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Evaluation of Low Energy Pack Ration by Short-Term Feeding to Soldiers

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ABSTRACT

Fifteen soldiers were fed, during intensive training including a patrol operation, on low energy pack (LEP) ration for eight days for evaluating the suitability of the LEP ration providing 2100 kcal. Measurements were taken for body weight, skinfold thickness, blood cholesterol and phospholipids, glucose tolerance, and a battery of physical performance tests. Data were compared with another two identical groups of soldiers fed either a normal energy pack (NEP) ration (3526 kcal) or a normal energy fresh (NEF) ration (3631 kcal). The group on LEP ration lost 1.2 kg in body weight while the other two groups maintained their body weight with marginal fluctuations. Besides the slight loss of weight and a transient impairment of glucose tolerance, the subjects on LEP ration showed no other abnormality in any of the parameters studied. The study revealed that the LEP ration was suitable for feeding soldiers for short durations.

1. INTRODUCTION

An infantry soldier is heavily burdened when he operates away from the base during a long-range patrol or combat situations, in which he has to carry a battery of fighting equipments and ration packs[1]. Since load has a direct effect on energy

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expenditure and hence the physical efficiency[2], it is necessary to curtail the load to the minimum on order to maintain the physical efficiency. In such circumstances, it has been suggested that the fighting men undertaking arduous physical work must be trained to accept a low energy ration for short durations for subsistence[3]. The objective is to reduce the overall load of the men by curtailing ration packs, since arms and ammunition so vital for the mission cannot be dispensed with even partially.

The assumption that energy intake should meet the energy expenditure on a day-to-day basis for maintenance of good health is not always sacrosanct. From the practical considerations, perhaps it may not be possible to meet the energy need on a daily basis, particularly so, in the case of military personnel operating away from base where cooking facilities hardly exist. In such cases they have to carry ready-to-eat convenient foods which do not need elaborate cooking, considering that the operational requirements assume priority over all other considerations.

World over, the military nutritionists had been trying to work out the minimum amount of food that can be supplied to troops without undermining their physical efficiency in performing military tasks. Sub-optimal feeding has been advocated in situations where logistic considerations demand optimisation of load carried by Service personnel. Reduced food intake has been investigated by several workers for its effect on physical performance, cardiovascular changes and its application to military situations[3-5].

No work has so far been carried out on the effect of low energy pack (LEP) rations on physical performance of Indian soldiers whose food habits and work rate are different from their western counterparts. Defence Food Research Laboratory has been developing a number of ready-to-eat convenient foods suited to Indian palate for use by the military personnel. It was felt desirable to utilise these foods to formulate LEP rations and evaluate their suitability for health and physical performance when used by soldiers engaged in hard physical work.

2. METHOD

2.1 Subjects and Experimental Protocol

A field trial was carried out during the monsoon months at an Infantry Training Centre located in a jungle terrain (827 m above sea level). Forty five healthy military personnel from three companies belonging to the same ethnic group were selected for the trial. At the time of the trial, the subjects had been on a strenuous regime of physical training for five months. The subjects were assigned to 3 groups, A, B and C of comparable age, height and weight (Table 1). They were clinically examined by a Service Medical Officer before and during the course of the trial to exclude overt metabolic or clinical disorders. The trial which lasted for 16 days was divided into two phases of 8 days each. The pattern of activities followed by the various groups remained the same during both the phases; however the type of ration consumed during the second phase was different.

Table 1. Physical characteristics of the subjects*

Group	Age (yr)	Height (cm)	Weight (kg)
A	21.6 ± 5.3	166.0 ± 3.4	53.8 ± 4.9
B	21.8 ± 5.7	167.7 ± 5.1	52.5 ± 5.2
C	21.7 ± 5.7	168.1 ± 4.1	55.1 ± 3.7

* Mean ± SD for 15 subjects in each group

2.2 Rations and Feeding Design

Three types of rations were used for the trial. They were the normal energy fresh (NEF) ration cooked daily in the kitchen (3631 kcal/man/day), normal energy pack (NEP) ready-to-eat ration (3526 kcal/man/day), and LEP ready-to-eat ration (2133 kcal/man/day). Table 2 shows the menus of the three rations. The NEF ration was issued from the kitchen to all the three groups during the first phase as per the entitlement. During the second phase while group A continued to receive NEF ration from the kitchen, each subject of groups B and C was issued daily one packet of NEP and LEP rations respectively. Alternative food items were included in the menus of these two rations for lunch and dinner. However, the different menus did not significantly alter the energy and protein content of the ration. Arrangements were so made that the subjects consumed a ration of a different menu every day which helped to avoid monotony of food by providing a variety of dishes.

