Food, physical growth and work output

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IN independent India's early years of planning, the subject of food, physical growth and work output assumed much importance because of the small physical stature and low nutritional status of our people. Food production has since increased considerably but so has the population and there is no sign that we have improved the nutritional status to anywhere near what we had expected with more and better food through food intervention. The vicious cycle of poverty leading to low intake and low intake leading to still greater poverty continues to haunt us. In the first part of this article we shall deal with limits to physical growth of children and in the second with the e. ɛct of inadequate food on development and work performance.

The Narangwal study

The work reported here and the underlying philosophy stemmed from the Narangwal study[1] carried out by the Indian Council of Medical Research (ICMR) with US assistance. The study included ten villages, two of which received medical care, three received nutrition and medical care, and two served as control without any service. The study showed that prevalence of morbidity, particularly because of gastrointestinal diseases, was the highest among villages which received medical care and the lowest among the controls. This was a surprising finding. There was clear indication that when households get into dialogue with medical care and nutrition services, they like to draw on the latter's help as much as they can in dealing with problems of health, illness and diet of members in the families. The fact that the control villages showed the lowest prevalence of morbidity did not escape the study group's attention and was ascribed to under-reporting.

The study group was well aware that all villages had already installed hand pumps, which provided relatively safe water, and latrines. But it took the view that, when hunger and malnutrition were acute and over 80 per cent of children suffered from them, the immediate thing to do was to strengthen medical services to deal with illness and institute programmes for food intervention to prevent malnutrition, rather than educate children and communities in the use of potable water and latrines. However, as time passed it became increasingly clear that food intervention failed to achieve growth rates comparable to those that had been observed in the USA. The growth rates observed at the end of three years fell short of the Harvard Median by 3 kg in the case of children from high castes and by 5 kg in the case of children from low castes. The same phenomenon was seen in the case of growth in height. The conclusion was that growth stops when the ethnic potential is reached. It meant that even when intake is increased through intervention to the US level by giving more and better food, the genetic potential cannot be achieved. Clearly diet and disease affect each other; they move in concert to show synergistic interaction. They are not equally important as originally postulated by Jose de Castro. This is conventional wisdom. The failure of the intervention programmes suggests that they cannot be regarded as equally important. It is strange indeed that so little research has been devoted to so basic a question. Lack of reliable data has been the principal reason. Fortunately such data are now available, which enable us to quantify the relative importance of lowering disease, morbidity and mortality versus that of dietary change for improvement in health. When these data are examined, we find a very high negative correlation between the surrogate measures of diet and disease in their effect on health. Thus, if someone is suffering from diarrhoea, not only will that person have a very low intake, but he or she will also be unable to effectively assimilate what little was eaten because of the rapid food transit time and disturbances in the absorption mechanism. The majority of illnesses, accompanied by anorexia and loss of appetite, in fact tend to aggravate malnutrition, both by demanding higher energy intake to meet the rise in basal metabolic rate which accompanies fever and by requiring higher intake of protein and other nutrients.

From the statistical point of view, the important and interesting factor here is that, given almost perfect determination of the health index by the two independent variables, a complex statistical analysis could be made to separate out the relative weights of each. The analysis showed that the fall in disease mortality accounted for fully 60% or more of the increase in life expectancy, whereas the increase in

