"Metabolic Efficiency" in Chronic Energy Deficiency

P.S. Shetty

In a recent article published in this Bulletin[15], an attempt had been made to summarise the metabolic responses that occur during energy deficiency in man. While discussing the reduction in Basal Metabolic Rate (BMR), which constitutes the major part of total daily energy expenditure, parallels were drawn between the observations made in adult human subjects who were acutely semi-starved (experimentally or therapeutically) and those who were apparent victims of "real-life" situations of long-standing energy deficiency, possibly since their childhood.

That the physiological and metabolic responses of the human body to chronic energy deficiency are similar to, and can be explained on the basis of, the changes observed in experimentally induced semi-starvation seems to be a universal assumption. This has led to considerable interest among the nutritionists researching human energy metabolism, to look for physiological changes suggestive of a possible increase in "the metabolic efficiency" of the active tissues when there is energy restriction of any sort.

Demonstration of a reduction in oxygen consumption per unit of active tissue mass,that is, per kg fat-free mass (FFM) or lean body mass (LBM), in undernutrition has been presumed to be indicative of enhanced "metabolic efficiency" of the active tissues. Current postulates regarding "adaptation" to undernutrition seem to rest heavily on this presumption. A further extension of this presumption is that decreased BMR per kg FFM (or LBM) when seen in undernutrition, reflects increased metabolic efficiency not only with respect to the basal state but also with respect to other components of energy expenditure (including all types of physical activity). Thus the presumed increase in "metabolic efficiency" in undernutrition is being claimed to signify a reduced energy cost of a given physical activity in the case of the undernourished individual!

This paper attempts to question the assumptions:

- that a decrease in the basal oxygen consumption that is, BMR expressed per unit of active tissues (FFM/LBM) is in fact an invariable and constant feature of undernutrition;
- that such decrease when observed is indicative of "metabolic efficiency" of the tissues; and
- that the metabolic responses seen during acute semi-starvation can in fact be extrapolated to chronically energy deficient individuals.

BMR Changes During Acute Semi-starvation

The paper also attempts to show that active tissues mass is not a homogeneous entity, and that undernutrition brings about changes in the composition of the "active tissues" and in the relative proportions of the muscular and visceral components thereof. These important factors need to be taken into consideration in assessing the significance of changes in BMR.

The experimental semi-starvation studies in human volunteers undertaken in this century by Benedict before the 1920s[4], and by Ancel Keys and his group during the Second World War[7], had demonstrated that following a period of energy restriction, individuals attain energy balance at a new, but lower level. This new plane of energy balance is attained partly by a reduction in energy output and partly as a consequence of changes in body composition. The observed decrease in BMR in these semi-starved subjects was explained on the basis of both a decrease resulting from loss of metabolically active tissues associated with the reduction in body weight as well as a decrease *per se* in the metabolic rate or activity of the remaining active tissue mass. It is this latter response that is being projected as an indication of the increased "metabolic efficiency"

The earliest investigations in this area favoured the view that the major factor contributing to the decline in BMR in semi-starvation was the reduction in oxygen consumption per unit of active tissue, because the reduction in overall BMR was apparently of a greater order than the loss of body weight. Subsequent observations, however, favoured a decrease in the mass of metabolically active tissue rather than a reduction in BMR per unit of active tissues, as the main factor responsible for the reduced overall BMR[19]. Attempts to quantify the contributions from both these changes indicated that with short-term experimental semi-starvation, 65 to 73 percent of the reduction in BMR was attributable to the decreased oxygen consumption per unit of the active tissues, while, with more prolonged restriction, only about 35 percent of the decrease in BMR was attributable to a decrease in cellular metabolic rate[7]. Similar findings have been reported from more recent studies on obese individuals who have been therapeutically energy-restricted in order to reduce excess body weight[13]. These studies in obese subjects also confirmed that during the acute phase of energy restriction (that is two to three weeks), the bulk of the reduction in metabolic rate was due to an actual decline in the metabolic activity of the active tissue mass.

