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Dietary guidelines for pregnancy: a review of current evidence

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Abstract

In a successful pregnancy maternal health is maintained, a healthy baby is delivered and the mother is able to nurture her newborn adequately. Despite continued interest in the role and importance of maternal diet in this process, we do not have a clear understanding of how the nutritional status of the mother influences fetal growth and development. Recent epidemiological evidence of an association between poor fetal growth and adult disease highlights the need to reconsider the influences which act on the fetus, and the role maternal nutrition may play.

Nutrient needs are increased in pregnancy. For the mother to be solely dependent upon her dietary intake to meet these demands, would represent a very high risk strategy. Hence adequate reserves are important for a successful outcome. Whilst there are numerous observational studies of diet during pregnancy, there are only limited data from well-controlled, randomised supplementation studies. A recent systematic review showed only dietary supplements balanced in energy and protein content to result consistently in improved fetal growth. There is no strong evidence that nutrient supplements confer benefit in women without overt deficiency.

To interpret future dietary studies in pregnancy we need to consider metabolic differences between women which may influence their ability to meet fetal nutrient demand, to allow for nutrient–nutrient interactions, and to take account of differences in timing in gestation. Consideration of these factors in studies of pregnancy, will lead to a clearer understanding of the links between maternal diet and fetal growth and development. Until we have this understanding, it is reasonable to expect that women entering pregnancy are provided with a diet which is adequate, based upon our normal understanding of requirements, and it is not acceptable for women to be expected to carry a pregnancy with an obvious or overt nutritional deficiency.

Keywords
Pregnancy
Dietary guidelines

Considerations

Background

The achievement of a successful pregnancy represents one of the fundamental functions of existence. The objectives can be identified as threefold: maternal health and well-being during the pregnancy itself, a healthy newborn baby, and the welfare of the mother to enable her to nurture the newborn adequately. The period of intrauterine growth and development constitutes the most vulnerable period in the life cycle and both biological and social adjustments are made to provide effective protection for this fundamental process. Central to this are the social conventions related to food and nutrition before and during pregnancy as well as the biological adaptations which take place in maternal metabolism. Together these provide a buffer against a potentially hostile environment.

Since the 1930s maternal mortality has decreased to relatively low levels in the developed world and it has been difficult to identify any specific aspect of diet or nutrition which might have contributed to this, of relevance to targeted programmatic interventions[1]. The fetus through its genetic endowment carries its own 'blueprint' for development, but this potential can only be realised if the supply of nutrients – energy, substrates and cofactors is sufficient to meet fetal demand. Growth and development is structured in time and therefore the pattern of nutrient demand varies as pregnancy advances. Hence the pattern of demand for energy and nutrients placed upon the mother varies at each stage of pregnancy. If the mother were solely dependent upon her dietary intake to meet the changing pattern of demand at each stage, this would represent a very high risk strategy. Therefore, it is hardly surprising that the preparation for pregnancy, and the ability to have

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adequate reserves to call on during the different stages is one characteristic which marks a successful outcome.

Since the 19th century there has been interest in understanding the role of maternal nutrition in the human reproductive process. This interest has led to a series of studies which have attempted to define the special dietary requirements of pregnancy, the majority of studies using weight at birth as a marker of the relative success of pregnancy. Some of the first scientific evidence of the influence of maternal nutrition on reproductive outcome came from study of European populations who experienced food-restriction during the Second World War 2. Subsequently evidence has come from cross-sectional observational studies and also from well-controlled randomised trials of nutrient supplementation in pregnancy.

Over the 20th century interest in the diet of pregnant women in the developed world lessened after some observational studies failed to identify any marked effects of diet on size at birth[2]. The absence of an effect, together with the knowledge that the vast majority of babies born to women in the developed world fall within the 'normal' range of birth weight, have led to the belief that the fetus is well protected from wide variations in nutrient intake, and that, outside the realm of chronic energy deficiency, maternal diet may not merit special attention.

There are at least three important problems with this concept. Firstly, for the mother, any characterisation of nutritional status has to embrace considerations of size and body composition, the quantity and quality of current dietary intake, and aspects of her metabolic capacity and functional metabolic reserve. For example, little is known about the contribution that physiological adjustments in nutrient absorption and excretion make to nutrient demands in pregnancy, or the extent to which this varies between women. Secondly, birth weight is a useful but incomplete statement of the relative success of pregnancy and the over-dependence on birth weight as the critical outcome variable may have limited our ability to observe other aspects of impaired growth and development. Certainly, a consideration of relative body proportions, as a measure of disproportionate growth or a limitation in the achievement of growth potential, enables a more refined statement of the success of a pregnancy. Thirdly, birth is an important point in development but is only part way through the 'fetal-infant' stage of development. Adequate maternal nutrition must embrace maternal needs, and be sufficient to support the demands for successful and effective lactation.