The menus were formulated out of dehydrated or canned foods comprising preserved *chapati*, canned *parotta*, canned *puri*, dehydrated vegetable rice, dehydrated curried vegetables, dehydrated curried *dals*, peanut *chikki*, and pickle packed in polyethylene sachets. The *chapaties* and the dehydrated foods were packed in flexible pouches and reconstituted before use by heating to boil the material with thrice its weight of water followed by simmering for 5-10 minutes. These foods were developed as reported earlier[6-12] by this Laboratory. All the products were stored for 4 months and microbiologically cleared before use.

The average food consumption of NEF ration by all the subjects during the first phase and by group A during the second phase was measured by recording the issue and the left overs. During the second phase, groups B and C consumed the entire quantity of foods provided. The proximate composition of NEF ration was computed using food composition tables as used by Malhotra, *et al*[13] and that of pack rations by analysing the individual item by AOAC method[14].

2.3 Body Measurements

Body weight: Body weights of the subjects were recorded at the start of the experiment and then at an interval of 4 days in the morning before breakfast after voiding using a scale with a sensitivity of 50 g.

Table 2(a). Ingredients of NEF ration

Item	Quantity (g)
Wheat flour	379
Rice	190
Cane Sugar	59
Hydrogenated oil	70
Pulses (*dal*)	75
Whole milk powder	85
Bengal gram flour	12
Mutton	95
Potato	95
Onion	55
Vegetable	167
Fruit	95
Common salt	16
Tea	8
Spices	18

Table 2(b). Menu for NEP ration

Item	Quantity
Bed tea	
Tea bar[a,e]	1
Breakfast	
Parotta[b]	90 g
Tea bar[a,e]	1
Lunch	
Rice[c,e]	150 g*
Curried green gram (*dal*)[c,e]	75 g
Pickle[d]	30 g
Chikki[e]	100 g
Evening tea	
Tea bar[a,e]	1
Dinner	
Rice[c,e]	150 g*
Curried green gram (*dal*)[c,e]	75 g
Pickle[d]	30 g
Chikki[e]	100 g

* or *parotta*[b] 120 g

Table 2(c). Menu for LEP ration

Items	1	2	3	4	5
Bed tea					
Tea bar[a,e]	1	1	1	1	1
Breakfast					
Parotta[b] (g)	90	90	–	–	90
Puri[b] (g)	–	–	115	115	–
Cabbage peas curry[c,e] (g)	–	30	–	30	–
Pickle[d] (g)	15	–	30	–	30
Tea bar[a]	1	1	1	1	1
Lunch					
Chapati[e] (g)	135	135	135	135	135
Potato peas curry[c,e] (g)	60	–	–	–	–
Spinach red gram curry[c,e] (g)	–	40	–	40	–
Curried green gram (*dal*)[c,e] (g)	–	–	60	–	60
Pickle[d] (g)	–	15	–	15	–
Evening tea					
Tea bar[ae]	1	1	1	1	1
Dinner					
Chapati[e] (g)	–	–	–	135	–
Parotta[b] (g)	–	–	–	–	120
Puri[b] (g)	115	115	–	–	–
Vegetable *pulav*[c,e] (g)	–	–	100	–	–
Curried green gram (*dal*)[c,e] (g)	30	45	–	60	–
Potato cauliflower curry[c,e] (g)	25	–	–	–	40
Pickle[d]	–	15	20	–	15
Chikki[d] (g)	–	–	25	–	–

(a): Contained sugar 20 g, whole milk powder 5 g, tea leaves 5 g; (b): canned food; (c): pre-cooked dehydrated foods requiring reconstitution. (d): packaged in polyethylene sachets; and (e): packaged in flexible pouch.

