Maternal Diet, Breast–Feeding Capacity, and Lactational Infertility

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From the charter of the United Nations University

ARTICLE I
Purposes and structure

1. The United Nations University shall be an international community of scholars, engaged in research, postgraduate training and dissemination of knowledge in furtherance of the purposes and principles of the Charter of the United Nations. In achieving its stated objectives, it shall function under the joint sponsorship of the United Nations and the United Nations Educational, Scientific and Cultural Organization (hereinafter referred to as UNESCO), through a central programming and co–ordinating body and a network of research and post graduate training centres and programmes located in the developed and developing countries.
2. The University shall devote its work to research into the pressing global problems of human survival, development and welfare that are the concern of the United Nations and its agencies, with due attention to the social sciences and the humanities as well as natural sciences, pure and applied.
3. The research programmes of the institutions of the University shall include, among other subjects, coexistence between peoples having different cultures, languages and social systems; peaceful relations between States and the maintenance of peace and security; human rights; economic and social change and development; the environment and the proper use of resources; basic scientific research and the application of the results of science and technology in the interests of development; and universal human values related to the improvement of the quality of life.
4. The University shall disseminate the knowledge gained in its activities to the United Nations and its agencies, to scholars and to the public, in order to increase dynamic interaction in the world–wide community of learning and research.
5. The University and all those who work in it shall act in accordance with the spirit of the provisions of the Charter of the United Nations and the Constitution of UNESCO and with the fundamental principles of contemporary international law.
6. The University shall hew as a central objective of its research and training centres and programmes the continuing growth of vigorous academic and scientific communities everywhere and particularly in the developing countries, devoted to their vital needs in the fields of learning and research within the framework of the aims assigned to those centres and programmes in the present Charter. It shall endeavour to alleviate the intellectual isolation of persons in such communities in the developing countries which might otherwise become a reason for their moving to developed countries.
7. In its post–graduate training the University shall assist scholars, especially young scholars, to participate in research in order to increase their capability to contribute to the extension, application and diffusion of knowledge. The University may also undertake the training of persons who will serve in international or national technical assistance programmes, particularly in regard to an interdisciplinary approach to the problems with which they will be called upon to deal.

ARTICLE II
Academic freedom and autonomy

1. The University shall enjoy autonomy within the framework of the United Nations. It shall also enjoy the academic freedom required for the achievement of its objectives, with particular reference to the choice of subjects and methods of research and training, the selection of persons and institutions to share in its tasks, and freedom of expression. The University shall decide freely on the use of the financial resources allocated for the execution of its functions ....

Preface

This is a report prepared after a workshop sponsored jointly by the United Nations University and the World Health Organization, held at Darwin College, Cambridge, United Kingdom, 9–11 March 1981. The meeting was set up under the chairmanship of Dr. Fred Sai to review the interrelationships between maternal diet, breast–milk production, and the return of fertility during lactation: the main components are summarized in the diagram. These interrelationships are of major importance to maternal and child health, particularly in the

Third World, affecting, as they do, not only infant nutrition but also birth spacing. It was the opinion of the organizers that this subject had not received its just attention, either in research programmes or in public health planning. As well as giving an account of the present state of knowledge, this report identifies areas where there is still a crucial need for further research and investigation, at both a fundamental and an operational level. Where possible, comments have also been made on the type of action that could profitably be begun immediately (see

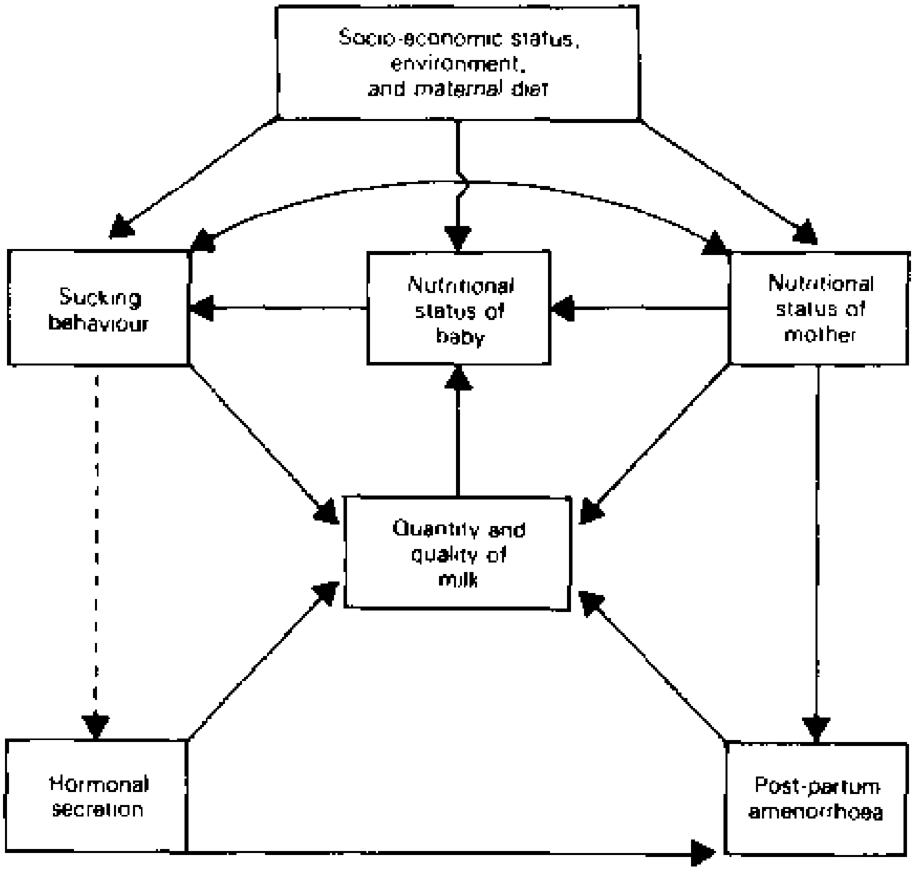

figure).

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1. Theoretical maternal dietary requirements to support lactation

1.1. All expert committees responsible for defining recommended allowances have reasoned that there should be a substantially greater dietary energy and nutrient intake during lactation (table 1). In fact, nutrient recommendations for lactating women are frequently higher than for any other person within the family group. The basis of most recommendations is that the average lactating mother produces 850 ml of milk each day and thus she needs to consume sufficient food to cover each dietary component secreted in her milk, after making due allowance for the efficiency with which the maternal diet can be utilized for milk production. While in principle this is a perfectly rational approach, there are a number of complicating factors that need to be taken into account; in particular it is becoming increasingly obvious that many of the allowances derived in this way greatly exceed the customary intake of mothers, particularly those living in the developing world, yet there may be no sign of any adverse effect. It is essential that this discrepancy is examined more closely, but it must be emphasized that current knowledge is inadequate to provide anything like a satisfactory explanation.

TABLE 1. Extra Daily Nutrient Allowances for Lactation

Nutrient	Non−pregnant non−lactating	Lactating	Increase
Energy (kcal)	2,100	2,600	500
Protein (g)	44	64	20
Retinol (µg)	800	1,200	400
Vitamin D (µg)	7.5	12.5	5
Vitamin E (mg)	8	11	3
Vitamin C (mg)	60	100	40
Riboflavin (mg)	1.3	1.8	0.5
Nicotinic acid (mg)	14	19	5
Vitamin B6 (mg)	2.0	2.5	0.5
Folate (µg)	400	500	100
Thiamin (mg)	1.1	1.6	0.5
Calcium (mg)	800	1,200	400
Iron (mg)	18	Sa	Sa
Zinc (mg)	15	25	10

a. The increased requirement cannot be obtained from the diet and thus supplemental iron is recommended. Source: ret. 1.

Energy requirements

1.2. The estimation of how much extra dietary energy must be provided during lactation is complicated by a number of physiological and social factors. The amount of work a woman does while lactating in contrast to that done during her pre−lactation state can vary considerably. In some societies breast−feeding is not allowed to make a difference, and women continue with hard manual work. In other countries or social classes, women are protected at this time and assume a more or less sedentary existence. The basis of the WHO/FAO recommendations(2) may be summarized as follows. If a mother delivers 850 ml of milk per day for six months, the total amount of energy required to make that milk be in the order of 135,000 kcal on the assumption that dietary energy is converted to milk energy with an efficiency of 90 per cent. The mother should, however, have laid down anticipatory reserves of fat during pregnancy, and if this has been of the recommended amount, 36,000 kcal, the net need for lactation will therefore be only 100,000 kcal, or around 550 kcal/d. Since the energy requirements for the average moderately active woman are 2,200 kcal/d, the total recommendation becomes 2,750 kcal/d. Clearly, however, if a woman breast−feeds beyond six months − and it must be recognized that the majority of mothers in the developing world breast−feed their children for about 18 to 24 months − the fat stores will have become used up and thus extra dietary energy after six months is theoretically necessary. Likewise, if a woman is forced to continue with heavy manual labour, the base−line value for calculating requirements is not 2,200 kcal/d but higher. Again, this consideration is not an unusual one as the majority of women engaged in subsistence farming are forced to work just as hard during lactation as at other times. Thus, in theory, lactating mothers in the developing world could need anything up to 3,300 kcal/d after the sixth month.

1.3. Recommendations developed for less arduous life−styles in the industrialized countries exhibit significant differences. In the United Kingdom, it is assumed that very few women will lactate beyond six months, and therefore no special consideration was given to "prolonged lactation." It was also assumed that mothers will be only moderately active and on average will therefore never need more than 2,700 kcal/d during lactation. In the United States the most recent NRC recommended daily dietary allowances for energy(1) recognize that there will be a range of needs and quote 2,2003,000 kcal/d for 19−22−year−old lactating women and 2,100−2,900 kcal/d for those over 23 years. Since the energy expenditure mode for the American nursing mother is likely to be lower than the midpoint of the range, it is clearly assumed that her intake can be considerably less than that of her counterpart in the developing world. It will be shown, however, that this assumption may require considerable qualification. It is becoming increasingly apparent that the efficiency with which the human body can utilize dietary energy for work and other physiological functions can vary with the level of dietary intake as well as with physiological status and environmental factors.

1.4. One further point deserves to be mentioned. In the calculation of these requirements it has been assumed that the mean energy content of breast−milk is 70 kcal/100 ml. In nearly every study on composition, milk has been obtained from the breast using a technique of manual or mechanical expression, the assumption being that expressed milk has the same composition as the milk the infant would have obtained during physiological suckling. The potential fallacy in this assumption has already been indicated by a number of investigations and, strictly speaking, we have no precise information on the energy intake of the infant and hence the true drain on the mother.

Protein

1.5. Fortunately, calculating protein allowances for lactation is not as complicated. On the basis of an 850 ml output, assuming it contains 1.2 9 of protein per 100 ml and that dietary nitrogen utilization is operating with normal efficiency, an extra 24 g/d of protein with a chemical score of 70 was recommended for lactation by FAO/WHO(2). The NRC(1) recommended an extra 20 g/d of good quality protein.

Generally speaking, the recommended lactation increment for a given nutrient is greater than for dietary energy. Thus, an examination of the protein and energy recommendations of FAO/WHO 12), for example, reveals a suggested increase of 59 per cent in the case of protein with a chemical score of 70, but only 25 per cent with energy, assuming the mother remains moderately active and is not lactating after the first six months. These recommendations would imply that, for women living on diets with a marginal protein content, the quality of food should improve during lactation. As it will be shown, however, there is little sign of this occurring in practice.

Vitamins and minerals

1.6. It is not unreasonable to claim that the most scientifically satisfactory recommendations are for energy and protein. To say this in spite of the shortcomings in our knowledge is a reflection of an even greater paucity of objective information concerning the other nutrients.

1.7. Vitamin A. Breast−milk contains about 50 µg of retinol/100 ml and, on the assumption that a mother will secrete 850 ml, an extra dietary allowance of 400 µg retinol equivalents has been made by most authorities. In the developing world much of the retinol is consumed in the form of ß−carotene, and in practice this can only be achieved if there is a considerable change in dietary pattern from that of the mother's pre−pregnant, non−lactating state: she would need to eat food quite different from that consumed by the rest of the family. One of the difficulties in defining retinol requirements is that the body contains substantial stores that may take many months, or even years, to deplete. When it is realized, however, that in many impoverished countries a mother may be pregnant or lactating virtually continually from 18 to 45 years, the value of the stores in providing temporary protection during pregnancy and lactation must be limited.

1.8. Vitamin D. It is a problem to make rational recommendations for vitamin D, as the natural source of cholecalciferol is via sunlight and synthesis in the skin. Some authorities would suggest there is no primary need for vitamin D, at least in adults, unless their life−styles force them to keep out of the sun, as might be the case with mothers lactating during the winter in northern latitudes, or where social customs keep women mainly indoors or heavily covered up when outside. The NRC (1) recommends an extra 5 µg cholecalciferol during lactation, which makes a total of 12.5 µg for women between 19 and 22 years old. Vitamin D is, however, not distributed widely in foods. Natural sources are fatty fish, eggs, liver, and butter, as well as fortified margarine. In some countries cow's milk is also fortified, but in most, this is limited to some brands of tinned milk. It is unlikely, however, that the typical poor mother in the developing world will have access to such foods. There is a growing body of opinion that the only practical way of ensuring an adequate vitamin D intake, if the photosynthetic process fails for whatever reason, is to take vitamin D capsules prophylactically as a medicine.

1.9. Vitamin C. Considerable extra allowances have been recommended for vitamin C in order to cover the vitamin C content of breast−milk. In the United States an additional 40 mg/d has been recommended in the most recent NRC report(1). This was justified by the fact that breast−milk normally contains 4055 mg ascorbic acid/litre. Once again this recommendation represents a far greater increment than that for energy and, in the developing world − where vitamin tablets are only available for the rich − the suggested level could only be achieved by major dietary modification: the total American recommendation for lactating women is 100 mg/d.

1.10. Thiamin. Estimated thiamin requirements have been based on energy intake, mainly because the vitamin is important in the intermediary metabolism of carbohydrates and fats, particularly the oxidation of pyruvic acid. Because human milk contains around 0.2 mg of thiamin in a typical day's supply, and because extra dietary energy is recommended for lactation, allowances for women have been raised at these times by an average of 0.5 mg/d. This represents an increase of about 50 per cent.

1.11. Riboflavin. Riboflavin is not widely distributed in foods in high concentrations, and if a lactating mother's diet is devoid of milk, liver, or fortified cereal products it is likely her intake will be below current recommended dietary allowances. The amount of riboflavin secreted in the milk by healthy breast−feeding mothers ranges from 0.3 to 0.5 mg per day, and the upper value has become the recommended dietary increment for lactation. Since the basic allowance for a woman during her reproductive years is 1.2−1.3 mg/d, the total allowance for a lactating woman is usually quoted as 1.8 mg/d.

Recent work in the Gambia, however, has indicated this may not be sufficient. Using a community−based approach, Bates and colleagues (3) determined, under prevailing circumstances, the intake of riboflavin compatible with accepted biochemical normality − an erythrocyte glutathione reductase activation coefficient of no more than 1.3. They concluded that an intake of 2.5 mg/d was necessary before 70 per cent of women achieved this desired level of function. Although these studies were carried out in the Gambia, parallel investigations in the United Kingdom indicated that such an intake was relevant there too. Intakes of this magnitude are, however, difficult to achieve in practice, which inevitably raises the question of whether prophylactic vitamin therapy, including riboflavin, may be just as necessary during pregnancy and lactation in the developing world as some authorities consider it to be in industrialized countries.

1.12. Nicotinic acid and its derivatives. The problem with defining requirements for nicotinic acid is that the vitamin is also synthesizable from tryptophan, although probably at low rate of efficiency. It is usually assumed that for every 60 mg of tryptophan consumed about 1 mg of nicotinic acid is made available to supplement the vitamin intake. There is, however, considerable variation between individuals, and the amount converted may be subject to nutritional state and status.

Another difficulty in defining requirements is availability. Much of the nicotinic acid in cereal foods is in a bound form and the extent to which this bound nicotinic acid is truly metabolically available is not known with certainty, but it is thought that this could be limited. The marginal protein intake of most lactating women in the developing world, plus the low tryptophan content of cereal proteins and the bound state of the nicotinic acid, all indicate that nicotinic acid could become a limiting nutrient. As with many nutrients discussed, however, the efficiency of food utilization, in this case the conversion of tryptophan to nicotinic acid, may be greater during pregnancy and lactation, but this is by no means certain. Because of a lack of fundamental scientific knowledge, most expert committees have been forced to assume that vitamin allowances should be increased proportionately with energy during lactation. It must be recognized, however, that this is rule−of−thumb reasoning; it has no physiological validity, as nicotinic acid, unlike thiamin, is not directly involved in energy metabolism. Because of the complex sources of nicotinic acid, allowances are usually quoted in "niacin equivalents," that for lactating women being 18−19 mg/d.

1.13. Vitamin B6. Vitamin B6 also presents a number of unsolved scientific problems, which makes the recommendation of dietary allowances difficult. Requirements seemingly vary according to the general composition of the diet; for example, they seem to rise with the level of protein and may also be greater with high-fat diets. There are also physiological factors influencing efficiency of utilization: for example, young men have been reported to utilize B6 more readily than older men. Thus it would not be unreasonable to suppose that lactating women may be able to compensate for a poor intake, although there is no proof for this. The low-fat and the moderate protein contents of the diets of women in the developing world may also "compensate" or a low intake of B6. Oral contraceptives, however, probably increase dietary needs, and the increasing use of this method of birth control, during lactation as well as at other times, might mitigate against this protective effect. Recommended dietary allowances for B6 during lactation must therefore be regarded with circumspection, and the extra allowance of 0.5 mg/d, making a total of 2.5 mg/d must be recognized as largely arbitrary.

1.14. Folic acid. Folic acid deficiency is always a potential problem during pregnancy because of the greatly enhanced physiological needs at that time. It is, in fact, the only vitamin for which the recommended increment is vastly greater during pregnancy than for lactation. In the industrialized world these needs are routinely overcome by the administration of commercial vitamin preparations in which folate is often given together with extra iron. Clearly, this service is not available to the vast majority of mothers in the developing world and thus the extra metabolic drain of pregnancy might be carried forward into lactation.

One difficulty in defining the adequacy of folate intake from traditional foods is the complex chemical nature of the folic acid derivatives found therein, which are chiefly in the form of formyl or methyl derivatives of tetrahydrofolic acid conjugated with additional glutamic acid residues. It is recognized that the efficiency of digestion and absorption of these derivatives is variable and incompletely understood. Once absorbed they exhibit different degrees of efficiency in their capacity to be converted into the co-enzyme form of the vitamin. Another problem is that tables of food composition, particularly those currently in use in the developing world, can be quite misleading in terms of folate content. Nutrient composition data are now obtained by a standardized microbiological assay procedure using Lactobacillus cased after incubation with chick-pancreas deconjugase. Gas chromatographic methods to separate the different folate derivatives are also being introduced.

The most recent NRC recommendations have retained an intake of 400 µg/d for non-pregnant, non-lactating mothers but have reduced the total allowance during lactation from 600 to 500 µg/d. The DHSS in the United Kingdom (4), on the other hand, originally set their basic allowance for women at 300 µg/d and for lactation 400,ug/d. The RDA difference between the two countries is even larger during pregnancy, 800 µg/d in the USA and only 500 µg/d in the United Kingdom. Even these lower values are rarely achieved in practice by pregnant and lactating women in the United Kingdom from dietary sources alone. At this moment in time it can only be concluded that much more research needs to be carried out before a truly meaningful RDA can be defined.

1.15. Vitamin B12. At the risk of seeming repetitious, requirements for B12, too, are difficult to define, the main reason being that healthy people have substantial liver stores that are readily available to the body as a whole. Proven deficiency is rare and is usually associated with poor digestion and absorption. Food of animal origin, particularly liver, is the best dietary source of B12, and thus vegans or people living almost exclusively on vegetable foods are potentially at risk. In the industrialized countries such people are protected by prophylactic B12, but, needless to say, this does not occur in the developing countries. The allowance for non-pregnant, non-lactating women of 3 µg/d is largely arbitrary. The extra 1 µg during lactation is based on the average B12, concentration in the milk of healthy women.

1.16. Calcium. Milk contains an appreciable amount of calcium, around 300 µg in a typical day's supply, and thus the RDA for this mineral is of especial importance during lactation. Physiological measures of calcium requirements in young adults have mainly been based on the amount needed to replace body losses. Interpretation of the data is difficult, however, since one gets quite different answers in studies carried out in people from the developing world vis-a-vis the industrialized countries. In men, 500 mg/d would appear to cover the needs of the vast majority in the former countries, while 800-900 mg/d seems necessary in Europe and North America. It would appear that a person who has become accustomed to a relatively large calcium intake becomes relatively inefficient in the ability to absorb calcium. Adaptation to low intakes has been shown to occur, but this can be slow and considerable differences have been noted in the ability of different individuals to re-accommodate to the new circumstances.

There is also an association between calcium balance and the protein content of the diet: the higher the level of dietary protein, the lower the efficiency of calcium maintenance. This nutrient interaction could partially explain why people in the developing world manage to survive on what seem to be impossible low intakes. Another dietary factor is the calcium-to-phosphorus ratio. In countries like the United States this ratio is unfavourable to positive calcium balance since the level of dietary phosphorus increases urinary excretion.

Thus, while women consuming less than the North American or European intakes of protein and phosphorus may maintain calcium balance on lower intakes of calcium, an allowance of 1,000−1,200 mg/d has nevertheless been made for all countries. Unless women have a reasonable supply of cow's milk in their diet it is unlikely that this recommendation will be met. The FAO acknowledges that many women receiving only a small amount or no milk in their diet have gone through several successful pregnancies and lactations on much lower calcium intakes. The FAO has stated, however, that the high recommendation is compatible with the best system of diet that can be given to mothers, even though unfortunately such advice cannot always be put into practice. It has to be borne in mind that the later loss of calcium from the bones that afflicts women after the menopause can lead to disabilities such as fractured femurs. Calcium provides a good example of where it is essential to define dietary needs on the basis of a mother's long−term well−being, not just upon an immediate, single physiological function such as capacity for lactation.

1.17. Iron. Iron is unique among the nutrients in that the recommended allowance is considerably greater for adult women than men, even when they are not pregnant or lactating. This is because of iron losses during menstruation, which can be a particular problem in heavy bleeders. Calculating the amount of dietary iron necessary to compensate for iron losses is complicated by the different chemical forms of iron found in food. Essentially it exists in two forms, haem iron and non−haem iron. Haem iron is relatively well absorbed and the NRC has stated (1) that the proportion can be as high as 23 per cent. The non−haem iron has a variable absorption and is affected by a number of factors, including the amount of dietary phytate that can bind iron and make it unavailable. This can be a particular problem in cereal foods, which are the basis of most people's diets in the developing world.

Ascorbic acid can enhance the absorption of non−haem iron, and there are also reports that the presence of haem iron can increase the absorption of non−haem iron. Thus it is clear that subtle changes in dietary composition can greatly affect the intrinsic value of a given food.

The intestine is the main organ of homoeostatic control. It is estimated that the customary efficiency of iron absorption from a Western diet is about 10 per cent of that ingested. When this become insufficient to meet needs, however, such as may occur during pregnancy, lactation, or after bleeding, or when iron intake is low, the efficiency can increase up to 20 or 30 per cent. There is a clear need for more detailed work on iron requirements to be carried out before meaningful RDAs can be defined. Such studies will need to take full account of local dietary habits, the iron state of individuals, and overall food composition.

In considering the needs of lactating women it is, as with most nutrients, difficult to separate considerations of pregnancy from those of lactation. To some extent the extra needs of the foetus and milk production are compensated for by absent or reduced menstruation losses. In the industrialized countries it is recognized, however, that at least during pregnancy the woman may not be able to satisfy her iron needs from dietary sources alone, and hence administration of iron−containing tablets is considered necessary. The NRC has recommended that for American women this prophylactic procedure should continue post−parturition, at least for the first two to three months, to restore iron reserves to pre−pregnancy levels. This would be of particular importance in those who are actively lactating, especially those who lactate for extended periods of time after menstruation may have returned.

In the developing world these clinical services may be totally absent. It is important not just to consider this in terms of anaemia; the socio−economic implications are just as crucial. Many women are forced to engage in heavy manual labour but their work capacity may well be impaired by iron deficiency, as has recently been demonstrated in Sri Lanka (P.E. Sousa, personal communication). It has to be accepted that there will be a considerable portion of women for whom dietary sources of iron will be totally inadequate and from whom repeated pregnancy−lactation cycles will take an increasing toll.

1.18. Zinc. Zinc is a mineral that has been of increasing interest to nutritionists studying human dietary requirements in recent years. Zinc is predominantly found in animal foods. It is also present in cereal products, amounts depending on the zinc content of the soils in which they were grown, but availability may be low due to binding with phytates. The most authoritative set of recommended dietary allowances for zinc and other trace elements are those of the American NRC(1). In practice, a high zinc intake is dependent on the proportion of animal foods consumed. Data from the developing world are indicative of potential deficiency even in non−lactating women. As with calcium, however, it seems not unlikely that need and efficiency of utilization will depend on the dietary level to which the individual has become accustomed, and uncritical extrapolation from American experiences to the developing countries may not be fully justified.

The RDA for zinc, as judged by the NRC, for non−pregnant, non−lactating women is 15 mg/d and an extra 10 mg is recommended for lactation. This 6070 per cent increase, which is considerably in excess of the dietary energy intake, could only be achieved in the developing world by a major switch to animal products in the diet. As with iron and calcium, it would be a very enlightened community indeed that provided a woman with a diet of considerably enhanced desirability compared with what the rest of the family were eating, especially the men!

Other nutrients

1.19. The list of nutrients considered essential for human health is constantly increasing and it would not be practical to discuss each and every one. The ninth edition of the NRC's Recommended Dietary Allowances (1) has included six additional trace elements − copper, manganese, fluoride, chromium, selenium, and molybdenum − in addition to sodium, potassium, magnesium, and iodine. There are, however, no special allowances made for lactation and one must assume that the basic allowance should be supplemented either to make an allowance for the quantities of nutrients secreted into the milk or, alternatively, in line with enhanced recommendations for dietary energy.

Some of the trace elements raise an additional problem in that they can be toxic at high intakes and thus upper safe levels are also supplied. It is unlikely, however, that these levels would ever be exceeded in a normal diet, and upper limits really act as a warning to those who may be tempted to consume excessive amounts of proprietary preparations. For lactating mothers in the developing world the major concern is more the impossibility of achieving anything approaching the lower safe level in a diet virtually devoid of animal products.

General conclusion

1.20. It is quite apparent that there are numerous major gaps in our knowledge about physiological responses during lactation that make the definition of meaningful recommended allowances for individual nutrients difficult. It is also clear that interaction between nutrients is a topic the importance of which has been grossly underestimated. Likewise, metabolic adaptation to low intakes leading to enhanced digestion, absorption, and utilization of dietary constituents also needs to be investigated. This is particularly important for the lactating mother who, for most nutrients, has a significantly greater recommended allowance than any other member of the household, including the husband.

On the basis of current recommendations, the quality of the diet in terms of the amount of nutrient per 1,000 kcal needs to be much better during pregnancy and lactation. If this is true, one would be shutting one's eyes to reality not to recognize the social improbability of such a recommendation ever being put into practice by a poor family in the developing world. Metabolic adaptations might minimize the need for such changes, but it is essential to examine the cost of such adaptations.

A woman plays a multiplicity of functions in addition to baby and milk production. In most communities she is an essential component of the country's agricultural economy; one needs to ensure that her capacity for work has not been compromised. Additionally, it is always possible that, while current function can be maintained at a reasonable level on a low nutrient intake, deficiencies may build up that can impair health and well−being later in life. The poorer countries of the world may well be forced to make sacrifices in this regard as part of the cost of achieving ultimate economic improvement. Be this as it may, scientists should clarify the health consequences of such politically motivated decisions and, wherever possible, develop sufficient factual understanding so that the worst effects can be alleviated.