Pregnancy outcome

At Birth

The most readily available measure of pregnancy outcome is the weight of the newborn. A poor outcome has been characterised as low birth weight (LBW) <2.5 kg at term, small for gestational age (SGA) or other measures of a deviation from predicted weight for a given gestation. All are markers of impaired fetal growth and express relative deficit in birth weight in the baby at a given gestation. Because fetal growth is a process in time, relatively low weight at term has to be differentiated as being distinct from low weight which arises simply as a result of being born prematurely.

In addition it may be possible to get measures of proportionality with the most commonly used being the ponderal index which relates mass to length (weight/length^3). Growth impairment in early gestation may be associated with a small, evenly proportioned newborn, whereas growth impairment in mid-late gestation is more likely associated with disproportion in growth. This may be seen as relative thinness in the neonate, although weight may fall within the normal range.

Small size at birth is associated with increased morbidity and mortality during the perinatal and neonatal period and during infancy[3].

Medium and longer term outcomes

Recent epidemiological studies have shown an inverse association between weight at birth and adult risk of development of specific degenerative conditions which include obesity, coronary heart disease, stroke, type 2 diabetes, some cancers and depression[4]. Of greatest importance is the finding that these associations are seen within the range of birth weight which is considered normal. These findings are not explained by differences in rates of prematurity, or by differences in adult lifestyle. They suggest that impairment of fetal growth, although in babies of relatively normal birth weight, results in poorer long-term health outcomes.

These data suggest that we have failed to consider the longer-term implications of fetal growth impairment, and raise the possibility that the apparently normal variations in fetal growth seen in the developed world reflect differences in intrauterine experience which are linked with very different adult health outcomes. In light of these findings there is a need to re-evaluate how normal variations in fetal growth and development relate to differences in fetal and/or maternal nutrition. We can no longer assume that a maternal diet associated with a baby born within the normal range of weight is optimal.

Sources of information

The following sections review what is currently known about the links between maternal nutrition and birth outcome, where possible using data from well-controlled trials, but supplementing these with observational data where necessary. Nutrients listed are those for which the best, or most complete evidence exists.

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Randomised controlled trials (RCTs) and supplementation studies

The most objective method to evaluate the importance of specific nutrients is from well-controlled, randomised supplementation studies. A recent systematic review by de Onis *et al.*[5] considered 12 nutritional interventions in pregnancy and is summarised below. Although these represent the only data which can yield definitive statements regarding nutrient intake and pregnancy outcome, other supplementation studies which were not included in the systematic review for methodological reasons, also contribute important information.

Observational, cross sectional studies

Numerous observational studies of nutrition in pregnancy exist in the literature. Whilst these cannot be used to define dietary guidelines, they are useful in establishing nutrients of importance, and areas of need for future research. A comprehensive review of observational studies examining the role of micronutrients in pregnancy has recently been published by Ramakrishnan[6].

The role of nutrition and nutritional status before pregnancy

There is very limited evidence relating pre-conceptional nutrition and nutritional status to pregnancy outcome

Dietary intakes

The limited literature examining the role of pre-conception nutrition in pregnancy outcome has focused on the effects on fertility and the prevention of neural tube defects[7]. Caan *et al.*[8] reported that among nutritionally vulnerable women participating in the WIC program, extended participation postpartum was associated with increased birth-weight in the subsequent pregnancy. There is a need for a much greater understanding of the importance of maternal diet before pregnancy.

Body composition

Most studies of nutritional status before pregnancy have examined the influence of body composition on pregnancy outcome. Height has been consistently shown to be associated with better pregnancy outcomes, taller women have heavier babies[9]. Both under and overweight have been associated with poorer perinatal outcomes[3]. Among chronically energy deficient women rates of LBW and SGA are raised. Even within the developed world, low pre-pregnancy BMI is consistently associated with reduced birth weight[9]. The effect of low pre-pregnant weight is offset by higher levels of weight gain in pregnancy, although pre-pregnant status is of more importance in predicting birth outcome. There is some evidence that for women who are short and fat there is a special risk of poorer fetal growth than for women who are taller and fat, or short and of appropriate weight[10]. Therefore, any intervention which leads to shorter women becoming fatter may have a deleterious effect on fetal growth.

