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Energy Expenditure and Nutritional Status of Sailors and Submarine Crew of the Indian Navy

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ABSTRACT

Nutritional requirements of sailors and submariners are different from those of ground forces as they work under confined environment as well as due to logistic constraints of cooking and storage of food. Study was conducted for a period of three months at Eastern Naval Command to evaluate nutrient requirements, nutritional status of Indian Navy personnel and adequacy of the existing ration scales. The study volunteers were from crew of two warships ($n = 35$) and submariners ($n = 20$) who were attached to their mother ships during time of data collection and offshore during rest of the period. Energy expenditure, nutrient intake, level of nutrients in body, and urinary excretion were measured along with changes in body composition. All variables were analysed before and after three months of nutritional monitoring. Energy expenditure at ship was in the range of 2449-4907 kcal/day with a mean of 3313 ± 578 kcal/day, while in the case of submariners, it was 3168 ± 282 (2606-3907) kcal/day. The energy intake in the case of sailors and submariners was not different either on shore establishment or at ship. Energy intake was found to be 3518 ± 286 kcal/day. The energy contribution from carbohydrates, fats, and protein was 59.9 per cent, 27.8 per cent and 12.3 per cent, respectively. No sign and symptoms of any nutritional deficiency were observed either initially or after three months. Status of micronutrients present in their blood and in their urinary excretions along with body composition were maintained, indicating adequacy of existing ration scales of Indian Navy.

Keywords: Energy expenditure, energy intake, nutritional status, micronutrients

1. INTRODUCTION

Nutritional requirements of Navy Personnel are different from those of ground forces due to logistic constraints posed when being away from sea-coast. The requirement of onboard food and its preparation need to be planned very carefully and well in advance. Scurvy and Beriberi were scourge of sea-farers in 17th and 18th centuries and records of efficient diet planning by Capt Cook during his voyage to South Seas (1772-75) and Admiral Takaki in 1882 are very well recognised by nutritionists and medical community[1]. Warships are very different from commercial ships, and are designed to give maximum level of lethality and self-protection from enemy. Space for storage of food items, living, and working is limited[2]. Ration contains items that can be stored well (including dehydrated vegetables, meat, canned products) and bread is used as the staple food. Ships have provision of cold rooms for storage of perishable items but deterioration of nutrient levels may take place on failure of such facilities. Problem of space is much more in submarines where cooking processes are also very much restricted[3]. Inside ships and submarines, exposure to hot environment and high sound levels cause main stress. Sea sickness characterised by nausea and vomiting is a medical problem of navy personnel during operations and it adversely affects nutritional status. Nutritional requirements of submarine crew in Indian context were worked out in 1976, at that time there was less mechanisation in comparison to the present days[3,4]. Subsequently various ready-to-eat products were developed and included in their ration scales. The objectives of the present study include assessing the calorie requirements and changes in nutritional status over a period of 3 months for evaluation of adequacy of existing ration scales of sailors and submariners.

2. MATERIALS AND METHODS

Study was conducted at Eastern Naval Command, during months of June to September in 2005. Study volunteers were selected randomly from crew of two warships (n = 35) and submariners (n = 20). They were attached to their mother ships during the period of data collection (10 days initially and at the end of three months) and during the remaining period, they were offshore. The personnel, who planned to take leave in between were excluded from the study. The mean age, dietary and life style, i.e., vegetarian, non-vegetarian, smoking, drinking habits of volunteers are summarised in Table 1.

Vegetarian group comprised lacto-vegetarian and egg eaters were included in non-vegetarian group.