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2. Measured dietary intakes of lactating women in different parts of the world

2.1. The energy and nutrient intake of the majority of lactating mothers in the developing world falls well below the RDA. There is now evidence that even the average woman from the industrialized countries also consumes less food than theoretical reasoning would indicate she should. This section reviews available data, but it must be emphasized that there is an unfortunate paucity of really accurate information. Many studies of dietary intake have been on whole families, and it is quite impossible to compute the intake of an individual from this information, especially an individual with specific physiological needs.

There has also been a diversity of techniques used: it is generally accepted that the method based on the precise weighing of the food eaten by each individual produces the most satisfactory data. This method is time-consuming, however, and it also requires an accurate knowledge of the nutrient composition of cooked dietary components to make optimum use of the data. Such information is rarely at hand in the developing world, and facilities for nutrient analysis are rare. Many investigators have had to fall back on semi-quantitative methods such as the 24-hour recall method. While this can be remarkably accurate in experienced hands, results from the recall method can also be of very dubious value. It is apparent that much more carefully controlled measurements of dietary intake are essential.

Energy

2.2. Table 2 summarizes the mean energy intakes that have been obtained in a number of studies carried out in the developing world on lactating women. The average WHO/FAO estimate of needs in a moderately active woman is 2,750 kcal/d (see section 1.3), and it is quite clear that measured values are considerably less. The highest mean intake was 1,950 kcal/d by found Martinez and Chavez (18) in Mexico during 1971; the rest of the measured intakes were 1,750 kcal/d or less. There is also evidence of seasonal variation; for example, measured intakes dropped to as low as 1,200-1,300 kcal/d during the worst part of the wet season in the Gambia (1). At this time, the traditional hungry season, food from the previous harvest has been used up and that from the new one is not yet ready. Some of the values in table 2 are so low, ranging from 40-70 per cent of the RDA, that many are near the theoretical amount required for only resting metabolism.

TABLE 2. Reported Energy Intakes of Child-bearing Women in Developing Countries

Source	**Country**	**Energy intake (kcal/d)**
Pregnancy		

Prentice (11 (wet season)	Gambia	1,350–1,450
Oomen and Malcolm (2)	New Guinea	1,360
Gopalan (3)	India	1,400
Venkatachalam (4)	India	1,410
Lechtig et al. (5)	Guatemala	1,500
Gebre–Medhin and Gobezie 16)	Ethiopia	1,540
Rajalakshmi (a)	India	1,570
Mora et al. (8)	Colombia	1,620
Prentice (1) (dry season)	Gambia	1,600–1,700
Arroyave (9)	Guatemala	1,720
Maletnlema and Bavu (10)	Tanzania	1,850
Demarchi et al. (11)	Iraq	1,880
Bagchi and Bose (12)	India	1,920
Thanangkul and Amatyakul (13)	Thailand	1,980
Mata et al. (14)	Guatemala	2,060
Lactation		
Prentice (1) (wet season)	Gambia	1,200–1,300
Karmarkar et al. (15)	India	1,300
Devadas and Murthy (16)	India	1,400
Karmarkar et al. (17)	India	1,440
Arroyave (9)	Guatemala	1,600
Rajalakshmi (7)	India	1,620
Prentice (1) (dry season)	Gambia	1,600–1,750
Martinez and Chavez (18)	Mexico	1,950

One is tempted to question the validity of such surprising data, but comparable information, also contained in table 2, for pregnant women is of the same order of magnitude. It is apparent that there is little or no increase in dietary energy intake between pregnancy and lactation. Since it seems highly unlikely that non–pregnant, non–lactating women could have been customarily eating much less than these amounts, it can reasonably be assumed that women in the developing world must subsist on the same low plane of energy intake, averaging about 1,600 kcal/d, throughout most of their reproductive life.

2.3. There have been few similar studies on lactating mothers in industrialized countries, although it has been reasoned that physiological needs for dietary energy may be lower because of the reduction in general level of activity that is possible in such societies: few women, for example, are forced to go out to work, especially to perform heavy manual labour, while they are nursing.

Table 3 describes some studies that have been carried out in different industrialized countries. The data of Thomson (20) date back to Scotland in the 1950s and contrast markedly with the more recently obtained values of Whitehead and colleagues (25) collected in Cambridge in 1980. There has, in fact, been a generalized reduction in food energy intake by most sectors of the community in the United Kingdom during this time period, perhaps reflecting different life–styles, but whether the differences can be explained on this basis is not certain. Generally speaking, earlier measured values did average around the RDA, but clearly this is not the case in present–day Cambridge. The data from Sweden for lactating mothers, collected in 1977

(23), and more recent data from Australia (26) are also identical with those from Cambridge. In contrast to the data from the developing countries, all the studies in the United Kingdom show that nursing mothers consume more dietary energy when they are lactating than in their non−pregnant, non−lactating state, although in Cambridge the increment is not as great as that recommended.

TABLE 3. Energy Intakes (kcal/d) of Mothers in Developed Countries with Breast−fed or Bottle−fed Infants

		Breast−feeding	Not−feeding
English and Hitchcock (19)	Australia	2,460	1,880
Thomson et al. (20)	Scotland	2,716	2,125
Naismith and Ritchie 121)	London, UK	2,930	2,070
Whichelow (22)	London, UK	2,728	1,958
Abrahamsson and Hofvander (23)	Sweden	2,280	−
Sims (24)	USA	2,124	−
Whitehead et al. (25)	Cambridge, UK	2,295	2,029
Rattigan et al. (26)	Perth, Australia	2,305	−

2.4. The very low intakes of dietary energy that have been recorded in the developing world represent a scientific enigma, especially when it is recognized that most of the women are successfully involved in lactation over an extended period of time − anything up to two years. It will be emphasized in subsequent parts of this report (see section 3.2) that there is a need for more extensive work on energy balance during lactation and on how maternal physiology adapts to the very considerable energy drain of lactation in women on a low intake.

Protein

2.5. It has already been pointed out in section 1.5 that the recommended allowance for dietary protein during lactation represents a proportionately greater increment than that for pregnancy. A combination of low−baseline total energy intakes, plus the virtual lack of any significant increase in food intake during lactation, or any change in dietary pattern towards more protein−rich foods, inevitably means that the RDA for protein may not be achieved during lactation in some developing countries. The situation is understandably worse in those countries that have starchy root crops like cassava of plantains as their dietary staple. In contrast to studies on the preschool child, however, there have been few comparative studies on the relative effects of protein and energy deficiencies on the process of lactation, although it is known that a clinical state closely resembling that of kwashiorkor can occur in lactating women who are forced to live solely on cassava or plantain without added foods such as meat, fish, or beans (section 3.3).

Vitamins and minerals

2.6. If the gap between the RDA and actual levels of energy consumption seems large, that for many vitamins and minerals is frequently even greater. It must be borne in mind, however, that the RDA for these nutrients has not always been precisely and rigorously defined (sections 1.6−1.15).

Table 4 shows the mean energy and nutrient consumption levels of lactating mothers of poor socioeconomic status in Baroda, India (27). Energy intake is about 60 per cent of the RDA, as is protein after allowing for the relative protein value of the diet. Calcium intake is, however, only 30–40 per cent of the international allowance, while that for vitamin A plus carotene precursors is as low as 10–15 per cent. Likewise, niacin (nicotinic acid equivalents), riboflavin, B12, and vitamin C amount to only 30 per cent or less of the RDA. The data also illustrate unexpected features, for example the intake of iron is untypically high, partly because of the use of iron cooking pots, although the availability of the iron might be low in view of the low vitamin C content of the diet. In most developing countries iron–deficiency anaemia is a considerable problem, both in children and their mothers.

TABLE 4. Maternal Dietary Intake of Poor Women in Urban Baroda, India, during Pregnancy and Lactation

kcal	1500–1600
Protein (9)	35–40
Fat (9)	30
Calcium (mg)	400
Vitamin C (mg)	10–15
Vitamin A (µg)	125
Iron (mg)	20–25
Folate (mg)	0.5–0.7
Vitamin B12 (µg)	0.5
Thiamin (mg)	1.0–1.5
Riboflavin (mg)	0.5
Niacin (mg)	5–6

Source: ref. 27.

Figures 1–3 illustrate comparable data from the Gambia in West Africa. Here the special emphasis is on seasonal variations. Intakes of vitamin C ((see

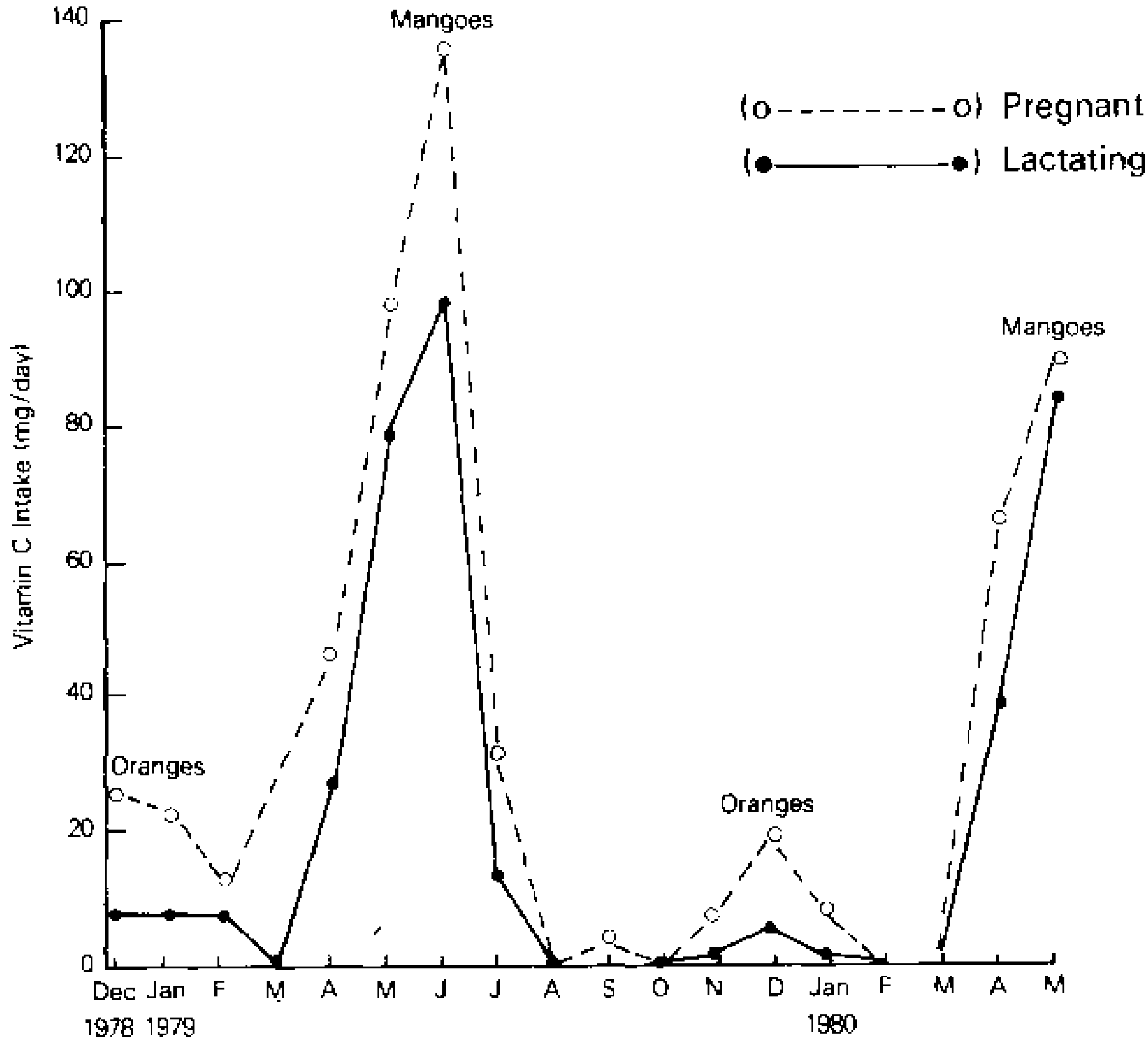

FIG. 1. Variations in Vitamin C Intake during Different Months of the Year by Pregnant and Lactating Mothers in the Gambia (Source: ref. 28))) (281 are high during the season when mangoes and citrus fruits are available, but exceptionally low at other times. Likewise, vitamin A plus carotene precursors are eaten by lactating mothers in variable amounts, although never up to the RDA (see

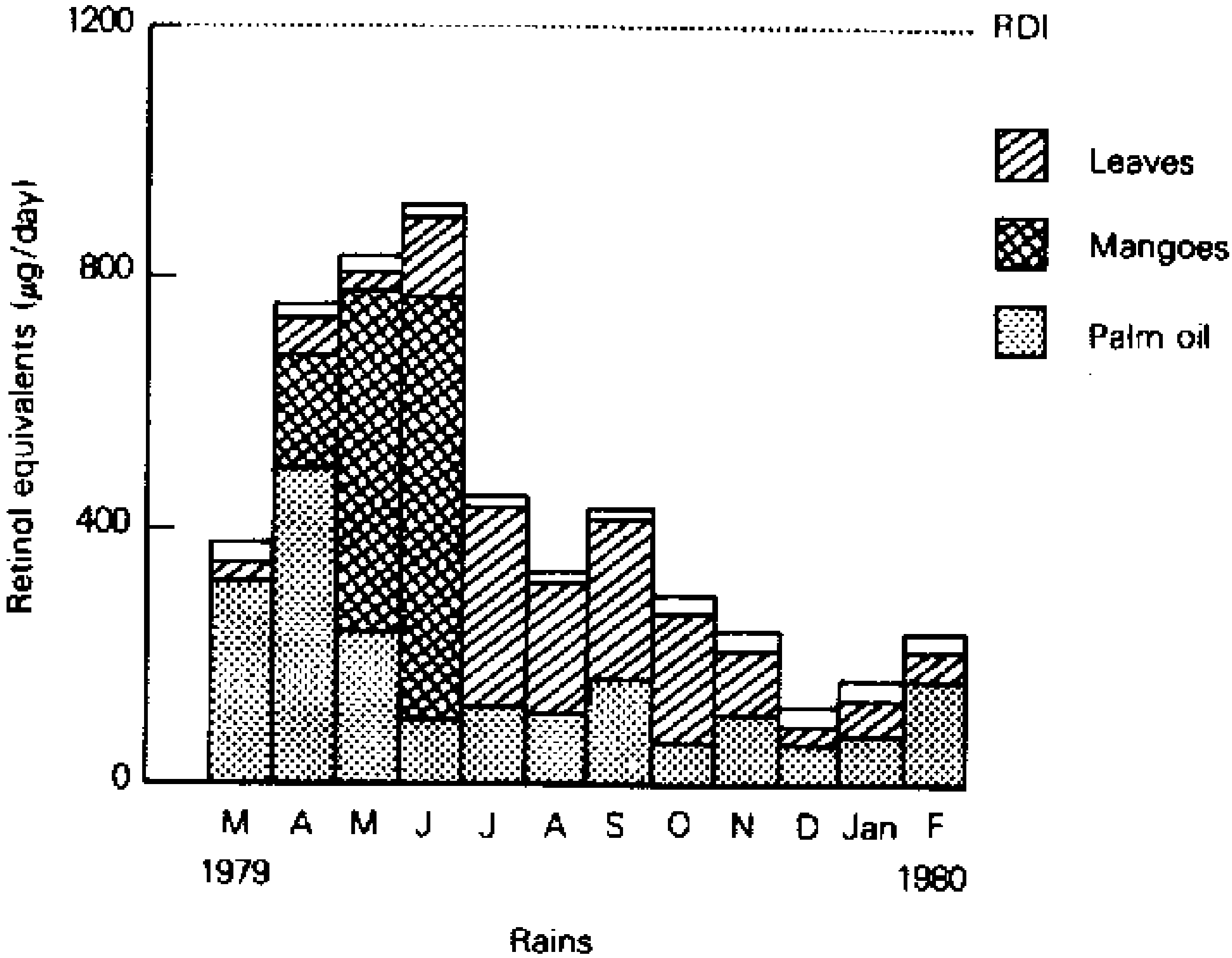

FIG. 2. Variations in Vitamin A Intake and Retinol Precursors during Different Months of the Year by Lactating Women in the Gambia (Source: Paul and Bates, unpublished data)). The June peak coincides with the mango season. In contrast, riboflavin intake is especially low at all times of the year. The overall position of riboflavin consumption relative to the RDA is very poor (29) and comparable with the situation found in Baroda.

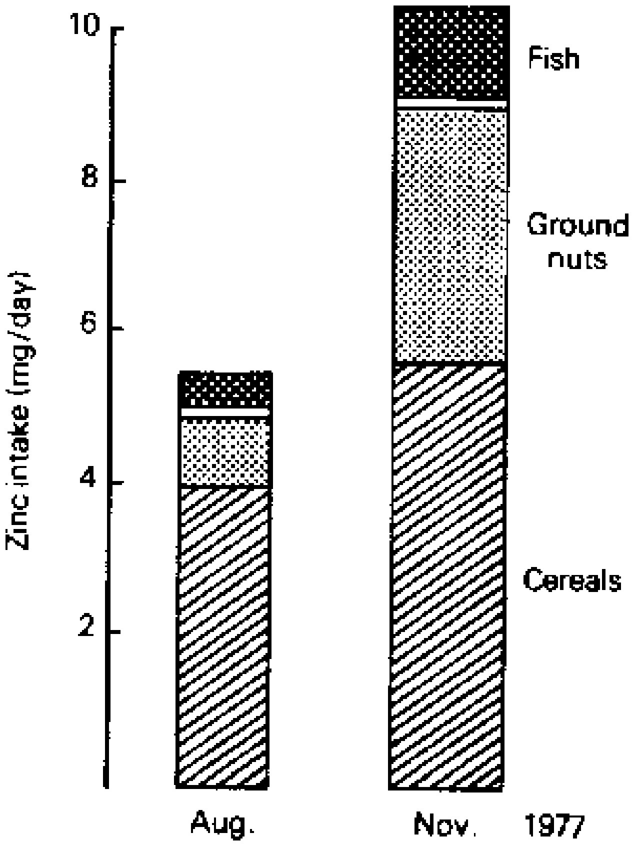

Figure 3 (see
FIG. 3. Zinc Intakes by Lactating Gambian Mothers during Different Months of the Year (Source: A.A. Paul, unpublished data)) shows corresponding intakes of dietary zinc and its dietary sources. The drop in groundnut consumption during the hungry season has a profound effect on zinc intake, although intakes are always low. It is a reasonably accurate rule−of−thumb to say that good sources of protein are frequently good sources of the trace elements, and dietary recommendations that used to be given for certain foods for their protein content might be just as valid for the trace elements! The NRC recommended allowance for zinc during lactation is 25 mg/d (30). In the Gambia at a good time of the year mean intake is only 40 per cent of this value and can be as low as 25 per cent of the RDA. There is certainly no evidence of a 33 per cent increase during pregnancy, let alone a 66 per cent one in lactation. Figure 4 (see

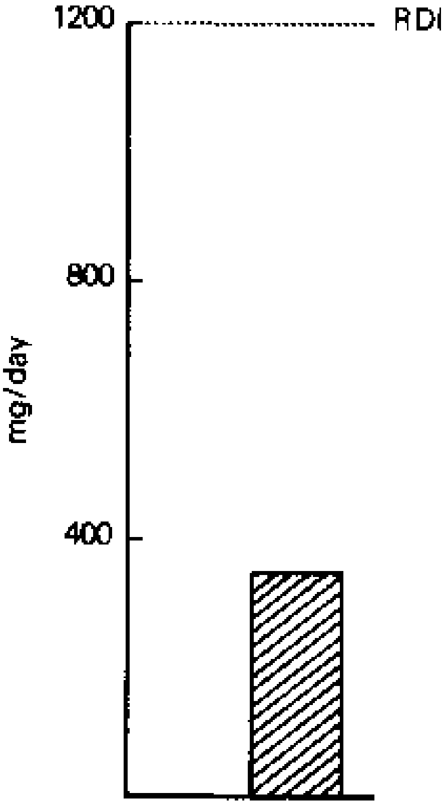

FIG. 4. Average Calcium Intakes of Lactating Mothers in the Gambia (Source: A.A. Paul, unpublished data)) shows the overall situation with calcium; throughout the year average intake is only about 350 mg/d, less than the increment recommended by the NRC and all other expert committees.

The influence of socio−economic status in the developing world on nutrient intake

2.7. Within any community, particularly one in the developing world, one also finds marked differences in intake reflecting socio−economic status. Figure 5 (see

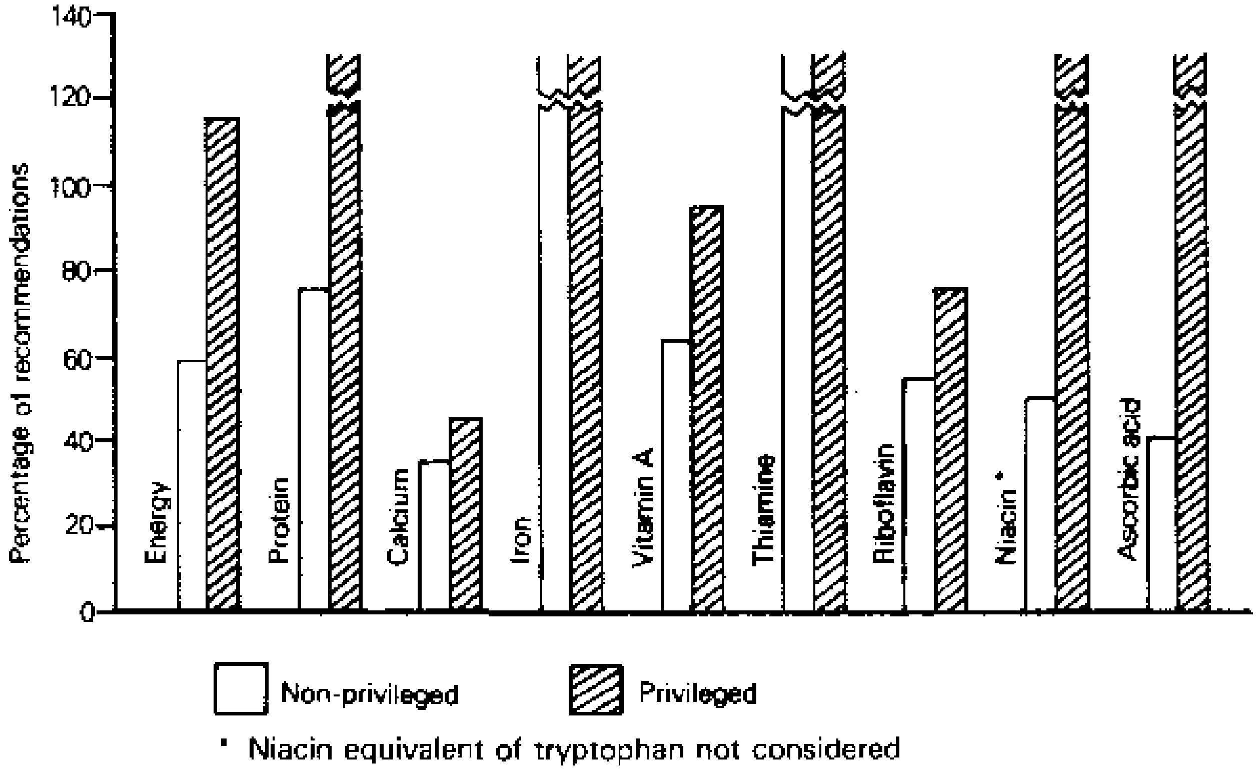

FIG. 5. Average Daily Energy and Nutrient Intake by Pregnant Ethiopian Women, Compared with FAO/WHO Recommendations (Source: refs. 6 and 31)) shows the average daily energy and nutrient intakes of pregnant Ethiopian women (6, 31). Unfortunately, there are no comparable quantitative data for lactation, but with the exception of the immediate post−natal period when, as Gebre−Medhin has described, special highly nutritious foods are provided, it is reasonable to conclude that the pattern of nutrients in the diet during most stages of lactation will be similar. It is readily apparent that the social differential for nutrients such as vitamin C and niacin (nicotinic acid) is substantially greater than for dietary energy. The data also serve to demonstrate important inter−country differences. In Ethiopia, in contrast to India and the Gambia, vitamin A and to a relative extent, riboflavin are in good supply. A further important difference occurs during lactation, when mothers are not only permitted but encouraged to drink a thick, nutritious traditional beer called tell. This has been shown to be a good source of folate and even B12 (31).

General conclusion

2.8. The failure of most women in developing countries to meet nationally and internationally recommended dietary allowances is clearly widespread. Although regional and socio−economic differences need to be taken into account, the discrepancy between actual and recommended dietary intakes in lactating women suggests that the basic assumptions used in formulating the dietary recommendations are in part incorrect and there is an urgent need for further research to define the physiological basis of this discrepancy.

Nevertheless it is clear that nutritional inadequacies exist in developing countries. It would be an oversimplification to say that this nutritional problem would be overcome if mothers could be encouraged to eat more of their existing foods. This advice would most certainly be ineffective and impracticable for a number of reasons.

First, the energy density of the customary diet in many developing countries is very low either because the staple has an intrinsically low energy content per unit of mass and volume, such as with cassava and plantain; or because the food has a lot of water added during the course of preparation, as in a stew or porridge; or because the raw materials used have a low fat content, and no fat or oil is used in food preparation. Thus, in the Gambia the average diet has an energy density of 1 kcal/g, and a woman would have to eat 3 kg of that food to achieve an intake of 3,000 kcal/d. As far as individual nutrients are concerned, dietary composition, in terms of nutrient content per head, is such that for many nutrients an excessive amount of dietary energy would have to be eaten if that individual were to meet the RDA. This is particular so during lactation, when the RDA is almost always proportionally higher for nutrients than for energy. Quite obviously major changes in food composition and methods of food preparation would be necessary if this discrepancy between current scientific theory and prevailing practice were to be resolved.

The energy, and especially the nutrient, gap during lactation presents nutritionists and health planners with a problem just as complex as the old "protein gap." As it was with protein, it is necessary to ask the question: Are the amounts recommended really necessary for adequate physiological function, health, and well-being? The following section of this report reviews the effects of these shortfalls in energy and nutrient intake both on lactational performance and on the health of the mother.

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3. Effect of diet on maternal health and lactational performance

3.1. Lactation understandably represents a drain on maternal body composition. During the early stages of pregnancy, fat should accumulate in the subcutaneous stores and protein should build up in the muscular tissue. Towards the end of pregnancy and throughout at least the first six months of lactation fat and protein are used to support final foetal growth an subsequently milk production. The main questions that need to be resolved are: What happens to milk output and composition when, for nutritional reasons, the mother has not been able to lay down these stores in pregnancy and her diet during lactation is just as inadequate? What are the physiological consequences for the mother of prolonged breast−feeding under these circumstances? It is the custom in many societies for this to continue up to two years or more. Any ill effects may be compounded by repeated pregnancy−lactation cycles; it is no exaggeration to say that many women in the developing world are either pregnant or lactation almost continually during the whole of their reproductive lives. These questions need to be answered within the context of the heavy manual workload performed by these women.

