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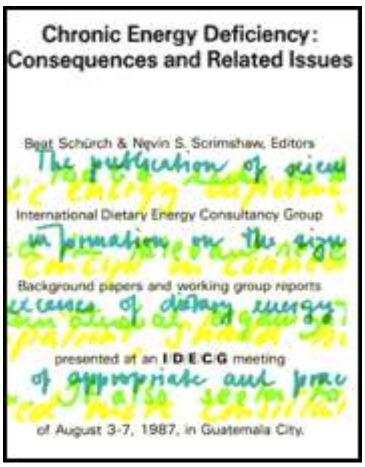

Chronic Energy Deficiency: Consequences and Related Issues

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Beat Schürch & Nevin S. Scrimshaw, Editors
International Dietary Energy Consultancy Group
Background papers and working group reports presented at an I/D/E/C/G meeting of August 3-7, 1987, in Guatemala City.

The International Dietary Energy Consultancy Group (**I/D/E/C/G**) has been established for the study of dietary energy intake in relation to the health and welfare of individuals and societies. Its specific objectives are:

1. The compilation and interpretation of research data on functional and other consequences of deficiency, change or excess of dietary energy.

2. The identification of related research needs and priorities, and the promotion of needed research.

3. The publication of scientific and policy statements and other information on the significance of chronic deficiencies and excesses of dietary energy.

4. The identification and promotion of appropriate and practical means of corrective action.

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Introduction

This book contains the background papers and working group reports presented at the first scientific meeting of the International Dietary Energy Consultancy Group (IDECG), which took place at the Instituto de Nutricion de Centro America y Panama (INCAP) in Guatemala City from August 3 to 7, 1987.

IDECG was founded in Geneva on September 3, 1986, by 15 scientists interested in human energy metabolism, on the joint initiative of the United Nations University (UNU) and the International Union of Nutritional Sciences (IUNS).

The objectives of IDECG, as defined at the Geneva meeting, are:

1. The compilation and interpretation of research data on consequences of deficiency, change, or excess of dietary energy.

2. The identification of related research needs and priorities, and the promotion of needed research.

3. The publication of policy statements and other information on the significance of chronic deficiencies and excesses of dietary energy.

4. The identification and promotion of appropriate and practical means of corrective action.

In order to meet these objectives, IDECG seeks to bring together scientists engaged in relevant research with representatives of international organizations concerned with the problem. It also seeks to involve in its work foundations and bilateral organizations, and governments interested in relevant research and policy actions. It develops summaries and policy recommendations identifies critical gaps in knowledge, promotes needed research, seeks to expand awareness of problems associated with energy deficiency, imbalance and excess, and proposes specific action programs.

The participants at the Geneva meeting decided that IDECG should, initially, focus on physiological, behavioral, social and economic consequences of chronic energy deficiency, and the significance of environmentally-induced small stature. An executive committee, consisting of N.S. Scrimshaw (UNU), J.G.A.J. Hautvast (IUNS) and B. Schürch (executive secretary of IDECG), in collaboration with other participants in the foundation meeting, planned the first scientific meeting of IDECG in Guatemala, at which these issues were dealt with.

The IDECG meeting in Guatemala had three main parts. It began with the presentation of eight commissioned background papers which are contained in this volume. This information was supplemented by reports on ongoing or recently completed studies in India (J.V.G.A. Durnin and P.S. Shetty), Benin (J.M.A. van Raaij), Ethiopia (A. Ferro-Luzzi), The Gambia (A. Prentice), Colombia (J.C. Reina), Guatemala (M. Immink and B. Torún), The Philippines (P. de Guzman and L. Adair), Indonesia (M.A. Husaini), Egypt (O. Galal), and Mexico (G. Pelto and L. Allen). On the last two days, the participants worked in three groups preparing reports on available knowledge, policy implications and needed research on how chronic energy deficiency can affect pregnancy, lactation and childhood; work capacity and work performance; and social and economic development. A fourth working group dealt with the structure, function and financing of IDECG.

A Steering Committee, consisting of a representative of UNU as chairperson, the secretary-general of IUNS, and the executive secretary of IDECG, will be responsible for IDECG's future policies. This Steering Committee will be guided by a Scientific Group, consisting of nine scientists appointed by the Rector of UNU for staggered three-year terms, a representative of FAO, WHO, UNICEF, and the World Bank.