Diet in pregnancy and birth outcome

Energy and macronutrients

Energy

The total energy cost of pregnancy is estimated to amount to 335 MJ. With the exception of a recent longitudinal study[11], any increase in energy intake during pregnancy appears modest, and less than estimates of the additional energy needed. This implies that there are either behavioural or metabolic adaptations taking place, such as through changes in basal metabolic rate, dietary induced thermogenesis, levels of physical activity and food intake, either separately or in combination. These changes show large inter-individual variability[12]. Energy supplementation in pregnancy has been shown to have variable effects on birth outcome, its impact may be related to the nutritional vulnerability of the woman[3], with a more obvious benefit in women who are nutritionally at risk.

Protein

Of all the nutritional interventions included within the systematic review of de Onis *et al.*[5], only balanced protein-energy supplementation in pregnancy resulted in a significant, reduction in the incidence of SGA. The majority of the trials, in which less than 25% of energy in the supplement was from protein, were conducted in underprivileged populations of women. Interventions with supplements of higher protein density have been associated with an increased incidence of SGA[13].

Essential fatty acids

Epidemiological evidence suggests an association between fish intake (and thus n-3 fatty acids) and birth weight[14], but RCTs of supplementation with fish oil have not clearly shown effects on birth weight[5]. Supplementation with fish oil during pregnancy results in improved docosahexaenoic acid status in infants at birth, which in turn may confer benefits in terms of neurodevelopment and merits further study[15].

Minerals, and trace elements

Iron

Data from controlled trials of pregnant women, even in industrialized countries, provide clear evidence of improved haematological status following iron supplementation[16]. Although maternal anaemia is associated with increased rates of prematurity and perinatal mortality[17], the RCTs included in the systematic review show that iron supplementation of pregnant women in

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developed settings does not have consistent effects on fetal outcome[5]. This may not be the case in populations where iron-deficiency is more common.

Zinc

Cross-sectional studies suggest that poor zinc status is associated with impaired fetal growth and poorer perinatal outcome[18,19]. Four RCTs (all in UK and US) in which maternal zinc intakes were supplemented with between 20 and 25 mg per day were included in the systematic review. There were inconsistencies across trials relating outcome to zinc supplementation, although in a trial of women with low plasma zinc levels, significant reductions in term-LBW were found[20]. de Onis *et al.*[5] concluded that further studies are needed to address the role of zinc nutrition in pregnancy. Since this review, results have been published of a RCT in Bangladesh in which women were supplemented with 30 mg zinc, and an observational study of zinc status and birth outcome in US women of low socioeconomic status[21,22]. Neither study showed a relationship between zinc status and birth outcome.

Calcium

The majority of trials supplementing pregnant women have been conducted with the aim of reducing hypertensive disorders in pregnancy[23]. With the exception of one recent study[24], RCTs have shown beneficial effects of calcium supplementation (of at least 1 g daily) on the incidence of high blood pressure, particularly among women with low dietary calcium intakes and those at high risk of gestational hypertension. There is weak evidence to support an effect of calcium supplementation on fetal growth[5]. Follow-up of calcium supplemented pregnancies (2 g daily) recently showed the 7-year old offspring to have reduced levels of blood pressure[25]. It is not known whether there are benefits of lower levels of calcium supplementation.

Magnesium

In cross-sectional studies birth weight has been shown to be positively related to magnesium intake in early pregnancy[26] and to magnesium concentration in cord blood[19]. In two RCTs conducted in developed countries[27,28] included in the systematic review[5], magnesium supplementation (15 mmol daily) resulted in lower incidence of term-LBW although in a further trial[29], 15 mmol supplementation from early pregnancy did not improve pregnancy outcome.

Copper

Although severe copper deficiency has been shown to be teratogenic in animal models, copper deficiency during pregnancy has not been described in humans[3]. Observational studies have shown inconsistent relationships between cord blood copper concentration and birth size[19,30]. There are no published studies of copper supplementation.

Iodine

Maternal iodine deficiency during pregnancy results in iodine deficiency disorders in the offspring. These include congenital anomalies, endemic cretinism as well as subclinical deficits in intellectual and motor function[31]. In iodine-deficient areas, maternal supplementation with iodine significantly reduces the incidence of these disorders[32]. Less is known about the influence of maternal iodine status on fetal growth, although higher birthweight has been observed in some supplementation studies[6]. In iodine-deficient areas, ensuring adequate iodine status among women of reproductive age should be a high priority.