Body size and composition

3.2. An examination of the literature from different parts of the world quickly reveals that dietary energy intake during lactation does have a marked effect on weight and body composition; this is only to be expected. What is surprising is that these physiological responses are not affected as much as one would have anticipated from the low dietary intakes encountered in the developing world. This is readily apparent from studies carried out by Prentice in the Gambial (1) (2). Figure 6 (see

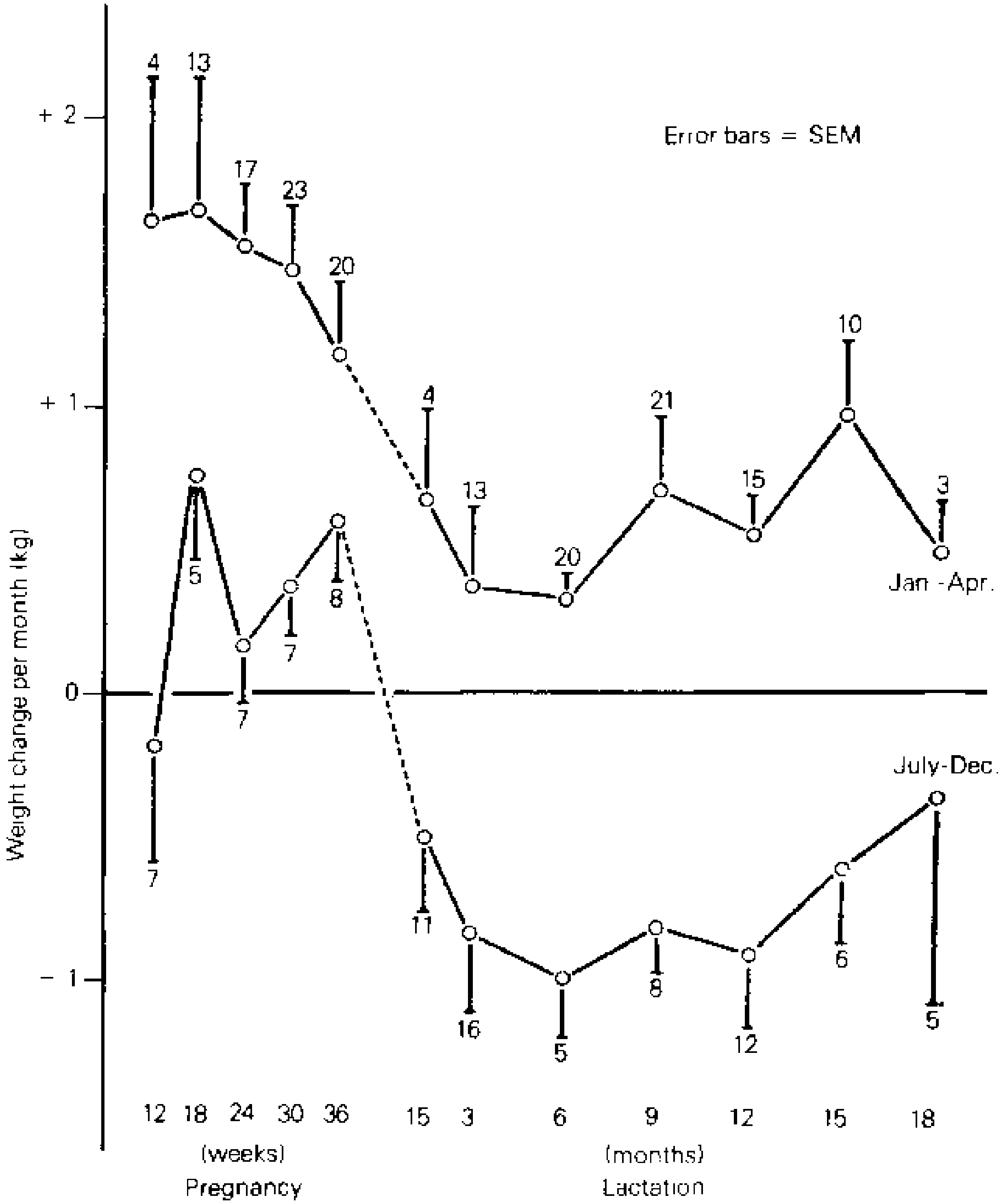

FIG. 6. Seasonal Weight Changes in Pregnant and Lactating Women in the Gambia (Source: ref. 1)) shows that during the wet season, from July to December, when food intake is low and farming is at its heaviest, weight gain during the last two trimesters of pregnancy averaged only 0.5 kg/month, and during lactation weight is lost at an average of 1 kg/month up to 12 months. In the dry season, however, when admittedly there is little heavy farm work, the mothers were slowly gaining weight during lactation at about 0.4 kg/month, in spite of the fact that their mean food energy intake is only 1,600–1,750 kcal/d depending on the month. These weight changes were mirrored by alterations in the sum of the skin–fold thickness at three sites: triceps, subscapular and supra–iliac. From January to April women actually appeared to be depositing subcutaneous fat. These astonishing findings can only imply that the Gambian mothers are operating at a totally different plane of energy utilization efficiency. As shown in section 3.18, the mothers were also able to maintain a very satisfactory level of milk production.

TABLE 5. Energy Intake of Indian Women during Pregnancy and Lactation as Compared to Estimated Requirement

	Pregnant women		Lactating women		Controls	
	Lower	Upper	Lower	Upper	Lower	Upper
	Class	class	class	class	class	class
Age (years)	25	26	25	27	25	27
Height (cm)	150	155	150	155	149	154
Weight (kg)	46	58	40	51	39	48
Surface area (m^2)	?	?	1.30	1.48	1.28	1.44
Conservative estimates of energy (kcal/d) required for:						
Prepregnant basal metabolism[a]	905	1,030	905	1,030	890	1,002
Activity at:						
(i) 15 car/kg	690	870	600	765	585	720
(ii) 10 car/kg	460	580	400	510	390	480
Increase during pregnancy[b]	181	206	–	–	–	–
Milk production[a]	–	–	500	300	–	–
Total:						
(i)	1,776	2,106	2,005	2,095	1,475	1,722
(ii)	1,546	1,816	1,805	1,840	1,280	1,482
Intake[c]	1,570	2,020	1,620	2,020	1,500	1,800

a. At 30 calories per m^2 per hour; (a) at 70 calories per 100 ml providing 10 per cent above the physiological fuel value of milk.
b. On the basis of a 20 per cent increase in BMR found in selected subject.
c. Based on estimates from aliquot collection of all the foods consumed for two consecutive days each month from the sixth or seventh month of pregnancy till six months after child–birth for 50 women in the lower class and 18 women in the upper class.

Source: ref. 3.

The same phenomenon has been discussed by Rajalakshmi from Baroda in India (3), who has produced the energy balance data shown in table 5. Using a very conservative estimate for pre–pregnant basal metabolism of 905 kcal/d and for activity at 10 kcal/kg, a mother producing 725 ml milk/d would theoretically need 1,805 kcal, but the actual intake of an average lower–class Baroda woman is only 1,620 kcal/d. As in the Gambia, there was no dramatic weight loss during lactation; one can only echo Rajalakshmi when she asked: "How does the poor woman maintain her body weight and overall health status in spite of a poor diet and generous secretion of nutrients in her milk?" Clearly this is a subject that merits a greater research input.

There needs to be caution, however, before too many inferences are drawn from observations on one single, pregnancy–lactation cycle. Gebre–Medhin has reported (4), for example, that among poor Ethiopian women there is a slight but definite downward trend in antecedent weight with increasing parity in relation to the weight measured at the beginning of the first pregnancy. This observation may reflect the cumulative effects of repeated pregnancies.

Papua New Guinea is another country where very low energy intakes have been recorded during pregnancy and lactation (5). Only four out of a total of 69 women living in the lowlands had intakes above 2,100 kcal/d, and six had customary intakes below 950 kcal. In spite of this there was little evidence that either pregnancy or lactation led eventually to a major decrease in maternal body weight of fat stores, and this was true even when there were repeated pregnancies. Durnin considered that this could be due to an overall reduction in activity. There was some evidence that the mothers spent less time walking and more sitting, the latter being partly enforced because of breastfeeding.

Durnin concluded that the enigma of low energy intakes during lactation could only be solved by careful studies on population groups: studies that would not be easy to carry out. The investigation of comparatively small changes in physical activity as part of a long−term prospective study covering, ideally, the non−pregnant state, the whole of pregnancy, plus the whole of the lactation period would be necessary, as well as measures of changes in body composition and metabolic rates. It would be desirable if these studies could be coupled with other investigations of general health and well−being, and also of the mothers' capacity to be active in caring for the home and family. These studies would require experienced investigators willing to partake in laborious, painstaking, well−controlled studies, but Durnin has reasoned that unless this occurs our understanding is unlikely to be enhanced and we will continue to make dietary recommendations that are grossly at variance with actuality.

Protein status of the mother

3.3. On theoretical grounds (sections 1.5, 2.3), protein status might be expected to be affected more during pregnancy and lactation than energy status. There have unfortunately been far too few studies involving measure meets related to protein nutritional status, such as plasma albumin and amino−acid concentrations, particularly in areas where the oedematous form of early childhood protein−energy malnutrition is more predominant. It is not improbable that specific pathophysiological signs of protein deficiency would be more prevalent within such a community. Vis, for example, has reported (6) the not infrequent appearance of kwashiorkor−like signs in malnourished lactating women in the Kivu province of Zaire, where the diet is made up of beans, sweet potatoes, and bananas. The same features have also often been observed in nearby Rwanda, and also in the Buganda district of Uganda during episodes of political and military strife that have affected the cultivation and distribution of food crops. As shown in section 3.18, there is also evidence that milk production may be more affected when dietary protein is limiting rather than energy.

The WHO/FAO and DHSS in the United Kingdom have both recommended more protein during lactation than pregnancy, while the NRC in the United States reasoned that protein needs are higher in pregnancy. It is not possible to resolve this difference of opinion without more detailed study, but in the Gambia, where the staples are cereal crops, millet, sorghum, and rice, and thus any protein deficiency is likely to be secondary to a lack of energy, biochemical signs attributable to protein deficiency do appear during pregnancy but not in lactation. Plasma amino acid patterns change in a manner identical to those seen in early pre−clinical kwashiorkor, and in some countries but not all, these seem to be related to falls in plasma albumin concentration greater than can be accounted for by haemodilution. Plasma albumin concentrations return to normal, however, during lactation. These results would be compatible with the concept that pregnancy might place a particular strain on protein metabolism. This is clearly an area that merits more intense study.

Maternal vitamin status

3.4. All available evidence shows that both the mother's own vitamin status and that of the milk she produces (see 3.12, 3.13) are very sensitive to dietary intake. Table 6 shows the percentage incidence of clinical symptoms and abnormal blood vitamin biochemistry among poor indian women living in Baroda, as reported by Rajalakshmi (3). Similarly, in the Gambia (7) there are marked biochemical signs of vitamin deficiency reflecting the poor maternal diet. The mean erythrocyte glutathione reductase activation coefficient in lactating mothers is 1.6 throughout lactation, with some values over 2.0. The upper limit of acceptability is 1.3 and thus these data must be interpreted as being indicative of widespread deficiency. It needs to emphasized, however, that signs of abnormality were even more marked during the late stages of pregnancy, with mean activation coefficients approaching 2.0. Again, this could mean that pregnancy produces a greater metabolic strain on the mother than lactation, even though the recommended dietary allowance is more during lactation.

TABLE 6. Nutritional Status of Poor Indian Women during Pregnancy and Lactation

	No. of cases			Percentage incidence		
				Pregnant[a]	Lactation[b]	Controls
	(P)	(L)	(C)	(P)	(L)	(C)
Clinical symptoms	33	66	39			
xerosis of conjunctive				48	23	18
pigmentation of conjunctiva				55	38	33
xerosis of cornea				33	3	5
pale tongue				73	67	62
fissured tongue				39	38	21
adipose tissue deficient[c]				36	11	26
oedema on dependent parts				3	2	0
anorexia				24	2	0
diarrhoea				9	2	0
Values per 100 ml						
blood haemoglobin<10m g	63	34	24	41	12	4
serum protein<6m g	63	34	24	45	9	8
serum b –carotene <15m g	41	30	11	30	3	18
serum vitamin A < 10m g	41	30	11	28	10	18
Radiological evidence of coarse trabeculae						
pelvis	0	27	5	–	26	50
wrist	0	27	5	–	7	20
Cortical thickness (cm) of bone						
second metacarpal	0	13	4	–	0.44±0.02	0.42±0.03
femur	0	34	4	–	1.30±0.03	1.50±0.02

a Close to term.
b. In established lactation.
c. As judged by mid–arm skinfold.

Source: ref. 3.

3.5. The vitamin C status of the mother is also very sensitive to dietary intake. Figure 7 (see

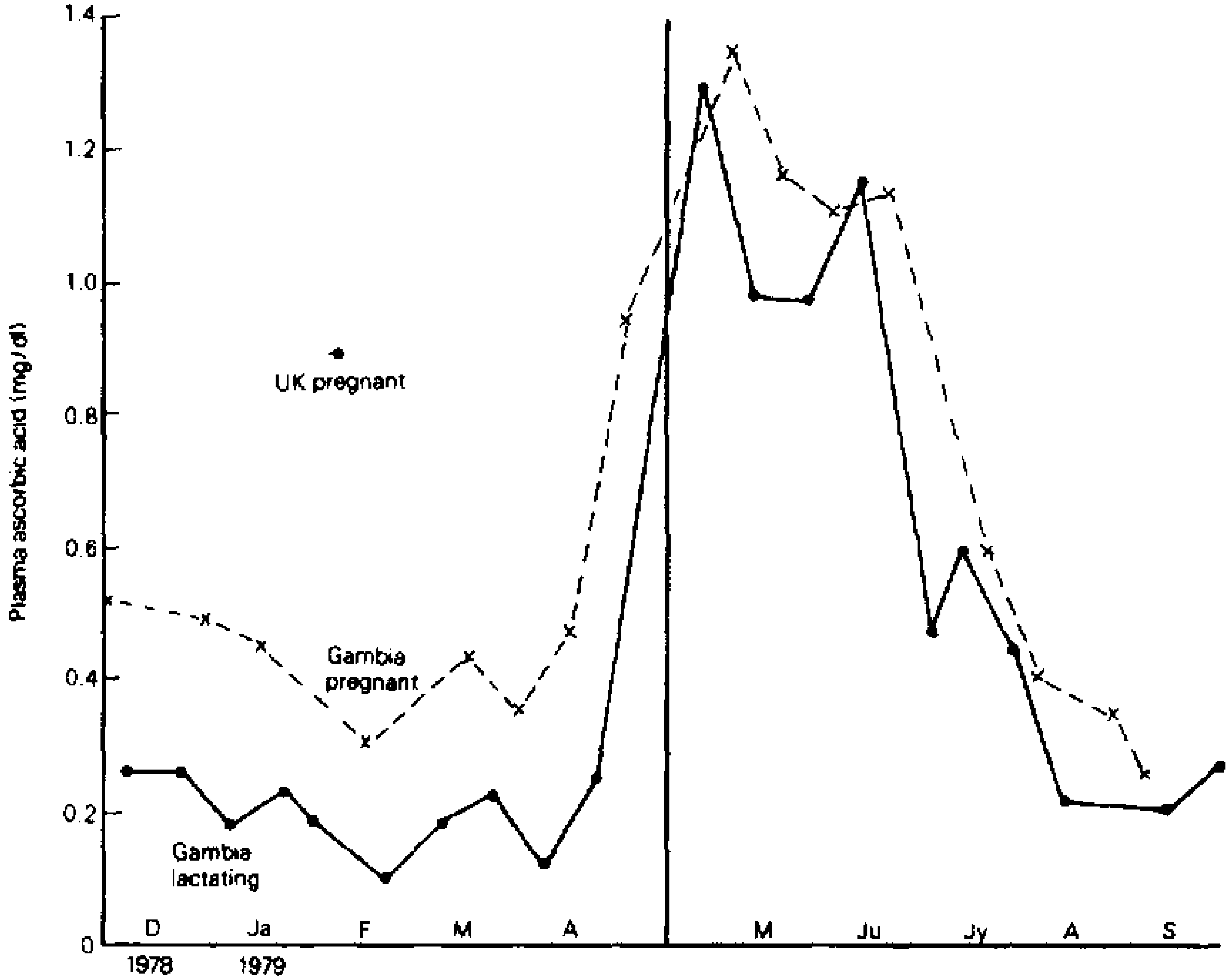

FIG. 7. Plasma Ascorbic Acid Concentrations in the Gambia by Season (Source: ref. 8)) shows plasma vitamin C levels in lactating women in the Gambia (8). These swing from a high level suggesting tissue saturation during the mango season down to almost unmeasurable levels in the rainy season, when intakes are extremely low. In contrast to riboflavin, plasma vitamin C levels were lower during lactation than in pregnancy. For example, during January 1979 mean lactating maternal values were around 0.2 mg per 100 ml, while in pregnant mothers the values were about 0.5 mg. A similar effect has been reported from Baroda (3), where the corresponding values were 0.58–0.75 mg per 100 ml during pregnancy but only 0.36–0.50 mg in lactation. The extra 40 mg/d of dietary vitamin C during lactation recommended by the NRC, but only an extra 20 mg/d in pregnancy, would therefore not seem unreasonable.

3.6. Vitamin A status can also be affected in lactation, although pregnancy again seems to be the time when the mother is most at risk. Rajalakshmi, for example (3), has found that among poor Indian women, serum levels fall during pregnancy but rise again after parturition, with an associated increase and decrease, respectively, in the prevalence of clinical symptoms of vitamin A deficiency. It was suggested that this could parallel the situation that has been observed in cattle, in which for some reason not completely understood, pregnancy can be associated with an increase in liver stores and the vitamin seems not so generally available to the other tissues.

In the Gambia, in spite of very low intakes, no gross clinical signs of vitamin A deficiency, such as keratomalacia or Bitot spots, have been observed even though plasma carotene levels vary in concentration closely following the seasonal variations in dietary intake, and plasma vitamin A concentrations are consistently lower than those observed in the United Kingdom (C.J. Bates, personal communication). The Gambian data would suggest that, at least within that country, the current RDA is unnecessarily high both for pregnancy and lactation. This could be because carotene rather than vitamin A is the major dietary source of retinol, and estimates of requirements are based on the assumption that six molecules of ,ß–carotene yield approximately only one molecule of retinol in vivo. It is known, however that this conversion varies in different foodstuffs and, more importantly, it may also vary with physiological status. Metabolic efficiency is believed to increase during pregnancy and lactation with energy (see 3.2) and other nutrients, and it is not unreasonable to postulate that this could be the same with ß−carotene and vitamin A. There is clearly a need for the 6:1 conversion factor to be reinvestigated under differing prevailing conditions during pregnancy and lactation in relation to the types of carotene−containing foods customarily consumed.

There is another possible explanation. Clinical vitamin A deficiency may not occur only as a result of exhausted body stores. Interaction with other nutrient deficiencies would also appear to be of crucial importance. Very recent evidence suggests that the classical signs develop from the combined effects of vitamin A deficiency plus protein and zinc deficiency (5, 10). This could well explain variability between countries in the relationship between vitamin A intake and the appearance of signs of clinical deficiency. There is clearly a need for these interactions to be studied on an objective basis to determine their relevance for practical nutritional and dietary planning.

3.7. The amount of folic acid required during lactation understandably depends on the status of the mother at the end of pregnancy. In the Gambia preliminary evidence shows that red−cell concentrations fall steadily during lactation, and some very low values have been obtained towards the end of the second year (Bates, personal communication). The women studied had been given a therapeutic iron−folate preparation during pregnancy as part of a standard clinical routine, but not during lactation. The extent to which it is the strain of pregnancy or the process of milk production that has been the cause of the megaloblastic anaemia observed in other countries early in lactation is uncertain. Chanarin, for example(11), found that 52 per cent of his cases were diagnosed postpartum, mostly in the first few weeks after delivery.

The problem of relating food folate intake to physiological performance has already been discussed (section 1.14). It is readily apparent that more work needs to be carried out, and such studies will have to take account of the effects of intercurrent infection. It is known in children that diseases such as malaria or hookworm can exacerbate poor folate status both in terms of FIGLU excretion and in the incidence of megaloblastic anaemia (12). There is also a close association between folate status and the prevalence of diarrhoeal disease (13).

Diet and breast−milk composition

Proximal Constituents

3.8. Generally speaking, it would appear that, except in extreme maternal undernutrition, the concentrations of total energy and protein in breast−milk are maintained at remarkably normal levels. In the Gambia, for example, where even during good times of the year dietary mean intake is only 1,700 kcal/d, the average energy content of the mother's milk is maintained at 72 kcal/100 ml, which compares well with the mean content of British mothers' milk, 69 kcal/100 ml. Even when mean intake was 1,100−1,200 kcal/d the energy content only dropped by about 10 per cent.

3.9. It is not easy to be precise about the effect of maternal diet on fat content, because concentration varies during the course of a feed – the fore−milk being more dilute than hind−milk. Most studies have been based on expressed milk, but more cannot be sure that this reproduces the same value that integrated measurements during actual breast−feeding would. In the Gambia, an estimate of the average fat content as consumed by the baby is 3.86 9/100 ml(14), in comparison with a value for British women of 4.2 9/100 ml(15). Whether the differences truly reflect maternal dietary differences, or whether they are due to different collection methods, is not known.

Hambraeus has reviewed the literature on the fatty acid composition of mothers' milk(16). It would seem that the milk fat resembles that of the mother's diet when her plane of energy intake is good, but when there is a shortage of food energy the milk fatty acid pattern resembles more that of the mother's subcutaneous fat stores. Maternal fat intake has no effect on the total triglyceride content, however, as illustrated by the Gambian data. The fat content of the Gambian diet is no greater than 10 per cent of the total energy, while in United Kingdom it is over 40 per cent, yet the fat concentrations are essentially the same.

3.10. The lactose content of human milk is high, around 7 9 per 100 ml. This component seems very stable in concentration as illustrated in table 7, which show that the milk of non−privileged Ethiopian mothers has very much the same lactose content as their Swedish and privileged Ethiopian counterparts (17).

TABLE 7. Lactose Content in Human Milk (9/100 ml, Means and SD)

Duration of lactation (months)	Swedish mothers	Ethiopian mothers	
		Privileged	Non-privileged
0–0.5	5.9 + 0.6	6.5 + 0.9	
0.5–1.5	7.0 + 0.6	6.6 + 0.6	7.4 + 0.5
1.5–3.5	7.3 + 0.5	7.6 + 0.2	7.4 + 0.5
3.5–6.5	7.6 + 0.4	7.5 + 0.3	
> 6.5	7.8 + 0.5		

Source: ref. 17.

3.11. The overall protein content of human milk also seems remarkably stable to despite changes in the maternal diet, as illustrated in table 8. Once again there is a remarkable similarity between the two sets of data from Swedish and non-privileged Ethiopian mothers(17). In the Gambia also, total protein content was essentially maintained at British levels despite an intake of marginal adequacy. During the period of the year when food intake was especially poor, some fall in milk total nitrogen content was observed, but this was by no more than 10 per cent. It must also be remembered that not all the protein in milk is a dietary source. Some of the fractions have specific functions as protective factors. The effect of diet on these components has still to be evaluated, a task complicated by the need to integrate the effects of dietary change with intercurrent infections afflicting both the mother and her baby.

TABLE 8. Nitrogen and Protein Composition of Mature Human Milk (mg per ml, Means and SD)

	Swedish Mothers	Non-privileged Ethiopian mothers
Total nitrogen	1.61 + 0.21	1.77 + 0.33
Non-protein nitrogen	0.41 + 0.04	0.36 + 0.05
alfa-lactalbumin	2.78 + 0.49	2.76 + 0.29
Lactoferrin	1.65 + 0.29	1.67 + 0.51
Serum albumin	0.39 + 0.04	0.36 + 0.07

Source: ref. 17.

Vitamins and Minerals

3.12. In contrast to the proximal constituents, vitamin content – particularly of the water-soluble vitamins – is very sensitive to dietary intake. In the Far East a maternal diet deficient in thiamin can result in infantile beri-beri(18). Riboflavin content is also affected by maternal diet, as illustrated in table 9 (1). In the Gambia, milk values are only two-thirds of those in the United Kingdom and only about half the reported American ones. Thus, despite the existence of mechanisms that favour the foetus and the suckling child at the expense of maternal stores, the baby is born biochemically deficient; because the breast-milk has a low riboflavin content, and any traditional supplementary food an even lower one, the baby remains deficient throughout infancy (19).

The vitamin C content of milk also parallels closely the monthly variations in vitamin intake and plasma ascorbic acid levels (see

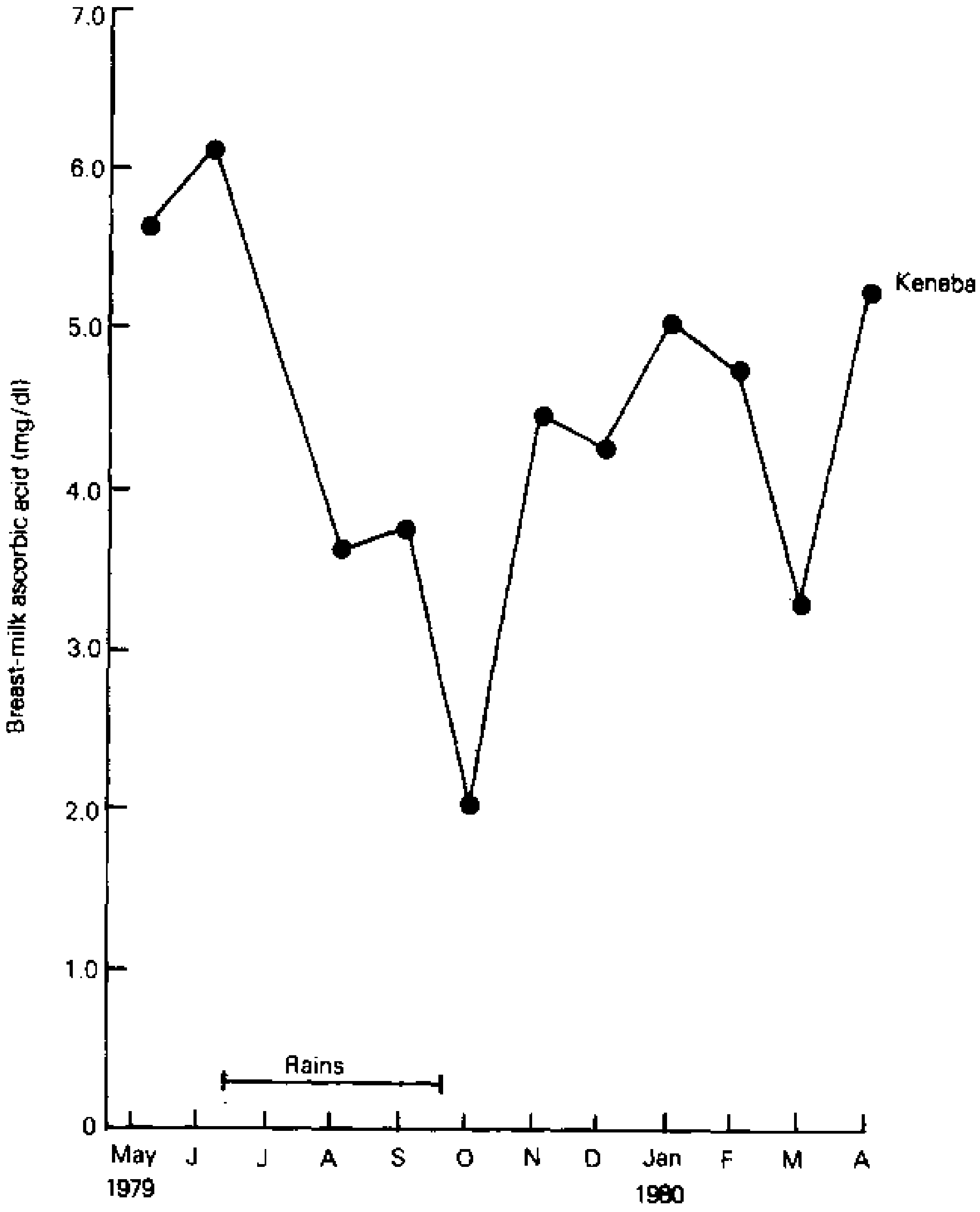

FIG. 8. Seasonal Changes in Breast−milk Ascorbic Acid in the Gambia (Source: ref. 8)) (8). Likewise, folic acid content is also affected (table 9). In the Gambian dry season, mean concentrations were 54 ng/ml, while in the wet season these had dropped to 38 ng/ml. A comparison of breast−milk concentrations of other water−soluble vitamins during the two seasons is shown in table 9.