Skinfold thickness: At the end of each phase, measurements of skinfold thickness were made using Lange's Calipers at three sites (triceps, sub-scapular and suprailiac). The body density was calculated from these skinfold measurements according to the method of Durnin and Womersley[15] from which the body fat was computed using Siri's formula[16].

2.4 Biochemical Analysis

Blood: Haemoglobin content of the blood collected from finger tips was measured by the method of Sahli[17] at the end of each phase. On the last day of both the phases of the trial period, glucose tolerance test was performed only on 4 subjects each from groups B and C as described by Varley[18]. The fasting blood collected from the antecubital vein for this purpose was also used for the estimation of cholesterol and phospholipids by the methods of Searcy and Bergquist[19], and King and Wootton[20] respectively.

Urine: 24-hour urine collection was made on the last day of each phase. Urine samples were tested for the presence of ketone bodies, albumin and sugar, as per the methods described by King and Wootton[20].

2.5 Activities

The subjects were undergoing active physical training at the time of the trial. The activities included a standard obstacle course, rifle firing practice, defence firing, jungle lane shooting, hill climbing, standing on guard duty, long distance route march in battle order, all of which simulated combat situation. The instructors living with the subjects recorded the duration of each activity in a diary. Using predetermined values for energy cost of activities and duration of each activity, the average energy expenditure of the subjects was worked out[13].

2.6 Physiological and Physical Performance Tests

During the last two days of each phase, the following tests were conducted.

2.6.1 Modified Harvard Step Test

The subjects were made to step up and down a stool 40 cm high at the rate of 30 steps per minute for five minutes. The fitness index was computed from the recovery pulse rates recorded manually by the palpitation method using the formula[21].

$$\text{Fitness index} = \frac{\text{Duration of exercise in seconds} \times 100}{2 \times \text{sum of heart rates during } 1\text{–}1\tfrac{1}{2},\ 2\text{–}2\tfrac{1}{2},\ 4\text{–}4\tfrac{1}{2} \text{ minutes}}$$

2.6.2 Maximal Oxygen Uptake

Maximal uptake of oxygen ($VO_{2\,max}$) was determined indirectly during the last 2 days of each phase by using nomogram formulated by Margaria, *et al*[22] and validated by Astrand, *et al*[23] and Joshep, *et al*[24] for Indian subjects, based on the heart rate response to sub-maximal exercise. A step test performed by the subjects on the 40 cm stool formed the sub-maximal exercise.

2.6.3 Obstacle Course

The time taken to cross a standard obstacle course of typical military patterns spread over a distance of about 1 km was noted.

2.6.4 Hill Climbing

The time taken to climb a hillock from the base to the top at a distance of 200 metres was recorded.

2.6.5 Statistical Analysis

Group data was reported as mean ± SD. Evaluation of significance between the groups was determined by Student's '*t*' test[25].

3. RESULTS AND DISCUSSION

3.1 Food Intake, Body Weight Changes and Energy Balance

The subjects of all the groups were offered the same amount of fresh ration during the first phase. The average energy intake 3568 kcal/day (Table 3) was derived from 95 g of fat, 100 g of protein and 578 g of carbohydrate which formed 24, 11 and 65 per cent of energy intake respectively. The energy intake was more than adequate to meet energy expenditure, since the subjects showed a slight gain in body weight (Table 4) During the second phase the group on NEF ration had a similar food intake, 3631 kcal/day (Table 3). While group B on NEP ration received 3526 kcal/day derived from 120 g of fat, 106.1 g protein and 506.3 g of carbohydrate, contributing to 30.6, 12.0 and 57.4 per cent of total energy intake respectively. The low energy group on the other hand consumed an LEP ration that provided 2133 kcal derived from 72.9 g of fat, 50.3 g of protein and 318.9 g of carbohydrate contributing respectively to 30.8, 9.4 and 59.4 per cent of total energy intake.