Vitamins

Vitamin A

Epidemiological studies have yielded inconsistent associations between poor vitamin A status and intrauterine growth retardation[19,33,34]. Supplementation, with vitamin A or beta-carotene in a population at risk of vitamin A deficiency resulted in a reduction in maternal mortality of around 40%[35] but did not affect the rate of fetal loss or early infant mortality[36]. There is a need to establish a safe upper limit of intake, since very high intakes of vitamin A (above 10000 IU) have been associated with teratogenic outcomes[37].

Folate

Five trials included in the systematic review[5] showed a significant reduction in the incidence of LBW with routine folic acid supplementation. The overall quality of these trials was variable and further research is needed. Apart from an influence on fetal growth, folic acid supplementation in early pregnancy has been clearly shown to be protective against the occurrence of neural tube defects in the fetus[38]. Until recently, standard supplementation with folic acid was started relatively late in pregnancy. It will be important to determine whether pre-conceptional supplementation, or early pregnancy supplementation exerts any effect upon maternal health, or growth and development of the fetus.

Vitamin D

In two European RCTs, vitamin D supplementation had inconsistent effects on weight at birth[39,40] but reduced the incidence of neonatal hypocalcaemia. Larger trials, particularly in areas with long winters, and in those groups of the population at special risk of vitamin D deficiency (from parts of the middle-east and the Indian subcontinent) are needed to establish whether vitamin D supplementation of vulnerable groups is needed.

Conclusions

From the systematic review of RCTs[5] and from the overview of observational evidence, no clear relationship between maternal nutrition and pregnancy outcome emerges, and there are very few nutrients for which definitive guidelines can be established. In view of the general sense of an increased need for nutrients during pregnancy, it is surprising that so little information exists. There are several important issues which make interpretation of the data difficult.

Firstly, existing studies have evaluated the effects of single nutrients in groups of women. This approach fails to account for heterogeneity within these groups in terms of the innate metabolic characteristics of individual women which may influence their ability to supply nutrients to the fetus.

Secondly, consideration of single nutrients in isolation does not take account of the influence of other nutrients in the maternal diet. Not only may deficiency in one nutrient act as a marker of other dietary deficiencies, a focus on single nutrients limits our understanding of nutrient–nutrient interactions wherein the effect of a limitation of one nutrient might be buffered by the ready availability of another. This might be seen most frequently for the availability of anti-oxidant nutrients and in their complex interactions. Further, a marginal deficiency of one nutrient might impair or impede the biological availability or metabolic utilization of another, for example the complex interaction in the availability of iron depending upon either vitamin A, riboflavin, vitamin C or calcium. The significance of nutrient–nutrient interactions for fetal growth is not known in adequate detail[6].

Thirdly, the majority of studies, both of supplementation and observational, have been conducted in mid-late pregnancy. Since the fetal growth trajectory is established very early in gestation, it is possible that mid-late pregnancy is too late for nutrient effects to be seen. Periconceptional nutritional status may exert a different and maybe a more powerful influence on fetal growth than status in late gestation. In this respect we could expect supplementation studies starting before conception to achieve greater effect on outcome. There is an urgent need to understand how maternal nutrition before, and in early pregnancy relates to fetal growth.

Fourthly, interactions with infections, which may be acute, subacute or chronic should be considered. These impose a competitive demand for nutrients in the short or longer term, shift the metabolic set and alter the ability to handle the available nutrients. Although this may be considered to be only of importance for the most underprivileged in society, there is increasing evidence that low grade inflammation might be more common in pregnancy than appreciated, and therefore needs to be taken into consideration in the interpretation of the available data.

Finally the reliance on birthweight as the outcome measure with which we evaluate the relative success of the pregnancy may mean that we have failed to observe effects of maternal nutrition on fetal growth and development. Evidence from follow-up of survivors of the Dutch Hunger Winter has shown that long-term disease outcomes can vary without evident changes in birthweight[41].

The setting of dietary guidelines for pregnancy

At present, our understanding of the role of maternal nutrition in fetal growth and development is limited. Although scientific studies have failed to describe clear links between maternal diet and fetal growth, it is unlikely that the quality of the maternal diet has no impact on nutrient availability to the fetus, and the importance of maternal diet cannot be discounted. In the absence of good scientific evidence it is reasonable to expect that women entering pregnancy are provided with a diet which is adequate, based upon our normal understanding of requirements, and it is not acceptable for women to be expected to carry a pregnancy with an obvious or overt nutritional deficiency. Dietary guidelines during pregnancy should emphasize the need to consume a varied, balanced diet against a background of reasonable activity and adequate rest.

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