TABLE 9. Seasonal Variations in Breast−milk Composition in the Gambia

	Dry season (N = 22)	**Wet season (N = 21)**
Mean stage of lactation (days)	149	132
Energy (kcal/100 ml)	69 ± 2	65 ± 2

Protein (9/100 ml)	1.10 ± 0.05	0.98 ± 0 07
Fat (9/100 ml)	4.36 ± 0.25	3.45 ± 0.22[a]
Lactose (9/100 ml)	6.35 ± 0.09	7.17 ± 0.09[b]
Biotin (ng/ml)	10.3 ± 0.87	8.97 ± 0.69
Pantothenic acid (μg/ml)	2.71 ± 0.14	2.04 ± 0.11[b]
Thiamin (μg/ml)	0.175 ± 0.005	0.157 ± 0.006
Riboflavin (μg/ml)	0.23 ± 0.01	0.21 ± 0.01
Vitamin B6 (μg/ml)	0.091 ± 0.004	0.115 ± 0.005[b]
Vitamin B12 (ng/ml)	0.290 ± 0.046	0.163 ± 0.040
Nicotinic acid (μg/ml)	1.49 ± 0.098	1.13 ± 0.111
Folic acid (ng/ml)	54.3 ± 5.7	38.2 ± 2.9[a]

Values are means SEM.
a. $p < 0.02$
b. $p < 0.001$
N = number of subjects
Source: ref. 1.

3.13. The situation with the fat−soluble vitamins is less dramatic but nevertheless clear−cut. A comparative study of breast−milk samples from well nourished Swedish mothers and underprivileged Ethiopian ones has shown a significantly higher vitamin A level in the former and a greater concentration of 9−carotene in the latter(20).

The fat−soluble vitamin D content of breast−milk is generally low even in well−nourished mothers. Recently, however, there has been a report of a water soluble conjugate, vitamin D sulphate, in human milk (21) but the biological activity of this derivative is still in question (22).

3.14. The mineral content of human breast−milk in relation to diet has been insufficiently studied. The calcium content is variable and there have been suggestions that malnourished mothers do produce milk with a lower average calcium content, but there is no concrete evidence to support this statement. Since calcium is crucial to both bone development and growth, this is an uncertainty that surely should be clarified. Most mothers in developing countries from poor socio−economic circumstances consume considerably less than the RDA, only about one−third of their counterparts in the Western world (see section 2.6).

The iron content of milk is very low in concentration, but it appears that it is absorbed with a very high degree of efficiency (23). This is partly, but by no means completely, because of the association of milk iron within a lacto−ferrin protein complex. It has been demonstrated in Ethiopia (17) that mothers on a high iron intake have particularly high concentrations of lacto−ferrin in their milk, even when they are living under poor circumstances. It seems therefore, that the synthesis of this protein is protected, at least under the dietary circumstances prevailing in Ethiopia. The response of lacto−ferrin to a diet low in both iron and protein is not known, however, and there is an obvious need for the effects of maternal iron balance on the various iron components of human milk to be further elucidated.

Diet and the quantity of milk produced

3.15. The general consensus is that the content of the proximal constituents of milk can be maintained within remarkably normal limits even in markedly undernourished mothers, and it is considered more likely to be the total volume produced that suffers. A major problem in defining the precise effect on volume is that we do not know with any degree of certainty how much milk one can expect from the average healthy, well−nourished mother. An arbitrary value of 850 ml has been used for theoretical calculations, but most measured, mean values in the industrial world have been less than this. In virtually every country so far investigated, volume rises steeply during the first month of life, but, as shown in figure 9 (see

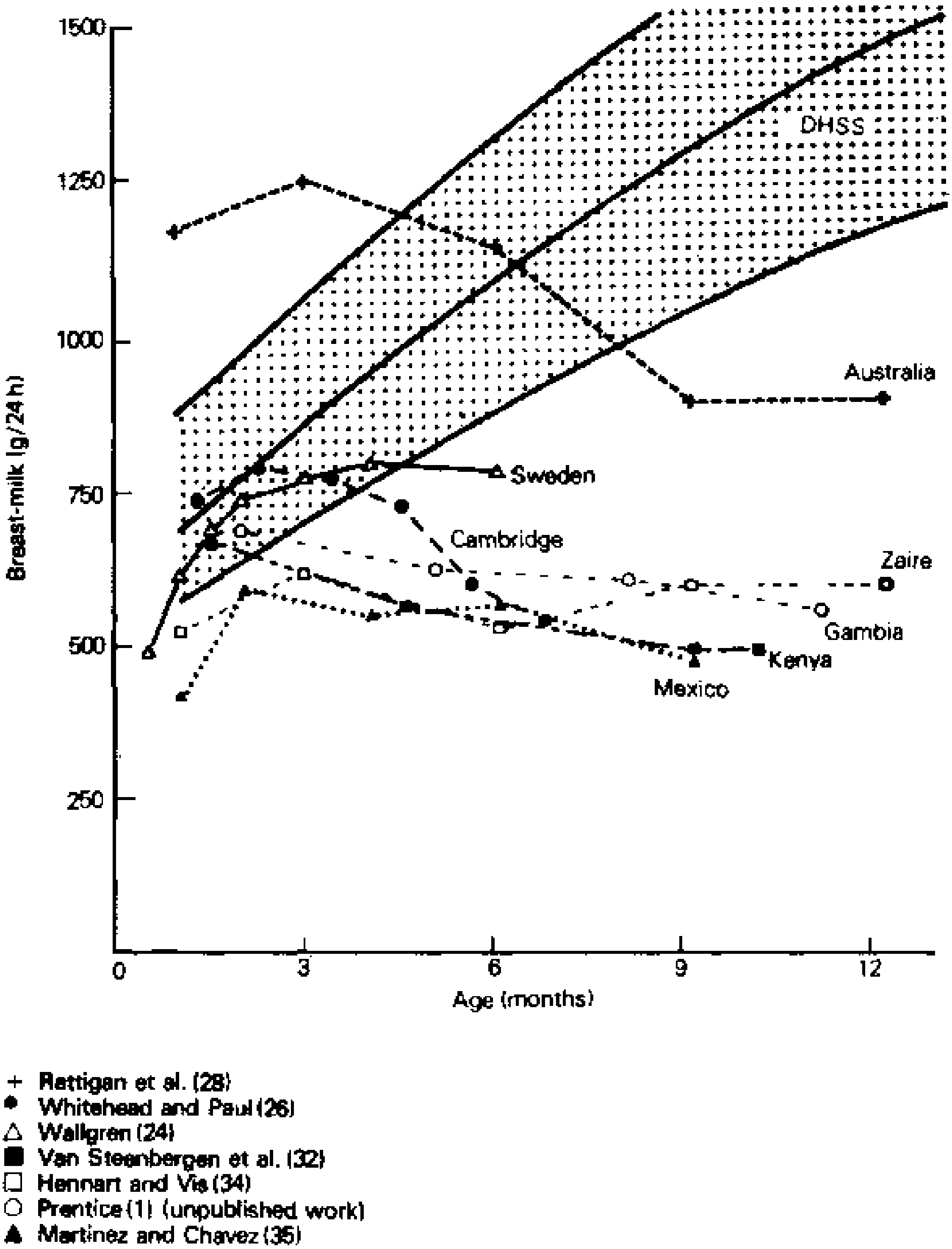

FIG. 9. Mean Daily Breast−milk Outputs during Infancy from Various Sources Compared with the Range Needed to Meet Estimated Requirements, Based on the Mean Values of the Department of Health and Social Security (DHSS) (36) (Source: ref. 31))(31), the rate of rise in milk output then falls off dramatically and total volumes quickly become less than those theoretically needed to satisfy energy requirements as the child grows older and larger. From table 10 it seems reasonable to conclude that the mean maximum volume in a wealthy country is more likely to be 700−800 ml than 800−900 ml.

TABLE 10. Milk Output (ml/24h) of Well−nourished Mothers from Industrialized Societies

		Month of lactation					
Author	**Country**	**1**	**2**	**3**	**4**	**5**	**6**

Wallgren[a] (24)	Sweden	610	727	766	784	–	778
		(416–839)	(508–964)	(497–1,029)	(577–1,065)		(510–1,123)
Lönnerdal et al. (17)	Sweden	724	752	–	–	756	–
		(490–958)[d]	(575–929)[d]			(476–1,036)[d]	
Hofvander et al.[b] (25)	Sweden	660	755	780	795	566	450
		(380–860)	(575–985)	(600–930)	(560–1,045)	(170–950)	(50–1,145)
Whitehead and Paul[b] (26)	UK	740	785	784	717	588	493
		(480–1,059)	(380–1,235)	(280–1,114)	(210–1,091)	(183–1,020)	(135–906)
Chandra[a] (27)	Canada	–	–	793	856	925	872
				(651–935)[d]	(658–1,054)[d]	(701–1,149)[d]	(602–1,124)[d]
Rattigan et al.[bc] (28)	Australia	1,187	1,238	–	–	–	1,128
		(799–1,611)	(862–1,543)				(608–1,610)
Pao et al.[b] (29)	USA	569	–	523	–	–	436
		(398–989)		(242–1,000)			(147–786)
Picciano et al[a] (30)	USA	606	601	626	–	–	–
		(336–876)[d]	(355–847)[d]	(392–860)[d]			

a. Exclusively breast–fed.
b. Includes mixed feeding.
c. Data obtained by weighing the mother, not the child (see text, 3.16).
d. Ranges calculated from mean ±2SD.

It is unwise, however, to think only about mean values; the range in Cambridge around two to three months is 4901,115 ml, and in Sweden the corresponding range from Holvander's data is 600–930 ml. An important and as yet unanswered question is whether mothers with low milk outputs did not have the capacity to produce more milk, or whether a whole variety of social and biological constraints were acting against them, such that they were functioning well below their maximum capacity.

3.16. The highest volumes reported in recent times are those from Hartmann's group in Western Australia (28). These values were obtained by test–weighing the mother. This method is highly correlated with the more usual method of test–weighing the baby. The regression co–efficient of 0.8 indicates that higher values are obtained by weighing the mother. Most of the difference between the two procedures is due to the sweating losses of both the mother and baby. Thus, the mean value for Western Australian mothers at two to three months compared with the European data would be around 1,000 ml rather than 1,200 ml. Clearly, even this value is significantly greater than any others that have been published, with the exception of old reports on "wet nurses" (37). The upper level of Hartmann's data is around 1,600 ml.

It is of obvious importance that the apparently much greater ability of Western Australian mothers to produce milk should be confirmed on a larger representative number of mothers from that community, and that the detailed and varied advice provided by the Australian Nursing Mothers Association is objectively evaluated to determine any crucial difference between European and Australian nursing practices. Recent evidence of the high incidence of breast–feeding in a wider range of Western Australian mothers is provided by the prospective growth study of Hitchcock and Owles (38), who found that 64 per cent of mothers were still breast–feeding at six months.

3.17. The study of twins and the mother's ability to feed two babies rather than one is also likely to be informative. Although twins, in the Third World, frequently suffer from infantile malnutrition, there is evidence that mothers in the industrialized countries can respond by producing milk well in excess of the normal range for singletons. Data obtained by Hartmann in Western Australia (39) on milk outputs in mothers with twins compared with mothers of single infants are given in figure 10 (see

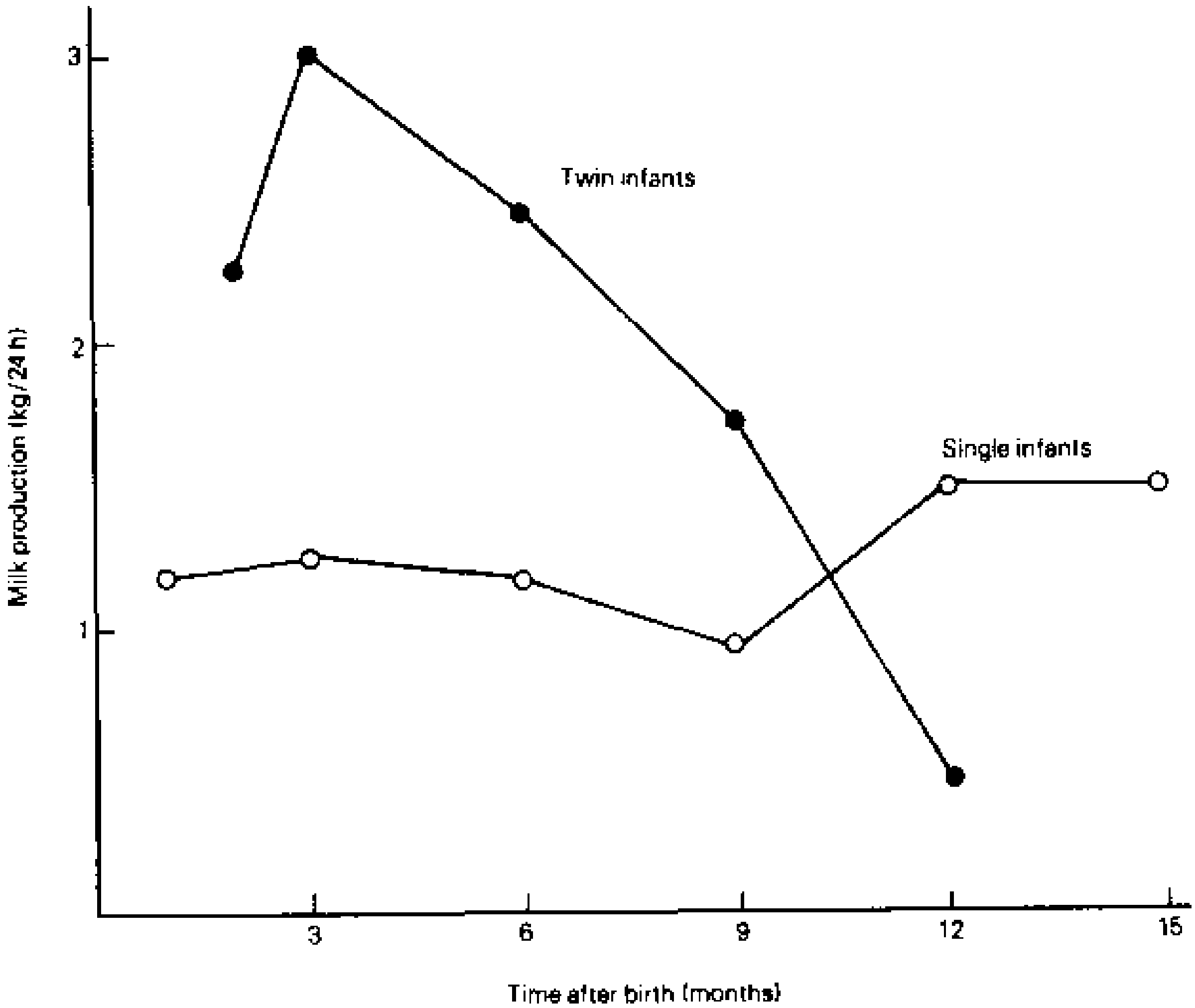

FIG. 10. Milk Outputs of Western Australian Women Breast−feeding Twins and Exclusively Breast−feeding Single Babies (Source: ref. 39)). This indicates that the greatly enhanced capacity exists only for the first six months of lactation.

3.18. The importance of the plane of nutrition on milk production has been extensively studied in dairy cows, and feeding standards based on the level of milk production have long been considered to be an important determinant of the profitability of the dairy industry. The influence of maternal diet on the level of milk production in women is much less clear. A summary of a number of studies on breast−milk consumption in developing countries is given in table 11. The ranges for the different countries are remarkably similar to those in table 10 for affluent countries. Mean values are, however, generally about 100 ml/d less at two to three months, though the mothers continue to breast−feed for much longer. These data are surprising when one considers the gross differences in dietary intake between the two types of country. The possibility exists, however, that the European mothers could have produced more milk if they had adopted different feeding practices, such as by feeding more frequently as is the custom in Western Australia, and thus the true effect of a poor diet might be masked. There is an obvious need for the optimization of milk production to be studied in wealthy countries as well as in poor ones.

There is evidence, however, that when food−energy intake falls to exceptionally low levels the mother's capacity to adapt is exceeded and milk output falls dramatically. This is illustrated in figure 11 (see

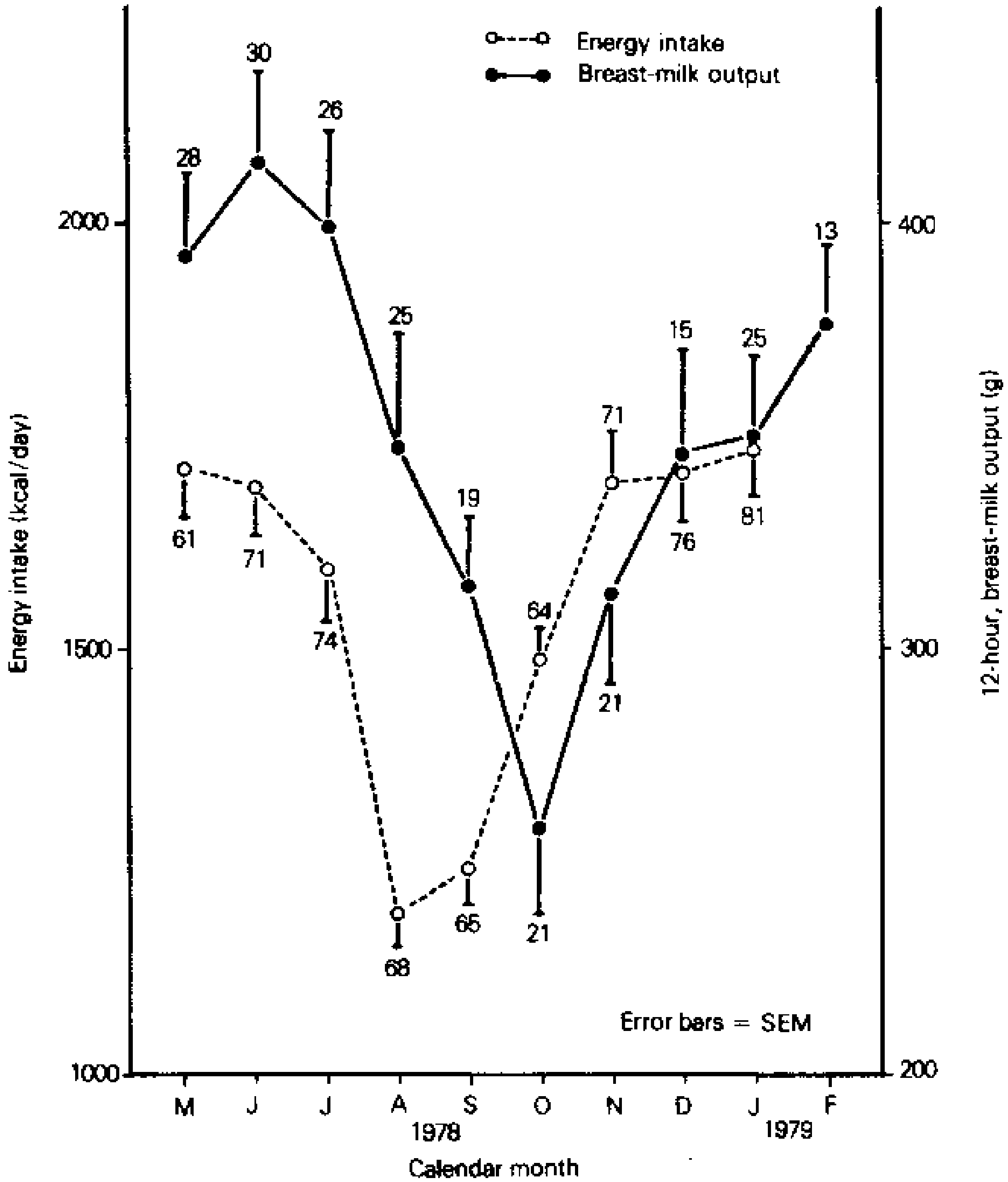

FIG. 11 Seasonal Variation in Energy Intake and Breast–milk Output in the Gambia (Source: ref. 1)), which describes the situation in the Gambia (1) during the rains when food energy intake in August–September drops to as low as, 1,100–1,200 kcal/d. Milk output drops markedly, but the mean volume of milk produced during the 12 hours of daylight is still 280 ml, which corresponds to around 600 ml/24 hr. Values of around 500–600 ml/d have also been reported from India by Gopalan (41), from Zaire by Vis et al. (34), by Van Steenbergen in Kenya (32, 33), and Martinez and Chavez from Mexico (35).

TABLE 11. Milk Output (ml/24h) of Women from the Developing World

Author and country	**Month of lactation**							
	1	**2**	**3**	**4**	**5**	**6**	**7–9**	**9–12**
Holemans et al.								

(40)	436	405	380	417	415	–	323	–
Zaire								
Hennart and Vis (34)	517	–	605	–	–	525	580	582
Zaire	(250–780)		(390–920)			(180–1,080)	(210–950)	(270–850)
Van Steenbergen et al. (32, 33)	–	675	–	–	555	–	487	–
Kenya		(271–1,079)[a]			(189–921)[a]		(153–821)[a]	
Martinez and								
Chavez (35)	–	577	–	537	–	561	–	462
Mexico		(433–842)		(455–663)		(432–850)		(337–670)
Prentice et al.	–	677	–	–	617	–	595	542
Gambia (unpublished data)		(525–1,055)			(355–885)		(435–744)	(210–730)

a. Ranges calculated from mean ±2SD.

Vis, from his work in Zaire (34), has suggested that milk output may be more affected in primary protein deficiency than in energy deficiency, hence the particularly low values in the Kivu province of Zaire. It is also possible that similar deficiencies may have existed in the Kenya study. It may be concluded that, to be sure of the effect of diet on breast–milk output, both variables, protein and energy intake, need to be measured. We need to determine unequivocally whether dietary composition, particularly a limiting protein content, is associated with an especially reduced milk production.

3.19. The major problem in comparing milk outputs between countries is the difficulty of doing so with a sufficient degree of precision. The test–weighing procedure inevitably interferes with normal life–styles and the interaction between the mother and her child: the child has to be separated from the mother at the beginning and end of each feed, even if just for a short time. Another problem is that the weight difference at each feed can be quite small. In Europe, where women feed their babies on average four to eight times per day, typical weight differences range between 100200 9, while in the developing world, where a child may be fed 10–15 times, this value is only 30–100 9. It is also necessary to modify the procedure to fit in with local circumstances and customs. With such scope for measurement error it is surprising there is so much uniformity in the data emerging from different parts of the world.

3.20. The net benefit of breast–milk to a child clearly depends on the product of volume and nutrient content. Table 12 shows such calculations made by Rajalakshmi (3) for lower and higher income families in India relative to the NRC RDA (42). As might be expected from the discussion in previous sections, infant energy and protein intakes exhibit relatively moderate deficits (20–25 per cent), while folate, vitamin A, and iron intakes suffer dramatically; intakes are of the order of only 10 per cent of the recommended value. Clearly, the effect will be different for different countries; in Ethiopia, for example, infant riboflavin intake would be more affected than in India, while iron intake would be relatively satisfactory.

TABLE 12. Nutrients Derived by Indian Breast–fed Babies as Compared with Recommended Allowances a

	Low–income group	**High–income group**	**Recommended allowances NRC (1974) (42)**
Food energy (per kg body–weight)	90	97	117

Protein (9) (per kg body−weight)	1.6	1.6	2.2
Calcium (mg)	230	230	360
Iron (mg)	1.2	1.3	10
Vitamin A (µg)	21	42	420
Thiamin (mg)	0.084	0.112	0.15
Riboflavin (mg)	0.168	0.217	0.20
Pantothenate (mg)	0.942	1.288	–
Niacin (mg)	0.791	1.057	2.5
Cyanocobalamin (µg)	0.063	0.077	0.15
Biotin (µg)	1.13	2.17	–
Pyridoxine (µg)	60.9	70.0	150
Folate (µg)	1.54	2.17	25

a. Calculated from milk composition data for 700 ml milk.
Source: ref. 3.

The effect of maternal dietary supplementation on milk output and composition

3.21. Table 13 summarizes the results of attempts to influence breast−milk production by providing dietary supplements to mothers of low socioeconomic status. Unfortunately, there have been all too few direct attempts to test the important hypothesis, "feed the nursing mother, thereby the infant", in spite of this crucial importance to public health and infant well−being in the third world. A general comment on the results would be that they have not been inspiring. There are a number of theoretical reasons why this might have been so, but one stands out: there has been generally too little attention given to the size of the deficit that needs to be filled. From the data in section 2.2 it is clear that the energy gap between mean intake and the RDA is at least 1,000 kcal/d, but few investigators have attempted to provide anything like this amount. Some of the studies have also been short−term ones and it would not be surprising if this failed to overcome a chronic problem. Furthermore, few investigators have attempted to assess the effect of their supplement on customary home intake, and it is always possible that it had only a substitution effect. For these and other reasons to be discussed, some circumspection is necessary before too firm a conclusion is arrived at on the basis of current knowledge.

TABLE 13. Dietary Supplementation and Milk Output: Studies Throughout the Years

Investigator	Year of study	Effect
Adair (43)	1925	Slight increase
Kleiner et al. (44)	1928	Slight increase in first week of infancy
Deem (45)	1931	10 per cent increase
Gunther and Stanier (46)	1946–1949	Reduced output in first week of infancy
Holemans et al. (34)	1954	Effect confined to early infancy: total volume still very low

Gopalan (41)	1958	Skimmed−milk supplementation produced no effect even when started from birth
Edozien et al. (47)	1960s	Increased output by 18 per cent when protein raised from 50−100 g/d, composition unaffected
Chavez et al. (48)	1975	Volume increased by 15 per cent but milk more dilute
Prentice et al. (14)	1980	Supplementation no significant effect on volume of milk output nor composition

3.22. Although there have been very few studies, interest in this subject has spanned a number of years. As long ago as 1925, Adair (43) attempted such intervention studies but, like Kleiner et al. in 1928(44) also working in the United States, were only able to increase milk output slightly and then only in very early lactation. It must be recognized, however, that the supplement provided was largely carbohydrate in nature. A little later, in 1931, Deem (45), working in New Zealand, investigated the effect of supplementation using a variety of diets, but unfortunately these were only given for a relatively short time, and perhaps because of this the increased milk yield was no greater than 10 per cent.

A study carried out on undernourished mothers in Wuppertal, Germany, just after the Second World War by Gunther and Stanier (46) actually produced lower breast−milk outputs in supplemented mothers in the first week postpartum, and this occurred whether they were given fat or protein and carbohydrate. The only rational conclusion one can make is that there must have been sample selection anomalies!