Table 3. Composition of the rations

Ration	Protein		Fat		Carbohydrate		Energy
	(g)	(%)*	(g)	(%)*	(g)	(%)*	(kcal)
NEF	104.0	11.5	99.0	24.5	581.0	64.0	3631
NEP	106.1	12.0	120.0	30.6	506.3	57.4	3526
LEP	50.3	9.4	72.9	30.8	318.9	59.4	2133

* Per cent of total energy.

During the first phase there was slight dislocation of the duties of the personnel resulting in slight lowering of energy expenditure. This could explain the slight increase observed in the body weights of all the groups at the end of the first phase (Table 4). At the end of the second phase all the men undertook a patrol duty covering 120 km which resulted in impairment of sleep. The strenuousness of the patrol duty and the impairment of sleep ,would have contributed to the slight weight loss observed in groups A and B.

Table 4. Effect of feeding of a low energy ration on body weight*

Group	First phase (days)			Second phase (days)		Weight change ‡
	0	4	8	12	16	
A	53.8 ± 4.9	53.9 ± 4.9	54.7 ± 4.6	54.3 ± 4.8	54.3 ± 4.9	− 0.4
B	52.5 ± 5.2	52.5 ± 4.9	52.9 ± 4.9	52.8 ± 5.1	52.8 ± 5.0	− 0.1
C	56.6 ± 7.0	56.2 ± 6.8	57.1 ± 6.8	55.8 ± 7.1	55.9 ± 6.8	− 1.2

* Mean ± SD for 15 subjects expressed in kg; values are not significantly different ($P < 0.05$) among themselves in each group; ‡ weight change is from 8th day to 16th day.

In the present experiment, the men on the hypocaloric ration lost body weight (1.2 kg/8 days) while the normal energy groups maintained body weights with marginal fluctuations. The subjects fed with LEP ration were on energy deficit of 1484 kcal/day or had a cumulative deficit of 11,872 kcal/man in 8 days (Table 5). These figures were computed from the energy expenditure value, 3412 kcal/day, plus an amount equal to six per cent added for metabolic and absorption loss[13]. From the figure for energy deficit and loss of body weight, the energy equivalent for 1 kg weight loss works out to be 9820 kcal which is considered rather too high. Calorie equivalent of weight loss has been reported to be lower during the first 10 days of restriction[26]. As such a higher degree of weight loss was expected. Miller and Mumford[27] on the other hand points out that it is not possible to calculate changes in body weight from a knowledge of energy intake and the amount of exercise alone. Edholm, *et al*[28] and Durnin[29] have

Table 5. Energy balance in subjects on different dietary regimens during second phase*

Group	Intake (kcal/day)	Expenditure (kcal/day)	Intake to balance expenditure ‡ (kcal/day)	Deficit	
				Per day (kcal)	Total in 8 days (kcal)
A	3526	3412	3617	− 91	− 728
B	3631	3412	3617	+ 14	+ 112
C	2133	3412	3617	− 1484	−11872

* Mean ± SD for 15 subjects; ‡ energy intake necessary to meet the expenditure to maintain energy balance, calculated from energy expenditure value, adding 6% for metabolic and digestion loss.

observed a delay in the food intake response in men in relation to the energy expenditure. Therefore, it may be assumed that body weight changes in relation to energy intake is not governed by a simple relationship, but is dependent upon several factors.

The subjects in the present experiment had been conditioned to a very high work rate since they were being engaged in strenuous exercises during the preceding period of five months at the current level of intake. It is therefore possible that the loss of weight lower than the expected may be due to compensatory alteration in energy metabolism, high level of metabolic efficiency, lower basal metabolic rate and greater physical fitness.

Edmundson[30] demonstrated low metabolic rate and low energy cost in pursuance of standard work task in men fed with a low energy ration (1535 kcal/day) compared to a group with high energy intake (2381 kcal/day). In a recent review Sukhatme and Margen[31] clearly brought out the variations in efficiency of energy utilisation and put forth the concept of autoregulatory homeostatic nature of energy balance. They found that at a lower threshold value of 1900 kcal an individual functions with a maximum efficiency of 50 per cent, whereas at an intake of 2550 kcal which is the average requirement for adult males, the efficiency drops to 37 per cent and at an intake of 3200 kcal it is still less. It is understood from these that energy requirement is a dynamic concept and that one cannot expect a stoichiometric relationship between energy intake and output concomitant with body weight changes.