We should like to thank Drs. Luis Octavio Angel, Maarten D.C. Immink and Benjamin Torún and their staff for making it possible to hold this first scientific IDECG meeting at INCAP, Drs. C.V.C. Barba, S. Grantham-McGregor and E. Jéquier for editorial review of this book, Mr. Giles Allen and Mrs. Ann-Marie Favre for proofreading, and Mrs. Nelleke Luong-van-My for technical assistance.

Beat Schürch
Nevin S. Scrimshaw

Research relating to energy adaptation in man

W.P.T. JAMES*

* The Rowett Research Institute, Greenburn Road, Bucksburn, Aberdeen AB2 9SB, U.K.

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1. General introduction

This paper deals specifically with the Sukhatme-Margen energy hypothesis set out in 1982. The hypothesis on the autoregulation of energy balance stems from the authors' earlier propositions in relation to protein metabolism (SUKHATME and MARGEN, 1978) and has to be taken seriously for two reasons. First, on a scientific basis we need to recognize that the regulation of energy balance in man is poorly understood and a proposition which claims to be revolutionary deserves serious consideration. The second reason is a political one, but of far greater importance than that assigned to it by many of the scientists involved in research on energy balance. Sukhatme and Margen have claimed that their hypothesis is of immense importance for food policy-makers; furthermore, the policy-makers themselves have attached great significance to it. Thus, the hypothesis formed an appreciable part of the argument in the 5th World Food Survey's assessment of malnutrition in the world (FAO, 1986). Indeed, the idea of "costless adaptations" to low energy intakes seemed so attractive that a novel way of determining a cut-off point in energy intake for categorizing "malnutrition" was devised. This led to a substantial reduction in the number of people assumed to be malnourished.

Those of us who consider that the Sukhatme-Margen hypothesis, in the light of current evidence, has some political features analogous to the proposition of an all-pervading deficiency of vitamin C in Homo sapiens promulgated by Linus Pauling are probably correct.

Linus Pauling's views are of great moment because he is a renowned scientist. Similarly, Sukhatme exerts enormous influence in the sphere of food policy because he was an internationally-renowned statistician working in FAO. His statistically-based hypothesis linked to physiological insights from Margen produces a powerful combination from prestigious authors. To dismiss simply the political consequences of the Sukhatme and Margen theory is acceptable for "ivory-tower" scientists, but I consider this approach to be somewhat irresponsible. The challenge for those of us who wish to see an appropriate application of current scientific thinking is how best to proceed.

Is the problem one of persuading planners, economists and community nutritionists that current evidence is already available to refute the hypothesis? If so, why have our arguments failed so far, or are there scientific issues which still remain unresolved? As will become apparent, Beaton and Viteri, in organizing a PAHO/WHO Workshop on the problem (PAHO/WHO/UNU, 1987), judged that the best way to cope with this major issue was to develop a set of protocols for testing the hypothesis. The expertise of international authorities in the field of energy regulation, together with the nutritional involvement of Margen, was used to set out a series of proposals. Before considering these, however, it is appropriate to examine the Sukhatme-Margen hypothesis in some detail in order to ensure that it is given appropriate emphasis. As will become apparent, the Beaton-Viteri proposals deal only with one part of the proposition. This has scientific advantages but some political drawbacks.

2. The Sukhatme-Margen hypothesis

The Sukhatme-Margen hypothesis depends substantially on statistical analyses of the apparent interindividual differences in energy requirements, the proposition being that much of these differences actually depend on the variation in requirement within individuals rather than between individuals. A careful reading of their paper shows that they simply state that WIDDOWSON'S classic data (1947) or those from the EDHOLM (1970) study can be used to suggest that "the body regulates its energy balance by adjusting either intake or expenditure or both, and that consequently the requirements cannot be considered as fixed and equal to the habitual intake". Any dispassionate reading of the literature would allow all experts to agree on the first part of this statement, and the crucial misunderstanding only develops with the final phrase "and equal to the habitual intake". In this and other statements, one finds that much of the difficulty with the Sukhatme-Margen hypothesis simply relates to terminology, and it is their emphasis, later in the paper, on the potential flexibility of energy expenditure by changes in metabolic efficiency through the changing use of different metabolic pathways which seems to present such problems.