3.23. Returning to the Third World, in 1954 in what was then the Belgian Congo, Holemans(40) investigated the milk yield of 27 women who had been receiving 40 9 of skimmed milk per day for one year. The results are given in figure 12 (see

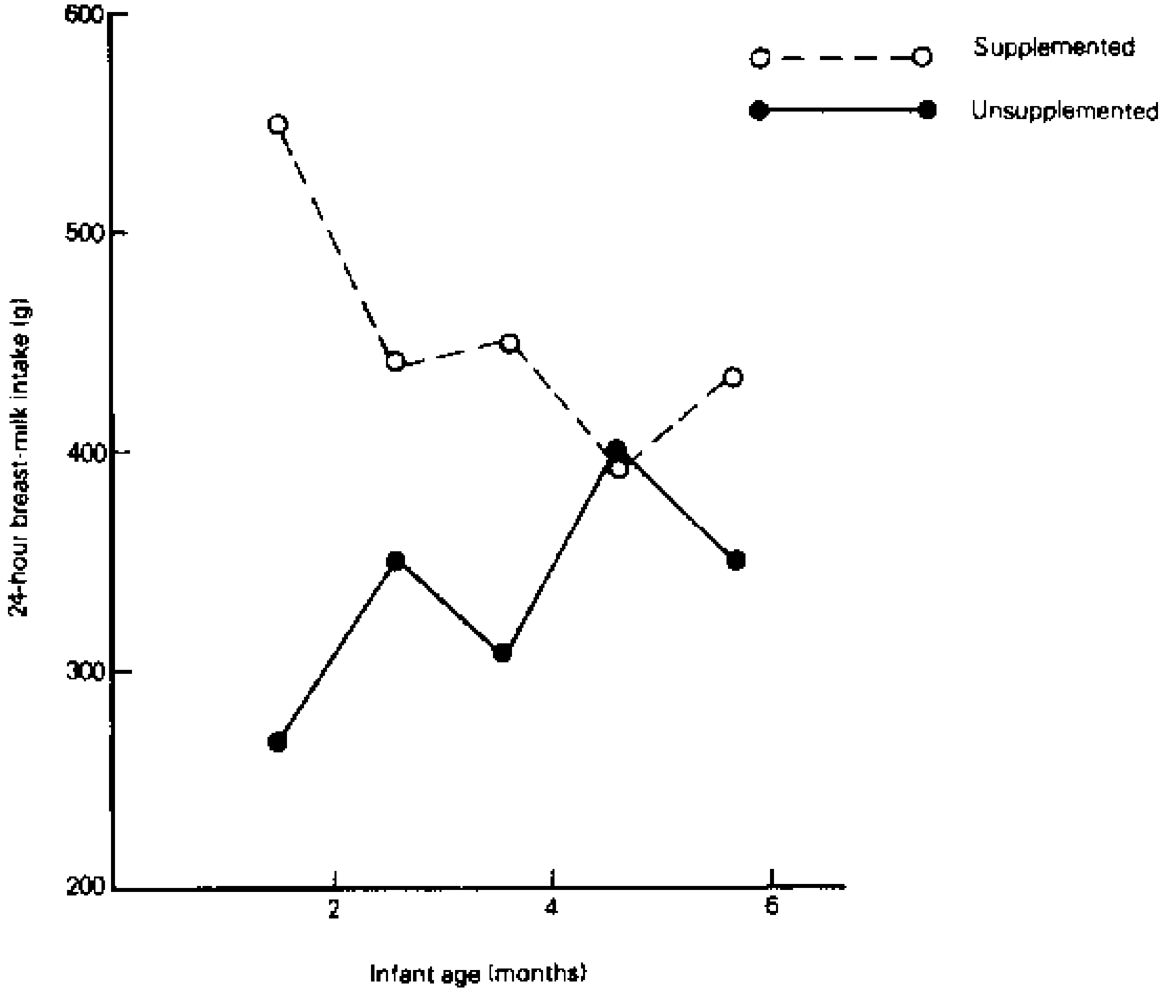

FIG. 12. The Effect of Maternal Dietary Supplementation on the Milk Intake of Young Babies from Zaire (Source: ref. 40)). Although there was some improvement during the first trimester of lactation, the resultant milk output was still very low in comparison with data collected from non-supplemented mothers in other countries. Here the problem could have been that the supplement, although given for a long time, both before and during lactation, supplied only relatively small amounts of dietary energy. The investigators were primarily concerned with filling a protein gap.

A little later, in 1958, Gopalan(41) fed a small group of mothers of 5-to13-month-old babies a series of diets containing 61, 99 and 114 9 of protein, respectively, for three consecutive ten-day periods. The diets were iso-caloric and supplied 2,900 kcal/d. The test-weighed mean milk outputs, however, were only 402, 512, and 490 ml/d. The explanation could have been the short duration of the study {only 30 days in total), and the fact that the children were mostly in the second half of infancy when the maternal supplementation commenced.

3.24. One of the best of the recent studies is that reported by Chavez et al. in 1975 from Mexico (48). This was a two-year longitudinal study in a poor and inadequately nourished rural community. The diet of the mothers was supplemented from the 45th day of gestation until weaning with 300 kcal/d. There were effects on both volume and composition, but these were such that benefits of an increased milk volume were mostly negated by the milk's becoming more dilute, by 15-20 per cent (see

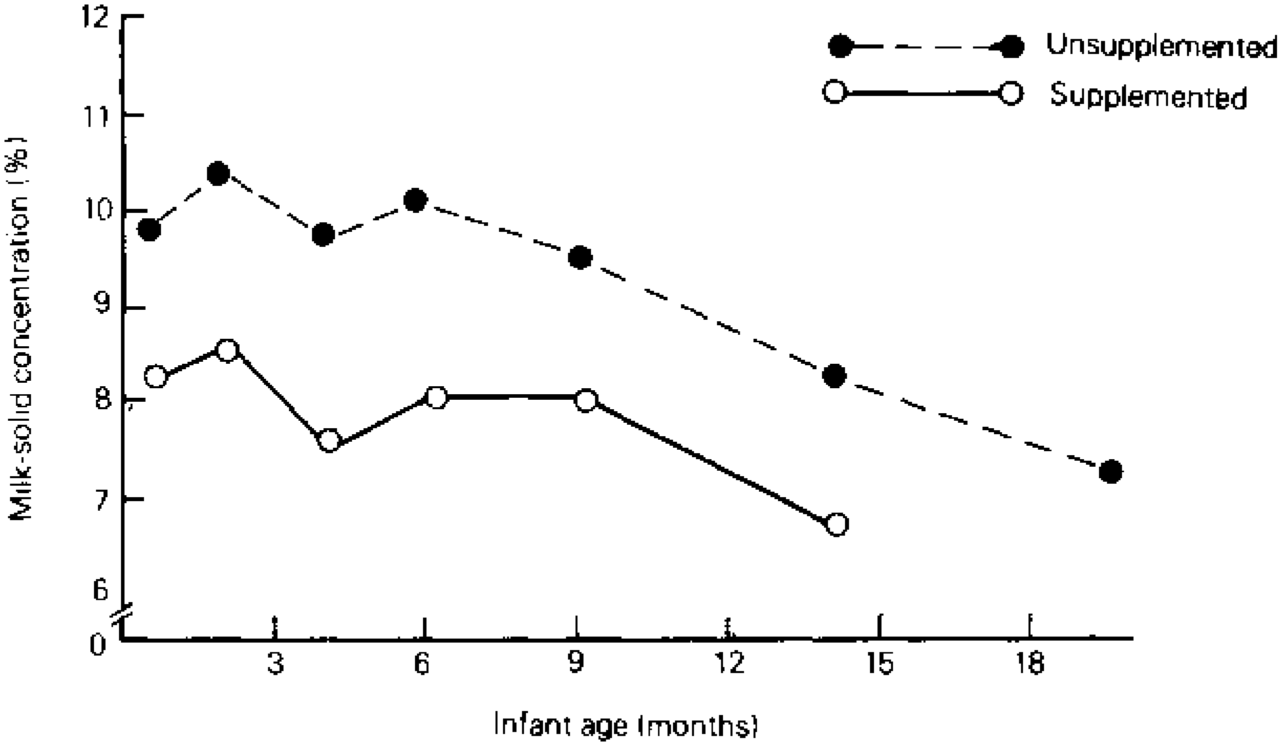

FIG. 13. Effect of Maternal Dietary Supplementation on the Solids Content of Mexican Mothers' Milk (Source: ref. 48)). Nevertheless, the impact on child growth was measurable. In this study the total mean protein and food energy consumed by the mothers by the eighth month of pregnancy was 74.9 9 and 2,225 kcal/d, and in lactation 78.6 9 and 2,365 kcal: the mean maximum milk yield achieved was 718 ml at four months.

3.25. Two other important studies in Latin America have been those of Herrera et al. in Bogota, Colombia(49), and Lechtig and Klein in Guatemala (50). Unfortunately, in neither investigation was breast-milk output measured and interpretation has to be confined to growth data. In the Colombian study (49) a supplement of 850 kcal and 38 9 protein/d unfortunately resulted in a net intake increment of only 133 kcal and 20 9 protein, because the supplement merely acted as a substitute for much of the food normally consumed at home. It therefore increased dietary intake but not to the expected level. Maternal prenatal nutritional status was shown to influence birth-weight and child growth during lactation but this was limited to the thinner women of the sample. The faster rate of infant growth was that which would have been predicted from the higher birth weight. It is arguable that a higher milk output must have been achieved in the supplemented thin women for their babies to respond in this way, but the more normal women were totally unaffected.

In the Guatemala study 150), too, the mother's diet was supplemented both during pregnancy and lactation, but unfortunately so also was the child's diet, and thus it is not easy to define with any exactness the relative contributions of each to infant growth. Nevertheless, the combined programme did achieve a statistically significant increase in attained height at 12 months of about one centimetre, and similar benefits were claimed for weight and head circumference. For the total population the increase in mean weight at 12 months of age was from 220 to 430 9, depending on the specific diet consumed.

3.26. The effect of diet on milk output and child growth is currently being studied in the Gambia(14). This investigation has a step−wise design; during the initial phase of the study the supplement was given during the whole of the first 18 months of lactation, in the second phase the supplementation has begun from the time pregnancy was diagnosed and then continued throughout lactation. By the time the third phase starts, women will have been supplemented throughout their previous lactation and will thus enter the supplemented new pregnancy cycle having enjoyed a much better plane of nutrition over a longer period of time.

After an initial year in which baseline dietary, anthropometric, and lactational data were collected for retrospective comparison, all the lactating mothers in the village were invited to take part. Attendance at supplement sessions has exceeded 97 per cent throughout the year, and consumption of the supplement at each attended session was always over 95 per cent. The supplement consists of a locally prepared groundnut−based biscuit also containing wheat−soy flour, dried skim milk, sugar, and oil. This is supplied six days a week, excluding public holidays, together with a tea drink fortified with a multivitamin supplement. The biscuit has a high energy density, about 4.7 kcal/g, and this type of supplement was chosen in the hope that it would have only a minimal effect on home food intake, which was also quantified. The mean daily intake of energy, home food plus supplement, rose from 1,568 to 2,291 kcal/d. Unfortunately, as shown in figure 14 (see

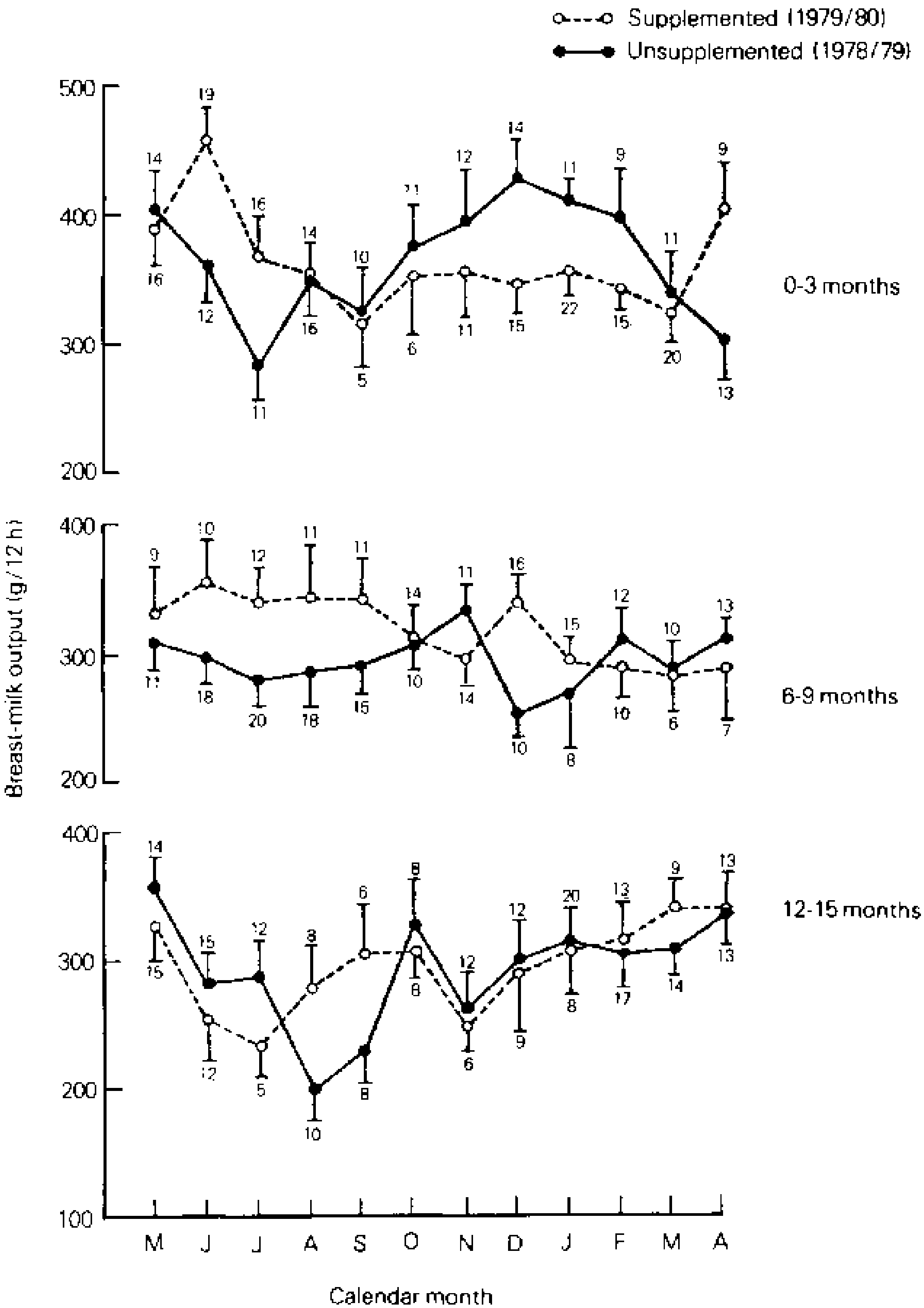

FIG. 14. Seasonal Changes in 12 h Breast−milk Output at Different Stages of Lactation in Unsupplemented and Supplemented Women. Mean and SEM and number of women are shown at each point (Source: ref. 14)), the effect on milk output has been negligible, as has the effect on milk composition.

General conclusion

3.27. It has to be concluded that the cost−effectiveness of maternal dietary supplementation as far as improving lactational capacity is concerned still has to be proved. One thing is certain, any public health programme adopting this approach will have to be carefully designed and administered if a truly convincing result is to be achieved. An improved diet during pregnancy leading to a reduction in the number of small−for−age babies seems to offer a greater potential. It is not improbable, however, that dietary well−being over a much longer time−span will be needed before an improvement in the overall pregnancy−lactation cycle will be achieved. This emphasizes the need for agencies funding applied research of this type to be prepared to do so for as long as is necessary to adequately establish the crucial biological facts. It is feared that the present inconclusive situation has been partly brought about by the lack of long−term funding for community−based fundamental and applied research. As will also be discussed, the mother and her well−being must also not be ignored in these investigations.

A major difficulty in assessing the success of dietary supplementation programmes is identifying the magnitude of change that it is reasonable to expect. The "standard" that has been used for most theoretical reasoning is 850 ml, although to satisfy the total energy needs of the average child up to the WHO/FAO estimated requirement solely from breast−feeding, for up to six months as advocated by authorities, would indicate a figure nearer 1,200 ml. We have seen, however, that the majority of studies among well−fed mothers have revealed a mean peak production value of only 760 ml. In these circumstances, it is arguable that a greater volume could not have been expected in the Gambia, as the mothers were already providing milk up to the customary norm. Chavez in Mexico (48) also achieved a mean peak value of only 718 ml in his supplemented mothers. Perhaps it is only under conditions of extreme dietary deprivation, when milk volume is very low, that maternal supplementation is likely to achieve a meaningful and worthwhile increment. It is quite obvious that a realistic and biologically attainable target needs to be identified with more certainty.

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4. Non–nutritional factors affecting milk production

4.1. It would give a totally erroneous impression to imply that maternal diet is the only, or indeed the major, variable influencing milk production. In recent years considerable interest has been focused on a number of sociological and physiological aspects including: economic, social and emotional pressures; the endocrine response; the operative condition of breast–feeding reflexes such as the suckling reflex; the frequency, duration, and intensity of the nursing stimulus; and so on. Many of these studies have been based in the metabolic ward or physiological laboratory, and there have unfortunately been few controlled community investigations on representative numbers of people living under different prevailing circumstances to clarify their wider public health significance.

Frequency of feeding

4.2. When one compares communities in the Third World with those in the industrialized countries, frequency of breast–feeding provides one of the greatest differences. In industrialized countries, eight times, quickly falling to five times, per day is a common finding, while in Third World countries the rate may be 12–20 times. Even within an apparently homogeneous environment important differences can be detected, however, as recently shown by Delgado et al. (1). who studied poor people in Guatemala on a prospective longitudinal basis. They showed that, at three months old, babies who were larger in weight and length and who had been heavier at birth were breast–fed less frequently per 24 hr than their fellows. Their mothers were also heavier and their fathers were taller. The same tendencies remained even up to 12 months, particularly the association with father's height. Delgado has reasoned that father's height reflects long−term socio−economic status. Infant morbidity was also higher the greater the number of breast−feedings per day.

These results would seen to run counter to accepted dogma that frequent feeding is a good thing and to be encouraged as a way optimizing milk output. Such advice might be valid when the average rate of feeding is only five times per day, but a quite different interpretation suggests itself under the circumstances prevailing in poor Guatemalan communities. Delgado has reasoned that those mothers who are relatively better nourished during pregnancy and lactation, produce milk more easily that undernourished mothers, and thus readily satisfy the needs of their infants. As a result the infants of better nourished mothers obtain the quantity of milk needed in fewer breastfeedings, in less time, and with less effort. The higher morbidity rate found in frequent feeders indirectly reflects associated poverty and, presumably, the less than satisfactory hygienic circumstances that exist within such homes. These investigations need to be repeated in many more centres using the same protocol.

These conflicting observations on the importance of suckling frequency may be related to the behavioural responses of the infant. Suckling in babies is not only initiated in response to a need for nourishment but also in response to a need for security and comfort. In addition, suckling can be initiated by the mother in an attempt to comfort a distressed infant.

Supplementary feeding

4.3. Another factor contributing to reduced milk outputs in many countries is that better nourished mothers are tempted to start supplementary feeding at too early a stage. Although true complementary feeding is to be encouraged between four and six months, it must be acknowledged that its ill−advised introduction, plus the apparent ease of bottle−feeding, frequently does result in the rapid abandonment of breast−feeding altogether.

The removal of some of the infant's drive for breast−milk also have an inhibitory effect on the mother's milk−producing capacity and she can be led into the mistaken belief that she is no longer physiologically capable of producing reasonable amounts of milk. On the other hand, if supplementary foods are introduced on a basis of infant choice (i.e. child−led introduction of supplementary foods) supplementation does not necessarily lead to the rapid abandonment of breast−feeding. The rational timing of the introduction of other foods is a complex issue. It is bound to vary with the specific physiological, sociological, and economic circumstances of each mother−baby pair. This topic is a subject of intense current debate and another United Nations report 12). It would be inappropriate for it to be pursued in greater detail here.

Menstruation

4.4. Although women do not ovulate during early lactation, the later stages of prolonged breast−feeding are frequently accompanied by menstruation. The factors influencing the onset of ovulation during breast−feeding form the main subject in the second part of this report. The reason why there is sometimes breast refusal during the menstrual cycle is unclear, but Hartmann and his colleagues (3) in Western Australia have found major, acute changes in milk composition occurring in the mid follicular and mid−luteal phases, though their exact signification awaits clarification.

Pregnancy

4.5. There are widespread taboos inhibiting breast−feeding during pregnancy, not without good reason for marginally nourished communities, because of the double stress to the mother. Some tribes in Africa firmly believe that the child in the womb will poison the baby being breast−fed. Whatever the local reason, recognition of pregnancy usually results in an abrupt cessation of breast−feeding. This is the origin of the term "kwashiorkor": the illness produced by a child being displaced from the breast by a new pregnancy.

The renewed interest in breast−feeding and its duration for longer periods in the Western world has resulted in many women becoming pregnant while breast−feeding, and a few but increasing numbers of well−nourished and healthy women breast−feed throughout pregnancy. In Australia, Hartmann has reported tandem feeding, breastfeeding both the newborn and older infant. The consequences of such feeding practices both in developed and developing countries clearly merit further investigation.

Smoking and drugs

4.6. Although the significance of therapeutic drug−taking for human lactation has been recognized, there is still an immense gap in this area. Also little is known of the effects of social drugs such as alcohol, caffeine, and nicotine. Hartmann has, however, observed some differences in milk composition at the initiation of lactation between smoking and non−smoking women that could interfere with the establishment of successful breast−feeding. Once this hurdle was overcome, however, there appeared to be little difference between the two groups of mothers.

Social pressures

4.7. Of all the factors influencing lactation, there can be little doubt about the overwhelming importance of social pressures. If the custom within a community is to breast−feed up to two years, then this is what the majority of women will do. If, however, the social attitude is that breast−feeding is rather distasteful, a not uncommon attitude in some communities in the industrialized world, there will be a low prevalence of breast−feeding. Such active discouragement compounds any real difficulties the mother may have, fuelling the worry that she may be physiologically inadequate and thus incapable of satisfying the dietary needs of her baby.

In many ways the mother in traditional societies is better off than her counterpart in the industrialized world. She at least has plenty opportunity to seek advice at a mother−to−mother level and is not dependent on the frequently uninformed views of health professionals. In this regard societies devoted to the promotion of breast−feeding, like the La Leche League, the Nursing Mothers Association of Australia and the National Childbirth Trust, in the United Kingdom, play an important role. It must be recognized, however, that such organizations can be just as much victims of misinformation as the health professionals. There is a widespread and urgent need for objective, broadly based studies on factors controlling lactation under both optimal and suboptimal breast−feeding situations in different socio−economic circumstances.

The effect of diet on the endocrinology and metabolism of lactation

4.8. On a number of occasions in this report reference is made to possible alterations in the overall physiology of lactating women that could make them metabolically more efficient when forced to subsist on a diet of marginal adequacy. The same processes are also of significance to the duration of lactational amenorrhoea.

Unfortunately, the metabolic control of human lactation is a subject about which there are huge gaps in our knowledge. Most available information is from animal studies, and the relevance of this to humans is debatable(4). The problem is highlighted by the fact that it was not until 1970 that human prolactin was identified as a separate hormone, and radio−assay techniques for its estimation were not available until 1972.

The biological processes that finally lead to the delivery of milk to the baby can conveniently be considered under the following headings (41: (a) the development of secretory tissue within the breast; (b) the initiation of lactation, or lactogenesis; (c) the maintenance of lactation, or galactopoesis; and (d) milk ejection.

Development of the breast

4.9. The enlargement of the gland at puberty is due to changes in the stroma, with deposition of periglandular adipose tissue. During the menstrual cycle there are changes in breast volume, probably accompanied by changes in the mammary epithelium, with increases in stromal oedema, luminal size, IgA, DNA and, perhaps, lactalbumin synthesis in the luteal phase of the cycle. These may be of great importance in preparing the breast for the major development of ductal and secretory tissue that takes place during pregnancy, but more research needs to be done on this subject.

The initial cycles after puberty are frequently anovular, as indeed they are during or immediately after lactation (see sections 7.2, 7.31. In the first trimester of pregnancy there is an extension and branching of the duct system; alveoli containing the secretory cells develop in the second trimester. The hormonal control of these changes is poorly understood, but studies in animals have suggested that insulin, cortisol, thyroid hormones, oestrogens and progesterone are required. Investigations in ruminants also indicate that placental lactogen (HPL) is necessary and levels of this hormone rise steadily throughout human pregnancy. Prolactin has also been implicated as being crucial, and this hormone exhibits massive increases in plasma concentration during pregnancy. Growth hormone, too, seems to play a specific role in some species, but a unique function is unlikely in humans, as placental lactogen and growth hormone have very similar actions.

It is quite clear that this is an area that should be investigated much more intensively, since inadequate breast development during pregnancy is known to be intimately implicated in poor lactational performance in animals. It is also reasonable to speculate that a poor diet during pregnancy may be just as significant to the preparation of the mammary glands for breast-feeding as is the development of the placenta for adequate intrauterine feeding.

4.10. Comparative studies in undernourished Gambian and well-nourished Cambridge women during pregnancy have indicated that a poor diet does lead to comparatively low circulation levels of insulin, T3 and oestradiol during each trimester IP.G. Lunn, personal communication). The concentrations of these hormones normally rise during pregnancy but this effect is by no means as great in the Gambia as it is in Cambridge. Unfortunately, the functional relationship between plasma concentrations and mammary-gland physiology is not fully understood, but insulin is the major anabolic hormone and the markedly elevated levels found in well-nourished pregnant women are presumably associated with placental, foetal, and breast growth as well as fat storage. Most of these are known to occur to a lesser extent in undernourished mothers, which would fit in with low plasma insulin levels.

If animals are made hypothyroid, mammary-gland development is reduced and eventual lactation is poor. Thus, the low T3 values found in the Gambia could also be of functional relevance. The comparatively low oestradiol concentrations are also probably tied up with the reduced fat deposition of the Gambian mothers. Cortisol concentrations were, however, very similar in the two groups, as were placental lactogen and progesterone. Prolactin concentrations were statistically significantly higher in the United Kingdom, but the overall difference was not great and the physiological significance, if any, must be small.

Lactogenesis

4.11. There is only limited information on the crucial metabolic and endocrine processes necessary for the initiation of lactation in humans. It seems, however, that as in the majority of animals so far studied, the main trigger for lactogenesis in the human is the drop in plasma progesterone level that occurs as a consequence of delivery and the loss of the placenta (4, 5). The period for which progesterone needs to be withdrawn is probably very short, since progestogens given for contraceptive purposes do not affect lactogenesis or lactation, provided they are given one or more days after delivery. It is generally postulated that the previously high concentrations of progesterone have had the effect of blocking the binding of prolactin to receptor sites in the mammary gland, thus preventing milk production during pregnancy. This is clearly not complete explanation, as women can produce a considerable amount of milk during pregnancy if they continue to nurse a previous baby. Furthermore, some secretory activity as well as the production of alfa−lactalbumin and lactose have been observed in non−nursing pregnant mothers before delivery.

The initiation of lactation is critically dependent on raised levels of prolactin around the time of delivery(4, 6). In this respect the malnourished mother appears not to be disadvantaged; certainly this is the case in the Gambia. In women who are unable to produce raised levels of prolactin, the initiation of lactation does not occur. Human growth hormone is not involved in human lactation, as it is in many other animals, since lactogenesis can occur in its absence.

Toaff (8) has hypothesized that the suckling reflex's initial impact overrides the inhibitory effects of gestogens (which are already present in the perinatal blood in massive amounts from placental origin). Suppression of the maintenance of lactation by oestrogens was, however, found in 25 reported studies after the post−partum period (8). The suppression is more substantial after several months of combined pills(9). There is, however, a need for further research, especially in developing countries to clarify the effect of oestrogens on lactation. There is also some argument about the size of women in relation to drug dosage.

Maintenance of lactation

4.12. There is much circumstantial evidence to support the view that prolactin continues to be of major importance for the maintenance of lactation. Del Pozo has demonstrated that if bromocryptine is administered, which totally inhibits prolactin secretion, milk production drops to zero within a few days even if mothers continue to use a breast pump (10). In well−nourished mothers it is known that basal prolactin concentrations fall rapidly after parturition, reaching normal values at two to three months(4, 11, 12). Thus, it would appear that only short bursts of prolactin secretion are necessary after each feed for the maintenance of lactation.

