633

FETAL STUNTING, FETAL WASTING AND MATERNAL NUTRITIONAL STATUS

by

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SUMMARY

To assess the nutritional status of newborn infants by a method roughly independent of a precise knowledge of gestational age, this paper suggests the use of two indices based on body measurements which may reflect malnutrition. On analogy with older children, the index determining whether a newborn infant has a small body size compared to its head circumference was called the "stunting index" whereas the one measuring the relative weight for body length was called the "wasting index". These indices were used to determine the relation between the nutritional status of the newborn infants and their mothers in an underprivileged population in Dakar which has a relatively low mean birth weight of between 3000 and 3200g, with seasonal variations. In a sample of 131 subjects, the morphology of the newborn infants was found to be largely independent of maternal mid upper arm circumference suggesting that the main limiting factor of fetal growth was not insufficiency of maternal nutritional reserves. To explain this observation and the well documented rapid growth of breast fed babies in Dakar, both facts difficult to understand if one assumes that fetal malnutrition at the end of pregnancy is the consequence of a poor maternal nutritional status, an alternative interpretation is suggested : imperfect adaptation of the cardio-vascular system to the upright posture at the end of pregnancy could be the main limiting factor of fetal growth in populations who do not have a grossly deficient food intake. Therefore, the slight fetal malnutrition observed in Dakar, may be a consequence of the intensive physical activity of the mothers with reduced opportunities for rest at the end of pregnancy. Clinical implications are discussed briefly : it is suggested that in more deprived areas, where energy deficiency of maternal diet does limit

fetal growth, reduction of maternal activity should be associated with energy supplementation to obtain optimal growth of the fetus.

Key words : pregnancy, fetus, growth, nutrition, posture.

In the human species, the fetal growth curve has a very characteristic shape. After being almost linear from the 28th to the 38th week of intrauterine life, there is a progressive reduction in the growth rate which is more marked and occurs earlier in the underprivileged social classes (Gruenwald, 1966). It seems unlikely that this decline in fetal growth rate is of genetic origin. Shortly after birth, away from the maternal environment, newborn infants regain a growth rate similar to the beginning of the third trimester of intrauterine life. Moreover, there is no irregularity in the growth curves of prematurely born babies near their theoretical term (Campbell, 1976).

Gruenwald (1966) has suggested that this growth faltering may be of nutritional origin. According to his observations, newborn babies whose weight is lower than it would have been had their growth remained constant, have anatomical characteristics reminescent of malnutrition in older children. Therefore, it is frequently concluded from his work and similar studies by Naeye (1965) that a low birth weight for gestational age is synonymous with intrauterine malnutrition.

Birth weight by itself however must be considered a bad indicator of the nutritional status of a newborn. First of all, it is very much influenced by the gestational age which in practice is frequently in doubt. Moreover, according to Gruenwald (1966) the birth weight would result from the interaction of two factors which can vary independently and which should not have the same significance : first the initial growth rate of the fetus and second the extent and timing of the decline in the growth curve. Only this second factor would be related to intrauterine nutrition. Consequently, if a newborn has a low birth weight, one should speak of malnutrition only if there is reason to believe that the low weight results from a pronounced growth faltering.

- With this in mind, in the work on nutritional relations between the mother and the newborn in Dakar, we took into consideration not the birth weight by itself, but different combinations of it with head circumference and body length. This represents an attempt to assess the nutritional status of the newborn infant not by the absolute value of its anthropometric parameters but by calculated indices describing its morphology. We speculated on the analogy with older children (Jelliffe, 1966) that a newborn infant with a relatively low weight and body length for head circumference was likely to have had intrauterine malnutrition regardless of the absolute value of these variables. Conversely, a small but correctly proportioned newborn infant would be classified as normally nourished and considered as having a low initial growth rate or as having a gestational age slightly below the average of the group.