The weather during the study period was warm (temperature range 25 °C to 35 °C) and highly humid (65-85 per cent) due to rains. Submariners stayed at their mess at shore establishment at the time points of data collection and Sailors at their respective ships and took food from their galley. During the study period, extensive maintenance and repair activities were being carried out as the ships and the submarine were in or near harbor. Nutrient and energy intakes,

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Table 1. Age, dietary habits and life style of volunteers

Group	Age (years) Mean ± SD	Vegetarian/ Non-vegetarian	Drinkers/ Non-drinkers	Smokers/ Non-smokers
Ships crew (n=35)	24.8 ± 5.2	16/19	9/26	5/30
Submariners (n=20)	26.5 ± 3.8	5/15	11/9	3/17

energy expenditure, body composition, biochemical and physiological markers of nutritional status were evaluated. All investigations were carried out initially and after three months while volunteers were on their authorised ration and the food consumption was *ad libitum*.

For estimation of calorie and nutrient intake, the duplicate plate samples were collected from three different volunteers at times of breakfast, lunch, and dinner for a period of 14 days to cover entire menu. Analyses of food samples were made as described earlier[5].

Energy expenditure was measured using 24 h activity monitoring using accelerometer-based Actical device (Mini Mitter Co. Inc. Bend, OR, USA) validated using doubly labeled water technique[6]. Subjects were asked to wear Actical device on wrist for 7 days continuously and minute by minute data were recorded and stored in the device and subsequently analysed.

Body composition, viz., body fat, body water, lean body mass were measured by bioelectrical impedance analysis (BIA) using Maltron Body Fat Analyser (BF 906, Maltron International Ltd., Ryleigh, Essex, England) using disposable electrodes along with anthropometric measurements.

Venous blood samples were drawn in the morning after overnight fast of 12 h. Hemoglobin contents were measured using Automatic Hematology Analyser (MS4, Melet Scholoesing laboratories, Pontoise, Cedex–France). An amount of 5 ml blood was collected in heparinised tubes, centrifuged at 1000 g for 10 min to recover plasma and stored in aliquots. Aliquots (200 µl) of plasma samples were stabilised with 10 per cent metaphosphoric acid for estimation of vitamin C. Erythrocytes were washed three times with 150 mM *KCl* and 10 per cent lysates (w/v) were prepared with distilled water for estimation of enzyme markers of vitamin status. Samples were brought in frozen condition to the laboratory where they were stored at –70 °C until analyzed. Twenty-four hour urine samples were collected in PVC cans containing known volume of 6 N *HCl* as preservative. Aliquots of urine were stored after measuring total volume and used for various estimations.

Estimations of different biochemical variables, i.e., vitamins and metabolites were made using standard protocols descried in Manual of Laboratory Techniques published by Indian Council of Medical Research[7]. The assessment of physical fitness of each person was made using Harvard step test described earlier[8]. As ration scales are different for sailors and submariners, the data were analysed separately for each group. Comparison of data obtained initially and after three months were made using students' t-test and p value <0.05 was considered as a significant change.

3. RESULTS AND DISCUSSION

Energy expenditure at ships was in the range of 2449-4907 kcal/day with a mean of 3313 ± 578 kcal/day, while in the case of submariners, it was 3168 ± 282 (2606-3907) kcal/day. During the study period, extensive maintenance activities were being carried out. Normal duties were repair and maintenance and various checks of equipment, machines, batteries, steering operations, operation of sonar, radar and wireless, keeping lookouts, chipping and painting, etc. Climbing upright ladders up and down between compartments and loading the ship are main type of vigorous activities.

Energy intake in the case of sailors and submariners was not different either at shore establishment and/or at ship/submarines. Energy intake was found to be 3518 ± 286 kcal/day. The energy contribution from carbohydrates, fats and proteins was 59.9 per cent, 27.8 per cent, and 12.3 per cent, respectively (Table 2). The crew of submarine is victualled onboard, when the submarine is at sea. In harbor, the crew is taken onboard a depot ship or to a shore-based mess. At this time, they are entitled for normal authorised ration scale. Only the essential staff responsible for maintenance and watch-keeping stays onboard and are victualled at the base mess. In an earlier study carried out by this Institute onboard in submarine, the average energy expenditure was determined to be 2625 kcal/day[4]. Higher energy expenditure of submariners in the present study may be attributed to attachment of submariners to their mother ship and subjects were busy in extensive maintenance activities during the study period. Energy intakes of subjects in present study are comparable to US Navy SEAL trainees