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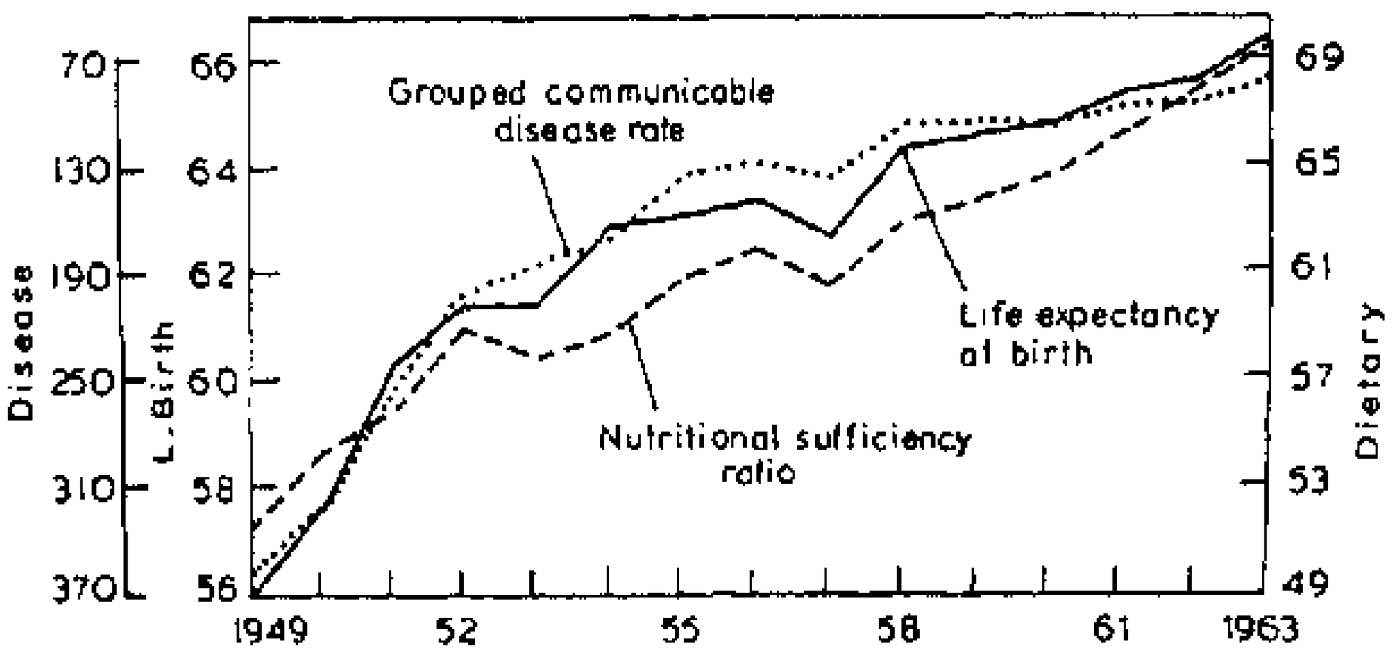


Fitted curves for length of life vs diet and disease in Japan, 1949–1963.

nutritional sufficiency accounted for only 40% or less of the improvement in health. Similar data for Japan (see figure) show that life expectancy went up from 56 years in 1949 to about 70 years in 1963.

Death seldom occurs without disease and from malnutrition alone. Indeed a significant proportion of the nutritional deficiency diseases occurring in poor nations have as their underlying cause a communicable disease insult. This is especially true in the case of protein calorie malnutrition in infants and children, where the underlying factor precipitating fully developed clinical symptoms of PCM is usually prolonged diarrhoea. Our observation is that, generally, disease is a more important component of health than diet. The empirical validation is heuristic and to know its truth one simply has to leave the laboratory and work in the villages.

The Kirkatwadi experiment

An intensive field study was undertaken in one village, Kirkatwadi, to study the effect of nutritional intervention on body weight and adult size and, in particular, to know whether education in the use of latrines and piped water takes as long as the Narangwal study group believed to bring home to the individual the responsibility for one's own well-being and that of the community to which one belongs. If education at the right time in the life of a child cannot bring home the importance of preventing malnutrition, what else can take its place to incorporate in life what one learns in order that an individual may have adequate supply of potable water to drink, and reduce person-to-person contact and unclean handling of food as a matter of instinct and habit? Can intervention through diet alone, supported by medical care, as under the Integrated Child Development Service (ICDS) be the right answer, as suggested by the Narangwal study? Will not the diet need to be supplemented by drugs in order to increase body weight and stature? Can consideration of continuous interaction of the biological environment of man with cultural, economic and physical environment be left out? Can man be equated with animals as Narangwal does? Can one, as an individual, not aspire or look forward to the day when he/she can live as humans should, aware of his/her obligations to communicate with mind to ensure that he/she abides by the moral and social philosophy to deal with the crisis of values with which he/she is confronted in the world today?

Our experience in Kirkatwadi confirmed that the answers to these questions lay in taking note of the continuous and intense interaction of cultural, economic and physical environments with biological environment. In many ways it was a pioneering experiment that we initiated in Kirkatwadi in 1976. The experiment showed that education along Gandhian lines organized around a given social action not only serves as a basis for bringing about a change in life-style, but, even more important, for reducing the gap in technology that we see between the developed and the developing countries by keeping development in science and technology in front of us as the guiding force. The technology gap has the same role to play whether we speak about differences between developed and developing countries or between urban and rural areas in the same country. The speed of change is so great and such are the dizzy heights that advances in science and technology have reached that, unless we keep modern technology as a goal before us, we will not be able to use information in science and technology as a lever to prepare ourselves for the future.