METHODS

The work was done in a maternity centre in Dakar serving women of a low socio-economic level. Previous nutritional surveys of this population reported a mean energy intake of slightly over 2000 kcal./day (Canonne and Chevassus-Agnes, 1978). A sample of newborn infants was taken in June 1978 at the end of the dry season, a time of the year when the birth weight is slightly above average (Dupin, Masse and Correa, 1952). Babies born between 7 a.m. and 1 p.m. on the days of the study were systematically examined. Those with a gestational age evaluated by neurological examination (Saint-Anne Dargassie, 1974) as being over 38 weeks and whose mothers had not had pre-eclampsia as defined by the simultaneous occurrence of hypertension, oedema and proteinuria were included in the survey. The total was 131 babies, mostly of Wolof, Peulhe, Toucouleur or Sere origin. The average parity of the mothers was 3,5 (s.d. = 2,1); there were 22 primiparae.

The accuracy of the measurements was ± 10g for Birth weight, ± 1mm for head circumference and ± 0,5 cm for body length. Subjects with cephalhaematoma were excluded. The height and mid upper arm circumference of every mother was also measured (accuracy = ± 1mm).

RESULTS

The mean values of the measurements of the newborn infants and their mothers are shown in Table 1 and 2. There is a strong correlation between the infant measurements as shown in Table 3, which means that these variables each give very similar information. To obtain independent indices describing morphological characteristics of every subject and providing a maximum of information, we made a principal component analysis. In other words, we transformed the standardized anthropometric data by a rotation of the axis in three independent indices Z1, Z2, Z3 which are sufficient to characterize a newborn infant.

The formula for the transformation of the standardized data can be deduced from the coordinates of the eigenvectors of the correlation matrix. We obtained :

$$Z1 = 0{,}61\ \text{Weight} + 0{,}59\ \text{Body Length}\ \pounds\ 0{,}53\ \text{Head Circumference}$$

$$Z2 = -0{,}25\ \text{Weight} - 0{,}49\ \text{Body Length} + 0{,}84\ \text{Head Circumference}$$

$$Z3 = -0{,}76\ \text{Weight} + 0{,}63\ \text{Body Length} + 0{,}16\ \text{Head Circumference}$$

These indices explain respectively 76%, 17% and 7% of the global variance. Their mean value for the whole sample is zero.

To illustrate these formulae, we will use them to calculate the indices of a newborn infant whose birth weight is 3226 g, body length is 49.4 cm and head circumference is 33,8 cm. These data represent the average values of newborn infants in Denver (Colorado, U.S.A.) at 40 weeks of gestational age according to the growth chart of Lubchenco (1963; 1966). Translated into standardized data, these parameters are respectively :

Birth weight	=	- 0,04
Body length	=	- 0,33
Head circumference	=	- 1,11

The value of the first index is :

$$Z1 = -0,61 \times 0,04 - 0,59 \times 0,33 - 0,53 \times 1,11 = -0,81$$

likewise :

$$Z2 = -0,77, Z3 = -0,36.$$

These three values are outside the interval of variation of the average of these indices in our sample ($p < 0,01$). This point will be discussed later.

After calculating indices Z1, Z2 and Z3 for every newborn infant, we examined their relation to maternal height and mid upper arm circumference. The correlation coefficients are given in Table 4. Briefly, Z1 is significantly and positively correlated with maternal height ($p < 0,05$), Z2 is very significantly negatively correlated with the same parameter ($p < 0.01$), Z3 is very significantly negatively correlated with maternal arm circumference ($p < 0,01$).

DISCUSSION

1. *Interpretation of the indices*

Index Z1 is positively correlated with the three anthropometric parameters of the newborn infants. As each one is closely related both to the gestational age and to the growth potential of every subject, this index may be considered as resulting from both variables.

Indices Z2 and Z3 are a measure of the extent to which the newborn morphology resembles that of older children who have had some degree of malnutrition. Z2 is high for babies with a low birth weight and a small body length for their head circumference, Z3 is high for those who have a low weight for body length. On analogy with older children, (Jelliffe, 1966) we will designate Z2 the "stunting index" and Z3 the "wasting index".