In undernourished mothers, however, high basal levels are maintained for periods up to two years(13, 14). Why this is so is not known, but it is reasonable to suppose that it is related to the need for frequent suckling, which appears to be the only way the baby can ensure for itself an adequate supply of milk. Dietary supplementation has definitely been shown to result in a significantly faster fall in basal plasma concentrations(14). The data in figure 15 (see

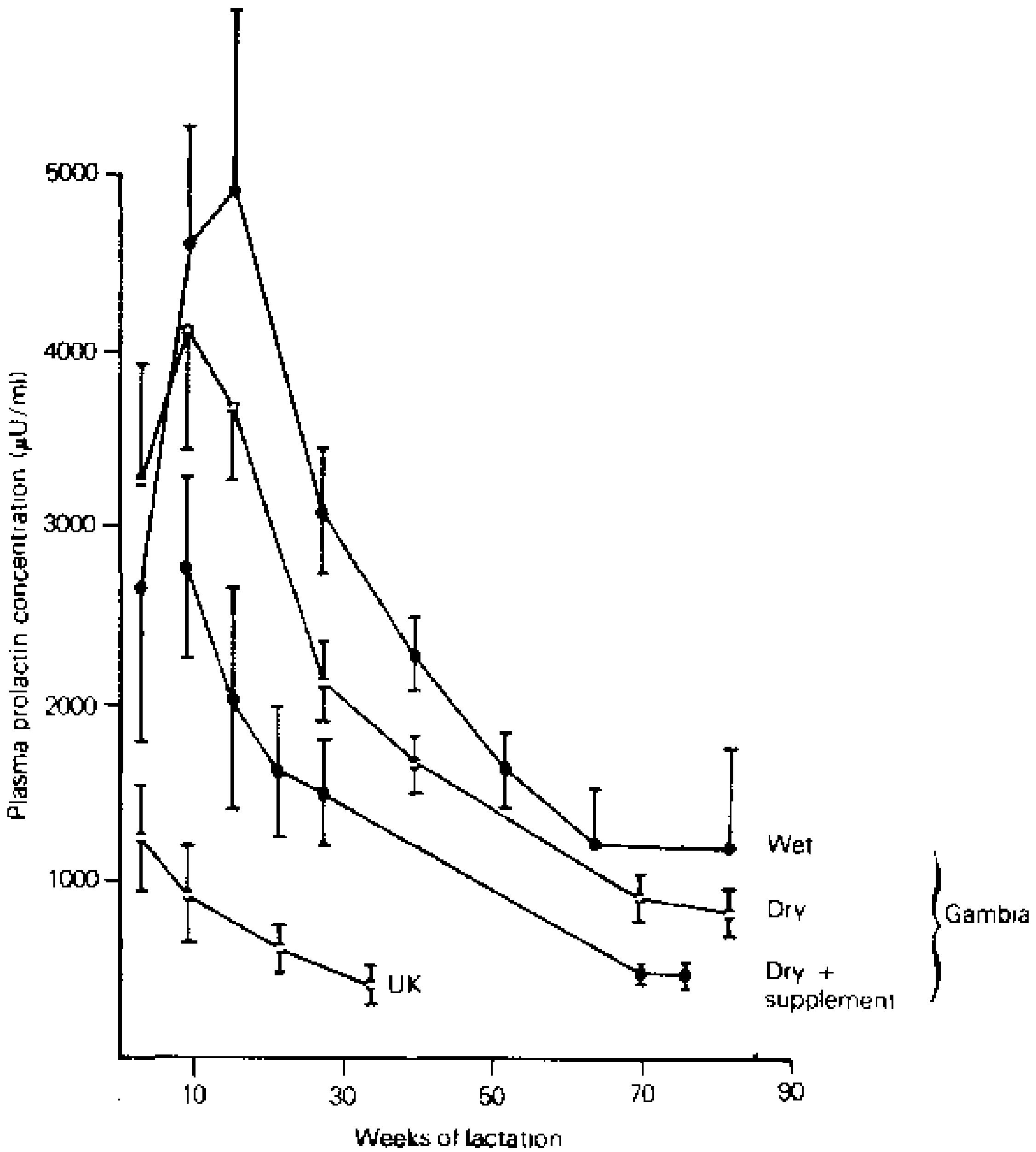

FIG. 15. Plasma–Prolactin Concentrations in Lactating Mothers in the United Kingdom and the Gambia. Values given as Mean SEM. Number of Observations in Each Group was: UK 37; Gambia Wet Season 128, Dry Season 109, Dry Season with Supplement 37 (Source: ref. 14)) are from the Gambia. Even though total intake of milk by these children was not greater (section 3.26), and the frequency of feeding was apparently unaffected, it has been postulated that the child could satisfy his needs with much greater ease.

The role of insulin and corticosteroids should also receive attention, as these hormones are as important as prolactin in the initiation and maintenance of lactation (15).

Oxytocin release

4.13. Milk ejection is also an important variable in human lactation, especially under the particularly stressful social circumstances that can prevail in industrialized countries. Only small quantities of milk in the breast are available to the baby if no oxytocin is released during the initial period of suckling 14). A vicious downward spiral can result if a mother is upset and does not release oxytocin: the baby quite naturally becomes agitated because of a lack of milk, and equally naturally the mother becomes more and more upset, which can have the effect of reinforcing the inhibition of oxytocin release. Exactly why the oxytocin–releasing reflex is so sensitive in many women living in industrialized communities is not known. Some encouraging results have been obtained in mothers resorting to nasal oxytocin sprays. Quite obviously this is an area that merits considerably more research.

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5. Family planning and its relation to nutritional well-being and to maternal and child health

Lactation and Birth Spacing

5.1. Lactational amenorrhoea is a well-recognized phenomenon and has frequently been presented as "nature's way of ensuring an adequate time interval between the birth of one baby an the next". Lactational amenorrhoea is a variable component, however, and its duration is influenced by a number of factors, notably dietary status and the specific hormonal responses of individual women, especially with respect to prolactin. It was largely because of the important endocrine links between diet, lactation and the return of fertility after child−birth that this multi−disciplinary workshop was organized.

The contraceptive effect of breast−feeding is frequently emphasized in public health teaching, but the fact that lactation is by no means 100 per cent effective as a method of birth−control is shown in table 14. In some countries − notably India, Zaire, and Ethiopia − a substantial number of women become pregnant while lactating and about 10 per cent become pregnant without menstruation. Quite clearly nutritionists and health workers who are involved in trying to improve the nutritional status of women during pregnancy and lactation need to be aware of potential side−effects on lactational infertility. It has indeed been argued that maternal dietary programmes need to be operated in close conjunction with those public health services providing family planning. In view of this, the working party felt it advisable to review current attitudes towards family planning, birth spacing, and child health in general.

TABLE 14. Percentage of Women Pregnant Who Were Still Breast−feeding and Who Said They Became Pregnant without Resumption of Menstruation

Country	Group	Breast−feeding	Pregnant without menstruation
Hungary	all	3.4	8.4
Sweden	all	0	11.1
Ethiopia	rural	30.4	4.2
Nigeria	rural	0	0.9
Zaire	rural	29.7	1.2
Chile	rural	4.2	7.3
Guatemala	rural	36.7	2.9
Philippines	rural	6.0	8.2
India	rural	70.0	11.3

Source: ref. 1.

Family planning in perspective

5.2. Family planning has been given many interpretations and meanings in different situations and over time. Within the context of this report, however, it is more rational to translate family planning as encompassing organized efforts to have child−bearing initiated at a culturally and biologically acceptable age, spacing the birth of individual children adequately, and stopping childbearing at an age commensurate with biological and social realities.

Family planning is not a new concept. Throughout history there have been taboos, customs, and practices that have evolved because of the need to ensure an adequate but not excessive or harmful rate of birth. The scientific rationale behind some of these taboos has not always been clear, but it is interesting that modern scientific investigations are beginning to provide an understanding as to why some customs have been so long maintained. Equally, it is apparent that these are times of rapid social change and in many situations newer life−styles, urbanization, women going out to work, and education, etc., have resulted in a loss of some valuable traditions. This has meant that in many societies child−bearing is taking place without the natural constraints that used to apply. As in so many facets of our life, we have been forced to apply modern technologies to ensure birth planning and the stabilization of population numbers.

It is widely held that the life−style and health status of mothers are closely related to the early viability and health of their offspring. Among the many factors that interact in this mother−child dyed, the following may be selected as being the most important: frank malnutrition, maternal age, nutritional state and status, birth interval and total family size.

Malnutrition

5.3. It is a general conclusion that malnutrition has to be extremely severe before it seriously affects actual fecundity, but it can influence the outcome of pregnancy, most notably by affecting placental growth, leading to babies with a low mean birth−weight. The seasonal effects on birth−weight found in the Gambia are shown in table 15(2). These data are similar to those obtained elsewhere; undernourished mothers tend to produce babies 300 9 smaller than well−nourished ones, and there is a greater proportion of children born less than 2.5 kg in weight. Low birth−weight babies are less likely to survive during the first year of life than normal birth−weight babies(3, 4, 5). Low birth−weight is closely associated with neonatal mortality rates (6).

TABLE 15. Seasonal Variations in Birth−weight in the Gambia

	Dry season	**Wet season**[a]
1976/77		
Birth−weight (kg)[b]	3.02 ± 0.07 (39)[c]	2.72 ± 0.08 (31)[d]
1978/79		
Birth−weight (kg)	2.94 ± 0.07 (33)	2.78 ± 0.11 (21)
Gestational age (weeks)	39.3 ± 0.25 (29)	38.6 ± 0.57 (19)
Expected weight for age (%)	89.0 ± 1.7 (29)	84.7 ± 2.6 (18)

a. Wet season defined as July to November.
b. Values are means ± SEM.
c. Number of subjects in parentheses.
d. $p < 0.01$.
Source: ref. 2.

Maternal Age

5.4. Maternal age is very important in pregnancy outcome and the early health of children (7). It is considered best for women to start having children in their early twenties and to stop at about 35 or soon thereafter (8, 9). Very young mothers have problems not only with their own health but with that of their children as well. The recent increase in teenage pregnancies in the industrialized countries has provided some opportunity to study the problem of child−bearing at too early an age (10), but more investigation is required, particularly in the developing countries. Here the mother may well still be growing towards her final mature stature, and the nutritional and metabolic stresses of pregnancy and lactation will be exceptionally severe. There are also more complications with the pregnancy itself and the baby, once it is born, also frequently faces grave difficulties. Irrespective of nutritional status, there is more likelihood of low−birth−weight children, of still−births and neo−natal deaths among the children of mothers who are younger than 20 years. The lower the age, the greater is the probability of difficulty. All studies of this problem have indicated that the optimum time for beginning child−bearing is 22 to 23 years.

Adolescent mothers also tend to be poor breast−feeders for various reasons. Their own pre−pregnancy nutritional status is often inadequate, the supervision of the pregnancy can be fraught with tension. After delivery, social requirements and pressures all militate against the proper establishment and maintenance of breast−feeding, with the customary far−reaching consequences for survival under the type of circumstances prevailing in the developing world. Frequently there are also pressures on the pregnant girl to have an abortion, and in practice this tends to be too late, often in the second trimester, and the complications that arise can be severe.

High maternal age, too, is of importance in this respect and, especially in the developing world, a woman having her first child in her early thirties is at special risk. Obstetric complications are greater and the risks of still–births, of immaturity and prematurity are also higher. Women who continue childbearing into their late thirties and forties are also at risk, as are their children. Congenital malformations increase with maternal age, and also with birth order, both having a separate, demonstrable effect.

Birth Intervals

5.5. Particularly in the developing world, pre–school child mortality is much higher among children in families with short birth intervals. Swenson(11), in a study in rural Bangladesh, reported that childhood mortality is significantly higher among children whose birth is followed by another pregnancy in less than 12 months compared with children whose birth is followed by another pregnancy in greater than 12 months.

Gordon and Wyon (12), in a study of 1,479 children in the Punjab, India, showed that infant mortality tended to increase with family size and short birth intervals. Over 50 years ago, in the United States, Woodbury(13) reported a decrease in both neonatal and infant mortality as birth interval increased from 12 to 48 months. Short birth intervals are also associated with a higher prevalence of malnutrition. Wray and Aguirre(14), in their study of preschool children in rural Colombia, showed that when inter–pregnancy interval was over 36 months there was an appreciable decline in malnutrition. They further showed that there was significantly less malnutrition, among children in families with four of fewer pre–school children compared with families with five or more. The birth intervals for a mother with four or five or more pre–school children must necessarily be very short.

It has been found in many studies that, when the interval between one birth and the delivery of the next child is at least 24 months after delivery, this proves to be the most satisfactory both for maternal and child health and wellbeing. In all studies in impoverished tropical countries where the birth interval is substantially less than two years, a higher incidence of protein–energy malnutrition has been reported. There is also a greater prevalence of diarrhoeal and other diseases.

Birth interval is also important in another respect. In many cultures the onset of pregnancy is the signal for a child to be weaned (see section 4.5). It is not impossible for fertility to return in under three months after the delivery of a child, and it is therefore theoretically possible for a woman to have two children in the same year. In the developing countries in general, or when mothers come from the lowest socio–economic stratum, any birth interval that does provide for long–term lactation and breast–feeding is very likely hazardous to that child's continued life; poverty and poor hygienic circumstances preclude the preparation and use of safe, nutritious commercial milk preparations or other weaning foods. In defining the minimum, safe birth interval it is always necessary to consider the prevailing circumstances of the mother and the society in which she lives, but all studies would suggest a minimum interval of two years.

Family Size

5.6. The total number of members in the family is also related to the incidence of adverse circumstances. Diarrhoeal and communicable disease have been shown to correlate positively with family size. Dingle et al. (15), in a longitudinal study of families, showed that the incidence of various common illnesses increased with family size. They observed that, not only does the number of episodes per family increase, but also the number of illnesses per person per year increases. The incidence of severe clinical malnutrition has also been shown to exhibit a marked increase after the seventh parity. In Ghana it has been shown that the food available to larger families, per head, was frequently lower than that available to smaller families, and this was reflected in growth rate (R. Orraca–Tetteh, personal communication).

The surveys made in Kivu and Rwanda (16, 17), show the same phenomenon: food intake per capita decreases with the size of the family. This seems a general rule when we deal with a self–subsistence economy. Mortality in infancy and the second year of life has also been shown to be high in families with over five children. Data from the Khanna Study (12) showed that the effect of family size on childhood mortality was more dramatic in the second year during which the seventh or later–born children had a second–year mortality six times greater than that of second–born children. Growth, too, is inversely related to family size.

These effects almost disappear, but not quite, when data from high socio−economic families are examined. Social and economic development, as well as the creation of accessible family welfare services, should contribute to diminishing most of the above ill−effects associated with large family size.

There has also been much speculation about the influence of family size on intellectual attainment(181. Studies in France, the United States, and the United Kingdom, using different measurements of intelligence, have all indicated that there is an inverse relationship with family size, but the exact nature of the association depends on social class. Thus, it is more apparent in the children of farm−workers, manual labourers, and unskilled office−workers than in the children of the professional classes. It has been concluded that family size is only one factor affecting intellectual attainment, and it is only when other external and social circumstances are also suboptimal that family size exerts a truly strong influence.

Maternal care

5.7. It would be wrong to think of child development only in terms of its interaction with malnutrution, infection, and social status. The amount of time a mother can spend with her baby is also of paramount importance. Such attention is inevitably concentrated on the youngest baby and therefore the weaned child who is not quite old enough to help himself is likely to be ignored much more than is desirable: he does not get sufficient maternal stimulation to optimize his neurological development. In extreme circumstances he may also not get his fair share of the family food. Studies of this phenomenon have shown the problem to be at its worst when a mother has more than one child under five years at the time a new pregnancy commences.

Lactation and breast−feeding

5.8. This was one of the central themes of the workshop and is thus discussed in detail in section 6. Maximal lactation and breast−feeding up to two years used to be a major mechanism by which two− to three−year birth spacing was achieved in many developing countries. Various taboos and religious beliefs that forbade intercourse while a mother was lactating supported this process, as did indirectly, polygamy and the separation of husband and wife into different sleeping huts. Breast−feeding does afford protection against conception, but its effectiveness cannot be specifically guaranteed in the individual woman. On a statistical basis there is no doubt about this phenomenon, and many studies have shown a marked difference in the return of menstruation between mothers who bottle−feed, partially breast feed, and completely breast−feed their babies. As with most of the factors considered, however, the effect is influenced by socio−economic class, and it has been postulated that part of the long−term protective effect of longterm lactation in the Third World can be attributed to the poor dietary and health status of the mother. This, too, is discussed in section 6.

Family−planning technologies and side−effects on lactation

5.9. As already indicated, sociological changes have removed, at least partially, traditional barriers to population growth, and our current way of life is making artificial contraceptive methods more and more necessary. Unfortunately, these can have side−effects that may affect early life and the well−being of women and children. The high−dose oestrogen−combined pill has, for example, been shown to have an inhibitory effect of lactation and is no longer in general use. There is general agreement, however, that pills with under 50 µg of oestrogens do not affect lactation, if introduced after lactation is fully established (see section 4.11.). There is, however, a need for this to be confirmed in the lesser−developed countries, as there is some argument about the size of the women in relation to drug dosage.

The effect of the pill on micronutrient metabolism and physiological needs also needs to be clarified(19). Recently, the mini−pill (progestin only) has been advocated as the best contraceptive during breast−feeding, but it has also been claimed that this can limit breast−milk output and hence may result in earlier than desirable weaning. Saint and Hartmann (unpublished data) have found that milk production was not depressed in mothers who began to take the mini−pill. However, there is a general belief by mothers in Perth that the mini−pill decreases milk production. Because of the crucial importance of long−term lactation to health and well−being in the developing world, this is clearly a problem that needs to be studied in greater detail.

For over 12 years injectable contraceptives, mainly Depo−Provera (depomedroxyprogesterone acetate, DMPA), developing and some developed countries. It has proved safe and efficient and has been shown to have either no adverse effect or an enhancing effect on lactation. It is also secreted in the milk and this makes some concerned about its effect on the baby. But it is not an easily assimilable substance and no adverse effect on babies has been noted in studies thus far.

Because the FDA and the British Committee on the Safety of Drugs have refused to approve the use of DMPA as a contraceptive, there is intense controversy about its use in developing countries. The only way to silence the critics is to produce more evidence on the safety and efficacy of the drug in use.

Some studies have reported that progestin alone by mouth or by injection enhances lactation. Choudhury (20) reported that DMPA when administered to lactating women at a dose of 150 mg, every three months significantly raised prolactin levels over a control group. He also observed that, while suckling increased prolactin levels in both groups, the difference was greater in women receiving the injection, indicating that the drug enhanced the release of prolactin in response to the suckling stimulus.

Zanartu et al. (21) also reported similar findings in Chile. They showed that at 12 months, 42 per cent of women on oral progestins were still breast−feeding, while all subjects from the control groups had stopped. Parveen et al. (22) in Bangladesh were unable to confirm this finding and they reported that DMPA did not significantly increase lactation and actually caused a decline in milk. Further studies are still needed.

The side−effects of hormone−based contraceptives have led many to favour more mechanical approaches, such as the coil, but this too can lead to nutritional problems through excessive bleeding in some women. Furthermore, there is the question of what happens to the copper released in women who have loops inserted during lactational amenorrhoea. The seemingly safest method from a health point of view, the condom, has in practice in high failure rate, mainly due to human error.

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6. The role of prolactin on the contraceptive effect of lactation, and the influence of breast–feeding practices and of maternal dietary status

6.1. It is clear that a substantial number of mothers who breast–feed experience a period of infertility and amenorrhoea. It is also clear that many women, in particular in Western societies, resume menstrual cyclicity while still breast–feedingl1). It is of major importance that the factors influencing these responses are clarified.

Past investigations on the changes in reproductive hormones post–partum have been basically of three kinds: la) cross–sectional studies in which single samples of blood have been collected from large numbers of women at various stages post–partum; (b) detailed studies in a few subjects; and (c) cross–sectional studies of pituitary responsiveness to hypothalamic–releasing factor stimulation such as a gonadotrophin–releasing hormone (GnRH). Unfortunately, in all studies of the first two types, the duration of suckling and whether supplements were also given to the baby have not been recorded, and in only a few has some estimate been made of the number of breastfeeding episodes. Thus, only a very general picture of the hormonal pattern associated with lactational infertility has emerged.

General summary of hormonal changes General Summary of Hormonal Changes(1)

6.2. Breast−feeding is associated with high plasma concentrations of prolactin, at least at the onset of lactation, the levels correlating to some extent with the number of suckling episodes 12). The prolactin response to suckling declines with time post−partum, but if suckling frequency is maintained at a high level basal levels may well remain above normal for 18 months or more (2, 3) (see fig. 15).

Blood levels of follicle−stimulating hormone IFSH) are necessary for ovarian follicular growth and development, and quickly return to normal menstrual cycle levels within a week or two post−partum. At no stage during lactational amenorrhoea do FSH levels appear to be inadequate for ovarian function. Pituitary levels of luteinizing hormone (LH) are very low immediately postpartum, but by 15 to 20 days blood levels have increased significantly and remain throughout lactation on the lower side of normal.

During lactational amenorrhoea in fully breast−feeding women, the response of LH to GnRH stimulation is diminished, while the FSH response is normal. In the same situation, women fail to show a positive feed−back response, with an increase in LH and FSH to exogenously administered oestrogen, whereas they show an enhanced negative feed−back effect with prolonged suppression of LH levels in contrast to normally cyclic women. In lactational amenorrhoea, ovarian oestrogen and progesterone secretion is below normal, and is equivalent to that seen in post−menopausal women in spite of normal levels of FSH.

Complete weaning results in an immediate drop in the blood levels of prolactin and an increase in blood levels of LH and oestradiol, indicating a prompt resumption of ovarian activity. Actual ovulation usually occurs within 14 to 30 days. These results suggest that a maintained suckling stimulus, and the associated hyperprolactinaemia, suppress LH but not FSH post−partum and lead to both a failure of ovarian follicular development and lactational amenorrhoea. There is also some information that if ovulation does occur it results in a deficient corpus luteum function.

Prolactin, breast−feeding frequency, and supplementary feeding in Scotland

6.3. These interrelationships have recently been studied on a prospective, longitudinal basis among a small group of mothers living in Edinburgh, Scotland 14, 5). The investigation was planned in such a way that account could be taken of the frequency and duration of breast−feeding and the introduction of supplementary food to the baby. This has produced valuable information on the return of fertility post−partum in relation to changes in the pattern of breastfeeding. The essential results are summarized in fig. 16 (see

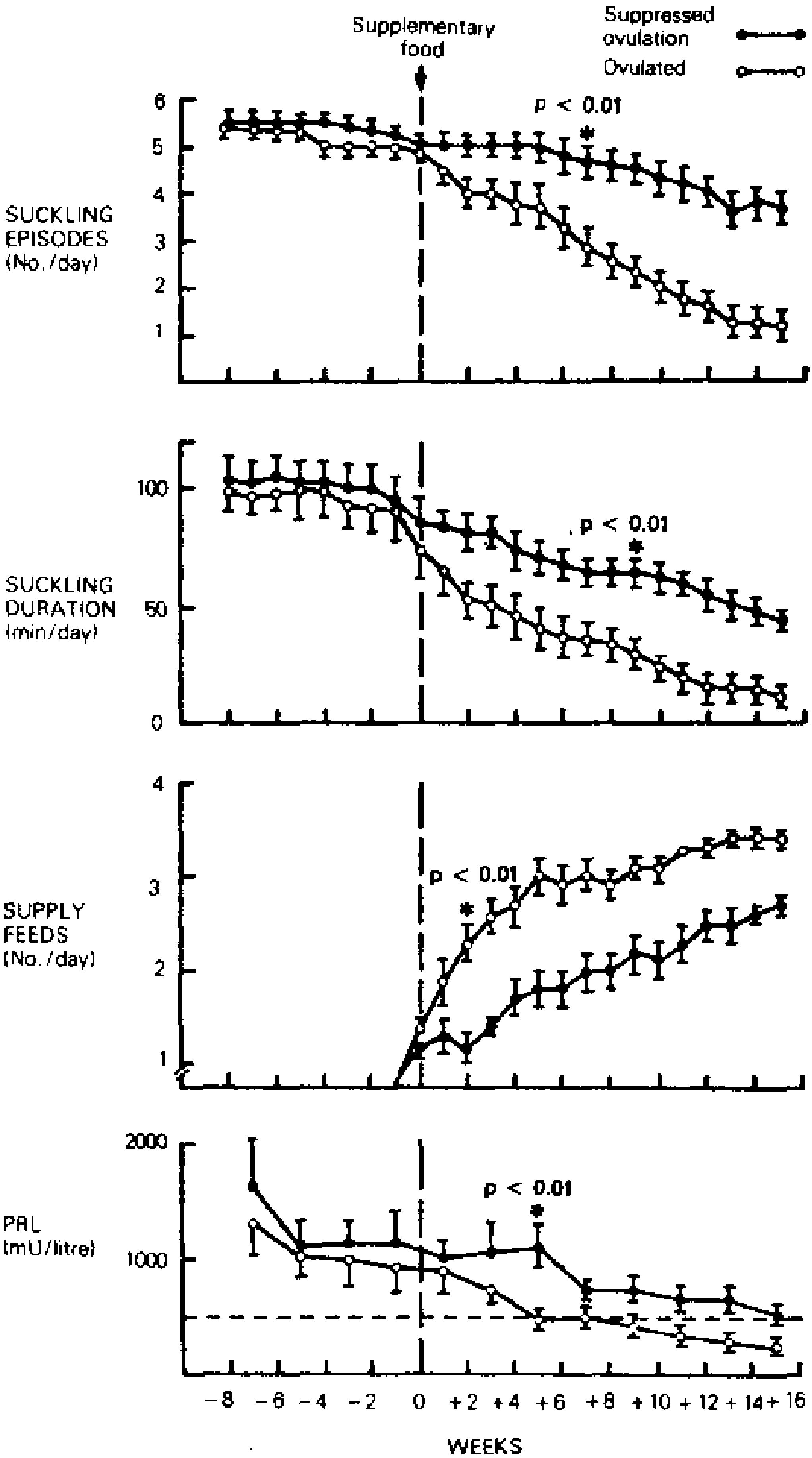

FIG. 16. Comparision of Suckling Episodes, Suckling Duration, Supplementary Feeds, and Basal Prolactin IMean Concentrations + SE) in Breast−feeding MothersWho Ovulated or Continued to Suppress Ovulation after Introduction of Supplementary Feeds. IPoints are significantly different from * onwards) (Source: ref. 4)).

Plasma prolactin concentrations remained significantly above normal levels until the frequency of feeding and the total duration of lactation per day fell. Thereafter all three parameters declined approximately in parallel and the changes were highly correlated. They also showed an inverse correlation with the introduction of supplementary food, which was introduced between three and 24 weeks postpartum. Before this no mother had ovulated, although two out of 27 had some unsustained follicular activity.

Following the introduction of supplementary food there was a progressive increase in the number of mothers showing evidence of ovarian activity, and within 16 weeks 20 out of 27 had follicular activity and 14 out of 27 had ovulated. While there was no difference in the suckling patterns or prolactin levels before the introduction of supplementary food, the non−ovulatary group had subsequently maintained both frequency and the daily duration of feeding at a higher level; they also introduced infant supplements less abruptly than did the ovulating group. Mean basal prolactin levels remained above the nonpregnant range in the non−ovulating group for at least 16 weeks after the onset of infant supplementary feeding. Values were significantly lower in the ovulating women.

6.4. Half of the women studied failed to ovulate throughout breast−feeding, and even in the remainder corpus luteum function, in terms of levels and duration of secretion of progesterone, was deficient. In some cases the increase in plasma progesterone concentrations was so minimal it was not clear whether ovulation had taken place or not, even though menstruation occurred. Four women who were apparently ovulating and wished to become pregnant failed to do so, presumably because of an inadequate luteal phase.

6.5. In all women FSH levels returned to normal within a short period postpartum, while LH levels remained suppressed until just before the increase in ovarian follicular development and oestrogen secretion.

Other studies have indicated that during lactational amenorrhoea, low LH levels are associated with an absence or reduction in the frequency of pulsatile LH discharges which are necessary for ovarian steroid secretion (6) This is related to a maintained suckling frequency of adequate duration and to plasma concentrations of prolactin. When breast−feeding declines with the associated decrease in prolactin levels, LH pulsatility returns to normal and ovarian follicular development resumes. It seems, however, that there are a few cases in which LH levels return to normal but the ovaries do not respond to this stimulation.

6.6. It is obvious that full breast−feeding, even in well−nourished women, inhibits ovarian activity completely for up to six months or more, but in undernourished mothers, who tend to feed their children much more often, this inhibition can be for two years even though infant supplementation has been introduced from three to six months. It is of interest that similar observations have been made on a number of Perth mothers who have breast−fed for two to three years. However, prolonged lactational amenorrhoea is not always assured even in mothers with similar patterns of breast−feeding. One critical factor would appear to be the maintenance of a high suckling stimulus both in terms of frequency and duration. The introduction of additional sources of food inevitably helps to satiate the baby's appetite, setting in motion a cascade of mechanisms that result in a release of the inhibition of ovarian activity. The rapidity of this response would appear to be greater in the industrialized countries, perhaps because "traditional" infant foods less adequately satisfy the child. The mechanism of suppression appears to be a decrease in the normal episodic secretion of LH caused by the neural suckling stimulus and/or the raised levels of prolactin, together with an increased sensitivity to the inhibitory effect of LH release of ovarian steroids, especially oestrogen.