BMR Changes In Chronic Undernutrition

BMRs may be expressed either in absolute terms (that is, KCals per day) or as per unit body surface area (BSA), the latter procedure being a generally accepted practice till recently. BMRs (per unit BSA) are low in individuals who are chronically undernourished or energy deficient. Undernourished German prisoners who had lost more than 25 percent of their body weight had BMRs per unit BSA 16 percent below normal values[3]. Male adults who were malnourished and semi-starved showed a 20 percent reduction in their BMRs per unit BSA[20]. Victims of severe malnutrition in the Warsaw ghettos also had markedly lower BMRs varying between −10 percent to −30 or −40 percent depending on the severity of the malnutrition[5]. Similar findings were reported in other groups of chronically malnourished individuals during the Second World War.

The picture was, however, confusing when attempts were made to express BMRs (not as per unit weight surface area but) as per unit weight of the active tissue mass. Some of the above studies on malnourished subjects where BMR per unit surface area was reduced, failed to show any significant decrease in BMR per unit of active tissue mass[3,20]. Ashworth while reporting a 12 percent reduction in BMR in Jamaican subjects on low calorie intakes also confirmed her inability to show a clear-cut evidence of reduction in metabolic rate per unit of active tissue[1].

We have attempted to study the possible similarities in the metabolic response to prolonged experimental semi-starvation and chronic undernutrition. BMR measurements made in undernourished labourers (not suffering from obvious infections) showed that the major share of the fall in BMR was attributable to a decrease in the total mass of lean tissues, and a smaller share to reduction in metabolic activity per unit of active tissue[14]. Recalculation of data from an earlier report by Ramanamurthy, Srikantia and Gopalan[12] also showed that the BMR expressed per unit active tissue was considerably lower in adult undernourished males.

As against these above observations, a large number of measurements made by us over the last five years, in chronically energy deficient subjects, have not only failed to show any evidence of enhanced metabolic efficiency but on the contrary have consistently shown that BMR per kg active tissue was if anything higher in undernourished subjects as compared to well nourished controls[17]. A comparable large series of measurements reported by Srikantia[18] also showed the same trend; BMR per unit body weight increasing as the weight for height expressed as a percent of the standard diminished below 70 percent.

Some of these differences may be attributable to:

- differences in techniques adopted to estimate the active tissue mass,
- differences with respect to the stage and the order of undernutrition (e.g. the subjects of Gopalan *et al* in the earlier studies were patients who had just recovered, or were still recovering, from famine oedema, unlike the subjects of some later studies).

Reduction in oxygen consumption per unit of active metabolising tissue would thus appear to be not an invariable finding in undernourished subjects. Apart from this fact, the important point that is being emphasised here is that it would be wrong to presume that reduction in oxygen consumption per unit of metabolising tissue, even in cases where such reduction may be present, (and the consequent lowering of BMR as expressed on body-surface area basis in such cases) are indicative of "increased efficiency". It would, on the other hand, seem more reasonable to consider such reduction as reflecting, if anything, a lower order of cell function resulting from cellular impairment arising from chronic undernutrition.

Since undernourished individuals who have similar anthropometric or functional characteristics may or may not have a reduced BMR per kg active tissue, either BMR per kg active tissue is not an index of metabolic efficiency as is being claimed, or, "metabolic efficiency" presumed because of observed reduction of BMR per active tissue in some cases of undernutrition is not a characteristic and constant feature of chronic energy deficiency. Changes in BMR per unit of active tissue mass should not be misinterpreted as indicating increased metabolic efficiency.

Changes In Composition Of Active Tissues In Undernutrition

Recent studies examining changes in body composition of adults with naturally occurring chronic undernutrition revealed a gradation of changes related to the severity of the deficiency[2]. Body cell mass was reduced even with moderate deficiency, the muscle cell mass being more affected than visceral cell mass. Muscle cell mass decreased linearly while the visceral cell mass showed little change with increasing severity of undernutrition. Our own studies also indicated a greater reduction in muscle cell mass with visceral mass apparently being spared[17]. Protein turnover using^{2} N labelled glycine in these chronically undernourished with elevated BMR per kg FFM, also revealed the existence of a greater visceral (largely hepatic) pool[16]. These findings may help explain the *increase* in BMR per unit active tissue demonstrated by us, since the FFM or LBM appears to have a higher proportion of the metabolically active visceral mass as opposed to a relatively less active muscle mass. Partitioning of the resting oxygen consumption in the basal state supported this condition[11].