Because of the way they are calculated, Z2 and Z3 vary independently of Z1. So, if one follows the interpretation of Z1 suggested, the assessment of nutritional status of the newborn infants obtained by evaluation of these indices is not influenced by the inaccuracy of gestational age or by the variations of growth potential. To some extent, Z2 and Z3 may be considered as "precise age independent indices" of nutritional status.

2. *Validity of the mathematical model*

The mathematical model we used to assess the nutritional status of the newborn infants assumes that the relation between the dimensions of the head and the body is mainly influenced by nutritional factors. This is not totally true. First, some individual variations of the morphology may be of genetic origin and this can bias the results. Moreover, the volume of the head of a newborn infant is proportionally greater when the gestational age is low (Vaughan and MacKay, 1975). To avoid distortion from this second factor,we selected a relatively homogenous sample of newborn infants for gestational age by testing their maturity neurologically.

Though this method of assessment of nutritional status is far from perfect, it should be more accurate than the usual one of comparing the birth weight of a newborn infant with the average for its gestational age which is based on the double assumption that all the subjects have the same initial growth rate and that their gestational age is known precisely. These hypotheses can never be verified in practice.

Whatever method is used, it seems indispensable to rely on a model based on the simultaneous analysis of several anthropometric variables. Mathematically, it is impossible to extract from the variations of the birth weight alone the relative importance of intrauterine nutrition and other factors to determine size at birth. It is necessary to consider at least one other variable submitted to the same influences but reacting differently.

3. *Comparison of the Dakar newborn infants with the Denver standards*

Previouslywe calculated the indices of the mean values of the anthropometric parameters of 40 week Denver newborn infants. As the mean birth weight of our sample is 3241g which is slightly above the Denver standard, one might assume that the nutritional status of Dakar newborn infants is very similar to the Denver one. The calculation of nutritional indices contradicts this first impression.

The "stunting" and "wasting" indices Z2 and Z3 which are supposed to be characteristic of intra-uterine malnutrition obtained by the transformation of the Denver data are clearly below zero which is by definition the mean value ofour sample. This suggests that the factors limiting the fetal growth at the end of intrauterine life are greater or occur sooner in Dakar than in Denver.

The first index Z1 is also higher in Dakar. This can be explained in two different ways : one might argue that the growth potential is higher in our sample or that the mean gestational age of the newborn infants examined is slightly more than 40 weeks. These two possibilities are not mutually exclusive. Unfortunately, the data give no indication of the correct interpretation.

Maybe ethnic factors influence the growth potential during fetal life. It was reported from New York that black newborn infants were heavier than white ones up to 28 or 30 weeks of gestational age although their subsequent birth weight was slightly lower (Erhardt *et al*, 1964). The possibility of a mean gestational age of slightly more than 40 weeks in my sample of infants must also be considered. Geber and Dean (1957) reported that the African newborn infant has an advanced degree of neurological maturation by European standards. This might be explained by a prolonged period of gestation (Saint Anne Dargassie, 1974). In the Rhesus Monkey, Riopelle and Hale (1975) have shown that climatic and nutritional factors have some influence on the duration of pregnancy.

These two possibilities of a different growth potential in our population or of a different gestation length suggest that the assessment of nutritional status of a newborn infant by its birth weight alone may be biased by unexpected factors. This underlines the urgent need to develop improved indices, independent of precise knowledge of gestational age for investigation of fetal nutrition in developing countries.

4. *Relation between maternal anthropometry and indices of the infants*

The observed positive correlation between Z1 and maternal height means that larger mothers tend to have large babies at birth. This is a general rule which applies even between different species (Hytten and Leitch, 1971). The relations of Z2 and Z3 with maternal anthropometry provides more original information about the influence of maternal nutritional status on fetal growth. We tried to use these indices to determine whether, in our sample, the infants whose morphology was suggestive of malnutrition were born to thinner women as might be expected if the poor nutritional status of the mothers was the main limiting factor of fetal growth.