Table 2. Nutrient intake of sailors and submariners

Nutrients	Intake
Energy (kcal)	3518 ± 286
Protein (g)	108 ± 25
Total Fat (g)	109 ± 24
Visible Fat (g)	68 ± 10
CHO (g)	527 ± 51
Vitamin A (µg)	625 ±102
Vitamin C (mg)	58 ± 22
Thiamin (mg)	1.7 ± 0.15
Riboflavin (mg)	1.6 ± 0.3
Niacin (mg)	33 ± 3.7
Iron (mg)	38.0 ± 6.6
Calcium (mg)	1410 ± 156
Phosphorus (mg)	1534 ± 125
Sodium (mg)	7000 ± 330
Potassium (mg)	2856 ± 135
Zinc (mg)	16.2 ± 1.30
Copper (mg)	2.80 ± 0.50
Energy contribution	
Carbohydrates per cent	59.9
Protein (per cent)	12.3
Fat (per cent)	27.8

which is reported to be 3886 kcal/day with 41.2 per cent calories contributed from fat[9,10].

The intake of carbohydrates, proteins and fats was within healthy limits while micronutrients, i.e., vitamins and minerals were also adequate (Table 2). The protein intake from animal sources is on higher side to maintain and buildup muscle mass, however it does not add any nutritional advantage since animal sources of protein are rich in dietary cholesterol along with total fat. Provision of lean meat in place of red meat can limit fat intake, which is nearly approaching upper limit of safe intake i.e., 30 per cent of total calories. Fish and sea-foods, which are good source of *n*-3 fatty acids, can help in maintaining *n*-6 to *n*-3 fatty acid ratio in optimum range (i.e., 5-10), since most of the refined oils used in cooking are rich in *n*-6 fatty acids[11].

Values are Mean ± SD/day (n=14 days) derived from plate samples collected for seven days initially and seven days in between study to represent entire menu.

No sign and symptoms of any nutritional deficiency were observed either initially or after three months in the study subjects. Body composition variables such as body fat, lean body mass, body water, bone minerals, waist-to-hip ratio and BMI were maintained over a period of three months (Table 3). This signifies adequate nutritional intake by the study group in relation to requirements for day-to-day activities and follow up of healthy life style[12].

The hemoglobin, plasma protein levels were within normal range initially as well as after three months, although there was an increase in total protein and albumin content (Table 4). The plasma levels of creatinine and 24 h urinary excretion were also in normal range though there was an increase in creatinine levels in plasma of submariners which may be an effect of meat intake prior the day of blood sampling. Urinary nitrogen indicates positive nitrogen balance of 9.5 g/d (Table 6). Nitrogen balance truly reflects both the somatic and visceral protein pools[13,14]. Total cholesterol, HDL- cholesterol and triglycerides measured in plasma were well within their acceptable ranges. There was decrease in total cholesterol and triglycerides in the case of sailors and in triglycerides levels of submariners after three months (Table 4).

The β-carotene levels were found decreased in sailors and submariners along with increase in vitamin A levels after three months (Table 4). Plasma vitamin A levels ≥ 20 μg/dL are

