

PROCEEDINGS OF THE NUTRITION SOCIETY

The Two Hundred and Eighty-eighth Scientific Meeting was held in the Atkins Building, Queen Elizabeth College, Campden Hill, London W8 7AH, on 5 December 1975

SYMPOSIUM ON 'SEX DIFFERENCES IN RESPONSE TO NUTRITIONAL VARIABLES'

Sex differences in energy intake and expenditure

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Men are different from women. We might even say 'males are different from females', which is not such an obviously basic statement, since a male child of only 3 months, might, apart from some superficial and relatively unimportant areas of distinction, appear to have few real differences from a 3-month-old female. However, it is an opinion which I shall attempt to argue, in relation to energy, that males are indeed basically different from females.

An interesting subject for conjecture is whether, energetically speaking, there are sexual differences between the sexes. I suppose there is a large cultural factor here, confused by social, psychological and individual variability. I have frequently thought what a great pity it is that, even in this pseudo-liberal, quasi-enlightened era, where the emphasis on sex is so exaggerated, the subject of sex receives so little scientific attention. I wish I knew—I was going to say 'more' but I really mean 'something'—about the effect of sexual activity on energy balance and whether this differs between the sexes. Apart from mildly Rabelaisian comments made in a non-scientific atmosphere, one rarely discusses the possible significance of the variation in energy expenditure related to sexual activity. It must be the only common and frequent source of physical activity which has received virtually no attention from nutritionists. I don't recall that it even appears in any of the tables in the comprehensive review of energy expenditure by Durnin & Passmore (1967). I don't think Garrow (1974) mentions it in his excellent book on energy balance. Yet, the difference between physically inactive evenings of excessive energy intake, drinking with the boys, followed by a long night's sleep in a state of torpor, when contrasted with frenetic evenings at a disco as a preliminary to a short night's sleep preceded and perhaps interrupted by periods of strenuous muscular activity, may have some bearing on the contrasting physiques of the lean and the obese. I realize this is not being expressed in the most seriously convincing way but the problem surely is of scientific interest. It is regarded as of sufficient medical importance to receive at least an honourable mention in a new publication on

physical activity and health, written under the auspices of the World Health Organization (Denolin, 1976).

Sex differences in energy requirements

The apparent importance of differences in energy intake and expenditure between males and females is seen in the tables of energy requirements in use at international and national level.

Table 1. *Recommended values for energy requirements of adult men and women (MJ(kcal)/d)*

		Level of activity							
		Light		Moderate		Heavy		Very heavy	
	Authority	MJ/d	(kcal/d)	MJ/d	(kcal/d)	MJ/d	(kcal/d)	MJ/d	(kcal/d)
Adult men	FAO/WHO*	11.30	(2700)	12.55	(3000)	14.64	(3500)	16.74	(4000)
	UK†	11.30	(2700)	12.55	(3000)	15.06	(3600)	—	—
	USA‡	11.30	(2700)	12.55	(3000)	14.23	(3400)	—	—
Adult women	FAO/WHO	8.37	(2000)	9.20	(2200)	10.88	(2600)	12.55	(3000)
	UK		9.20	(2200)		10.46	(2500)	—	—
	USA	8.37	(2000)	—	—	—	—	—	—

*FAO/WHO Expert Committee on Energy and Protein Requirements (FAO/WHO, 1973).

†UK Panel on Recommended Allowances of Nutrients (Department of Health and Social Security, 1969).

‡Food and Nutrition Board, Committee on Dietary Allowances ((US) National Research Council, 1974).

Table 1 shows the gross values for adult men and women suggested by FAO/WHO Expert Committee on Energy and Protein Requirements (FAO/WHO, 1973), the UK Panel on Recommended Allowances of Nutrients (Department of Health and Social Security, 1969), and the (US) National Research Council (1974). There are very large differences between males and females for all the occupational groups: sedentary women need 8.37 MJ (2000 kcal)/d, sedentary men 11.30 MJ (2700 kcal)/d, moderately active women 9.20 MJ (2200 kcal)/d, and moderately active men 12.55 MJ (3000 kcal)/d.