The experiment in Kirkatwadi was initiated by the Marathi Vignyan Parishad, Pune. The experiment was so novel in 1976 that it was far from easy to feel one's way through it. The school in Kirkatwadi was surrounded by heaps of garbage. So it was convenient to begin by asking the teacher and the parents whether they felt it desirable that children should play in these surroundings, fraught as it was with the risk of infection, which could spread by person-to-person contact. The answer was an emphatic 'no' but the children and the teachers alike expressed their inability to prevent garbage being thrown around the school since they were not present in the school all the 24 hours. We agreed that if we could erect a fence sufficiently strong to prevent people, goats and animals from entering the campus, we might be able to prevent garbage accumulating in the neighbourhood.

Simple as the experiment looked, it was not easy work organizing it. Even the task of demarking the campus area and securing approval of the district council and the municipal corporation to build a fence was far from easy; maintenance was even more difficult and securing participation of the entire community in erecting it was a novel experience altogether. However, once the fence was built and the campus was cleared of the garbage, we found to our delight that children willingly accepted the responsibility of keeping the campus clean.

Next on our list was the building of a latrine within the fence. Later in the same year we set up a *balwadi* and instituted a new health education syllabus in the primary school. This was followed by capping the well, chlorinating water and assisting villagers in the building of latrines and biogas plants attached to their houses. For the first time, the villagers got biogas in their households with which they could cook their meals. Analysis of morbidity data showed a distinct fall in the prevalence of diarrhoeal morbidity.

We followed up this experience by initiating a new eight-village project with funds from the Department of Science and Technology. The villages selected for the project were Rahatwade, Vardade, Marnewadi, Babhulsar, Arvi, Kasarsai, Murhevasti and Khandala.

In 1984, following the Kirkatwadi model, we had fences built around the schools in all the eight villages, with a latrine within each campus. This was followed up by setting up a *balwadi* in each village. A new health education syllabus was instituted. In 1986 wells in four of the eight villages were capped and well water was regularly chlorinated and analysed for coliform bacteria. In two of these villages, latrines were built, one for every three households. Morbidity was regularly recorded. We found that the prevalence of diarrhoeal morbidity was reduced by over one-third at the end of the third year. Simultaneously with these measures, height and weight were also recorded. Rate of physical growth was significantly higher in villages where potable water was available and latrines were constructed.