Table 3. Body composition of sailors–ship crew and submariners

Parameters	Ship Crew		Submarine Crew	
	Initial	After 3 months	Initial	After 3 months
Weight (kg)	58.46 ± 8.71	58.26 ± 8.86	62.83± 7.95	62.79 ± 8.56
Height (cm)	169.0 ± 5.14	169.0 ± 5.3	169.7 ± 5.83	169.2 ± 5.8
Body fat (per cent)	11.9 ± 4.51	11.94 ± 4.35	14.39 ± 3.73	14.03 ± 3.83
Body fat (kg)	7.26 ± 3.8	7.23 ± 3.70	9.23 ± 3.38	9.04 ± 3.57
Lean body mass kg)	51.1± 5.40	51.0± 5.52	53.63 ± 5.21	53.76 ± 5.62
Body water (L)	37.4± 3.98	37.3 ± 4.08	39.24± 3.84	39.33 ± 4.08
Bone minerals (kg)	3.4 ± 0.56	3.39± 0.52	3.09 ± 0.44	3.28± 0.43
Cell solids (kg)	10.6± 1.48	10.3 ± 1.39	11.01± 1.28	11.00 ± 1.42
Waist: Hip	0.85± 0.03	0.85 ± 0.03	0.88 ± 0.03	0.86 ± 0.04
Body mass index (kg/m^2)	20.4 ± 2.5	20.4 ± 2.5	21.7 ± 1.8	21.8 ± 1.8
BMR (kcal)	1493 ± 130	1490 ± 131	1556 ± 110	1555 ± 120

Values are Mean ± SD; Ship crew (n = 35), Submariners (n = 20); Values are not significantly different in comparison to initial.

Table 4. Hemoglobin, plasma proteins, lipid profile, creatinine, vitamin A, β-carotene, vitamin E and ascorbic acid level in plasma samples of sailors and submariners

Parameters	Ship crew		Submariners	
	Initial	After 3 months	Initial	After 3 months
Hemoglobin (g/dl)	15.4 ± 1.1	15.5 ±0.8	14.8 ± 0.9	14.7 ± 0.9
Total protein (g/dl)	6.2 ± 0.7	6.9± 0.8^{+++}	6.2 ± 0.7	6.8 ± 0.8^{+}
Albumin (g/dl)	3.4± 0.4	4.1± 0.3^{+++}	3.3± 0.4	4.0± 0.2^{+++}
Globulin (g/dl)	2.8 ± 0.8	2.8 ± 0.9	3.0 ± 0.8	2.8 ± 0.9
A/G Ratio	1.2 ± 0.7	1.5 ± 0.6	1.11 ± 0.7	1.4 ± 0.7
Creatinine (mg/dl)	1.26 ± 0.10	1.30 ± 0.14	1.27 ±0.09	1.37 ±0.12^{+}
Total cholesterol (mg/dl)	125 ± 25	104 ± 22 $^{++}$	130 ± 26	123 ± 15
HDL - cholesterol (mg/dl)	36.4 ± 6	35 ± 4	36 ± 7	35 ± 4
LDL- cholesterol (mg/dl)	67 ± 23	54 ± 22^{+}	69 ± 27	72 ± 20
Triglycerides(mg/dl)	123 ± 60	82 ± 37^{+++}	143 ± 80	85 ± 40^{++}
Vitamin A (μg/dl)	21.7 ± 6.1	30.8 ± 7.5 $^{+++}$	22.6 ± 5.3	33.2 ± 6.0 $^{+++}$
β- Carotene (μg/dl)	57.6 ± 16.0	23.8 ± 7.8 $^{+++}$	62.5 ± 6.8	21.8 ± 5.3 $^{+++}$
Vitamin E (mg/l)	15.5 ± 7.0	26.8 ± 9.3 $^{+++}$	14.1 ± 6.3	29.9± 3.5 $^{+++}$
Vitamin C (mg/dl)	0.70 ± 0.6	0.79 ± 0.67	0.53 ± .51	0.57 ± 0.56

Values are Mean ± SD; Ship Crew n=35, Submariners n=20;
$^{+}$ $p < 0.05$; $^{++}$ $p < 0.01$; $^{+++}$ $p < 0.001$ in comparison with initial