We are not dealing here with a theoretical situation; these are not just sets of desirable energy requirements, but are based on measurements of actual intakes and expenditures on several hundred men and women: they pertain to real situations and the simple table could easily be replaced by a more complex one, quoting published findings, showing the same differences.

The descriptive terms 'light activity', 'moderate activity', etc., are meant to imply some reasonably uniform set of circumstances: indeed these circumstances are described in some detail in the FAO/WHO (1973) publication. Both men and women spend (/d) 8 h at work, 8 h in bed, 4–6 h sitting, and the remainder in walking, active recreation or in household duties. Since these were derived from

earlier descriptions formulated in the UK, not surprisingly the UK categories of classification are also similar for men and women. Clearly, similar conditions are meant to apply to both sexes.

A specific illustration might make the comparison between men and women easier. A typically sedentary occupation for very large numbers of adult men and women is office work of one kind or another. Obviously, the working conditions, the work done and the physical movement required are uniform irrespective of the sex of the group.

What then are the reasons for the large differences between males and females in energy requirements? Is it simply difference in body size?

Table 2. *Recommended values for energy requirements of adult men and women (kJ(kcal)/kg body-weight per d)*

		Body-wt (kg)	Level of activity							
			Light		Moderate		Heavy		Very Heavy	
			kJ	(kcal)	kJ	(kcal)	kJ	(kcal)	kJ	(kcal)
Adult men	FAO/WHO*	65	176	(42)	192	(46)	226	(54)	269	(62)
	UK†	65	176	(42)	192	(46)	230	(55)	—	—
	USA‡	70	163	(39)	180	(43)	205	(49)	—	—
Adult women	FAO/WHO	55	151	(36)	167	(40)	197	(47)	230	(55)
	UK	55	—	—	167	(40)	—	—	188	(45)
	USA	58	142	(34)	—	—	—	—	—	—

*FAO/WHO Expert Committee on Energy and Protein Requirements (FAO/WHO, 1973).

†UK Panel on Recommended Allowances of Nutrients (Department of Health and Social Security, 1969).

‡Food and Nutrition Board, Committee on Dietary Allowances ((US) National Research Council, 1974).

Energy per unit body-weight. Table 2 shows the same information as Table 1 but as kJ (kcal)/kg gross body-weight. Again there are quite large sex differences. Also, the appearance of near uniformity in the standards for adult males is slightly distorted by the reduced USA values resulting from the heavier body-weight of the 'average' American male, although the difference between the USA male and female is similar to the others.

If the differences are not due to the way of life of the sexes (typically demonstrated in the 'light activity' category) nor to differences in body-weight, what are the reasons? An explanation which I do not find convincing, and which is not adduced in any of the above publications, is that the energy requirements are a function of the fat-free mass (FFM) of the body and not of the total body mass.

Energy per unit FFM. On this basis some simple calculations can be done. For an average man of 30 years, perhaps 20% of his body-weight of 65 kg is fat, and therefore 52 kg is FFM. The equivalent values in a 30-year-old, 55 kg woman might be 30% fat and 38.5 kg FFM (see Table 3). Energy requirements then become 218 kJ (52 kcal)/kg FFM for both sexes: there is no sex difference.

Table 3. *Energy requirements of adult men and women calculated per kg fat-free mass (FFM)*

	Total body-wt (kg)	Body fat		FFM (kg)	Energy requirement (/d)			
		% body-wt	kg		Total		/kg FFM	
					MJ	(kcal)	kJ	(kcal)
Men	65	20	13	52	11.30	(2700)	218	(52)
Women	55	30	16.5	38.5	8.37	(2000)	218	(52)

However, this result is probably spurious. FFM is not a physiologically acceptable unit of reference for total daily energy expenditures. The concept is too naïve. The FFM consists of a mixture of metabolically active (e.g. liver, muscles) and inactive (e.g. skeleton) tissue, whereas adipose tissue is relatively active, and there is a good deal of experimental evidence to show that for specific 'activities' such as walking, cycling, digging, and even sitting or lying in bed, energy expenditure is closely related to gross body-weight and not necessarily to FFM.

