Dr. Rajendra Prasad Memorial Lecture*

DIET AND DISEASE

P.V. Sukhatme

As you all know we were expecting to have with us this morning Prof. Pranab Mukherjee, Deputy Chairman of the Planning commission to deliver Dr. Rajendra Prasad Memorial Lecture. Much as he wanted to come, he is unable to be present because the parliament is in session. I had, therefore, no option but to abide by the wishes of the Executive Council, which has asked me to deliver this lecture. I do so with great pleasure. I hope however that you realise that I do not have any written text and have necessarily to use transparencies to convey my thoughts on the topic I have chosen for the lecture viz. Diet & Disease.

2. I shall open my lecture with Figure 1 showing Japan's experience of change in life expectancy during the period 1949-63. Japan at the end of the World War II was much in the same position that India is during the nineties. In many ways the situation in Japan was worse. There was almost total lack of personal and communal sanitation all over rural area. In urban society the majority of the population were living in hutments. Industry was almost non-existent and agriculture was devastated not only by internal disruption but also by withdrawal of food imports. Morbidity was high; especially among children and yet within about 10 years from 1950 Japan was able to reduce it by over 60 per cent. Simultaneously Japan was able to increase the food intake per household. A sample of 10,000 households was canvassed to obtain this data. Japan is known for the cooperation their people offer to surveys initiated by the Government. This is perhaps the largest household survey I have seen operating any where in the world-the objective methods of measurement ensured reliability of data but even more important was the trust they placed in the synergism between morbidity and intake to provide the basis for policy decisions.

3. Reduction in morbidity means reduction of the number of days lost in illness. This had a great effect in creating awareness of the need for limiting

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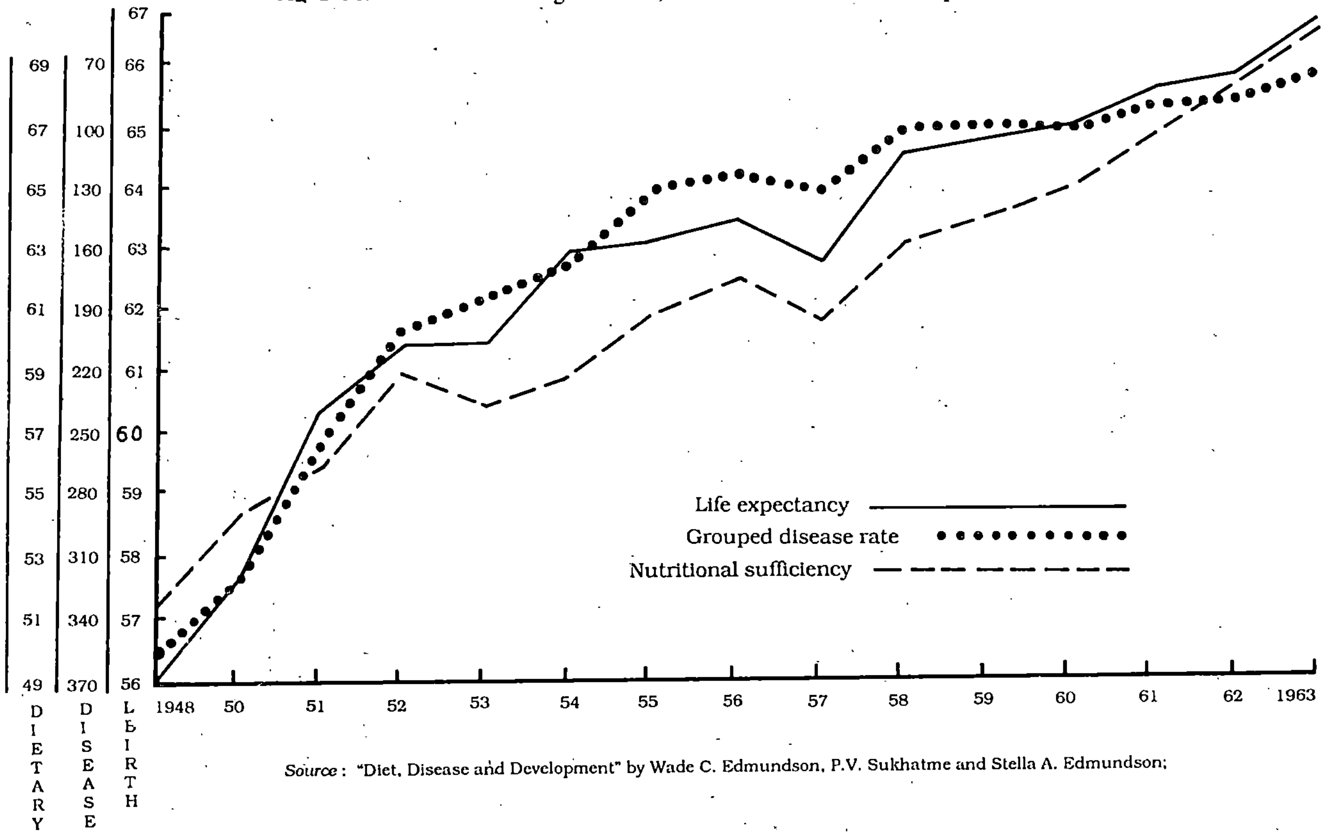
Fig. 1. Fitted Curves for Length of Life, Versus Diet & Disease in Japan, 1949 to 1963.