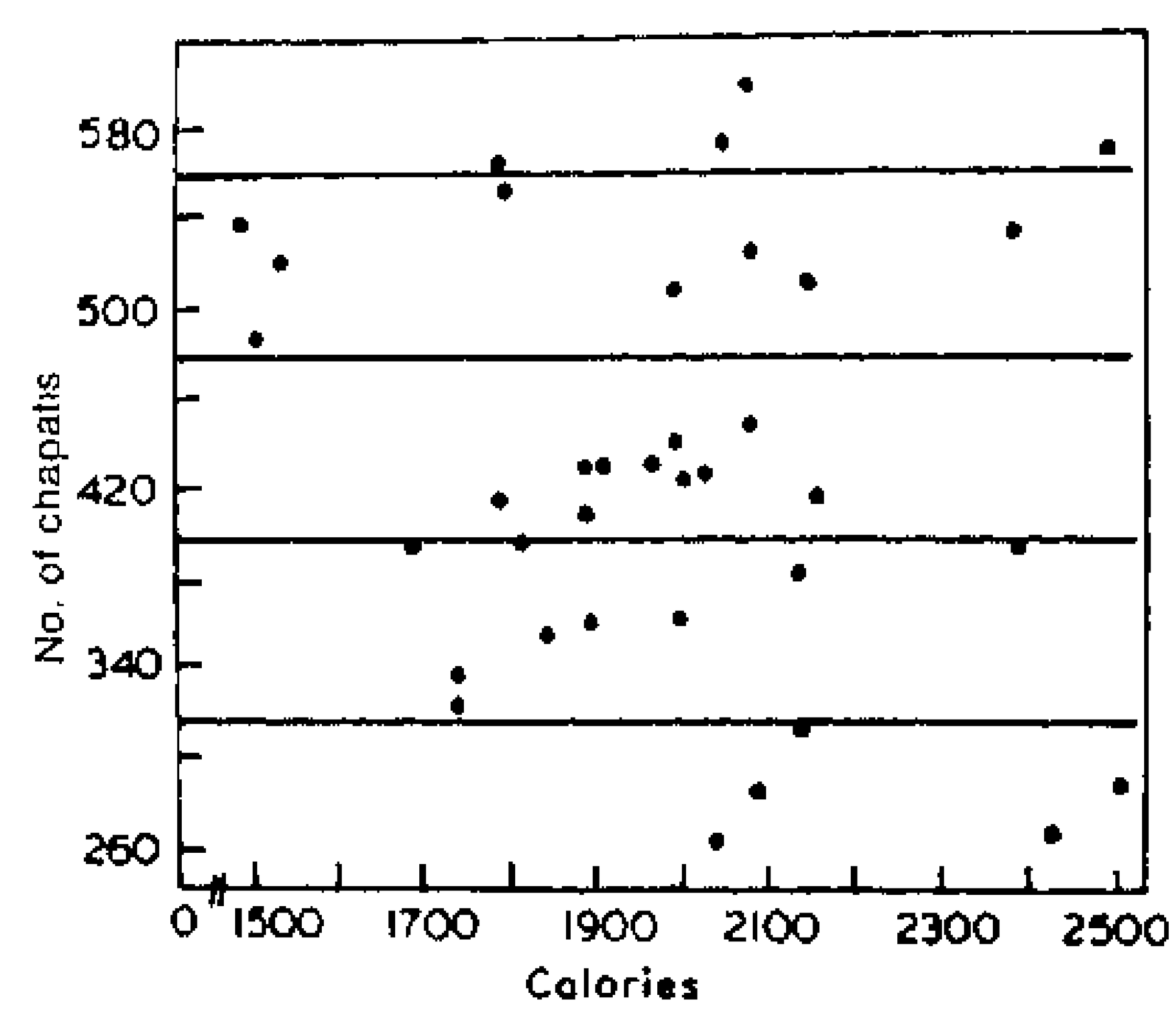
The Narangwal experiment was published as a great success story of ICMR. The success was ascribed to dramatic advances that were reported in the understanding of synergistic interaction between malnutrition and infection. The research was directed by Prof. C. E. Taylor and other renowned experts from India and the US. This naturally lent weight to their findings and in fact led the Government of India to establish ICDS all over the country. In actual fact, as already stated, the expectation about increase in weight and height was not realized. While diet and disease are both important components of health, diet apparently is not fully effective in improving stature unless disease is under control. The warning, by Gopalan[2], that unless feeding programmes are organized to bring our intake in line with that in the US, our children will develop into a population of sub-standard quality and our economic and social development will be completely arrested has thus very little support in the available evidence. Our experience in villages tells us that what is needed is education around appropriate social action to bring about a lasting change in life-style to improve personal hygiene and cleanliness in and around households to reduce morbidity. Our evaluation of these data suggests a distinct improvement in the rate of physical growth of children compared to that of children in villages without facilities for potable water and latrines and sanitation.

Energy intake and work output

Conventional wisdom asserts that chronic undernutrition, thought to be widespread in low-income countries, must result in low levels of human performance. The hypothesis is especially expounded by international agencies. Statements such as 'an undernourished man avoids physical effort, takes excessive rest, works less and eats less, and is therefore caught in a vicious cycle or poverty, malnutrition and impaired labour power' are common in their writings. However, as Myrdal[3] has pointed out, most of these statements are based on superficial observations of work in the field. They hardly pay any attention to economic activities other than cultivation. It is assumed by default that much of the potential working time is dissipated in enforced idleness. But considering other activities, people in low-income countries work longer hours. Their work cannot be described as technologically efficient but it is surely time-consuming and vigorous. The plain fact is that the poor would not survive if they did not put in long hours of work.

The Indira community kitchen study

Perhaps the best way of describing the relationship between intake and work output is to illustrate it with data such as that on the Indira community kitchen. There is hardly any relation (see figure) between the number of *chapatis* per unit of time and the energy intake of women working in the kitchen. Such a phenomenon is impossible to explain unless individuals differ in their metabolic effiency of converting intake into work output and/or put in extra hours of work. The relative efficiency of work output is seen to increase as the intake decreases.



Correlation between intake and work output.