The index of wasting (Z3) was significantly negatively correlated with maternal mid upper arm circumference. This suggests that some of the women examined had insufficient nutritional reserves to support fetal growth up to the end of pregnancy. This phenomenon however must be considered as relatively minor : Z3 explains only a small part of the global variance (7%) which means that it had little influence on the morphology of the infants. The index of stunting (Z2) accounted for much more of the morphological variation in the sample (17% of the global variance). However, it was not correlated with maternal mid upper arm circumference. In other words, the degree of fetal deprivation assessed by the relative proportions of the head and the body was largely independent of this indicator of maternal nutritional status. This finding is surprising in the light of the widely held belief that poor maternal nutritional reserves are the principal limiting factor of fetal growth in developing countries. The intervention of other factors independent of maternal nutritional status, suggested by the results, could explain why breast fed babies have very rapid growth after birth in Dakar despite a relatively low mean birth weight (Masse, 1969).

To explain these facts, impossible to understand on a purely nutritional basis, we suggest a non-nutritional interpretation of variations of fetal growth in different social groups drawn from the theory of evolution (Briend, in preparation). The growth faltering observed just before birth in man must be considered as an imperfection; there is no reason to believe that deprivation of the fetus just before the stress of delivery would be of any value to the species. Very likely, this imperfection appeared at the same time as the acquisition of the upright position which was associated with a relative diminution of the dimensions of the pelvis and of the trunk and the appearance of lumber lordosis. These skeletal modifications predispose to compression by the pregnant uterus of the aorta and inferior vena cava. The resulting haemodynamic changes have unfavourable implications for the placental blood flow and hence for fetal nutrition and are aggravated by the standing position. The negative correlation we observed between Z2 (stunting) and maternal height may be a consequence of the reduction of the space available for fetal development.

This hypothesis implies that pregnant women must be considered as imperfectly adapted to the upright position and that their way of life at the end of pregnancy may influence fetal nutrition. This could explain why the decline of fetal growth at the end of intrauterine life that exists in industralized countries seems particularly pronounced inour sample : in Dakar, women of low socio-economic level are very active physically and remain on their feet up to the end of pregnancy with little possibility of rest.

CONCLUSION

In Dakar, the mean birth weight, between 3000g and 3200g with seasonal variations (Dupin, Masse and Correa, 1962) is low compared to European standards. It is similar to that observed in groups of low socio-economic level in developed countries (Gruenwald, 1966). In our sample of full term newborn infants,we observed that their morphology, assessed by the relative dimensions of the head and the body, was reminescent of malnutrition in older children, which suggested that they may have undergone slight nutritional deprivation in late fetal life.

It seems difficult to explain these two facts on a purely nutritional basis and to relate them to an insufficiency of the maternal diet. First, in our sample, the morphology of the infants was largely indpendent of the mid upper arm circumference of the mothers when the reserse should have been observed if a poor maternal nutritional status had been the main limiting factor of fetal growth. On the other hand, it is well documented that in Dakar, breast fed babies have rapid growth, at least during the first months of life and catch up very quickly to international standards (Masse, 1969). An alternative explanation must be considered and we suggest that impairment of fetal growth in Dakar, may be the consequence of the effect of excessive maternal activity on placental blood flow.

This conclusion leads us to raise some questions. There is good evidence that, in contrast to Dakar, energy deficiency of the maternal diet is the main limiting factor of fetal growth in many deprived areas of developing countries, (Lechtig *et al*, 1975). However, we question whether supplementation of the maternal diet alone is really able to overcome this type of fetal malnutrition. Such an approach totally ignores the huge work load that falls on mothers in developing countries and which, we believe, even in urban areas such as Dakar, may itself affect fetal growth. Would it not also be advisable to reduce the energy expenditure of the women by reducing their more strenuous work? This, we believe, would suppress unfavourable effects on placental blood flow, amplify the effect of any dietary supplement on energy balance, and improve the standard of child care during the first months of life. Thus reduction of maternal activity should be associated with energy supplementation of the maternal diet to obtain optimal fetal growth in developing countries.