Source: "Diet, Disease and Development" by Wade C. Edmundson, P.V. Sukhatme and Stella A. Edmundson;

family size. Parents began to see in it greater and greater chances of survival of their children.

4. This has a special lesson for India where too much emphasis is given to external inducements and incentives and too little is done to create internal awakening on the need to reduce family size. The urge must come from within not from without. The lesson then is that in India we must not confine our role only to improvement of total food production and calculation of per capita availability from year to year. What we need is to work out a trend of actual nutrition intake by assessing intake of household from day to day and week to week and simultaneously following up trend in morbidity from day to day and week to week. Only then we can ensure that the trend will provide reliable indices of improved trend of health and quality of life. As Figure 1 shows Japan was able to improve nutrition availability of food from year to year and side by side decreasing trend in morbidity in the same households. The two trends of diet and disease are synergistic in the sense that one stimulates the other and vice-versa; together they account for 99 per cent of the total variation in the expectation of life.

5. We have undoubtedly made considerable progress in improving the total availability of food, but we have not taken adequate care to improve self-help and make villages livable for man to live as humans should. Morbidity in our villages continues to be high. The number of days lost in illness such as diarrhoea, dysentery and upper respiratory diseases also continues to be high with the result that the work productivity is low. However, once we get convinced that diet and disease are both important components of health and that a child with infection and/or inadequate personal hygiene is unlikely to grow satisfactorily irrespective of what food we give him, we can achieve what Japan did by awakening the village children and their parents to the need for improving primary necessities of life. It is unfortunate but true that while we have money for urban planning, we have no allocation for rural development. Public health in rural area under our constitution is a Government responsibility and this has been ignored unwittingly all along, in our emphasis on urban planning. Fortunately there is now realisation that we must set apart funds for rural development to ensure that villages are made livable and that we must reduce morbidity rapidly, lest much of all the funds that we are spending today in the name of nutrition intervention to improve the health of children will continue to be wasted.

6. We could have predicted long ago using the Narangwal experience that unless personal and communal hygiene is improved, protected supply of drinking water is made available and waste water is not allowed to stagnate, we would have little hope of improving the health and nutrition status of our

children through nutrition intervention. Figures 2 and 3 reproduce the experience of Narangwal. This was a project executed by ICMR under direction of U.S. experts. These results have been published in I.C.M.R. journal some 20 years back. It was the expectation of our nutrition experts that intervention age for age providing food equal in quality and quantity to that consumed by U.S.