Recent experimental work on animals has also shown that when the ratio of visceral mass to body weight increases, this change is associated with an increase in BMR corrected for metabolic body size[10]. Added to these changes in body composition there is also the question of the increased water content, mainly in the extracellular fluid compartment seen during chronic undernutrition[2] which may also affect the BMR per unit FFM. Chronically undernourished subjects who have to do hard physical labour may be expected to have relatively more dense bones which may also influence this parameter and thereby contribute further to the misleading impression of an apparent increase in metabolic efficiency. Thus BMR per unit active tissue in different states of undernutrition would reflect the range of changes in body composition during the evolution and progression of the undernutrition process. Quantification of fat-free (or lean) body mass would by itself be inadequate: techniques need to be evolved to further partition FFM (or LBM) into muscle and visceral masses.

Concluding Comments

What then does the much debated so called "adaptation" add up to? If enhanced "metabolic efficiency" cannot be convincingly demonstrated in the BMR component of basal energy expenditure in chronically energy-deficient subjects it is unlikely to be demonstrable with respect to the energy cost of their physical activities as well. Ramanamurthy *et al*[12] had in fact shown that the energy expenditure for a given exercise, over and above the basal figure before and after nutritional rehabilitation of undernourished subjects were nearly identical when expressed in absolute terms. When, however, energy expenditure for a given exercise was expressed as percent increase over basal metabolism, the values were 174.5 percent before and 134.7 percent after rehabilitation. This difference was obviously due to the rise in basal metabolism after rehabilitation. This is in consonance with the observation of Gopalan[6] who had challenged the basis of the assumption of a constant fixed relationship between BMR and energy cost of activities (irrespective of the level of BMR).

With changes in the thermogenic component not likely to contribute anything substantial to savings in energy output, the only significant "adaptive" changes that occur during long-term energy deficiency are:

- a reduction in body size (both with respect to stature and body weight)

• a behavioural reduction in spontaneous physical activity[8]. Neither of these is acceptable as a desirable form of adaptive response to long standing low energy intakes.

Based on the S.G. Srikantia Memorial lecture delivered at the Annual Conference of the Nutrition Society of India, at Trivandrum in November 1989.

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Nutrition Society of India

The Silver Jubilee year of the Society will start with the Society's Annual Meeting at the National Institute of Nutrition, on December 1, 2 and 3, 1990. A number of symposia, with participants from India and abroad, will be held. For details, contact: Dr. Kamala Krishnaswami, Secretary at NIN, Hyderabad.

REVIEWS AND COMMENTS

1. The National Nutrition Monitoring Bureau

The National Nutrition Monitoring Bureau (NNMB) has been the major authentic source of information regarding dietary intakes and nutritional status of populations in different parts of India. Its periodic reports have been of immense value to policy-makers, planners and nutrition scientists. NNMB data are gathered through painstaking surveys carried out methodically and with appropriate standardised techniques by well-trained investigators, using a statistical sampling design evolved by some of India's most outstanding statisticians.

The latest (1988- 89) Reports of NNMB provide, as usual, a mine of useful information. In particular, we wish to draw attention to parts of these Reports wherein the dietary and nutritional patterns obtained in the country in the mid-'70s (1975) and now in the late '80s (1988-89) have been compared.

Comments

NNMB surveys do not cover the entire country. Moreover, "average" figures, in a country with wide inter-regional and intra-regional differences, have their inherent limitations. Subject to these limitations, some broad conclusions emerge from the latest NNMB Reports.

• Daily per caput incomes in the households surveyed were found to have increased between the two survey periods; but, as the authors of the Report point out, this has to be interpreted in the light of the inflation and consequent decline in the value of the rupee in the intervening period. Assessments of household incomes are well-known to be subject to limitations and errors; even so, these income-data provide a broad indication of the economic state of the families.