3. Is energy balance regulated in man?

Put simply, the Sukhatme-Margen hypothesis, in my view, is not a hypothesis but a statement of fact, if it is taken to signify that body energy is regulated by alterations in intake and/or expenditure. There is now abundant evidence that food intake is regulated in both children and adults (see JAMES, 1985) and that this regulation is apparent within 2-7 days of covert changes in the energy density of the diet. It also seems fairly clear that pre-menopausal women show a cyclical change in both energy intake and expenditure through the course of a normal menstrual cycle so that in addition to "regulation" in the classic sense there is a controlled cyclicity of energy balance. This seems true at least in young women. Given this cyclicity with intakes on average 10-20% higher in the luteal than the follicular phase of the cycle, we know that measurements of weekly food intakes, measured randomly in young women, will lead to an erroneously large standard deviation of intakes, if these intakes are meant to indicate *habitual* intakes, which I will take to apply to the average of the intake over "several" months. This latter definition may therefore neglect the changes in the average intake from season to season which could reflect, for example in developing countries, the response to a change in the physical demands in the home or work.

Sukhatme and Margen did not make their hypothesis sex-specific; most of their examples relate to studies conducted by others, e.g., by Edholm and Acheson on young men. Almost all of the studies on the control of food intake have been undertaken with young male volunteers, and there is clear evidence of appetite regulation. Thus, in terms of body energy homeostasis, it would not be surprising to observe autocorrelations evolving over time. Sukhatme and Margen neatly show that in ACHESON'S Antarctic subjects (1980) the SD obtained from weekly intakes measured repeatedly are too large for those expected if energy intakes were independent from day to day. They affirm that the customary weekly intake and output have variations of about 12%. This, to me, is evidence of food intake regulation, but Sukhatme and Margen, in noting the discrepancy in Acheson's data on body weight changes and cumulative energy imbalance, simply proceed to neglect error problems cited by Acheson and claim that the variable patterns of intake and expenditure have a rhythm consistent with and indeed characteristic of autoregulation.

In *Table 1* are provided unpublished data on "large" and "small" eaters obtained recently by McNeill in Aberdeen. These two groups were selected after 36 young male volunteers had weighed their food for a week, i.e., using the same technique as that employed by WIDDOWSON (1947), EDHOLM *et al.* (1970) and ACHESON (1980). The groups were from the two extremes of intake but, when detailed studies were conducted in calorimeter chambers under conditions of controlled activity, there was little evidence of any metabolic difference between the groups. The physical activity index was calculated from activity diaries and the extensive literature, and analyses of the published cost of different activities prepared at the Rowett in Aberdeen for FAO as part of the new approach to calculating energy requirements. Only 16% of the different intake could be assigned to differences in time spent on physical activity, implying that the week's weighed food intake did not reflect the long-term energy needs of the men. Either "spontaneous" changes in food intake would lead to a regression to the mean - had intakes been measured for longer - or physiological controls were operating with temporary swings in intake to the more extreme values. Alternatively, the intakes were spuriously high or low because of a Hawthorne effect, whereby the investigation itself affected the result. What does seem apparent, if we accept the data as accurate, is that, as in Edholm's study, interindividual differences in energy expenditure are much less than anticipated. I favour the second of the three explanations for a variable intake, i.e., physiological swings in intake account for the wide range observed. If substantial *metabolic* intraindividual variation were possible, then we should have seen a greater range in energy expenditure.

Table 1. The energy turnover of young men classified as either small or large eaters

		Small eaters n=5	**Large eaters n = 5**	**Significance of Difference**
Age	yrs	21.2	22.6	ns
Weight	kg	67.9	67.7	ns
Height	m	1.75	1.81	ns

% body fat*		13.9	10.3	ns
FFM	kg	58.5	60.7	ns
Daily energy intake	MJ/d	85	15.3	<0.01
Basal Metabolic Rate	MJ/d	7.20	7.38	ns
	MJ/kg FFM/d	0.123	0.122	ns
24-h energy expenditure	MJ/d	10.59	10.71	ns
	MJ/kg FFM/d	0.181	0.176	ns
Physical Activity Index as ratio to BMR		1.38	1.53	<0.05

* Percentage body fat estimated from the regression equations of DURNIN and WOMERSLEY (1974). Fat-free mass was estimated by subtracting the estimated fat content from total body weight. The estimates of the physical activity index and the data on energy intake relate to the free-living condition whereas the 24-hour energy expenditure data and basal metabolic rate are those obtained while subjects eat a fixed diet of standardized composition in amounts related to their measured basal metabolic rate. The calorimetric data are not those reflecting the response to the purported intakes of each individual.