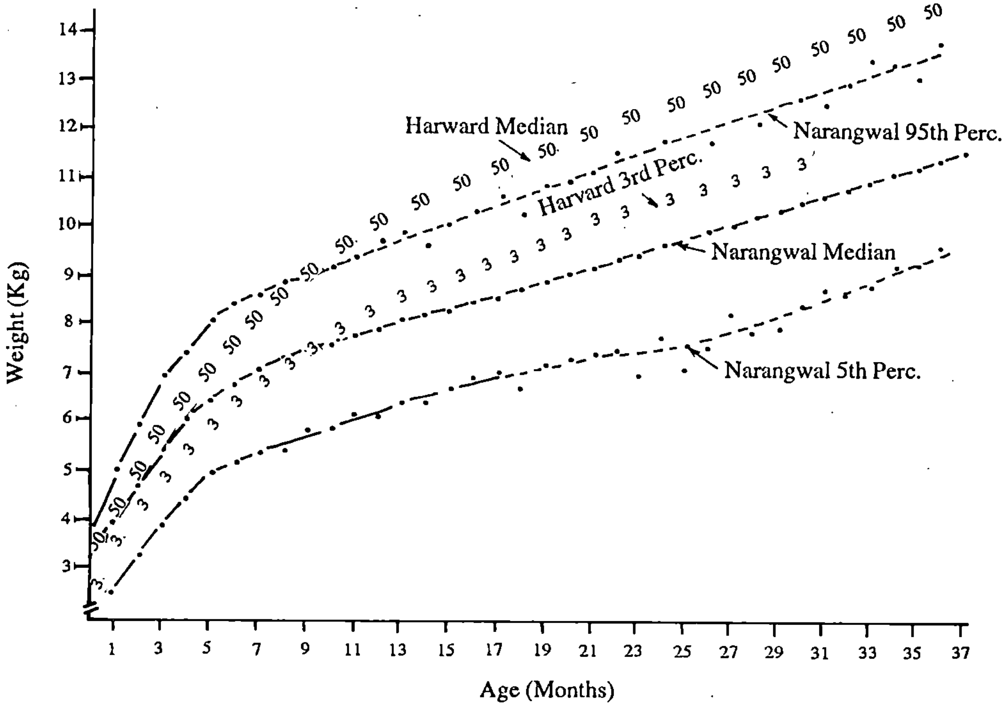


Fig. 2. Weight for age standard curves (median, fifth and ninty-fifth percentiles) for male Narangwal Nutrition Project Children below 3 years of age.

children would achieve improvement in nutrition status and health in children comparable to that of Harward children. In actual practice as Figures 2 & 3 show the increase in body weight recorded by our children over a period of three years is considerably smaller than what was expected on the Harward standard. Some children recorded a gain of only 1 kg. on average. Others recorded a gain of 3 kg. as against the Harward standard of 6 to 7 kg. with the same amount of food. It was found that those who recorded lowest gain mostly came from low caste; those who recorded a gain of about 3 kg. came from economically better placed households. But there was hardly any family recording a gain comparable to the Harward medium. The obvious inference is that morbidity was much higher in Narangwal than in U.S.A.

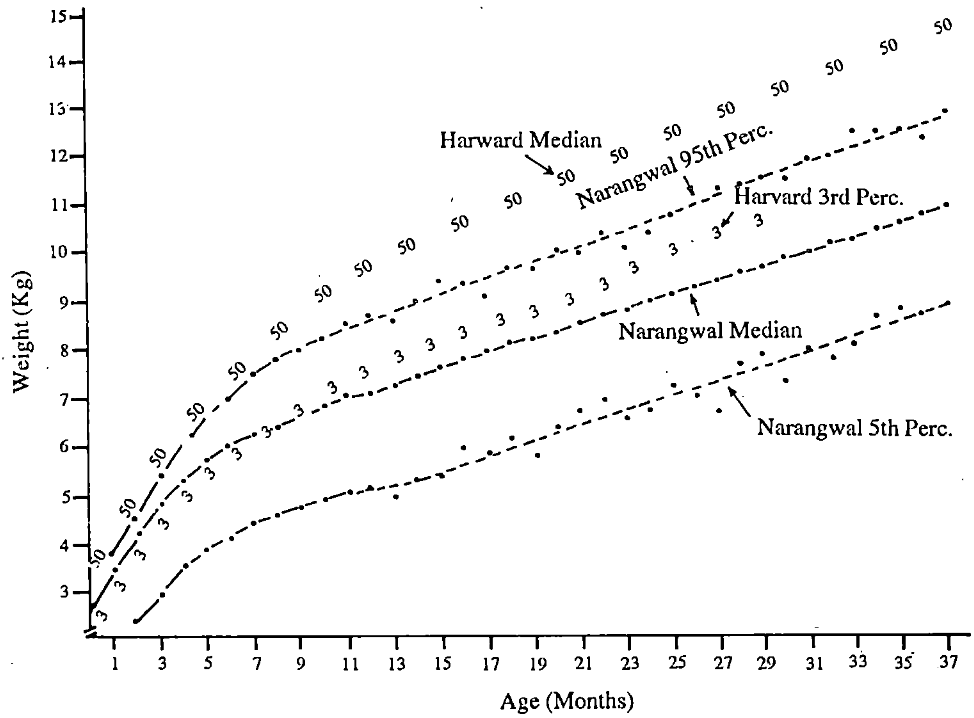


Fig. 3. Weight for age standard curves (median, fifth & ninty-fifth percentiles) for female Narangwal Nutrition Project Children below 3 years of age.

7. The extent to which low caste children predominated among the Narangwal households can be seen from Figure 4. Most of these families were poor with little or no protected supply of water to drink, no toilets for defaecation, little personal or household hygiene and no sanitation. The lesson is obvious we should have insisted on programmes to provide potable water and improved sanitation to bring down morbidity. Instead we accepted the advice of world experts associated with the project to provide food intervention on the ground that it would take long time to educate people in hygiene and sanitation. This was done on the ground that we do not have much time to wait. Already physical, economic and social development has been seriously arrested and to wait further will be to invite disaster.