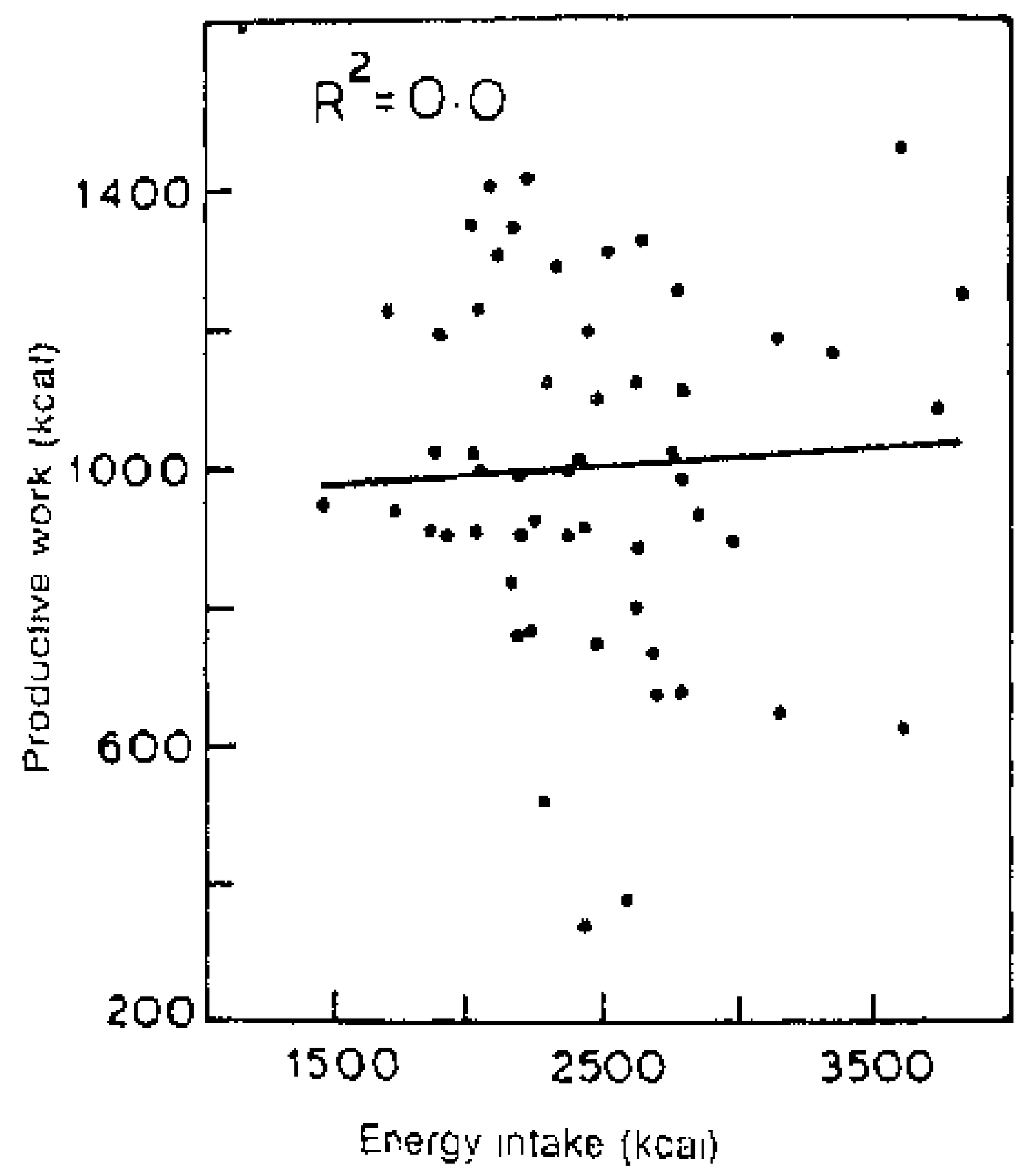
It had been taken for granted that since the women (in the study) were drawn from the poorest of the poor and were assured of getting enough food for themselves and for their family, they would first improve their intake and body weight and make themselves employable as it were before doing the heavy manual work that is reflected in the levels of productivity shown in the figure. Rolling *chapatis* at the rate of one a minute in two shifts of four hours each calls for hard muscular work and high concentration to ensure that *chapatis* are rolled to size and weight uniformly and baked properly. It was expected that the women would gain in body weight to develop the strength needed for such muscular work. But there was no evidence of this (see table). The distribution of weights remained about the same all through the year from April 1981 to March 1982. Of the 30 women, 14 gained in weight, 7 remained at the same level when they joined and 9 in fact lost weight. Clearly the women maintained high work output on a range of body weights, which ranged from 36 to 52 kg as before. Even in the case of women who gained or lost weight, the difference is not more than 1 kg over a period of a year. It is therefore not undernutrition as judged by body weight relative to the Harvard standard that leads to low level of activity. Before joining the kitchen the women were poor, in that they had hardly any home or shelter worth the description, little clothing, no hygiene and sanitation worth the name, and no education. Indeed many of these women had been behind bars for petty thefts when they were recruited for the kitchen. Their poverty really arose from the fact that they hardly lived as human beings, nor were treated as such. They did not lack food, which they managed somehow by begging, borrowing or stealing. Like the range in intake, the range in body weight was also wide, suggesting that, for any given level of activity, work output per unit of calorie intake is the highest for the lower range of body weight, as low as 35 kg, and decreases as weight increases to 55 kg.