The importance of gross body-weight, quite independent of sex, is shown in Fig. 1, where the regression lines for men and women walking while carrying various loads are practically identical.

Resting metabolic rate

To try and obtain a more convincing explanation of the sex differences in energy expenditures it is necessary to examine other aspects of the problem. First of all, what is the evidence that there are basic differences in resting metabolic rate between men and women? The literature on basal metabolic rate (BMR) is massive and by no means always in accord. The great Magnus-Levy (Magnus-Levy & Falk, 1899) did not believe that there were any differences between the BMR of adult men and women until old age was reached. DuBois (1927) and Harris & Benedict (1919) thought that the differences were of the order of a 6–7% lower BMR in women. The standards used by Fleisch (1954) show a difference of 5–7%. However, these values reflect the difference between the BMR of men and women related to surface area. If body-weight is the reference, differences become reduced to only 1% at age 20, 3% at age 30 and 4% at age 40.

In infants and children, interpretation varies considerably but Fleisch (1954) shows no difference up to 4 years of age, then a gradual increase from 1% at 4, 2.5% at 6, 3% at 12, and a gap of 8–9% between the sexes at 15–16 years. Most authors seem agreed that in old age the BMR of women is still lower than that of men, by about 6–7%.

The confusing nature of the literature on BMR, and the danger of making too many fine distinctions from the data, is well brought out in the excellent review of the USA data by Sargent (1961): for example, in studies on Californian children, there were differences in BMR related to socio-economic status, boys from the poorer classes, although of the same body-weight, having a lower BMR than boys