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REFERENCES

Briend A.: Fetal malnutrition - the price of upright posture. In prepration (1979).

Campbell S.: Fetal growth. In: Fetal physiology and medicine, ed. R.W. Beard and P.W. Nathanielsz, p. 271-301. W.B. Saunders Company Ltd, London (1976).

Canonne P., Chevassus-Agnès S.: Enqete de consommation alimentaire F.A.O./O.R.A.N.A., Dakar (1978).

Dupin H., Masse L., Correa P.: Contribution à l'étude despoids de naissance à la maternité africaine de Dakar; évolution an cours des annees, variations saisonnières. Courriet du C.I.E. 12, 4, 1-30 (1962).

Erhardt C.L., Doshi G.B., Nelson F.G., Kroll B.H., Weiner L.: Influence of weights and gestation on perinatal and neonatal mortality by ethnic group. Am. J. Pub. Health. 54, 1841-55 (1964).

Geber M., Dean R.F.A.: The state of development of newborn African children. Lancet, i, 1216-9 (1957).

Gruenwald I.: Growth of the human fetus : I. Normal growth and its variations. Am. J. Obstet. Gynec. 94, 112-119 (1966).

Hytten F.E., Leitch I.: The physiology of human pregnancy. 2nd ed. Blackwell Scientific Publications, London (1971).

Jelliffe D.B.: The assessment of the nutritional status of the community - WHO Monograph, Geneve. (1966).

Lechtig A., Habicht J.P., Delgado M., Klein R.E., Yarbrough C.: Effect of food supplementation during pregnancy on birth weight. Pediatrics, 56, 508-20 (1975).

Lubchenco L.O., Hansman C., Dressler M., Boyd E.: Intrauterine growth as estimated from liveborn birth weight data at 24-42 weeks of gestation. Pediatrics, 32, 793-800 (1963).

Lubchenco L.O., Hansman C., Boyd E.: Intrauterine growth in length and head circumference as estimated from live birth at gestational ages from 26 to 42 weeks. Pediatrics, 37, 403-8 (1966).

Masse G.: Croissance et developpement de l'enfant à Dakar. Centre International de l'Enfrance- Paris (1969).

Naeye R.L.: Malnutrition, a probable cause of fetal growth retardation. Arch. Pathol. 79, 284-91 (1965).

Riopelle A.J., Hale P.A.: Nutritional and environmental factors affecting gestation length in rhesus monkey. Am. J. Clin. Nutr. 28, 1170-6 (1975).

Saint-Anne Dargassie S.: Le développement neurologique du nouveau né à terme et prematuré. Masson et Cic Paris, (1974).

Vaughan V.C., MacKay R.J.: Nelsons Textbook of Pediatrics. 10th ed. W.B. Saunders Company, Philadelphia (1975).

Table 1

ANTHROPOMETRIC PARAMETERS OF THE NEWBORN INFANTS

	Weight (g)	Body length (cm)	Head Circumference (mm)
mean	3241	50	351
s.d.	392	1,8	11

Table 2

ANTHROPOMETRIC PARAMETERS OF THE MOTHERS

	Height (cm)	Arm circumference (mm)
Mean	162	261
s.d.	6	33

Table 3

CORRELATION MATRIX OF THE ANTHROPOMETRIC PARAMETERS OF THE NEWBORN INFANTS

	Birth Weight	Body Length	Head circumference
Birth weight	1	0,790	0,606
Body length	0,790	1	0,519
Head circumference	0,606	0,519	1

Table 4

CORRELATION MATRIX OF INDICES Z1, Z2 and Z3 WITH MATERNAL ANTHROPOMETRIC PARAMETERS

	Z1	Z2 (stunting)	Z3 (wasting)
Height	0,176*	- 0,243*	- 0,152 ns
Arm circumference	0,143 ns	0,04 ns	- 0,249**

ns : non significant

* : p less than 0,05

** : p less than 0,01