Distribution of body weights of 30 adult women in the Indira Community Kitchen study

	Number of women	
Body weight in kg	April 1981	March 1982
34–36	03	03
37–39	04	04
40–42	10	06
43–45	03	09
46–48	05	05
49–51	05	02
52–54	00	01
Mean body weight	42.06	42.09
Std deviation	4.07	4.04

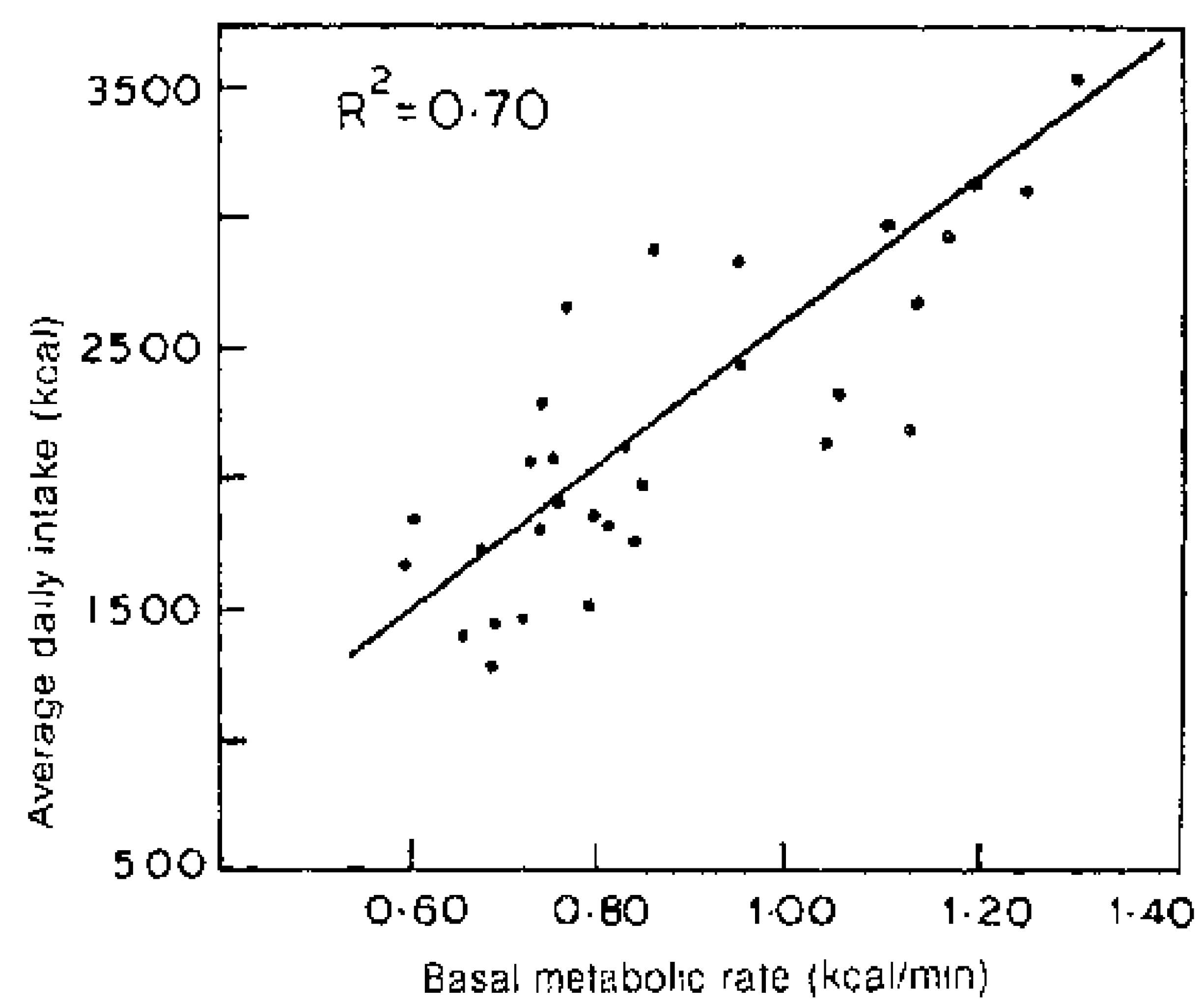
The Javanese evidence

Even before we carried out our experiment in the Indira community kitchen. Edmundson[4] had collected evidence in Java to reach a similar conclusion. In his study he recorded energy intake and minute-to-minute activity of 54 adult male farmers for a period of one year and a total of 324 man-days—six days of observation every two months on each subject. The subjects were monitored from the time they woke up in the morning until they retired at night. The mean energy outputs for ten basic activities were determined by measuring the subjects' gaseous exchange with a calorimeter and analysing respiratory gases with a microscholander gas analyser. Edmundson reported that average work output per unit of energy intake was 80% higher in the lower range of intake than in the higher. Clearly, as in our experiment, these differences could only be explained on the basis of the hypothesis of increase in metabolic efficiency in the lower range of intake.



Comparison of food/energy intake and productive economic work output.

Edmundson tested this hypothesis by carrying out a small pilot study on 10 individuals included in the previous study, five of whom belonged to the high-intake group and five to the low-intake group. All the 10 individuals were of about the same build in height and weight. Energy intake was obtained in a manner similar to that in the experiment reported in 1979 except that all food was weighed for six consecutive days. Basal metabolic rates (BMR) were measured and data were collected under controlled laboratory conditions. The results (see table) showed that the mean difference in the basal energy needs of the high- and low-intake groups