4. The time basis of energy regulation

At this stage it is important to assess whether Sukhatme and Margen go further. Following a mathematical analysis of their own data on successive N balance, the authors point out that "although intake may not be equal to expenditure, even when averaged over one week, humans are probably in balance every day with varying intervals between peaks and troughs and varying amplitudes in daily balance" (p. 359, column 1, paragraph 2). This sentence contains two different ideas, the first of which is straightforward. Given a cycle of daily food intake and night fasting, it is clear that there has to be a time when intake and expenditure are equivalent and the person is in energy balance. The last part of the sentence should presumably have read "... varying amplitudes in daily *im*balance" to signify the degree to which, on a daily basis, the difference between 24-hour intake and expenditure will vary.

The authors seem to conform with this reworded concept by claiming in paragraph 4 that it "follows from the evidence that humans possess a physiological regulatory mechanism for controlling *appetite and energy expenditure*". This subtle change is unwarranted, and the conclusion is in any case based simply on their interpretation of Edholm's data on recruits without regard to the wealth of other data on the regulation of energy balance. There is nothing intrinsic to the EDHOLM (1970) data, which demands that *both* intake and expenditure are regulated; so the authors begin to slide towards the proposition that energy expenditure must be regulated - a view which is the one which most observers take to be the main theme of the Sukhatme-Margen hypothesis. The authors then maintain that "regulation implies adaptation", a view disputed by many including WATERLOW (1985). The analysis in their Table 3 of the variance in mean balance, i.e., intake minus expenditure, averaged over two, three or more successive days is a new way of specifying that imbalances reduce with time, but this can not only include error measurements but would also apply if intakes, for example, were randomly variable from day to day. It does not necessarily imply that there is regulation of energy expenditure.

5. Altered metabolic rate

Sukhatme and Margen specify that there is "no absolute energy requirement for any day or period". This is self-evident if one chooses not to specify the degree of physical activity and food intake, but simply assesses free-living people undertaking a variable pattern of activity and eating. The authors' sentence seems to be more subtle, however, implying that people can change their metabolic efficiency so that, while engaging in similar activity and eating, they adjust their total energy expenditure. It is this concept which is tackled by Beaton and Viteri, because Sukhatme and Margen clearly prefer regulation of expenditure rather than intake as the mechanism for autocorrelations in energy imbalances (see p. 361, column 2): "it seems more likely that the body regulates its energy balance by varying the efficiency of energy utilization". They then proceed to propose that from their own studies on RMR and the thermic effects of meals the "cost of maintenance cannot be constant as assumed in the literature but that it is regulated".

6. Other Sukhatme analyses

SUKHATME and NARAIN (1983) have extended their analysis of the intraindividual variation in energy requirement and dealt with its implications. Again, they rely exclusively on Edholm's study and are concerned with a detailed statistical analysis, but the references cited include only the published account of this work, rather than a re-analysis of the available primary data. The emphasis in this later paper shifts to the genetic contribution to the control of physiological adaptation, but no novel analysis emerges. In another analysis by SUKHATME (1977), the emphasis is again on the Edholm study and is based on an analysis of variance of daily energy intake and expenditure over time. Unfortunately, as noted by Sukhatme, the Edholm data relate to simultaneous measurements of intake and expenditure in three nonconsecutive weeks, so it is impossible to assess the autocorrelation hypothesis directly. Again, much of the confusion may relate to the definition of a "physiological mechanism for controlling appetite and energy expenditure". The precise meaning of the hypothesis is unclear since the emphasis changes from regulation of intake to suggestions that the metabolic efficiency of the body may vary. An extensive discussion by Sukhatme about enzyme mechanisms for altering efficiency implies that he perceives changes in metabolic efficiency as a key feature.