6.7. It is obvious, however, that lactational infertility cannot be explained on the basis of prolactin alone. When ovarian activity resumes during lactation, ovulation is frequently followed by the formation of inadequate corpora lutea which are probably not compatible with pregnancy, thus menses is not a reliable guide to fecundity. The mechanisms linking neural suckling and the brain, the increase in prolactin, and the suppression of LH secretion are not known, and a truly adequate understanding of lactational infertility depends on filling these gaps in out knowledge.

The effect of maternal diet on the endocrinology of lactational infertility in the Gambia

6.8. The key information suggesting that there might be a link between maternal dietary adequacy and the duration of infertility in lactating mothers has already been discussed (section 4.12). The basic hypothesis is that the undernourished mother has more difficulty in synthesizing milk, thus the child has to suck more intensively and usually more frequently and for longer periods of time in order to obtain an adequate amount of milk. This would produce an intense neural suckling stimulus that would inhibit LH release and ovulation either through prolactin, by direct neural action, or both. Recent work from the Gambia (3, 7), in which the diet of a large group of rural mothers was considerably enhanced by the provision of a biscuit-based supplement (see section 3.26), appears to have substantiated this basic hypothesis. As figure 14 shows, plasma prolactin concentrations were significantly lower at practically all stages of lactation in women who received the supplement.

6.9. It is not possible to explain exactly why such a dramatic effect on prolactin was produced; the total volume of milk the child subsequently consumed did not improve, nor did the actual frequency of feeding (7). Unfortunately the time the mother was forced to spend feeding her child was not measured, nor could any objective assessment be made of the intensity of that feeding. it was suggested, however, that the increased levels of prolactin reflected the ease with which the mother was able to produce the milk (3).

6.10. The desperately low levels of dietary-energy and nutrient intake of women in the Third World, including the Gambia, has already been discussed in section 2.2. Under such circumstances it is vital that the nutrients that are absorbed are actively channelled towards the tissues where they are most urgently required. Considering the structural and functional similarities between prolactin and growth hormone, it is not unreasonable to suggest that this could be at least part of the functional role of the elevated prolactin concentrations found in undernourished mothers. If prolactin does act by ensuring that an adequate supply of nutrients is made available to the breast to preferentially maintain milk synthesis, then it is probable that the amount of hormone required would need to be higher when maternal diet is deficient than when it is good.

6.11. There is another potential role for elevated prolactin levels. Malnourished mothers during pregnancy are unable to accumulate large stores of fat as do their well-nourished counterparts. Since this fat is an important source of milk energy, it is not unreasonable to suppose that a stronger stimulus, such as could be provided by persistently high prolactin levels, will be necessary to ensure the mobilization of what little fat there is. Although this idea is hypothetical, there is evidence from rats that prolactin does act directly in this way (8). The proposed mechanism is also very similar to the well-documented human growth-hormone-induced lipolysis and enhancement of milk production that occurs in dairy cattle (9). The basic mechanisms are summarized in figure 17 (see

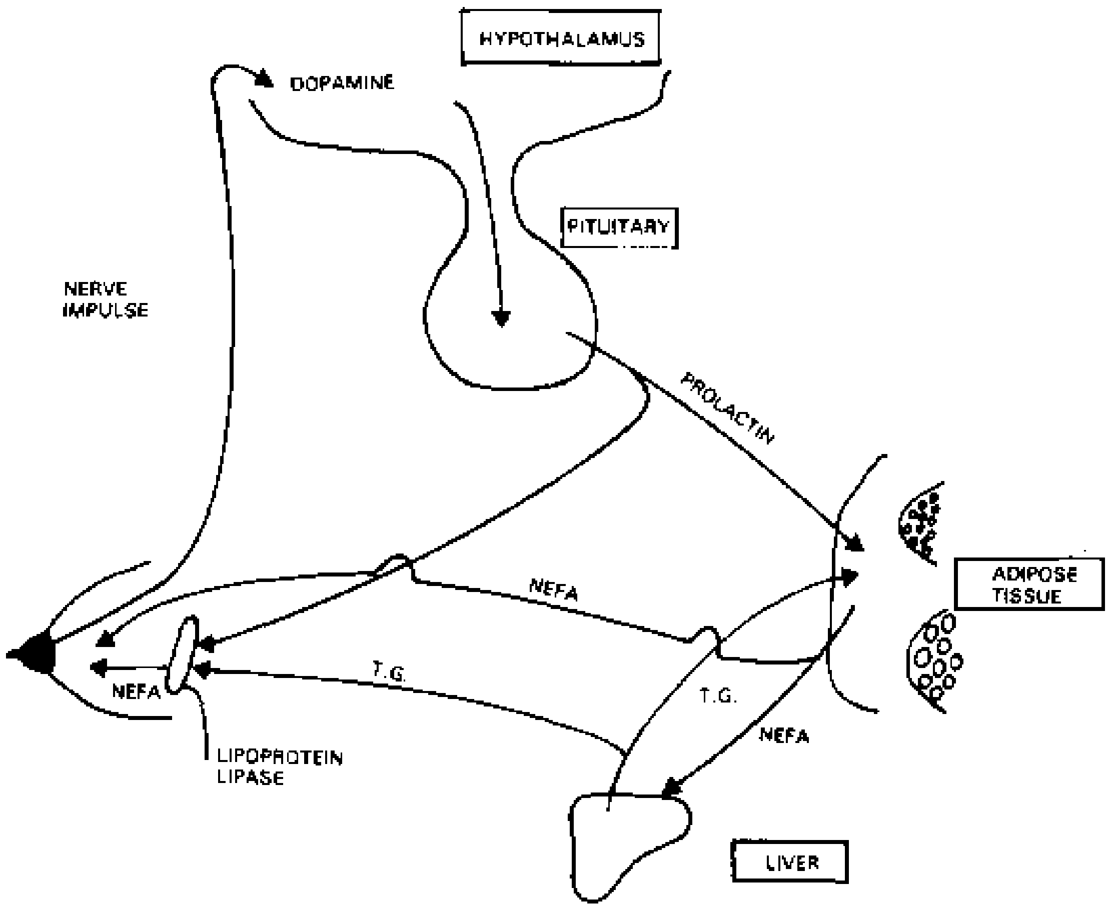

FIG. 17. Nutritionally Relevant Hormonal Interactions Relating to Milk Production (Lunn, unpublished data)).

6.12. In order to test whether or not reduced concentrations of prolactin were leading to a reduction in lactational infertility, plasma concentrations of oestradiol and progesterone were also measured, and the values are shown in figure 18 (see

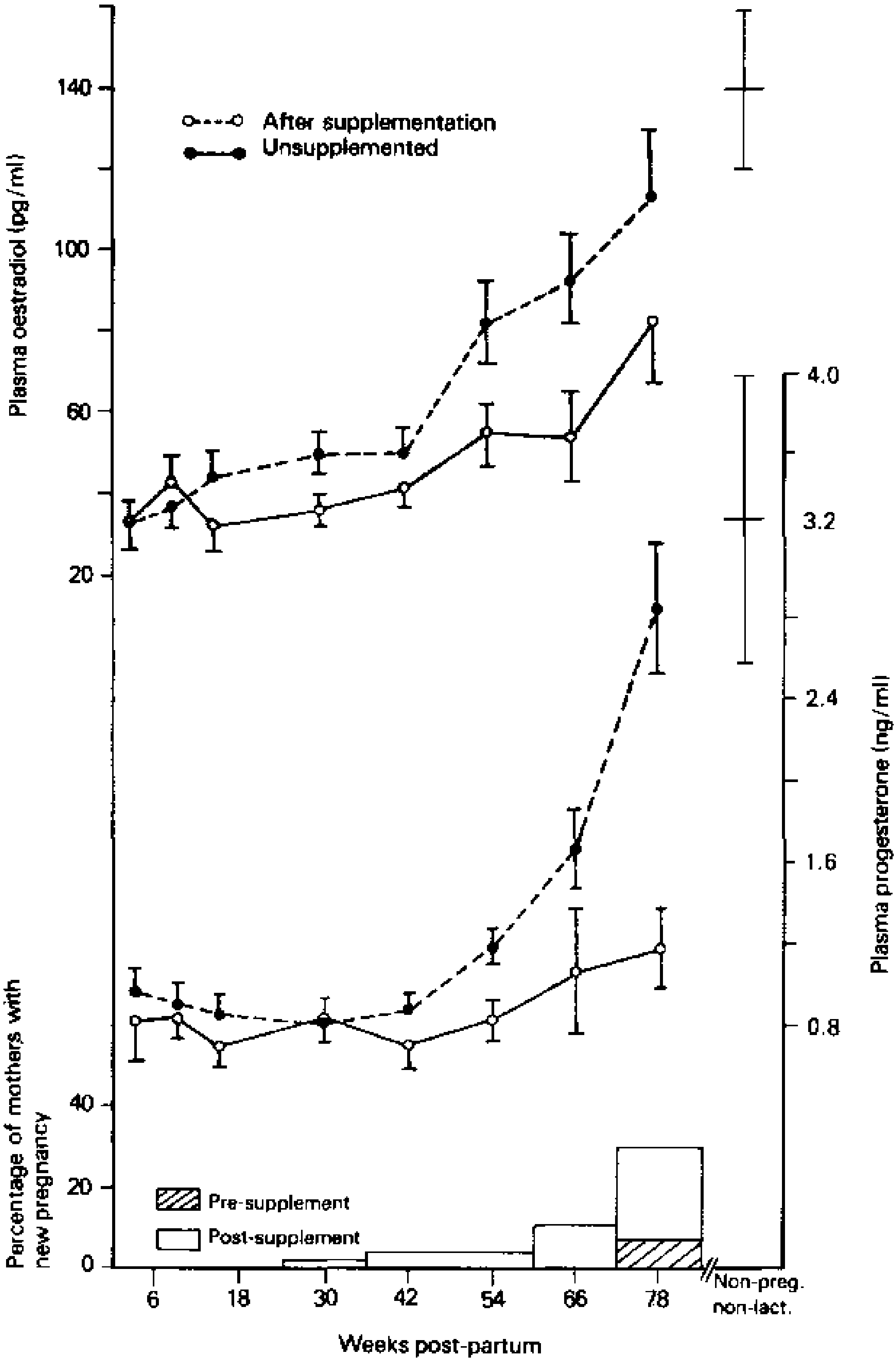

FIG. 18. The Effect of Dietary Supplementation on Plasma Oestradiol and Progesterone Concentrations in Lactating Women (Source: ref. 9))(10). The sharp increase in plasma oestradiol concentrations, indicative of the time when the women were resuming their menstrual cycles, occurred about 14 weeks sooner in the supplemented mothers. Even more dramatic were the differences in plasma progesterone. Mean values for

the supplemented women started to show some increase by 54 weeks postpartum and continued to rise after this time towards the value found in nonpregnant, non−lactating women. In contrast, there was little evidence of a general return of fertility in the unsupplemented mothers even at 78 weeks.

These biochemical data were supported by an analysis of the proportion of lactating women becoming pregnant again by 18 months. In the unsupplemented mothers it was 19 per cent, and in the supplemented ones 33 per cent. This was in spite of a taboo against sex while lactating. Clearly this rule was not being strictly adhered to, but the decrease in birth interval might have been even more pronounced in its absence.

6.13. The results of this controlled intervention study are totally compatible with the epidemiological findings of Chavez in Mexico (11), of Delgado in Guatemala(12), and Vis's group in Zaire (13, and H.L. Vis, personal communication), and also of Prema in India(14) but are at variance with the experiences of Chowdhury (15) and of Bongaarts (16), whose statistical predictions led them to conclude that the effect of diet on birth−spacing would be insignificant. The size of any effect, however, presumably depends on the degree of difference in dietary intake.

In the Gambian study, dietary energy intake was boosted to a level customarily encountered only in much more affluent women in the Western world, and this could be why the response was more dramatic. The contraceptive effect of prolactin can be looked upon as a protective mechanism, which, when food is less readily available, prevents a new pregnancy occurring too precipitously, which would further exacerbate the nutritional stress in the mother as well as her child. With adequate nutrition, such a barrier to reproduction may not be such a biological necessity.

Conclusion

6.14. The message seems clear that there is reasonably good substantive information indicating that improving maternal diet without concurrently introducing some artificial form of contraception may shorten the birth interval and consequently increase birth−rate. It is of crucial importance that this effect is studied directly in other developing countries in addition to the Gambia, so that its public−health significance can be judged with complete confidence.

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7. Mother–child nutrition at a public–health level

7.1. It is frequently claimed that we know enough to bring about a significant improvement in nutritional health; the impediment is our political unwillingness to implement the necessary economic reforms. This report is an unsuitable forum for a detailed discussion of the latter issue, and this section will therefore concentrate on what we do or do not know, and present a general discussion of the problems involved in the practical implementation oh health programmes at a community level.

The state of current knowledge

7.2. It is clear that the dietary intake of many pregnant and lactating mothers in the Third World is well below current recommendations both for energy and many nutrients; there are a number of reasons for this, depending on socio–economic circumstances. It must be recognized, however, that our estimates for physiological needs may be somewhat excessive and thus the current recommendations may not be a realistic target for health planners.

7.3. Nevertheless, it is a fact that the weight and body–composition changes that take place during the pregnancies of average women in developing countries fall short of that considered desirable in the Western world, and the results are low average birth–weights and a greater incidence of light–for–age babies. It is generally accepted that low birth–weight is a considerable handicap for the child's subsequent growth and development, especially under circumstances prevailing in the developing world.

7.4. There is strong evidence that the Third World lactating mother's health and well–being is affected by her customary diet, and although she may produce remarkably large amounts of milk for long periods of time, this is only achieved by intensive child suckling.

7.5. Unless the food intake of lactating mothers is exceptionally low, milk output seems to peak at about 750 ml/d. Dietary supplementation of the mother does not boost volumes above this level, although there is strong circumstantial evidence that, as during pregnancy, the mother's own health and physiological function can be substantially improved, leading to a greater capacity for work and feeling of general well−being.

7.6. Between four to six months children will begin to need some supplementary feeding, depending on the mother's milk output and the individual physiological needs of the particular child. Some children are able to grow and function for longer than six months on breast−milk alone, but equally, other children may need supplementation before four months.

7.7. The precise time is bound to vary from child to child, but there is no reason why this should lead the mother to stop breast−feeding; breast−milk is likely to be far better, nutritionally, than any other food the child will receive, particularly in the developing world.

7.8. The nutritional importance of breast−feeding needs to be stressed in all public health programmes, but so does the rational introduction of other forms of feeding.

7.9. In the developing countries there can be no doubt that both mothers and their young children constitute the group most clinically vulnerable to malnutrition: both need to be given equal consideration in the development of community nutrition programmes. Such programmes, whether primarily educational or involving the actual provision of supplementary food, must be integrated with other aspects of public health, such as those concerned with the prevention of disease, immunization, and the early treatment of common infections. Because of the link between an improved nutritional status and the return of fertility during lactation and the proven beneficial effects of good birth spacing, both for mother and child, family−planning programmes are of special relevance.

The Mexican "Minimum package"

7.10. A plan for a "minimum package" for nutritional health was introduced to the workshop by Dr. Chavez of the National Institute for Nutrition in Mexico City. It will be applied in 3,300 primary health centres covering the whole country. These are situated such that there is approximately one doctor for each 20,000 inhabitants. These doctors will be supported by health "promotors" beated in each community within the area served by each centre. A system of indicators will be used to detect problems before they become too serious. The action package has been kept simple in order to make it easy to apply and to be maintained longitudinally. It has three components, one for pregnancy, one for infancy, and the third to deal with problems in children over one year old.

7.11. For pregnancy, a main consideration is dietary education regarding different mixtures of regional foods advisable for the pregnant mother. Teaching sessions will be supported by posters and pamphlets. Depending on precise area needs, this dietary education will be supported by therapeutic iron and vitamin supplements. Special attention will also be given to teaching hygiene to prepare the woman for her eventual motherhood. Towards the end of pregnancy the importance of immediately breast−feeding the newborn will be stressed, plus the introduction of more adequate hygienic measures surrounding child−birth.

7.12. When the baby is two months old the mother will be taught to prepare supplementary foods. Again, depending on the region, vitamin status will be safeguarded by administering to the baby A, C or D, as appropriate. Between four and six months the provision of supplementary foods will be recommended, particularly to those who are low in weight. Teaching will also be provided on how to integrate the child into the family diet. Depending on the area and socio−economic level, complete weaning occurs between six and fourteen months of age. Around six months, therapeutic iron will also be provided as needed.

7.13. When the child reaches one year of age, he will be tested and treated for parasite infestation. Additional dietary education will be provided, paying special attention to regionally available food.

7.14. This nutritional package for the mother and child will be backed by national educational measures via radio and television, and by a system for the distribution and sale of low−cost foods. Supportive education will also be carried out in schools and other governmental organizations.

The evaluation of success or failure

7.15. When developing countries have limited resources and there are competing demands for them, it is inevitable that there will be pressures to set priorities, with demonstrable success scoring highly. Some countries have assessed the viability of programmes by examining the effectiveness with which they have reached target groups(1). In the Sri Lanka Country−Wide Programme, for example, 75 per cent of mothers at risk were reached, but the success rate with children with second− and third−degree protein−energy malnutrition was only 50 per cent. It could be concluded, therefore, that mothers were a better proposition. Decisions should, however, not be made merely on the number of beneficiaries; coverage cannot be the sole estimate of a programme's effectiveness, even if it does look good in the statistics book.

7.16. A nutrition intervention programme should be evaluated in terms of improvement in nutritional status (see chapter 9), but unfortunately success is difficult to identify using such criteria. In Sri Lanka (2), after a decade of maternal supplementation, estimates of the incidence of low birth−weight remain unchanged. Likewise, current surveys of pre−school−child malnutrition do not show a change from a survey carried out in 1975/76. This lack of success is a common finding; Beaton and Ghassemi have recently reviewed a number of international programmes, and it was impossible to demonstrate a significant improvement in any of them (1).

7.17. Why this is so is not easy to determine, but at least some of the blame must rest on logistic failures. It is considered in Sri Lanka, for example, that community involvement is crucial to the success of a government−sponsored programme, as this helps to minimize such problems at the local level.

7.18. General education has also been shown to be an important factor. Soysa 12) has related the level of education of Sri Lankan women to their utilization of health services and has found a positive correlation. She has claimed that literacy is one of the main factors responsible for the reduction in birth−rates in Sri Lanka. She has postulated that one of the reasons why nutrition messages are not getting through to the rural areas is because of inadequate attempts to improve conventional methods of education.

7.19. One common "leakage" of food aid identified in Sri Lanka was intra−familial, and perhaps the only practical approach is towards whole family units. This would increase the cost of a food−aid programme, but no woman in any culture will restrict food to her own use; she will always share it with her family. Thus, it might produce a better success rate if the whole family were aided, not just those clinically at risk.

The wider influence of maternal and child nutrition programmes

7.20. With all the complex social, economic, and political factors working against health improvements, it is not surprising that there is such a high apparent failure rate. There can, however, be positive achievements that are rarely taken into account. The introduction of a specific nutritional programme directed at the mother and her child succeeds in focusing the attention of governments on a specific health issue in a way that more indirect ways, such as wage increases, never can. This is an all−important factor politically and socially in shaping national policy. Clear research evidence must come from many countries before supplementary feeding is condemned outright as being totally ineffective and hence of low priority. This highlights the need for collaborative research of an applied nature between different developing countries.

General conclusion

7.21. In conclusion, it can be said that primary health centres must care for the nutritional health of both the mother and her children. Doctors and nurses, as well as auxiliaries, must be trained in maternal and child care and not just in obstetrics or paediatrics. Because an improvement in the nutrition and health status of a lactating woman can probably lead to an enhancement of her fertility, community−relevant family−planning procedures need to be identified and introduced as part of a complete health package.

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8. Criteria for the assessment at the community level of the effectiveness of public−health measures relating to maternal and child nutrition

8.1. In the running of public health programmes there is always a danger of an overemphasis on assessment and evaluation. As Jelliffe and Jelliffe (1) have recently stated, sometimes a compulsive insistence on scientific investigation can delay proof of the obvious and thus impede the introduction of necessary preventive measures. The reason we have to concern ourselves with assessment, however, is that resources are becoming increasingly limited, and it is necessary to know what we have achieved and what we have failed to achieve. Assessment criteria may conveniently be discussed under four headings: mortality, morbidity, growth, and finally, indices based on functional capacity.

Child mortality

8.2. Mortality rate, particularly infant mortality rate, is one of the classical public−health indices, and the one−to−four−year age−group mortality rate has frequently been used in comparative international surveys as an index of the prevalence of undernutrition in different countries (2). Internationally there is evidence of quite dramatic decreases in infant and pre−school mortality rates in recent years (3); measures of population dynamics are always more revealing than single assessments of mortality. To be realistic, however, it will be some time before there are completely reliable statistics for most developing countries, but even quite simple retrospective studies on relatively small samples can be valuable. Mothers can be asked questions such as, "How many children have you had, how many are still alive, and at what ages did they die?" Demographers have developed techniques for converting this level of information into more conventional statements about infant and child mortality.

8.3. In the interpretation of mortality data it is obviously important to take into account the cause of death. In the Gambia, for example, McGregor has shown that prior to 1973, 50 per cent of rural children had died before the age of five years (4). In Guatemala, by contrast, the corresponding figure was only about 25 per cent (5). This difference does not seem to be related in any significant way to dietary intake, and it would seem reasonable to speculate that the high mortality rates encountered in Africa might be related to infection, particularly endemic malaria, just as much as to food shortage. The relation between nutritional state and malaria is complex; both adversely affect total immune competence. Whatever the reason, it does emphasize that mortality as an indicator of nutritional status can be a very blunt instrument without additional knowledge concerning specific causes.

8.4. One also needs detailed information about the age at death. In the context of this report it is especially relevant to examine the distribution of deaths during the first year of life. The PAHO survey in Latin America and the Caribbean (6) showed than in most of the areas studied, about twice as many deaths occurred between one and six months as between six and twelve months. Figure 19 (see

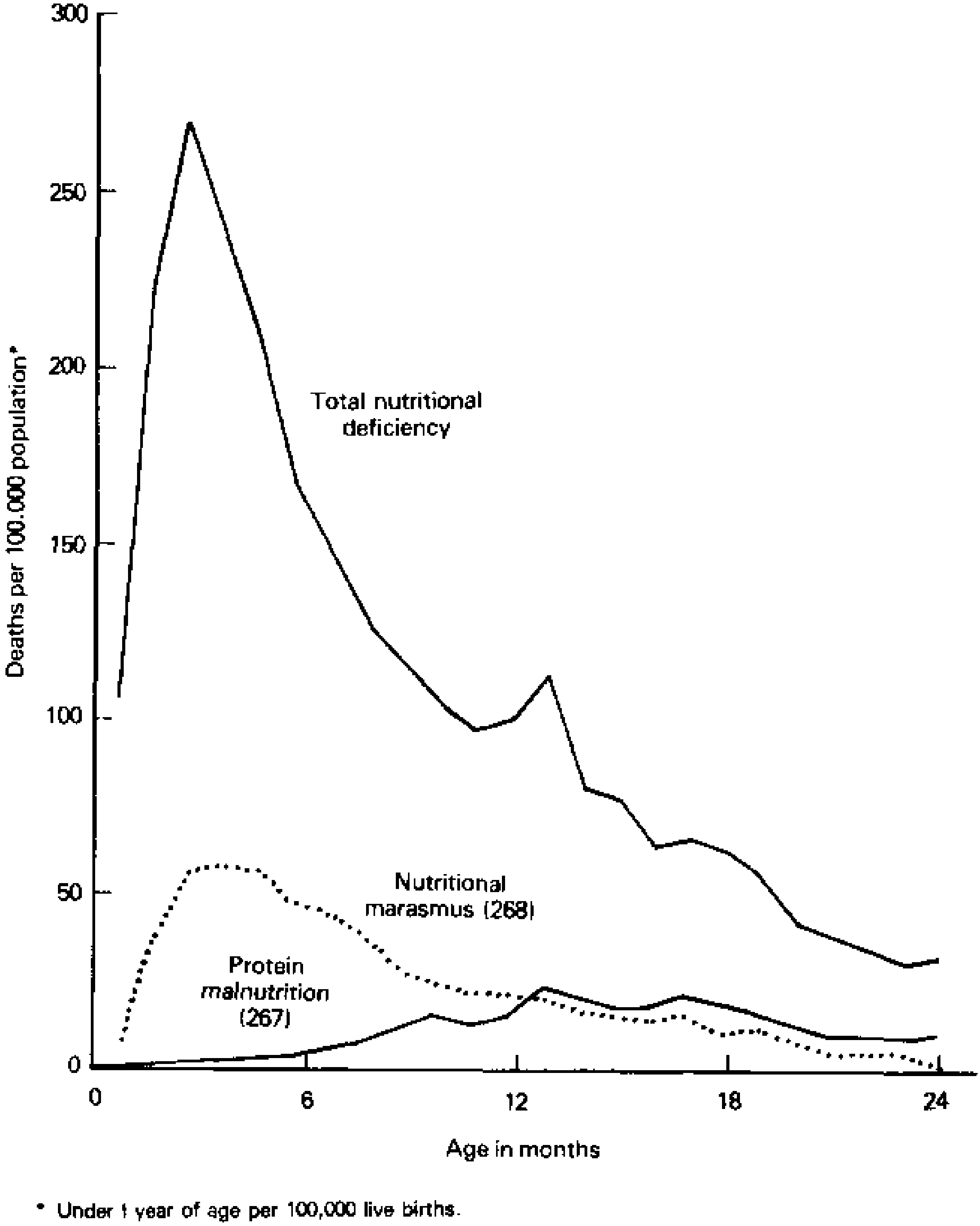


FIG. 19. Mortality from Nutritional Deficiency, Protein Malnutrition, and Nutritional Marasmus by Month of Age in the First Two Years of Life in 13 Latin American Countries Combined (Source: ref. 6)) gives the summary for the 13 Latin American projects combined. This finding is important, as it does not follow the predicted pattern if inadequacy of breast-milk and the introduction of contaminated weaning foods are the major aetiological factors in this high infant mortality. The PAHO data show that the distribution of deaths within the first year was the same whether the children were breast-fed or not.