8. Instead, we now find ourselves in a worse situation. We are spending huge funds on nutrition only to find that this intervention has failed and villages have remained much as before without basic amenities of water, toilets and sanitation. The heart of the problem lies in education and community kitchens such as Indira Community Kitchen Projects, where the poor help the poor on

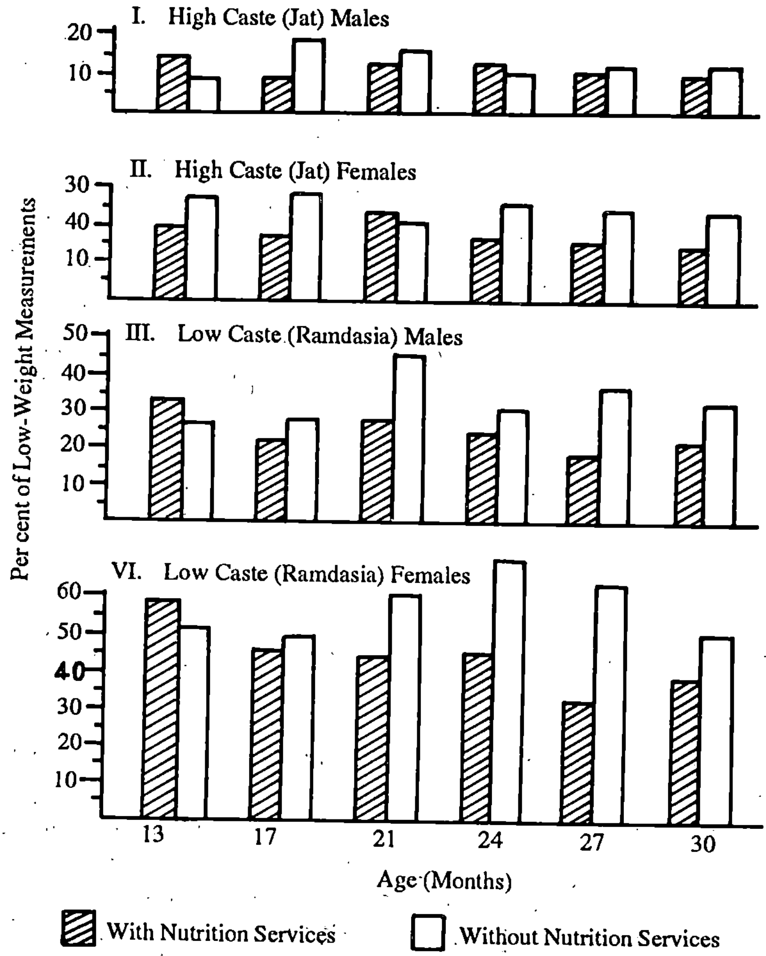


Fig. 4. Percent of low weight measurements (weight below 70 per cent of Harvard median) according to sex, caste, age and service programs.

no profit no loss basis and create awakening among the women and children to help themselves. It is common experience that if a child is taught to wash his hands before eating, others follow him. If one uses pit latrine, others use it. It is also our experience that if children are entrusted with group responsibility of supervision that no one goes near the well to draw water by bucket and use it for washing clothes, utensils, bathing and washing animals, the children faithfully inform the authority to ensure quick action. Instead our rural areas find themselves in a situation, where money is spent but little return in the form of improved health and nutrition has been received. What is essential for communal co-operation is to create desire to serve the community, which has helped one to grow in life and once that desire for self help and discipline is created among the children, it is our experience that the children love to cooperate to do the job of teaching themselves.

9. I shall now turn to the relationship between energy intake and work output. The conventional wisdom asserts that the 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 of poverty, malnutrition and impaired labour power are common in their writings. However, 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 potential working time is dissipated in enforced idleness. When attention is paid to other activities, it is almost always found that the poor 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.

10. Perhaps the best way of describing the relationship between intake and work output is to illustrate it on data such as that of I.C.K. (Indira Community Kitchen) with which I am familiar. These are shown in Figure 5.

As the figure shows, there is hardly any relation between number of chapaties per unit of time and energy intake of women working in the Kitchen. Such a phenomenon is impossible to explain unless individuals differ in their metabolic efficiency 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.

11. We had taken it for granted that since the women are drawn from the poorest of the poor and are assured of getting enough food for themselves and for their family, they will first improve upon their intake and body weight and make themselves employable as it were before they do heavy manual work that is reflected in the levels of productivity shown in figure. Rolling chapaties at the rate of one a minute in two shifts of 4 hours each calls for hard muscular work and high concentration to ensure that chapaties are rolled to size and weigh uniformly and baked properly. One has to visit and see for oneself the sight to appreciate the intensity of the work involved. It was the natural expectation of all of us that women will gain in body weight to develop the