3.2 Clinical and Biochemical Tests

The haemoglobin content in blood remained normal in all the groups varying between 14.7 ± 1.4 and 15.4 ± 1.3 per cent in the normal and energy deficient groups respectively. None of the subjects showed albuminurea, glycosurea or ketonurea. Clinical examination of the subjects did not indicate abnormalities. However, there was slight impairment of glucose tolerance on hypocaloric feeding (Fig. 1). The glucose levels at the end of both 60th and 90th minutes in the low energy group were significantly higher ($P < 0.01$) than in normal energy group and showed a delay in returning to normal values. The impaired glucose tolerance exhibited by the low energy group may be attributed to a delay in the rate of glucose disposal or a decrease in net peripheral uptake. It is well-recognised that man tolerates the energy deprivation by shifting the energy metabolism to fat dependent processes resulting in an increased circulating free fatty acids (FFA). It has been suggested that FFA inhibits glucose uptake and the homeostasis in glucose is brought about by glucose-fatty acid cycle[32]. It is also likely that during energy deprivation the organism develops reduced sensitivity to action of insulin which might also have caused temporary intolerance. Further, changes in insulin production and/or degradation are possibly the other factors contributing to the slight glucose intolerance displayed by the subjects on low energy diet. These changes are expected to disappear once the sub-optimal feeding is discontinued.

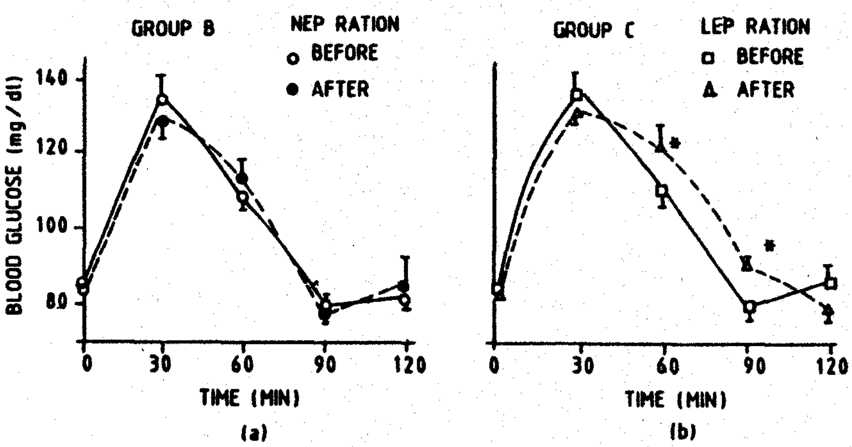

Figure 1. Oral glucose tolerance test in groups B and C; (a) NEP ration, (b) LEP ration; vertical bars denote SE and * indicates significant difference ($P < 0.01$).

The serum cholesterol and phospholipid levels have shown a decreasing trend during energy restriction (Table 6) indicating possibly a higher level of utilisation of fatty acids. However, because of wide variation in the values, these changes did not reach a level of significance. These subjects did not show any ketonurea. The higher level of carbohydrate present in the Indian dietary is a desirable factor to prevent ketosis[33]. Clinical examination did not indicate the presence of any symptoms of ill-health.

Table 6. Blood cholesterol and phospholipid contents in groups B and C*

Group	Total cholesterol (mg/dl)		Phospholipids (mg/dl)	
	First phase	Second phase	First phase	Second phase
B	132.1 ± 28.4	$136.4 \pm 15.3^+$	245.5 ± 16.4	$194.3 \pm 51.1^+$
C	159.9 ± 12.4	$136.8 \pm 42.4^+$	224.5 ± 16.4	$199.3 \pm 28.2^+$

* Mean ± SD for 4 subjects in each group; $^+$ not significantly different ($P < 0.05$) from first phase values.