It should be noted that the policy implications and indeed the basis for the statistical analysis of food supplies which Sukhatme has used to emphasize that households may be less malnourished than expected - these statistical analyses and policy implications have been heavily criticized by DANDEKAR (1982) on both statistical grounds and because of changes in definition and the basis for analysis.

7. Problems in testing the Sukhatme-Margen hypothesis

The principal problem in any attempt to test the Sukhatme-Margen hypothesis is to obtain an agreed specification of the hypothesis.

If the hypothesis is a general proposition about the capacity of man to change metabolic efficiency in response to a sustained change in intake, without changing body energy stores or spontaneous physical activity, then the hypothesis can only be tested with difficulty.

If the hypothesis is a general one, can it be tested simply in young men anywhere? There seems to be an emotional objection, for example, to testing this theory in North America and then applying the findings to Asia. In practice, the hypothesis is changed and the question becomes:

(a) Do women and children behave similarly?

(b) Does preceding childhood malnutrition affect the ability to alter metabolic efficiency?

(c) Do long-standing climatic and nutritional deficiencies alter the capacity or sensitivity of any adaptive mechanisms?

(d) At what point do modest changes in body energy mean that the hypothesis is rejected?

(e) Even if there are reductions in body energy stores and/or physical activity, does it matter? Are not behavioural changes, the ability to take initiatives, sense of well-being and capacity to co-operate in emergencies more important than a purist physiological approach to the sequence of events which occur when energy intakes change?

The assessment which follows considers only the general case of adaptation in normal healthy adult men.

Table 2. The reproducibility of 24-hour energy expenditure in adults studied under standardized conditions in calorimetric chambers or a suit

Subjects	**Number**	**Calorimetric technique**	**Number of measurements**	**Time interval Days**	**Reproducibility**			**Reference**
					Difference	**%**	**CV %**	
		Direct	2			2.0		BLAZA (1980)
Male	8	Indirect	2	4-5			1.5	DALLOSSO *et al.* (1982)
		Suit: direct	2	»14			3.3	WEBB & ABRAMS (1983)
Male/Female	9	Suit: direct	2	<30			6.0	WEBB & ANNIS (1983)
Male	8	Direct	2	7			2.2	GARBY *et al.* (1984)
Female	10		3-6*				1.9	DE BOER *et al.* (1987)

Female	5	Indirect	2	5-7			1.3	MCNEILL *et al.* (in press)

* Three consecutive 24-hour measurements were repeated 2-24 months later.

8. The reproducibility of metabolic rates in man

Table 2 summarizes a series of studies, mostly conducted on young men, showing that, on a constant diet and with a regulated pattern of physical activity, there is an astonishing reproducibility in 24-hour energy expenditure. This does not, of course, disprove adaptive thermogenesis, but it does suggest that there is little evidence of cyclicity of energy expenditure in men. Furthermore, for "adaptive" changes to occur in energy output in response to the usual fluctuating daily energy intakes prior to the subjects being placed on a standardized diet, these changes must occur very rapidly within a day or two so that further changes were not discriminated on repeated calorimetry. Alternatively, the changes must occur over periods in excess of 2-4 weeks, the periods over which repeated observations have been made.

A recent study by DE BOER *et al.* (1987) refutes the concept of sudden rapid swings in energy expenditure in response to changes in intake. De Boer had people living in a whole-body calorimeter with intakes altering every day from 50 to 150% of their habitual intakes. Under these circumstances, the 24-hour energy expenditure decreased and increased by about 5% in response to a change in intake ten times larger. The effect was consistent only with the cost of digesting, absorbing and processing the food ingested on each day.

A further manifestation of the limited magnitude of spontaneous changes in thermogenesis comes from observations on men and women studied over 24-hour periods under temporarily standardized conditions of energy balance. *Figure 1* shows that, providing account is taken of physical activity and the fat-free mass of the subject, the interindividual variability of 24-hour energy expenditure amounts to only 6-8%. Thus spontaneous interindividual variability in energy metabolism is surprisingly small. These published data accord with McNeill's further observations on "small and large eaters".

None of these sets of observations allows one to conclude that adaptive changes in energy metabolism do not occur in response to sustained changes in energy intake.