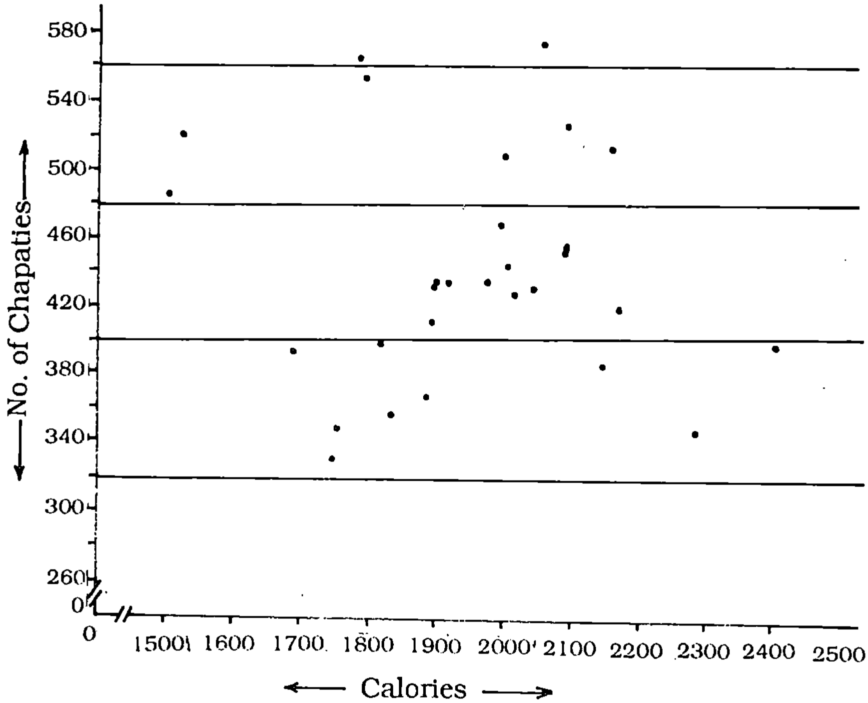


Fig. 5. Relationship between intake and work output.

strength needed for such muscular work. But there was no such evidence as can be seen from Table 1.

Table 1. Distribution of body weights of 30 adult women as on April 1981 and March 82

Body weight in kg.	April 1981	March 1982
34-36	3	3
37-39	4	4
40-42	10	6
43-45	3	9
46-48	5	5
49-51	5	2
52-54	0	1
Mean body weight	42.6	42.9
Std.Deviation	4.7	4.4

12. It will be seen that the distribution of weights remained about the same all through the year from April 81 to March 82. It was thus clear that women

are seen to maintain high work output on a range of body weights which ranged from 36 to 52 kg as before. Like the range in intake, the range in body weight was also wide, and suggested that for any given level of activity work output per unit of calorie intake is the highest for lower range of body weight, as low as 35 kg. and decreases as weight increases to 55 kg.

13. Even before we carried out our experiment in ICK, Edmundson (1979) 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 at two months interval on each subject. The subjects were monitored from the time they wake up in the morning and untill they retired at night. The mean energy output for 10 basic activities was 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 range of energy intake. Clearly as in our ICK experiment, these differences could only be explained on the hypothesis of increase in metabolic efficiency in the lower range of intake.

14. 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 higher intake group and five to the low intake group. All the 10 individuals were of about the same built 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. BMRs were measured and data were collected under controlled laboratory conditions. The results of the study are summarised below in Table 2.

Table 2 Results of the pilot study on 10 individuals

	Mean energy intake in Cal.	BMR/ minute	Ht cm	Wt kg	Basal need for 24 hours kcals
High intake group	2754	1.32	162.0	52.1	1900
Low intake group	1773	0.68	161.6	52.8	980

15. It will be seen that the mean difference in the basal energy needs of the high and low intake group is very large. Thus, whereas the basal energy

need of the high intake group is 1900 calories on average, that of the low intake group is 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 is 793 calories. In other words, work output remains about the same even though the high intake group has consumed twice as many calories as the low intake group. The study confirms a higher metabolic efficiency of the low intake group.

16. A complete picture for all the 54 subjects, each observed for 6 days in the course of the year at an interval of 2 months is given in Figure 6. It will be seen that there is hardly any association between intake and work output.