3.3 Skinfold Measurements and Body Composition

The sum of the three skinfold thicknesses (Table 7) measured at triceps, sub-scapular and suprailiac both before and after the low caloric regimens did not indicate any significant change although one did expect some alteration due to changes in body weight. The percentage of body far calculated from skinfold measurements also did not show any difference between the normal energy and low energy groups. It may be noted that in this study, no critical appraisal of lean body mass, body fat or body water compartments could be made because the direct methods available are too complex to be used on a large scale in a field study.

The body fat changes as computed from skinfold measurements showed that there was negligible effect on the total energy reserve. The percentage of body fat in

Table 7. Aggregate of three skinfold thicknesses and body fat computed from skinfold measurements*

Group	Skinfold thickness (mm)		Body fat (%)	
	First phase	Second phase	First phase	Second phase
A	16.5 ± 6.6	16.3 ± 2.3	5.55 ± 1.49	6.07 ± 1.61
B	14.7 ± 2.5	14.8 ± 3.0	5.86 ± 1.88	5.91 ± 2.19
C	16.7 ± 4.9	16.4 ± 6.1	6.57 ± 1.93	5.67 ± 2.27

* Mean ± SD for 15 subjects in each group; values of second phase are not significantly different ($P < 0.05$) from those of first phase.

these subjects was found to be much lower than in the average Indian soldiers, but was comparable with those reported for college athletes of the same age and weight[33]. The low body fat is attributed to the fact that the subjects were young recruits belonging to the low socio-economic group; secondly they were under a stress of severe physical training at the time of start of the study. All these factors could have accounted for the low amount of subcutaneous fat in the body. Therefore the loss of body weight of 1.2 kg did not result in changes of fat in the body.

3.4 Physical and Physiological Performance

Results of modified Harvard step test (Table 8) indicate an improvement in the scores in all the groups during the second phase. This has been also reported by Consolazio, *et al*[1] and was attributed to training effect and does not reflect any

Table 8. Physiological and physical performance test scores*

Group	First phase	Second phase
Modified Harvard step test (*score*)		
A	96.8 ± 10.1	124.4 ± 13.5[a]
B	96.1 ± 12.3	128.6 ± 15.7[a]
C	92.2 ± 7.1	125.5 ± 10.8[a]
VO_{2max} (ml/kg/min)[b]		
A	48.7 ± 2.4	53.8 ± 4.3[a]
B	48.8 ± 3.5	54.8 ± 2.3[a]
C	48.4 ± 2.2	55.6 ± 1.3[a]
Obstacle course (min)		
A	13.4 ± 1.4	13.8 ± 1.6
B	15.6 ± 1.2	15.4 ± 1.1
C	15.6 ± 1.6	15.3 ± 1.1
Hill climbing (min)		
A	2.4 ± 0.2	2.5 ± 0.2
B	2.3 ± 0.2	2.7 ± 0.3
C	2.4 ± 0.2	2.6 ± 0.3

* Mean ± SD for 15 subjects in each group; (a): significantly different from first phase values ($P < 0.05$); and (b): estimated from heart beat response to sub-maximal exercise.

improvement in work performance. The VO_{2max} followed the same pattern as in Harvard step test. There was an improvement in the second phase; VO_{2max} is generally accepted as the most objective method by which one can determine the physical fitness of an individual. In this study the VO_{2max} was predicted from cardiac frequency during sub-maximal exercise. This method, inspite of its limitations, appears to be the most practicable and the best suited for a field trial simulating combat situations. The data on obstacle course and hill climbing (Table 8) did not show any difference between the control and the group with low calorie intake. However, the subjects of the low calorie intake group complained of exhaustion after the event. The motivation and competitive spirit was high in the subjects during these tests. The results clearly indicated that there was no deterioration in performance of soldiers during the period of 8 days due to feeding on low energy rations which met 60 per cent of daily energy requirement compared to the controls fed adequately. It is concluded that the low energy ready-to-eat pack ration is suitable for field operations lasting for 8 days.

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