As a further illustration of the importance of considering infection as well as diet in the interpretation of infant mortality rates, the findings of Martorell from Santa Maria Cauqué, Guatemala (7) on the age–incidence of diarrhoeal illness are important. The peak morbidity occurs between six and twelve months, i.e. after the peak of mortality, suggesting that weanling diarrhoea is not the major cause of the high infant mortality. On the other hand, Mata (8) in more recent studies in Costa Rica, has shown a very clear relationship between infant mortality rate and deaths from diarrhoea (see

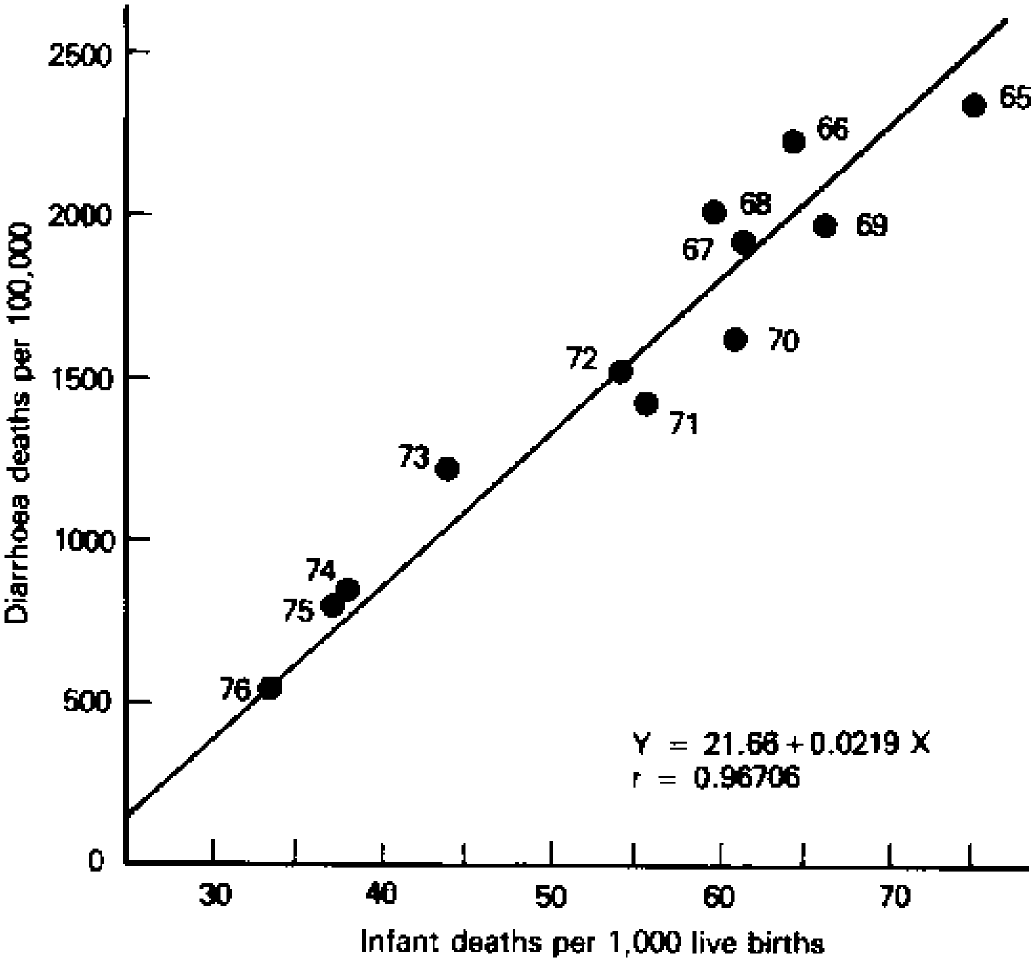


FIG. 20. Correlation between Infant Mortality and Diarrhoeal Disease in Costa Rica, 1965–1976 (Source: ref. 8)). Whatever the explanation for this difference, it is obvious that a proper assessment of the need for, and the adequacy of, different public–health measures, including dietary intervention, cannot be made unless one understands the natural history and causal relationships involved.

Morbidity

8.5. To get an accurate estimate of the incidence and severity of diseases that may be related to nutritional state is obviously difficult; diarrhoeal disease is the condition that has received most attention in so far as the young child is concerned. For a reliable check on incidence, observations really need to be made on the population sample at least every two weeks, and if the cause is also to be determined, this becomes a highly skilled and formidable undertaking. Interpretation can be complicated by large swings in seasonal incidence, as observed in the Gambia, Nigeria, and Nepal. Figure 21 (see

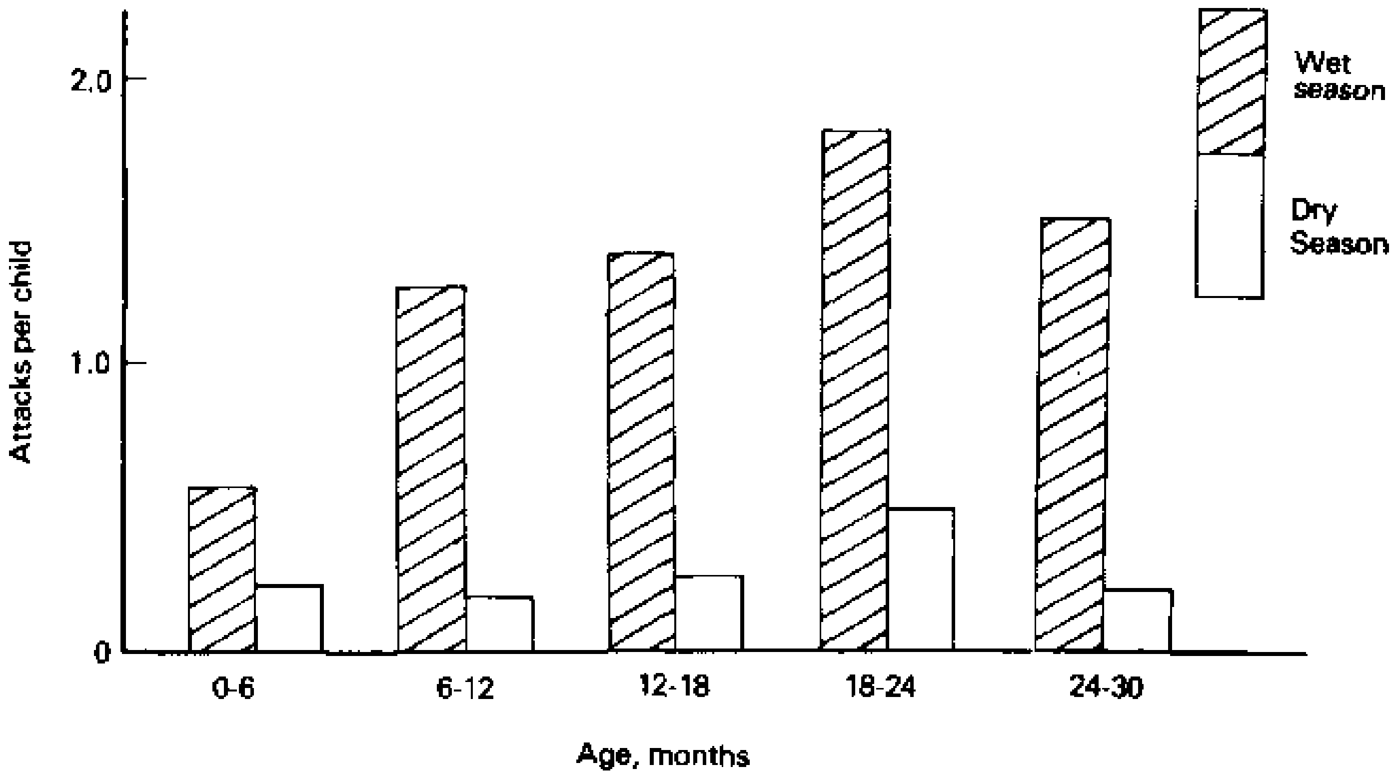


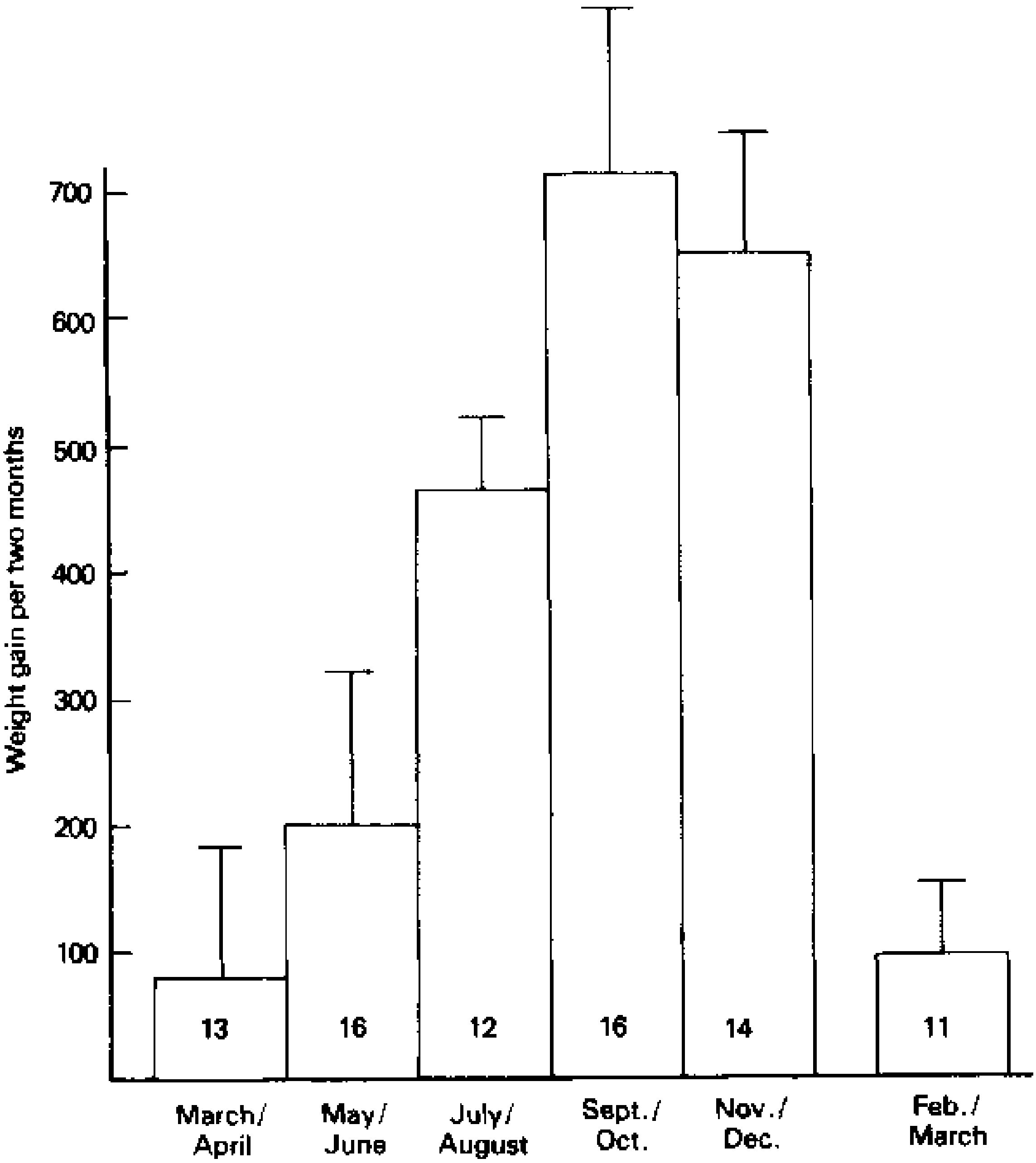
FIG. 21. Incidence of Diarrhoea in Northern Nigeria According to Season (Incidence is Number of Attacks per Child per Three Months) (Data by courtesy of A.M. Tomkins)) shows differences in attacks for diarrhoea in the wet and dry seasons in Malumfashi, northern Nigeria, by age. We also need to know not only the frequency of episodes of infection but also their duration, which is an important indicator of severity. Both Mata in Costa Rica and Tomkins in Nigeria have shown that the duration of an infection is much longer in a malnourished, than in a well–nourished, individual, even though the number of episodes may have been very similar.

It is only fair to conclude that, although a reduction in morbidity, particularly from diarrhoeal disease, could be a very relevant indicator of the success of a maternal–child intervention, because of the number of variables and the resources required, the approach is more suitable as a research tool than for the routine assessment of a public health programme.

Anthropometry of the child

8.6. Much has been written about the assessment of nutritional status in infants and young children by anthropometry. The usual cross–sectional approach is, however, relatively insensitive to change unless it is dramatic.

More precise information can be obtained by measurements of growth velocity. This naturally requires longitudinal measures, but the advantage is that quite small samples can give meaningful results. Figure 22



(see
FIG. 22. Weight Gain in Children Aged 5–32 Months in Nepal during Two Monthly Periods (Mean ± SE) (Source: D. Nabarro, unpublished data)) shows seasonal difference in growth from the village of Dhankuta in Nepal; the sensitivity of growth velocity is obvious.

As already emphasized in relation to mortality and morbidity, it is important to look separately at children in different age–ranges and not to group them all together. There is an additional reason for this in anthropometric assessment. In most populations the prevalence of wasting decreases after the first two years, while that of stunting increases (9); it is thus not possible to interpret the response of three–year–old children in the same way as one–year–olds.

8.7. More information is needed about the significance of growth deficits. An important indicator is increased risk of death. Figure 23 (see

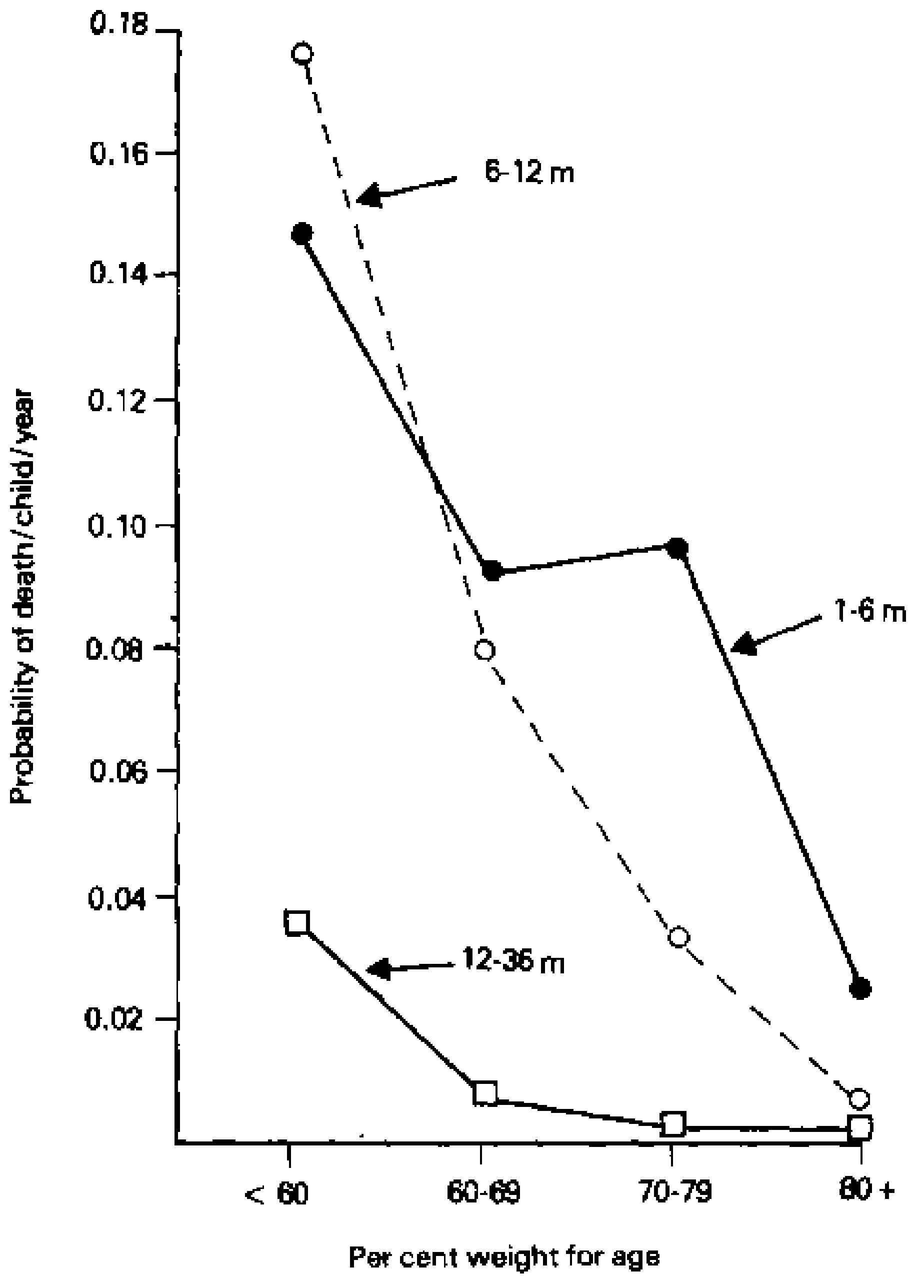


FIG. 23. Mortality Rate in Relation to Weight for Age in the Punjab, India (Redrawn from Kielman and McCord) (Source: ref. 11)), from studies in the Punjab (10), shows the relationship between risk and degree of deficit in weight for age. The risk increases steeply with increasing deficit. A point, however, which has not been sufficiently emphasized is that for a given deficit the risk is much greater for younger children. Consequently the threshold or cut–off point at which the extra risk is appreciable varies with age. Below one year the threshold is at about 80 per cent of standard, between one and three years at about 70 per cent.

A very important study in Bangladesh (11) has traced the relationship between risk of death and degrees of wasting and stunting. Children who were severely wasted and stunted had very high mortality rates, but moderate degrees of stunting did not carry any extra risk.

8.8. Mortality is a very crude and extreme indicator of functional impairment. Since in some countries up to 50 per cent of pre–school children may be classified as stunted by the usual criteria (height–for–age less than 90 per cent of reference), it becomes extremely important to know more about the cause and significance of stunting. Does being small matter?

Some workers look upon stunting as a successful adaptation to a shortage of food, although not successful enough for the child to overcome completely the changes in his environment. This issue is of more than intellectual interest. There is no use in having an indicator unless it is useful for making decisions. The usefulness will depend on the type of decision to be made. If the decision is about the need for a feeding programme, then our ignorance about the causes and physiological significance of stunting is embarrassing.

Anthropometric status of the mother

8.9. To safeguard the nutritional health of women during their reproductive age, it is important to consider pre−pregnant status as well as that during pregnancy and lactation. The most meaningful measurements are weight−for−height and thigh circumference. The various skinfold measurements, such as triceps, biceps, subscapular, and pert−umbilical, may also be of value, although whether these provide clinically relevant information, not given by weight−for−height alone, is open to question and needs to be clarified. In countries where kwashiorkor is the major form of protein−energy malnutrition, the measurement of plasma albumin is important, as is blood haemoglobin where there is anaemia.

During pregnancy the most relevant anthropometric measurement is the amount of weight gained during its course. For the United Kingdom the recommended amount is 12.5 kg (12), and it would be considered undesirable if the mean increment for a population fell below 10 kg. This is a level of performance rarely achieved by poor women in the developing world. Research is desperatly needed in which anthropometric change is quantitatively related, both to the health and well−being of the mother, as well as to the success of the pregnancy and the subsequent growth and development of the baby. This work is necessary for the definition of health targets relevant to health planning in the Third World.

The biochemical measurements listed in the previous paragraph can be of even greater importance during pregnancy. For example, protein deficiency may compound the fall in albumin concentration that normally accompanies pregnancy because of haemodilution. Plasma amino−acid patterns can also be informative, but this is a subject for research; such measurements could not be recommended for public health programmes at the present time.

Babies' birth−weight, height, and head circumference relative to gestational age at birth are crucial parameters. Birth−weights in poor economic circumstances in the developing world are much lower than in Europe and North America, but this cannot be solely attributable to dietary deficiency since infections like malaria can profoundly affect birth−weigh/(13). The proportion of children born with a weight below 2.5 kg is a particularly relevant statistic because neonatal and infant mortality rise sharply below this point. In research programmes, placental weight is also an important measurement.

Assessment of maternal nutritional status during lactation is more difficult. Weight is normally lost during lactation at a rate of 570 g/month (14), but, as described in section 3.2, considerable metabolic adaptations occur and excessive weight loss is not observed unless food intake is exceptionally low. An important measurement is the baby's milk intake, although there is a wide normal range, and at an individual level only values below 500 ml/24 hr between one and five months of age can definitely be considered inadequate: however, a population mean volume of 650 ml would be considered low. As with bodyweight, it is apparent that considerable metabolic adaptation protects milk supply against the worst effects of dietary deficiency. For lactating women it is likely that assessments of overall health and well−being plus her capacity for an active life are likely to be the most revealing.

Functional measurements

8.10. There is one final type of measurement of great potential value: measurement of functional capacity, an obvious example being the level of physical activity. Thomson(15), describing trials organized in the United Kingdom by Boyd Orr and others in the 1920s to test the effect of giving milk to school−children, wrote: "Acceleration of growth was confirmed and clinical examination of the children and reports from teachers suggested that the milk−fed children had improved in general condition and became much more alert and more boisterous and difficult to control than others." The difference in height growth between supplemented and unsupplemented children in this trial was 6 mm/year, but the difference in activity was likely to have been of much greater importance.

A reduced level of activity in children consuming inadequate but not disastrously low amounts of dietary energy has also been reported among rural children living in Uganda (16). Studies at INCAP in Guatemala

(17) have likewise demonstrated that energy intake of pre-school children can be reduced from 90 to 80 kcal/kg without affecting nitrogen balance or growth, but this is only possible because of a reduction in energy expenditure.

Activity is an even more relevant functional parameter for pregnant and lactating women, as they represent an important component of the labouring work-force, particularly in rural areas of the developing world. As discussed in section 1.17, studies in Sri Lanka have demonstrated that iron supplementation enables work output to be increased. Investigations into work capacity and energy output need to be designed with imagination and flexibility; however, it is possible for a woman to complete the same task with a minimum of extraneous effort or with more joie de vivre. It is not unreasonable to suggest that the latter style of working provides a greater sense of well-being and general happiness. In the Gambia the unanimous first reason given by pregnant and lactating mothers for the popularity of the biscuit supplement (see section 3.26) was that it gave them more "power" for work. Since there is, as yet, no evidence that they were doing more actual work, it can only be concluded that this statement means the mothers were better able to work well within their capacity rather than at the extreme limit.

It is quite apparent that the use of functional tests is a subject that merits a much greater research input. Quite apart from their intrinsic physiological interest, it would enable the merits of nutritional intervention programmes to be translated into terms relevant to national development planning. They might be taken more seriously by politicians and government officials than would more medical and biochemical measurements whose significance is less obvious.

Nutritional indices as measures of social development

8.11. All the types of indicators discussed can be useful as long as their limitations are appreciated. They can be used for the obvious direct purpose of assessing the effect of interventions on nutrition and health, but also as indirect indicators of social development. An example of the latter use is a large-scale integrated rural development programme currently being funded by the British government in Nepal, in which there are inputs from agriculture, animal husbandry, forestry, irrigation, and education as well a health. The concept of using nutritional status indicators for this purpose has been accepted enthusiastically.

To maintain this enthusiasm, however, and to provide the governments of both nations with meaningful information, it will be necessary to establish an appropriate methodology in which data will be collected on a continuing basis and, of equal importance, whose results will be analysed and made available quickly so that necessary changes in the overall programme can be made when necessary.

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9. Outstanding gaps in knowledge, and research recommendations

9.1. There are discrepancies between recommended dietary allowances during pregnancy and lactation and actual consumption levels, particularly in the developing world, but also in industrialized countries. Research is urgently required so that, where necessary, RDAs can be revised after considering metabolic adaptations to a higher efficiency when intake is low or physiological needs become elevated. Climate, work load, and environmental hygiene also need to be taken into account.

9.2. The response of a mother's capacity to produce milk needs to be studied in circumstances where protein deficiency as well as total energy deficiency are limiting factors. There is circumstantial evidence that lactation is more affected in countries where kwashiorkor is the principal form of pre-school child malnutrition.

9.3. More information is required on the range of breast-milk volumes produced by healthy, totally breast-feeding mothers, and mothers with optimal management of their lactations, so that realistic norms can be identified and goals established for maternal supplementation programmes. Such studies should be longitudinal rather than cross-sectional in nature.

9.4. We need to know with much greater certainty for how long breastfeeding alone is adequate for healthy growth, neurological development, and adequate immune competence. The range of biological variability within healthy communities should also be studied; cultural and biological factors limiting breast-feeding and lactational capacity need to be clarified on an objective basis.

9.5. Ways of identifying lactational inadequacy must be devised. Growth-charts for infants who have been successfully fed entirely from the breast should be constructed with a special emphasis on the first six months of life. The current, tentative conclusion is that initially breast-fed children may grow with a higher velocity during the first three months than bottle-fed ones, but then fall away in the second trimester of infancy. This needs to be confirmed.

We need to know more about functional significance of growth faltering and of moderate deficits in linear growth. Do such deficits produce a direct handicap – reduced resistance to infection, for example? Or do the risks result indirectly from a generally deprived environment? Could stunting be regarded as a reasonably successful biological adaptation?

9.6. Hypogalactia should be made a subject for priority research and include investigations into its biological background, lack of response to hormonal stimulus, or, in the case of undernourished women, to dietary supplementation. The possibility of pre-adult and pre-natal causes should be considered as well as post-natal ones. Objective criteria should be developed so that a predisposition towards hypogalactia can be diagnosed or predicted. Methods of treatment should be sought.

9.7. The precise physiological role of suckling behaviour on the mother's capacity for milk production needs to be studied more objectively, with particular reference to the frequency and length of contact at the breast. The optimal level of physical contact between mother and baby for successful long−term breast−feeding should be identified both during the daytime and at night. We need to know with greater precision the extent to which the baby can stimulate a greater milk output as his size and physiological needs grow, and at what point the mother's capacity is truly exceeded rather than limited by social constraints or conventional attitudes.

9.8. Research should be carried out on the timing of the onset of breastfeeding to determine how important commencement almost immediately after birth is to the subsequent success of lactation. It is of major importance that the differences in the initiation of lactation in women under different socioeconomic circumstances be studied. Such studies should be related to the different beliefs and taboos associated with colostnum and to the subsequent establishment of lactation. This is an obvious area for a multi−centre research programme.

9.9. A major multi−centre study needs to be set up whereby the effect of dietary supplementation on the lactational capacity of previously undernourished mothers can be assessed. This study should boost mean intakes as near as possible to current RDAs, care being taken not to affect adversely the customary intake of home food. Centres should be chosen so that correction of protein deficiency as well as energy defiency can be studied. The intervention programme needs to be planned to shed light upon what can be expected from short−term supplementation, such as during a single pregnancy−lactation cycle, as well as over a longer proportion of a mother's reproductive life.

Milk output and nutrient content should be measured at regular intervals, and any changes in the mother's nutritional status, general well−being, and physical activity should also be assessed. The growth of the baby from birth throughout infancy should also be monitored on a regular basis, as should patterns of morbidity both in the baby and the mother. The effect of supplementary feeding in pregnancy on birth−weight should also be assessed.

9.10. Major shortcomings in our knowledge of the fundamental metabolic and endocrine control of pregnancy and lactation should be acknowledged, because they affect the confidence with which practical intervention programmes can be planned to deal effectively with the essential features of maternal undernutrition without leading to impossibly complex and expensive public health programmes.

9.11. Although there is a wealth of subjective and anecdotal information concerning the interaction between lactation and fertility, this subject has received too little scientific consideration, and the collection of objective information from a range of countries is of priority importance. Of associated relevance to the major theme of this report are teenage pregnancies and the biological, sociological, and psychological problems faced by young, immature girls when they attempt to breast−feed.

9.12. New studies are required on the health significance of different intervals of birth−spacing. This investigation needs to be carried out on a representative range of countries and in mothers of differing socio−economic status, as potential hazards are likely to vary substantially with these variables. Such knowledge is vital before the importance of changes in lactational infertility can be interpreted with confidence. In addition, more information is needed about the distribution of infant mortality within the first year of life, and the causes of death at different times.

9.13. The precise role of prolactin and the cascade of hormonal events that terminate lactational infertility need to be clarified. Variations in baseline prolactin concentrations between well−nourished and underfed women need to be investigated in a wider range of countries than has occurred so far, and the causes identified. The relationship between circulating prolactin and breast−milk volume as well as fertility needs to be defined. A multi−centre study to provide answers to these questions could be run in conjunction with those described in recommendations 9.9. and 9.11.

9.14. During the planning and execution of these multi−centre studies, attention must be focused upon the potential translation of the results into primary health−care programmes. Since it is unlikely to be possible for all needy women to be assisted, selective criteria need to be devised for the identification of mothers and children, or preferably families, who are most at risk. Any nutritional programme must be integrated within a wider maternal and child−health framework, with special attention being paid to personal preferences and national policies towards birth−spacing, family planning, and population control. Standards and goals need to be identified for national programmes, and the success of the scheme should be determined by regular surveillance, measuring parameters relevant to both health and national productivity, and development.

9.15. Primary health centres must be organized in such a way that they provide both for the nutritional health and well-being of the mother as well as her child. Doctors, nurses, and health assistants staffing or responsible for such centres need to be trained in maternal and child care as an integrated whole, and not obstetrics and paediatrics as separate specialities.

9.16. Although more research is required (see recommendations 9.13 and 9.14), health workers must be made aware that improving a lactating mother's health and nutritional state may well affect the return of fertility during lactation. Where relevant, family-planning procedures need to be identified to deal with this effect.

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