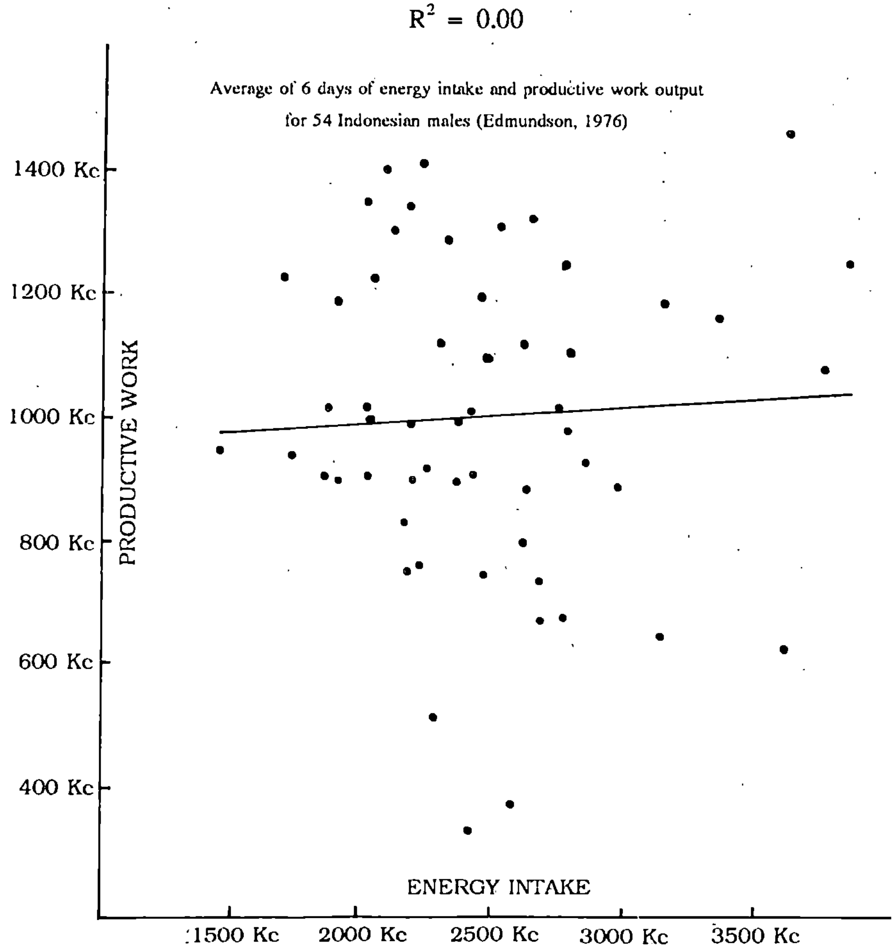


Fig. 6. Relationship between energy intake & productive work out put

17. The analysis of variance of the same data is presented in Table 3.

Table 3. Anova for energy intake (K cals × 10^{-2})

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

It will be seen that the mean square between individuals is significantly larger than the mean square within individuals. There is thus a 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 are real differences representing biochemical individuality.

18. But the study does not end here. When the common external environment is held constant and the individual is followed over time we find that the within 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 call this additional component of variance as arising from the interaction 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 week 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

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

or

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

where ρ is the serial correlation. and σ_w^{2*} is the intra-individual variance component.

19. If we now find that the coefficient of correlation $\bar{r}$ so calculated is statistically significant, it means that we not only have a case of stochastic variance but stochastic stationary stable value for the variance given by $\bar{r}\,\sigma_w^{*2}$.

20. 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 procedure of information processing is analogous to the way computer programmers write their program by putting instructions together into sub-routines 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 (J. Eccles 1976).

21. It needs to be emphasised here that a stable value for the variance component $\bar{r}\,\sigma_w^{*2}$ means that the individual has 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 man's system in a state satisfactory for carrying out his day to day activity without stress.

22. The third feature of these results is that it brings out the feasibility of shifting intake under sustained perturbation of individual's macro-environment within limits of homeostatic range of the individual.

23. Even in the long-term genetic adaptation which is what most workers refer to in current nutrition literature, small body size does not necessarily interfere with the 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.

24. The implications of these data for economic policy 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. The difference arises from the fact that a small individual with low energy intake will use a smaller part of his intake for maintenance and produce same work per unit of intake as a person with large intake. It means that when the intake is small, as in the lower part of the homeostatic range, or the individual is of small size, there are compensatory mechanisms controlled by the endocrine system in man such as a higher level of metabolic efficiency and greater physical fitness which allow such individual to be economically efficient.

25. To summarise, there is a long and complex path way between energy intake and work output. Low intake dose dictate low output but it is also true that a small individual on low intake utilises his 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.

26. In its physiological sense, total energy expenditure includes metabolic maintenance of the body, that is respiration, circulation, anabolism and metabolism of nutrients to include thermogensis as also energy required for deposition and glandular secretion. Further a highly significant energy expenditure also occurs during disease state when the immune processes are mobilised. The last component of the physiological energy is the muscular activity over and above the basal state. Only a part of this total muscular energy is applied towards economically productive work. This is the real key to understanding the slender relationship between intake and work output. If the energy used in metabolic maintenance, continuous secretion immune response processes and free time activity was equal for all and all poor people were uniform in size, then there would be a direct and deterministic link between the intake and economic productivity of man as postulated by international experts in the vicious cycle of poverty. But this is not the case. The size of humans is highly variable, the energy need for metabolic maintenance is also highly variable. The proportion of total energy used for productive work is also highly variable. Further whenever energy constraints are encountered by man, powerful mechanisms are activated by the body in an attempt to establish equilibrium between the internal and the external environment. It is these factors which enable an individual to increase metabolic efficiency and effect changes in discretionary work output.

