of nothing but meat. This is a remarkable fact, for it would be quite impossible for a white man to consume the amounts of vitamin C normally considered as minimum requirements, from meat alone. In order to obtain 30 mg ascorbic acid, it would be necessary to consume 3—6 lbs. of meat per day, if the ascorbic acid content is 1—2 mg per 100 g of meat.

The explanation may be that the actual vitamin C requirement in reality is less than 30 mg per man in arctic conditions, or that the content of antiscorbutic substance in meat is higher than the figures obtained by the standard methods of essay, or that such a diet of meat causes changes in the intestinal flora, resulting in a decreased bacterial destruction of ascorbic acid or improved absorption of ascorbic acid. Finally, the possibility of synthesis of vitamin C in man has to be considered, and a possible relation between vitamins A and C.

Although our knowledge regarding these conditions is incomplete, it has been found that a prolonged meat diet caused a marked reduction in the amount of coli in the intestines (DuBois, personal communication).

In some laboratory animals we have observed an increase in the vitamin C contents of the internal organs following ingestion of moderate excess of vitamin A (Rodahl, 1950). In this connection it should be noted that the

Eskimo diet is normally extremely high in vitamin A (12,000—50,000 I. U. daily). Toxic doses of vitamin A, on the other hand, may produce a condition which is similar to scurvy (Rodahl, 1949 c).

The arctic flora is extremely rich in vitamin C, and the vitamin C content increases with the latitude (Rodahl, 1944, 1953). At the same time it is observed that the vitamin A content of Arctic mammalian livers is sufficiently high to cause symptoms of hypervitaminosis A when eaten by man or animals. It is known that some of the arctic mammals, which have a very high vitamin A intake, have a tendency also to select food rich in vitamin C (Rodahl, 1950).

On the basis of the available evidence of the relationship between vitamin A and vitamin C, it is suggested that the high vitamin A intake may possibly play a part in the apparently low dietary vitamin C requirements in Eskimos and certain arctic people subsisting on a high meat diet, low in vitamin C, without developing scurvy.

Another factor which must not be overlooked when considering the significance of food in relation to health and well-being in arctic conditions, is the psychic effect of the winter darkness on the vitality, appetite and fitness. For food alone cannot remedy the unfavorable effects of depression and malaise which sometimes occur during the arctic night in poorly adjusted men who get on each other's nerves when isolated in the arctic environment.

## 7. Summary and conclusions.

A series of nutritional surveys together with detailed clinical, physiological and biochemical examinations was carried out among a group of airmen and a group of infantry soldiers, (average age 20 $^1/_2$ years, average weight 70.0 kg, average height 125 cm) during the four seasons of the year at Ladd Air Force Base in Alaska from 1950 to 1952. Simultaneously studies were made among four groups of Eskimos for comparison.

Individual food weighings showed an average gross consumption of 3000 calories per man per day in the Air Force group and 3200 calories in the Infantry group. The average calorie expenditure for the four seasons was estimated to about 2800 calories per man per day on the basis of the time-activity data. Under these conditions no appreciable weight change occurred, and the subjects remained in excellent health throughout the period of the study. It is therefore concluded that the calorie requirements of garrison troops in Alaska, engaged in regular duties similar to those at Ladd Air Force Base, would be in the order of approximately 3000-5000 calories per man per day at any season of the year.

In adult male Eskimos at four different locations in Alaska (Barter Island, Anaktuvuk Pass, Kotzebue and Gambell), an average gross consumption of approximately 3100 calories was sufficient to maintain the body weight with an estimated energy expenditure of roughly 2700 calories.

These findings are in striking contrast to figures previously published for calorie requirements of troops stationed in Alaska, but in agreement with studies among Eskimos and trappers in Greenland.

Of the total calories consumed by the soldiers, an average of 13 per cent was derived from protein, 38 per cent from fat, and 49 per cent from carbohydrate. In the Infantry group the percentage of calories supplied from fat was the same both in the winter and summer. In the Air Force group, however, 44.7 per cent of the calories came from fat in the winter as against only 35.7 per cent in the summer.

The percentage of calories furnished by protein, fat and carbohydrate in American troops living in Alaska is not significantly different from those reported for United States troops eating a garrison ration in temperate or tropic climates. Europeans living in the arctic environment, however, have a greater consumption of protein and fat, as is also the case in the Eskimos.

Infantrymen consuming 138 g protein per day showed a positive nitrogen balance. The average figures for the protein intake were no higher than those reported for soldiers at various military posts in the U. S. A., but above the figures recommended as standard allowances in temperate climates. On the basis of the incomplete data available, it is suggested that the dietary protein should probably be higher than 1 g per kg body weight in soldiers on arctic duty.

It appears that the consumption of minerals was ample under the conditions studied (0.9—2.3 g calcium, 1.4—1.6 g phosphorus and 15—28 mg iron).

Although the present material does not allow any definite conclusion to be drawn regarding the human vitamin requirements under arctic conditions, it appears on the basis of the available evidence that when less than half of the vitamin A is consumed in the form of carotene, the daily requirements for troops stationed in Alaska would not be in excess of 4000—6000 I. U. vitamin A. The thiamine intake was slightly more than 2 mg daily both in the airmen and infantrymen (2.2 mg or 733 I. U.) and it appears from the present survey that the thiamine requirements for soldiers in Alaska is not in excess of this amount. In the present survey the average daily consumption of vitamin C was 74 mg in the airmen and 102 mg in the infantrymen. The lowest figures were observed in the fall in the Air Force group when 32 mg vitamin C were consumed daily. Under these conditions no evidence of vitamin C deficiency was detected. The average consumption of vitamin C in these soldiers is considerably higher than the figures recommended for an average man in temperate environments. While animal experiments have clearly indicated an increased requirement for vitamin C in the cold, it is still questionable whether additional supplies of vitamin C may increase man's ability to withstand cold, particularly since man has been known to remain in excellent health in the Arctic for long periods on 15 mg ascorbic acid or less daily. In some of our Eskimo subjects the vitamin C intake was below the figures normally considered as the physiological minimum, although no evidence of deficiency symptoms was detected, as was also the case in the white trappers in Greenland.

The consumption of riboflavin and nicotinic acid was slightly higher than the dietary allowances recommended by the National Research Council for physically active men in temperate environments.

It is recommended that further studies should be initiated in order to determine the energy requirement of different activities under varying arctic conditions, as well as the lower limits of vitamin requirements and the relationship between vitamin intake and man's health and performance in the arctic environments.

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Preliminary topographical maps [1:50 000] covering claims to land in Svalbard and a preliminary map of Hopen 1 : 100 000 may be obtained separately.

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