Perinatal Medicine

Fifth European Congress of Perinatal Medicine
Uppsala, Sweden
9–12 June 1976

Editors: Gösta Rooth, Lars-Eric Bratteby

Distributed by
Almqvist & Wiksell International
Stockholm, Sweden

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Effect of Maternal Nutrition on Infants Growth and Mortality in a Developing Country

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Introduction

The incidence of low-birthweight (LBW≤2.5 kg) babies is excessive in rural and urban low socio-economic groups in pre-industrialized countries. Since a large part of the population in these countries is in this socio-economic stratum, low-birthweight infants constitute a large proportion of the total newborn population. About 22 million LBW babies were born in developing countries during 1975 and in these countries the rate of LBW babies was on the average three times higher than in developed countries (28). Since most of the LBW babies presumably were full-term newborns, their low weights reflected fetal growth retardation.

Low-birthweight infants have a higher mortality during the first year of life than infants of normal birthweight (2, 35). In addition, they show impaired mental development (15, 41) and it is possible that this impairment influences their ability to develop into functioning adults. Thus, fetal undergrowth is probably one of the major public health problems in developing countries.

It is widely believed that in these countries the factors which account for most of fetal growth retardation are environmental and therefore, preventable (19, 20, 21, 23, 25, 29, 32, 34). Experiments in animals have shown that severe caloric or protein malnutrition in the mother delays fetal growth (42).

In humans, an effect of maternal nutrition on birthweight has been demonstrated in cases of acute starvation (1, 8, 39). However, studies of the influence of chronic moderate malnutrition on fetal growth have yielded results somewhat more difficult to interpret (16, 20, 21, 23). Consequently, it has not been feasible to estimate expected impacts of public health programmes aimed to ameliorate the problem of fetal growth retardation and its sequelae.

This paper presents results of a study in which two nutritional supplements were made available to a chronically malnourished population. The food supplements were provided to pregnant and lactating women as well as to their children in four rural villages of Guatemala. Data collection included physical growth, mental development, health and socio-economic status. Finally, preventive and out-patient curative medical care was provided free of cost to all residents of the four villages.

Material and Methods

A. *Experimental design.* The data presented here are drawn from an on-going longitudinal study of the effects of chronic malnutrition on physical growth and mental development (12). The experimental design and the principal examinations made during the pre- and postnatal periods are presented in Table 1. Two types of food supplements are provided: atole[1] and fresco.[2] Two villages receive atole while the

[1] The name of a gruel, commonly made with corn.
[2] Spanish for a refreshing, cool drink.