27. Given the current belief that BMR is essentially fixed for a given body size and climatic region it is expected that work output would increase rapidly following nutrition intervention at low levels of intake. Thus if a small male with a BMR of 1400 calories per day changes his intake of 1900 to 2400 calories per day, that person would double his potential for productive work from 500 to 1000 calories. But experimental evidence does not corroborate these results because basal need is more determined by the compensatory mechanism than by man's body weight. Available data are unanimous in showing that average energy intake for a group of subjects is in consonance with the average energy output. However, there is no association between average intake and estimated work output for single subjects as shown in figures reproduced above. All this means that a group of trained observers or supervisors watching women working in the Kitchen or villagers 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. (see Fig. 7)

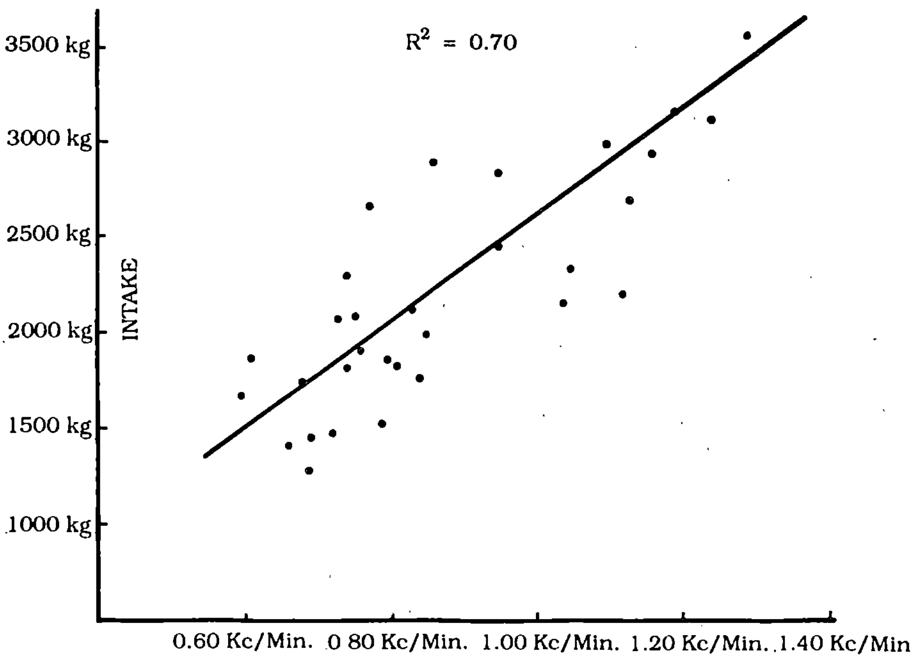


Fig. 7. Relationship between average daily energy intake and BMR.

28. In reality available experimental data tells us much more than what has been summarised above. As we saw under the impact of sustained

perturbation of common external environment, the component of error variance does not remain static from day to day in life of an individual, but is increased by an amount equal to the covariance between man's genetic entities and micro environmental effect. Clearly, not all DNA are transcribed and translated into messenger RNA genes but that man has the capacity to control transcription and translation of DNA as occasion demands. The case is analogous to that of E-coli when the organism is faced with a change of substratum in the form of galactoside and senses that it cannot grow satisfactorily unless the repressor protein is delinked from chromosomes and uses available energy to put the entire battery of genes to code for the enzymes it needs to cope with the change in the environment. A precisely similar phenomenon takes place when a micro environmental change, like food supplement, threatens to increase obesity, the organism delinks the repressor protein and develops negative feed-back to change the metabolic efficiency of its energy intake. Considered from the economic work output point of view this is an extremely important phenomenon of regulated adaptation. Available evidence amply demonstrates that an individual on low plane of nutrition can increase efficiency of energy conversion.

29. The real world difference between free time activity and economically productive work activity seems to have been totally overlooked in setting up the concept of vicious cycle of poverty. This realisation came in 1981 when Immick and Viteri reported the difference between total physiological energy expenditure and economic energy expenditure in their survey in Guatemala and found absolutely no increase in productivity for sugar workers given energy supplements. Total physiologic energy expenditure obviously increased after supplementation but the "economically productive work time did not change either in intensity or duration". Intensity of productive activity and especially the waking time spent in useful economic work are the real keys to productivity. It is the differential allocation of time which most strongly determines human productivity. Individuals vary greatly in the amount of time they devote to economically productive effort (work which involves a change in the form or place utility) and there is a correspondingly great variation in free time (resting, social and religious activity).