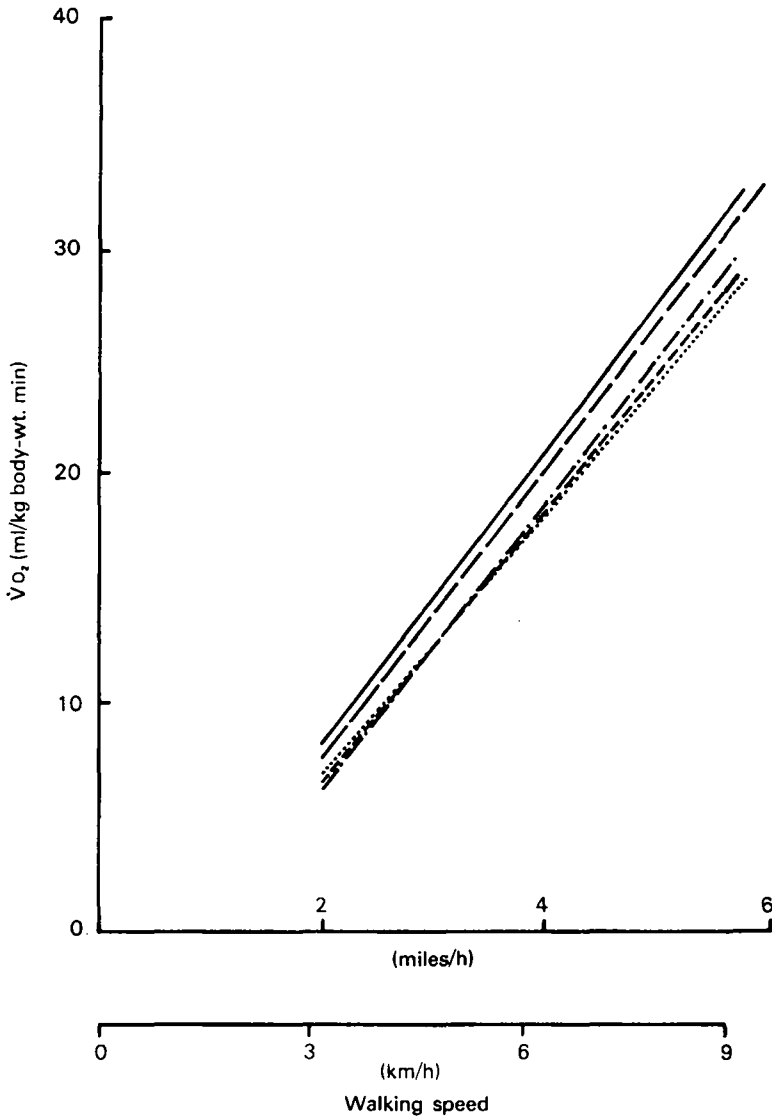


Fig. 1. Regression lines of oxygen consumption ($\dot{V}O_2$) and speed of walking while carrying various loads for ten men and ten women. —, Men, no load; - - -, women, no load; · - · - ·, both sexes, 10 kg load; · · · · ·, both sexes, 15 kg load; - · - · - ·, both sexes, 20 kg load.

from the upper socio-economic groups (Eichorn, 1955). This might be due to differences in muscle mass but, although information is not given, this seems unlikely since the body-weights were similar.

Influence of sex hormones on metabolism and behaviour

If there is an actual difference between males and females in metabolic rate, the assumption might be that this is a phenomenon related to the influence of

endocrine function on metabolic activity at a widespread tissue level. Therefore, it seems strange that these differences are still apparent in old people. In any event, the difference in BMR between adult men and women (about 7%), even if it were due to general endocrine action on tissue metabolism, is still much less than the discrepancy between total daily energy expenditures of comparable groups of men and women expressed per unit body-weight (15–17%).

Suppose the difference were due to factors other than those related to secondary sexual alterations manifesting themselves at puberty and regressing in middle and later life, and that it was even more fundamental in nature and continued throughout the whole lifespan. I am thinking of an influence developed over the long history of man's evolution, during most of which he was a hunter-gatherer, when he evolved physical characteristics and mental and psychological tendencies most advantageous for this way of life. One such tendency might be concerned with a state of anticipation for, and possibly in an increased habitual level of, physical activity in the male. It could be manifest in ways which are difficult to measure and which might have largely escaped our attention, for example in a general increase of muscle tone and even a slightly enhanced thyroid function. It is known, from the work of Harris in Oxford and from other related studies, that it is possible for certain regions in the brain (notably in the hypothalamic area) to become 'imprinted' by the action of certain sex hormones, oestrogens and probably androgens. This can occur in the earliest stages of development, possibly even in utero. Behavioural studies have demonstrated that this 'imprint' may be responsible for such typical male characteristics as aggression, and it is not improbable that muscle function, in a broad sense, and muscular movement, even the predisposition to muscular movement, may equally be affected by this process. There is a great deal of evidence in support of this thesis from research on small mammals (Richter, 1965) and on primates: Lunde & Hamburg (1972) have interestingly summarized some of this work. There is even some information on humans. For example Ehrhardt & Money (1967) have described 'tomboy' characteristics, the most striking one of which was 'preference for and active participation in outdoor, athletic activities', in nine out of ten girls whose mothers had received testosterone during pregnancy. Indeed, this is surely exactly how we think about 'tomboys', that they are physically much more active than the 'normal' female.

It is also quite possible that part of the difference in both total energy expenditures and in basal metabolic rates between males and females may be due to a slightly enhanced thyroid activity in the male. I am not aware that this has previously been suggested, but there are slight differences in response by females to thyroid-stimulating hormone which might imply a normal state of slight underactivity of the thyroid. Sex hormones might have variable binding effects on thyroid hormone in the peripheral circulation.