is very large: whereas the basal energy need of the high-intake group was 1900 calories on average, that of the low-intake group was only 980 calories. Subtracting the basal need from the mean energy intake, we find that the calorie cost of the work output for the high-intake group comes to 854 calories and that for the low-intake group is 793 calories. In other words, work output remains about the same even



Comparison of energy intake and basal metabolic rate.

Results of the pilot study by Edmundson in Java

	Mean energy intake in cal	BMR/ minute	Height in cm	Weight in kg	Basal need for 24 hours in kcal
High-intake group	2754	1.32	162.0	52.1	1900
Low-intake group	1773	0.68	161.6	52.8	980

Analysis of variance for energy intake (kcal × 10^{-2})

Source	d.f.	M.S.S.	F	True estimates
Between subjects	53	145.9	3.12	16.5
Within subjects	270	46.6		46.6

though the high-intake group has consumed twice as many calories as the low-intake group. These results confirm a higher metabolic efficiency of the low-intake group.

Analysis of variance shows that the mean square between individuals is significantly larger than the mean square within individuals. There is thus clear evidence here of the non-independent hierarchical structure of variation. This means that the differences between individuals cannot be attributed to chance only. Part of these differences is real difference, representing genetic potential for coping with variation in energy intake, and the remainder has its origin in environmental effects permanently associated with the individual's development within the intra-uterine and external environments experienced by him. In technical jargon, if we use E for the expected value, we write

$$E(145.9) = 6\sigma_b^2 + \sigma_w^2$$

and

$$E(46.6) = \sigma_w^2.$$

On solving these we get for σ_b^2 and σ_w^2 the values shown in the last column of the table, and for intraclass correlation r $(=\sigma_b^2/(\sigma_b^2+\sigma_w^2))$ a value of 0.26, which is statistically significant.