It is distressing that in over one-third of the households surveyed, the daily per caput income was less than Rs.2. Allowing for a family size of five members, this would work out to a total daily income of less than Rs.10 per family (of five members) that is, about 75 American cents! In over three-fourths of the households, the daily family income was less than Rs.25 (about a dollar and 50 cents). These figures, in the context of current food prices, should provide an indication of the type of diets that alone the families can afford. No amount of juggling of the "poverty-line", nor all the sophistry of international debates on "adaptation" to undernutrition, can hide the inevitability of chronic hunger that these data imply.

In nearly 40 percent of households, diets continued to be deficient either with respect to calories, or proteins + calories; and the position in this regard had not improved in the intervening years (38.5 percent in 1975 and 40.4 percent in 1988-89).

• There has been a significant reduction in the prevalence of "severe malnutrition" (children with body weights

Table 1: Percent distribution of households according to protein and calorie adequacy

	P C – –	P C + –	P C – +	P C + +
1975	18.9	18.9	0.7	61.5
1988-89	20.2	19.6	0.6	59.6

P : protein; C : calorie; + : adequate; – : deficient.

Table 2 : Percent distribution of children (1-5 years) (Gomez scale)

	Normal	Mild	Moderate	Severe
1975				
Boys	3.0	25.4	55.6	16.0
Girls	2.8	25.6	51.2	20.4
1988-89				
Boys	4.2	33.9	52.6	9.3
Girls	5.7	34.3	50.9	9.1

less than 60 percent of expected weights for age) in both boys and girls under five years of age. This was reflected in a somewhat higher percentage of children falling in the "normal" or "mild malnutrition" categories in the Gomez scale. The prevalence of "moderate malnutrition" (children with body weights between 75 percent to 60 percent of expected normal weights) showed only a very marginal change. The decline in "severe malnutrition" could either imply better child-rearing practices or (what appears more likely) more prompt attention to superadded infections which usually tip children of poor households from the "moderate" to the "severe" category of undernutrition.

- The latest NNMB Reports, in line with its previous Reports, fail to provide evidence of gender discrimination (in favour of boys as against girls). The difference between sexes with respect to prevalence of "severe malnutrition" (higher in girls) seen in some states in the earlier period (1975) seems to have narrowed down considerably to marginal levels in 1988-89.

- It is interesting that among the seven states covered in the NNMB operation in 1988-89, Tamil Nadu ranks next only to the "unique" state of Kerala from the points of view of both the highest percentage of "normal" children and lowest percentage of "severely malnourished children" in the Gomez scale. It may be perhaps wrong to read too much into these figures; but these data have to be seen in conjuction with those on "percent distribution of households according to daily per capita income" in the seven states,which shows that Tamil Nadu is the only one of the seven states which actually showed a significant *worsening* of the situation regarding household per capita incomes between the two survey periods. During the years intervening between the two surveys, Tamil Nadu has had the benefit of a massive free, state-sponsored, Noonmeal Programme covering practically all poor children above two years of age in the state.

It is noteworthy that during the same period, Kerala registered a substantial *improvement in household per capita income profile, accompanied* by a far better performance (than Tamil Nadu) with respect to improvement of child nutrition *in the absence of a massive free feeding operation.*

C. Gopalan

2. Palm Oil In India

The nutritional aspects of palm oil had been discussed in a paper in an earlier issue of this Bulletin[1]. It may be useful, in this connection, to consider future prospects with respect to oil palm and palm oil in India.

Shortages of edible oil in India have led to substantial imports from Malaysia of palm oil and palmolein. Their distribution at reasonable prices through ration shops has bred familiarity with, and easy acceptance of, the products. It has also led to serious consideration of the possibilities of growing the oil palm in India on a large scale as a source of edible oil. Under favourable conditions of latitude, soil and rainfall, the oil palm yields as much as six tonnes of oil per hectare, some six to eight times that of groundnut or soyabean. Production starts about five years after planting, reaches a peak about five years later, and continues at this level for about 30 years before tapering off for another 20 years. It needs some fertiliser, good management and above all plenty of water. The enormous bunches of fruit have to be cut down using knives attached to long poles, and transferred at once to the factory to be sterilised and stripped of the bright orange, plum-sized fruits, which are crushed for oil. The oil is deep orange in colour through the presence of beta-carotene, which is removed during subsequent refining. Palm oil is partly solid at ambient temperatures. Since this causes problems during transport, the solid portion is squeezed out after chilling the oil slightly, and the liquid palmolein is the chief product of commerce.