Here then we have a process which is acting not only on the rate of tissue metabolism (and affecting the BMR) but which also modifies behaviour and operates, in the normal individual, throughout the whole of life.

Male and female energy expenditures in children and the elderly

The data of Widdowson (1947) on energy intakes of children in the UK measured in the 1930's, recent work by Darke and her colleagues (unpublished results) on school and preschool children, and the results of Black, Billewicz & Thomson (1976) on young children, all show obvious differences in energy intakes by males and females, even at very young ages. If the explanation I have suggested is appropriate, then we would indeed expect energy requirements for young male children to be higher than those for females. At present, this is recommended only from 9 years old in the UK tables, and from 10 years old in the USA tables, although FAO/WHO begin to discriminate from 3 years onwards.

We should also anticipate that even elderly people would continue to demonstrate a sex difference in energy expenditures, and this is in conformity with the recommended energy intakes of the FAO/WHO (1973) and (US) National Research Council (1974) tables. Superficially it also appears to be the situation with the UK tables, the value for men 65–75 years old being 9.83 MJ (2350 kcal)/d whereas 55–75-year-old women apparently need 8.58 MJ (2050 kcal)/d; for 75 years and over the equivalent values are 8.79 MJ (2100 kcal)/d for men and 7.95 MJ (1900 kcal)/d for women. However, relative to body-weight, these UK recommendations are not sensible since, for the age-groups around 60–70 years old the values are 156 kJ (37.3 kcal)/kg per d for men and 162 kJ (38.7 kcal)/kg per d for women, and for the 75 years upwards groups they are 139 kJ (33.3 kcal)/kg per d for men and 150 kJ (35.8 kcal)/kg per d for women: in other words, the values for the women are higher than those for the men. Not only are these results not sensible as far as fitting in with my proposed theory, they also do not fit in with practical situations, and the energy intakes of more than 800 elderly people studied by Darke and her colleagues (Department of Health and Social Security, unpublished results) show clearly that the recommended values for the men are almost exactly equivalent to their actual intakes, whereas the mean energy intakes of the elderly women were very much lower than the recommended levels. The values of 162 kJ (38.7 kcal)/kg and 150 kJ (35.8 kcal)/kg for the women are therefore too high and should be reduced; actual values obtained by Lonergan, Milne, Maule & Williamson (1975) on 475 elderly people in Edinburgh were 154 kJ (36.8 kcal)/kg per d for men aged 62–74 years and 118 kJ (28.2 kcal)/kg for women of that age, and 131 kJ (31.4 kcal)/kg for men of 75 years and over and 120 kJ (28.6 kcal)/kg for women of that age.

Special adaptations in the female

There may, of course, be variations in the general picture I have tried to draw of the fundamental energetic differences between males and females. These variations are not necessarily in the basic biological state, but may be the consequence of particular adaptations to special environmental stresses. For example, although in two New Guinean populations (Norgan, Ferro-Luzzi & Durnin, 1974) the energy intake of the men was higher than of the women, the difference was reduced or reversed in the groups of older children (Table 4). Indeed, the intake of the coastal

girls was higher than that of the adult women. This may well represent an adaptation to a difficult environment, with the adolescent girls being allowed a relatively easy life and a favoured nutritional state in order to provide them with a satisfactory physique to withstand their arduous adult existence.

Table 4. *Energy intakes of New Guinean populations**

		Energy intake (/d)			
		/kg body-wt		Total	
		kJ	(kcal)	MJ	(kcal)
Coastal populations					
Adult	Males	146	(35)	8.12	(1940)
	Females	130	(31)	5.94	(1420)
10-14 years	Males	255	(61)	6.86	(1640)
	Females	222	(53)	6.69	(1600)
5-9 years	Males	339	(81)	6.07	(1450)
	Females	331	(79)	5.65	(1350)
Highland populations					
Adult	Males	184	(44)	10.54	(2520)
	Females	176	(42)	8.79	(2100)
10-14 years	Males	238	(57)	7.15	(1710)
	Females	283	(57)	7.91	(1890)
5-9 years	Males	351	(84)	6.69	(1600)
	Females	326	(78)	6.19	(1480)

*From Norgan, Ferro-Luzzi & Durnin (1974).