30. Of course time spent on working and energy expended on work are not same things. Nevertheless, there is a strong positive relationship between these two factors. Naturally, females, being smaller, expend less energy on any equivalent task than males. The larger and heavier males are stronger and thus able to perform some extremely heavy work tasks which are beyond the maximal effort of the female. However, this strength differential between large and small individuals or between males and females, has often been over emphasised in

current nutrition literature. Simply because one is capable of a higher maximal physical output does not mean one will utilise that capability. As noted already the time spent on heavy work activities requiring outputs of energy higher than 6 calories per minute is very small, less than 15 minutes for most of us. The fact is that the vast majority of the economically productive agricultural activities in India and Indonesia could be performed well by large or small, males or females.

31. Overall, if males are examined alone, there appears to be no relationship between food energy intake and productive energy expenditure. This was the result of Edmundson's studies. It was also the result of Immick and Viteri's study and in a similar fashion and at a similar level of statistical insignificance. Tandon and colleagues found almost no correlation ($r = .05$) between the food energy intake and productive work output of 198 Indian road workers.

32. When the productive energy expenditures of women alone are examined, there is also no significant relationship to input as we saw already in our study of Indira Community Kitchen. Of particular interest were the wide range of intakes (1500 to 2200 calories).

33. When the energy intakes and productive energy expenditure of village women and men are compared, women have significantly higher outputs of time and slightly higher outputs of energy in economically productive activities. However, women invariably have a lower energy intakes than men. In Katavi village in India the average energy intakes of females at 1852 calories per day were significantly lower than average daily intakes of males at 2350 calories ($p < 0.01$). In terms of useful, economically productive work, the females averaged 11 hours per day in productive labour versus the male average of only 8 hours ($p < 0.01$). Finally, even after correcting for weight differentials, the amount of energy the females expended on productive labour was slightly higher than the productive energy expenditure of males. The average female expenditure on productive labour was 1196 calories versus the male average of only 1183 calories. These data contradict the naive speculative relationship between energy intake and productivity theorised in the concept of vicious cycle of Poverty.

34. Thus, there is no reason whatsoever to link energy intake to economic productivity except at the extremes where unusually high intakes may correlate with unusually low outputs of economically productive work energy or extremely low intakes may correlate with low outputs of economically productive work energy.

35. **To conclude :**

(i) Those populations with low intakes have been labelled "undernourished" and those with high intakes have been called 'overnourished'. These broad classifications have little developmental significance. A statement to the effect that many people in the Third World are underfed and therefore physically underactive has no more significance than its illogical corollary that many westemers are overfed and therefore hyperactive. Both physical and social adaptation occurs in peoples with low energy intakes. 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.

(ii) The major problem with low energy intakes is not endemic starvation nor restricted economic productivity, it is rather that forced adaptation results in marginal reserves which may be insufficient to cope with any additional external stress. In the four main villages we studied intensively in Indonesia and India, our subjects had intakes per kilogram of body mass of 42.3, 44.5, 49.9 and 57.0 calories. Subjects with intakes of around 50 calories per kg. were active, well muscled and had adequate reserves of fat. However, we do not suggest that when subjects are on intakes of about 40 calories per kg. we can regard their low intakes as optimal. The present tendency to set single reference points for population energy needs is both biologically unsound and intellectually misleading. What is needed is a weight corrected range representing an optimum, a minimum and a maximum recommended intake. We could never feel comfortable with recommended energy requirements that are set below 50 ± 10 cal. per kg. per day for active, hard working, adult agriculturalists in developing countries. These figures would not be significantly different from the present recommendations, if these were just weight corrected and expressed as ranges of possible intakes that could and do occur without serious health consequences.

(iii) The developmental lesson apparent in the research is that many international recommendations for human energy intake have failed to consider human variation and adaptation. These recommendations have been grossly misinterpreted by some international agencies and social scientists who have viewed failure to meet these recommended levels as indications of impaired labour power, permanent states of hunger or even starvation. In years of field experience in Asia we have seen cases of specific vitamin and mineral deficiencies but rarely seen individuals who were actually starving. Undernutrition exists but its incidence and significance is much less important than malnutrition. In future more emphasis needs to be placed on the quality of the diet and less on the quantity of food intake. Furthermore, as we have pointed out, numerous times, it is unwise and perhaps even immoral to examine the complex problems of human health and nutrition only in terms of human energy needs and nutrition intervention. The key health problems in India and in developing countries are polluted water, unsanitary disposal of excreta, and high levels of pneumonia and dysentery. The real health needs of people in the developing agricultural nations absolutely demand a more holistic approach to their multiple problems.

36. It seems therefore futile to continue with nutrition intervention in the hope that the economic, physical and social development will gather momentum with more and better food. A more practical approach is to prevent malnutrition by creating conditions for making villages liveable in order that man will be able to live as humans do and in the process ensure health for all by 2000 A.D.