In 1988 Malaysia produced over 50 lakh tonnes of palm oil (of which 43 lakh tonnes were exported) and Indonesia 20 lakh tonnes. Because of high productivity and efficient technology it is the cheapest oil on the world market, favoured by countries like India seeking to buy oil.

Growing The Oil Palm In India

Traditionally the palm has flourished between about 12° North and 12° South latitudes, and Kerala and Andaman Islands lie within these limits. Following successful experimental plantations, first at Thodapuzha and then in Palode in Kerala, Oil Palm (India) Ltd. was started as a commercial venture near Kottayam on 3,705 hectares of forest land. Later some 1,600 hectares were developed in the Andaman Islands. Yields of the oil from the Kerala plantations seem to be about three tonnes per hectare, about half the Malaysian figure; even though the annual rainfall in both places is about 2,200 mm, Kerala has five rainless months against none at all in Malaysia.

In most parts of India irrigation will be essential to sustain yields, but the style and pattern of this irrigation will be an important matter for study. Irrigation is believed to be available in Andhra Pradesh and Karnataka, and 2.5 lakh hectares in each of these states have been identified by an Expert Committee for raising oil palms. Development under the aegis of a National Oil Palm Development Board either through cooperatives, or the corporate/company sector, or the private/public sector has been recommended by the Committee. Pilot projects have been put into operation in Maharashtra and in the Bhadra Project Area in Shimoga (Karnataka) to examine the problems of cultivation and irrigation, furnish seed for other plantings, and set up oil extraction units.

The apparently healthy growth and bearing of stray oil palms in many states of India, from Andhra Pradesh and Tamil Nadu to Assam and West Bengal, especially where water is available, seem to indicate that latitudes of growth may not be a real constraint.

Costs of growing the oil palm are high, and the long fallow period also ties up capital. The cost has been estimated by the Committee at Rs.27,000 per hectare over the five-year fallow period; from the seventh year, product returns will yield a cash surplus. Only very large plantations can afford to process the fruit bunches at once, an essential to ensure oil quality. Small plantations will need to have group processing facilities and a system of continuous and reliable transport, since the fruit bunches mature all the year round and harvesting is almost a daily activity.

An important concern for India is whether oil palms can replace forested land without ecological damage. Both in Kerala and in the Andamans such replacement has been steadfastly refused by the government since national forest cover is already appallingly low. The experience of Malaysia seems to show that there is no loss of topsoil, the major hazard, if a certain protocol is followed. The ground must first be covered with certain types of fast-growing creeper vegetation. Once these are firmly established, in a matter of weeks, existing trees can be felled and the palm trees set down. Extensive growing of the oil palm over 17 lakh hectares in Malaysia has not altered the rainfall pattern or quantity. Of course in areas of sparse vegetation, a new forest cover made up of oil palms would be a decided bonus. In the past, poor fertilisation and fruit set were frequently encountered. The introduction of a weevil, *Elaeidobius kamerunicus,* which effects cross pollination, has totally overcome this difficulty. Encouraging barn owls to roost serves to control the rat population.

A few years ago, tissue culture techniques were lauded as a means of multiplying high quality palms. When these plants were grown in Malaysia, the mature trees frequently yielded fruit bunches that rotted before they ripened, suggesting caution in such multiplication. The type of palm grown in Malaysia is termed tenera, a cross between the dura fruit type with thick shells and pisifera fruit with no shell. In Palode, Kerala, various types of crossing and backcrossing are being investigated. The oil from the Malaysian tenera palm has an iodine value close to 53, and carries 50 percent of saturated fatty acids, 40 percent of oleic acid and 10 percent of linoleic acid. Crossing tenera with related palms has raised the iodine value of the oil even to 70. This will be a liquid oil that may have both economic and health advantage over the present palm oil.