Table 5. Erythrocyte enzyme markers of vitamin status of sailors and submariners

Parameters	Ship crew		Submariners	
	Initial	After 3 months	Initial	After 3 months
Transketolase TPP activation factor	1.16 ± 0.72	1.11 ± 0.5	1.17 ± 0.74	1.16 ± 0.36
Glutathione reductase FAD activation factor	1.58 ± 0.21	1.63 ± 0.20	1.59 ± 0.15	1.72 ± 0.6
Aspartate aminotransferase PLP activation factor	1.67 ± 0.30	$0.62 \pm 0.4^{+++}$	1.76 ± 0.23	$0.66 \pm 0.04^{+++}$

Values are Mean ± SD; Ship Crew n=35, Submariners n=20; $^{+++}$ p<0.001 in comparison with initial

acceptable and indicative of good amount of vitamin A stored in the liver. Micronutrients like β-carotene and carotenoids obtained from fruits and vegetables have got anti-oxidant property and protect from degenerative diseases and certain types of cancers[15]. There was an increase in plasma vitamin E content, which may be due to good intake during the season or lower levels of oxidative stress when crew was at base (Table 4). Ascorbic acid facilitates the intestinal absorption of nonheme iron, is involved in the formation of collagen and is needed for proper adrenal function. The levels of vitamin C in plasma were found in normal range and almost the same initially and after three months of study (Table 6). There was a slight decrease in urinary vitamin C levels after three months but the levels were well within the normal acceptable physiological range, i.e. 6-18 mg/day (Table 6).

Table 6. Urinary excretion of vitamins, metabolites and nitrogen by sailors and submariners

Parameters	Ship crew	Submariners
Thiamine (mg/day)	0.42 ± 0.20	0.32 ± 0.25
Riboflavin (mg/day)	0.45 ± 0.28	0.44 ± 0.14
N- Methyl nicotinamide (mg/day)	21.8 ± 11.4	22.5 ± 8.7
Methyl malonic acid (μM/day)	41.0 ± 9.5	58.0 ± 11.0
Vitamin C (mg/day)	18.7 ± 15	14.7 ± 5.5
Creatinine (g/ day)	1.5 ± 0.8	1.4 ± 0.5
Nitrogen (g/day)	5.8 ± 3.2	5.0 ± 2.4

Values are Mean ± SD; n = 35 Ship crew, n = 20 Submariners
Urine samples collected only during initial phase

Status of B group of vitamins was assayed by monitoring their excretory levels in 24 h urine[13]. The measurement of status of B group of vitamins is very important using functional tests due to the fact that physical activity and stress affects their requirement[16]. In the present study, the adequacy of thiamin nutrition has been assessed through the tissue saturation status, taking into consideration the transketolase activity in erythrocytes and urinary excretion of thiamin. Erythrocyte transketolase activity remained almost the same throughout the study period. The activity coefficient was also remained almost the same after three month (Table 5). The urinary excretion of thiamin was also found well within the normal range during the study period.

Riboflavin status was assessed by erythrocyte glutathione reductase activity and by 24 h urinary excretion of riboflavin. In the present study, estimation of glutathione reductase activity was done with flavin adenosine dinucleotide to find the changes in activity. Activity coefficient was well within the acceptable biological reference range (Table 5). Significant decrease in erythrocyte aspartate aminotransferase activity coefficient was observed after three months, indicating improvement in vitamin B_6 status (Table 5).

Excretions of normal levels of N-methyl nicotinamide and methylmalonic acid in the present investigations are well within the physiological reference range and confirm sufficient intake of nicotinic acid and vitamin B_{12} (Table 6).

4. CONCLUSION

The study indicates that existing ration scale and food supplies of Indian Navy both for sailors as well as submariners are adequate in terms of calories and nutrients. There is always a scope to increase variety of food items with advancement of food technology and availability of ready-to-eat products with wholesome nutrient contents. With existing nutritional knowledge and fast growing food industry in the country, it may be possible to meet stringent demands of Navy and other Defence forces.

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