Within-individual variance

When the common external environment is held constant and the individual is followed over time we find that the within-individual variance component does not remain purely environmental. Instead we find that the week-to-week variation is significantly larger than the within-week variance component in the same individual, indicating that the day-to-day observations are serially correlated. This is the reason why intra-individual variation remains wide and cannot be reduced by averaging to the extent it would be if the genetic physiological process of energy metabolism had remained the same each day. We may consider this additional component of variance as arising from the interaction (covariance) between the genetic entities possessed by the individual and the micro-environment provided by the food intake on different days. This is to say, if σ_p^2 stands for the true variance between weeks and σ_d^2 for the within-week variance as the individual moves in time, and

$$\bar{r} = \frac{\sigma_p^2}{\sigma_p^2 + \sigma_d^2},$$

we may express the variance of the mean of n observations in repeated sampling of the same individual as

$$\sigma_w^{2*}\left[\bar{r} + \frac{1-r}{n}\right]$$

or

$$\simeq \frac{\sigma_w^{2*}}{n}\left[\frac{1+\rho}{1-\rho}\right],$$

where ρ is the serial correlation and σ_w^{2*} refers to correlated case arising from intra-individual differences as distinct from σ_w^2 in the uncorrelated case. If we now find that the coefficient of correlation r so calculated is statistically significant, it means that we not only have a case of stochastic variance but a stochastic stationary stable value for variance, given by $\bar{r}\ \sigma_w^2$. Results of experiments carried out in our metabolic unit confirm this[5].

This hypothesis concerning the non-independent nature of the intra-individual variance component is of fundamental importance in understanding recent developments in biology. The hierarchic nature of the non-independent sources of variance indicates that the process of mental information processing is analogous to the way computer programmers write their programs by putting instructions together into subroutines rather than rewriting a complete detailed instruction on every occasion that it is needed. It is this which makes it possible for mind to interact with environment as perceived through the senses. The interaction is spontaneous, arising as flow of information or as attribute of information theory. There is no energy exchange in the transaction, though once the mind reacts it will change the pattern of energy operation in the modules of the brain[6].

It needs to be emphasized here that a stable value for the variance component $\bar{r}\sigma_w^{2*}$ means that the individual has a capacity to generate negative feedback and create order whenever there is disruption. Such a process of generating negative feedback and creating order not only affirms that intake will equal expenditure on average but also affirms that it represents a process to regulate variance. In particular, it tells us whether the process of regulating variance is stable and adequate to maintain the body's system in a state satisfactory for carrying out day-to-day activity without stress. Garby *et al.*[7], on the other hand, hold that the variation is random, arising principally from measurement errors. The third feature of these results is that it brings out the feasibility of shifting intake under sustained perturbation of the individual's macro-environment within the limits of the homoeostatic range of the individual.

Even in long-term genetic adaptation, which is what most workers refer to in current nutrition literature, small body size does not necessarily interfere with economic work output, given appropriate macro-environment or the daily habit of the villagers to put in extra hours, while always ensuring that the intake per kg is kept at the level enjoyed by healthy, active reference individuals.

Implications for nutrition policy

The implications of these data are that, on a given food/energy intake, a small individual has more muscular energy left over for both social and free-time activity as well as economic work activity above the basal state than a large individual. There is therefore no reason to assume that absolute energy intake is a determinant of work output. It is true that intake of energy will equal output of energy, but a small person will use less energy for maintenance and produce more work per unit of intake. It means that when the intake is small, as in the lower part of the homoeostatic range, or the individual is of small size, there are compensatory mechanisms, controlled by the endocrine system, such as a higher level of metabolic efficiency and greater physical fitness, which allow such individuals to be economically efficient.

To summarize, there is a long and complex pathway between energy intake and work output. Low intake does dictate low output but it is also true that a small individual on low intake utilizes the intake more efficiently than a large person. Small villagers on a low plane of nutrition may likewise devote more of their time to economically productive labour. Large intake dictates higher total output but that output need not be directed towards productive work, with the result that large intake may be less efficient in changing food energy to energy for work. Thus a group of trained observers or supervisors observing villagers or women working in the kitchen could detect no discernible difference in the observed work output of individuals with low and high energy intake. These findings have been confirmed by further studies on 16 male and female farmers in India undertaken by Edmundson since 1983.

Without elaborating further, we conclude that a statement to the effect that many people in the Third World with low intake are underfed and, therefore, physically underactive has no more significance than its illogical corollary that many Westerners are overfed and therefore hyperactive. Both physical and social adaptation occur in people with low energy intake. Poorer individuals and populations with low food intakes may be small and lean, yet they work long and hard and are extremely efficient at converting food energy into physical work.

It is evident that increase in intake alone cannot improve performance or productivity of man. While this problem needs to be explored in greater detail, it seems futile to continue with nutritional intervention in the hope that economic, physical and social development will gather momentum with more and better food. A more practical approach is to prevent malnutrition by creating conditions that make villages more liveable.

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