Palm Oil In India

The high natural beta-carotene content of crude palm oil (about 600 ppm) is a nutritional bonus. Normally this is removed at the very start of refining so as to yield as light an oil as possible for a range of edible commercial uses. It is technologically possible to remove the free fatty acids present in crude palm oil using high vacuum distillation, a process called physical refining, while still leaving the carotene intact in the oil. For uses where the presence of pro-vitamin A would be useful, as in child-feeding programmes, this refining route deserves attention in India.

The Regional Research Laboratory, Trivandrum has developed an excellent prototype unit for the extraction of crude palm oil on a small scale (one tonne of fresh fruit bunches per hour, and three tonnes of detached fruit) and is now working on matched units for refining of the oil. These pilot plants are also linked with the likelihood that small oil palm plantations may arise in India with modest production of fruit which will nevertheless need to be processed without delay to avoid rapid rise of free fatty acids in the oil. The nutritional aspects of crude, carotene-rich palm oil are being examined by the National Institute of Nutrition, Hyderabad. Both partly-refined palm oil and the fully-refined product could have their uses in India.

K.T. Achaya

The author is an expert in oilseed chemistry and technology, and a noted scholar in the History of Indian Food.

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3. Commercial Baby Foods: Misusing The Media

• The Government of India had set up a committee on "Code for Baby Foods" to draw up regulations regarding the use and promotion of commercial baby foods. The recommendations of that committee, which included top health scientists, paediatricians, representatives of consumer organisations and of voluntary associations, were approved by the Government of India.

• On December 19, 1983 Government of India passed the "Indian National Code for Protection and Promotion of Breast-feeding" in the form of Resolution No. 18-11/81-NT. Article 5.1 of this Code states: *"There shall be no advertising or other form of promotion to the general public of products within the scope of this code"*. The scope included baby foods and feeding bottles.

• On November 18, 1986, cutting across party lines, the opposition joined hands with the Government and unanimously passed the "Infant Milk Foods and Feeding Bottles Bill" presented before the House by the then Minister of Human Resource Development. *Again, the first and the most important regulatory clause of the Bill states: "No person shall advertise, or take part in the publication of any advertisement, for the distribution, sale or supply of infant milk foods or feeding bottles".*

• India is a signatory to the International Baby Food Code which prohibits *all* advertising of baby foods to the public. This was passed in the World Health Assembly in 1981 after the Indian delegation strongly spoke *for* the Code.

The Volte Face

Under these circumstances all those interested in the promotion of health/nutritional status of our babies must have been shocked by the statement of a Minister in our Parliament on April 23 this year that the Information and Broadcasting Ministry has decided that advertisements for baby foods can be accepted by AIR and Doordarshan TV under certain conditions.

The risk of babies dying from diarrhoea and dehydration is 25 times more in artificially fed babies compared to the breast-fed. Moreover, among the artificially fed, the risk is more in babies given baby foods compared to liquid cow's milk. Numerous studies have confirmed that poor women in our country can produce enough milk of good quality for meeting the needs of these babies in the first four to six months of life.

Commercial baby foods, due to unethical advertising practices, have already made deep inroads into breastfeeding practices among the poor in the metropolitan urban slums of the country with disastrous results. Advertising commercial baby foods through radio and TV, which now reach out to the remotest villages, will only facilitate the extension of this unfortunate trend to the rural areas as well, much to the detriment of child health.

Breast-feeding has been traditionally the sheet anchor of infant nutrition in our country. We should do nothing which could result in the erosion of this most valuable asset.

It is hoped that the Minister's answer in Parliament, referred to above, does not reflect a firm policy decision. Advertisements of commercial foods through the public media must be banned in view of the recommendations already approved and agreed to by the Government.

R.K. Anand

The author is a leading consulting paediatrician of Bombay and a member of the Committee on Code for Baby Foods.

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