Another adaptation of energy expenditure, specific to the female, is vividly illustrated by results obtained on non-pregnant, pregnant and lactating New Guinean women. Pregnancy and lactation are considered by the FAO/WHO Expert Committee on Energy and Protein Requirements (FAO/WHO, 1973) and by all similar national committees, to be physiological states which necessitate a large increase in energy in the diet: pregnancy, as an average over the last 6 months, is supposed to need an extra 1.46 MJ (350 kcal)/d and lactation an extra 2.30 MJ (550 kcal)/d.

Table 5 gives the very surprising results that the effects of pregnancy and lactation on energy intakes are surprisingly small. What is the explanation? It could, of course, be that the New Guinean women were living on their body stores and gradually losing weight with each pregnancy. This was not so. Analysis of the anthropometric data collected in the demographic survey by Harvey (1973), and the data of Greenfield, Clark & Serjeantson (1973), show no sign of a decreasing body-weight related to parity.

How then can a pregnant or lactating woman maintain a physiological state without a large increase in her energy intake? In their recent study on highland New Guinean women Greenfield & Clark (1975) have shown that the energy expenditure is reduced in pregnancy, particularly in the last 3 months, and that physical activity is also reduced in lactation, more so in the first 6 months

Table 5. *Energy intakes of New Guinean women**

	Energy intake (/d)			
	/kg body-wt		Total	
	kJ	(kcal)	MJ	(kcal)
Coastal women				
NPNL	130	(31)	5.86	(1400)
Lactating	130	(31)	6.11	(1460)
Pregnant	117	(28)	5.90	(1410)
Highland women				
NPNL	167	(40)	8.66	(2070)
Lactating	188	(45)	9.08	(2170)
Pregnant	155	(37)	8.37	(2000)

NPNL, non-pregnant, non-lactating.

*From Norgan, Ferro-Luzzi & Durmin (1974).

(lactation often continues for 2 years or more) and more so also with the first child than with subsequent children. The women walked less, spent longer periods sitting (partly enforced because of the breast-feeding) and worked shorter periods in the garden. These findings fit well with our own data in Table 5.

It seems to me that it is at least possible that these adaptations are entirely physiological. It may even be advantageous for pregnant and lactating women to spend more time sitting and to be physically less active: their requirements for extra energy may therefore at present be considerably overestimated and may be occasionally a prescription for the development of obesity.

These physiological and cultural female adaptations, in the adolescent to increase the reserve of adipose tissue, and in the adult to conserve energy during pregnancy and lactation, are not paralleled in the male, in environments where adequate food is available, by any similar mechanism I can think of.

On the other hand, the male drive to activity may subserve a protective function in inducing levels of energy expenditure which, even in our largely sedentary mechanized way of life, may be sufficient to allow a more effective action of the appetite control centre in the hypothalamus. This may account for the lower prevalence in men of what is called obesity, if indeed there is a lower prevalence, an important statistic which is unknown at present and which nobody responsible for nutritional research seems very interested to find out.

Having said that obesity may be less prevalent in men I feel constrained to reiterate yet again that mild obesity in the healthy female may be quite normal: from the evolutionary point of view, mild obesity in women may well represent a desirable physiological state.

This is a rather sad way to end. I had thought that an implication from my presentation might be that, in some respects, the male is still the physically active, dominant sex. It seems inappropriate to finish by suggesting that, in the context of the great energetic disorder of our present-day way of life, obesity, the higher levels of energy expenditure by the male are not, for health, sufficiently protective or sensible, and the female is biologically better constructed.

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Printed in Great Britain