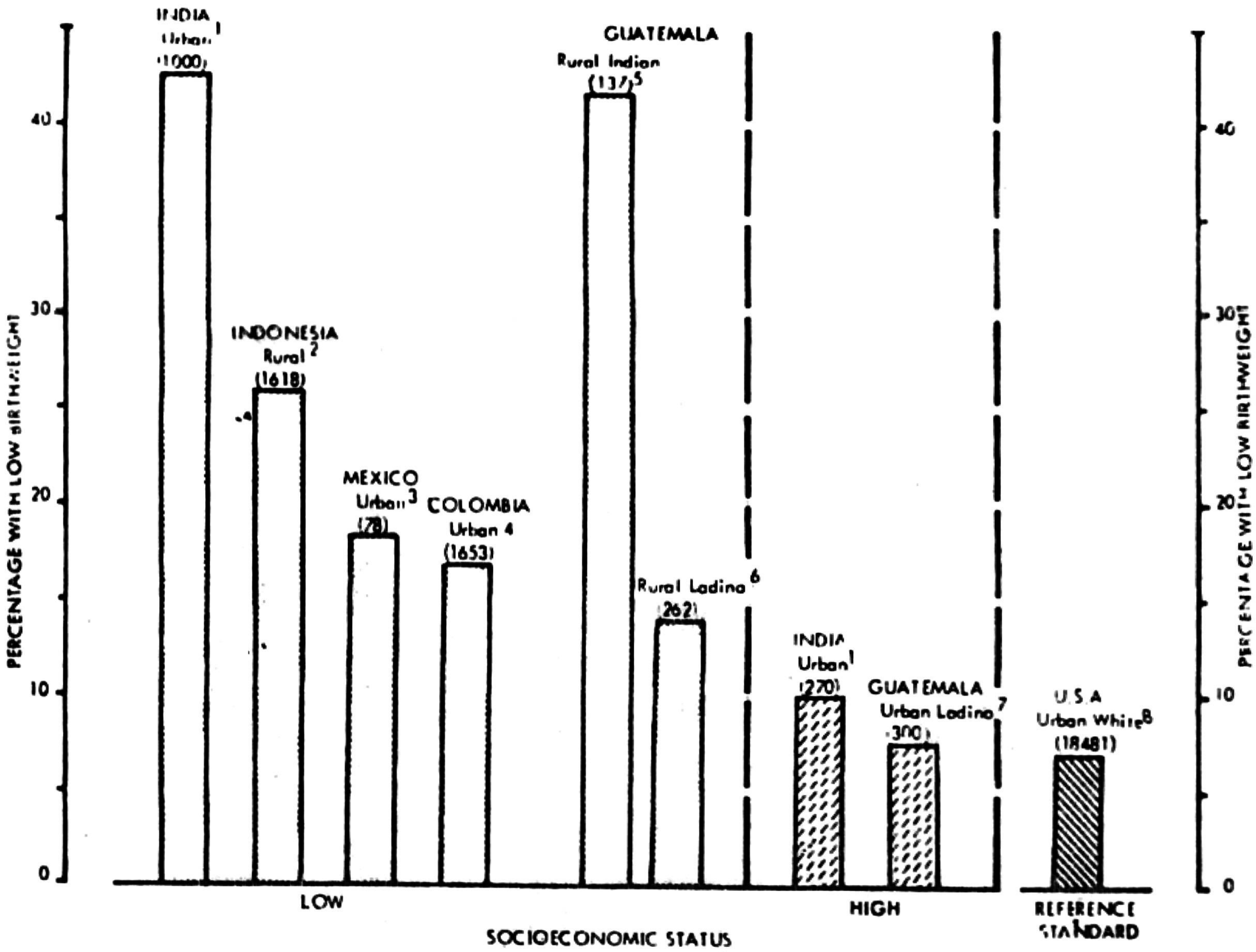

Fig. 1. Relationship between socio-economic status and the proportion of infants with low birthweight (≤2.5 kg) in preindustrialized societies. Number of cases in parentheses. 1. Computed from Udani 1963; 2. Shattock 1968; 3. Cravioto 1967; 4. Oberndorfer 1965; 5. Mata et al. 1971; 6. Lechtig et al. 1972; 7. Hurtado-Vega 1962; 8. Niswander et al. 1972.

other two receive fresco. Attendance to the supplementation center is voluntary and consequently a wide range of supplement intake is observed. Table 2 presents the nutrient content for both atole and fresco. It should be stressed that the fresco contains no protein and that it provides only one third of the calories contained in an equal volume of atole. In addition, both preparations contain similar concentrations of the vitamins and minerals which are possibly limiting in the diets of this population.

B. *Study population.* The study population is a rural population in which moderate malnutrition and infectious diseases are endemic (17, 19, 23). The villages and their inhabitants are very poor, the median family income being approximately $200 per annum. The typical house is built of adobe and has no sanitary facilities. Drinking water is contaminated with enteric bacteria. Corn and beans are the principal staples of the home diet, and animal protein comprises 12% of total protein intake (23, 25). The average maternal height and weight are low: 149 cm and 49 kg, respectively. The number of previous deliveries among the women studied ranges between 0 and 13 and the reproductive age span is from 14 to 46 years (23).

C. *Variables and sample size.* For the present analyses, ingestion of supplemented calories was selected at the criteria to assess supplement intake to facilitate comparison between the two types of food supplement: fresco and atole, because the home diet appears to be more limiting in calories than in proteins (23). We stress that while calories appear to be limiting in this study population, other populations may present very different nutritional situations. The principal outcome variables were the prevalence of

Table 1. *Experimental design (four villages)*

Two villages: atole[a] = protein-calorie supplement, two villages: fresco[b] = calorie supplement

A. *Maternal and child information collected*

1. Independent variable:
   Measurement of subject's attendance to feeding center and amount of supplement ingested
2. Dependent variables:
   Assessment of physical growth
   Assessment of mental development
   Infant mortality
3. Additional variables:
   Obstetrical history[c]
   Information on delivery
   Clinical examination
   Dietary survey
   Morbidity survey
   Socio-economic survey of the family

[a] The name of a gruel commonly made with corn.
[b] Spanish for a refreshing, cool drink.
[c] Diagnosis of pregnancy by absence of menstruation.

Table 2. *Nutrient content per cup[a] (180 ml)*

	Atole	Fresco
Total calories (kcal)	163	59
Protein (g)	11	–
Fats (g)	0.7	–
Carbohydrates (g)	27	15.3
Ascorbic Acid (mg)	4.0	4.0
Calcium (g)	0.4	–
Phosphorus (g)	0.3	–
Thiamine (mg)	1.1	1.1
Riboflavin (mg)	1.5	1.5
Niacin (mg)	18.5	18.5
Vitamin A (mg)	1.2	1.2
Iron (mg)	5.4	5.0
Fluorine (mg)	0.2	0.2

[a] Review date: 11 October 1973. Figures rounded to the nearest tenth.

physical growth retardation at birth and at 36 months of age and infant mortality. •

Table 3 presents the sample size for each of the variables examined in the present paper. The total sample of 1 083 children was made up of 671 births which occurred in the 4 villages from January 1969 until February 1973, and 412 children alive and under 3 years of age at the beginning of data collection in January 1969. The results reported are for the total sample up to 36 months of age. On 31 May 1974 the youngest child in the longitudinal cohort reached 15 months of age; the sample of later ages is at this moment incomplete.

Results and Discussion

Figure 2 presents the proportion of mothers with low weight gain during pregnancy for three levels of maternal supplementation. It is clear that this proportion was very low in the well-supplemented group.

Given the known association between weight gain during pregnancy and birthweight (30), an effect of caloric supplementation on birthweight was also expected.

Figure 3 shows that the percentage of low birthweight babies was consistently almost half in the better supplemented group than in the lower supplemented group in both the fresco and the atole groups. Since home caloric intake was similar in both groups (23), the supplemental calories represented additional calories to the maternal diet. In the high calorie supplementation group, this addition amounted to approximately 35 000 calories, or about 200 extra cal/day during the last two trimesters of pregnancy.

This association between caloric supplementation and birthweight was not explained by maternal size, home diet, morbidity, obstetrical characteristics or socio-economic status (23). Most importantly, this association was also observed across two consecutive births by the same mother (23). Thus, based on these findings, we conclude that caloric supplementation during pregnancy produced the decrement of LBW babies in this population (23).

Table 3. *Sample size[a]*

Variable	No. of children born into sample	Total no. of children observed
Children available	671	1 083
Physical growth:		
At birth	405	405
At 36 months	330[a]	581[a]
Infant mortality:		
First 12 months of age	661	821

[a] Up to 30 November 1974.

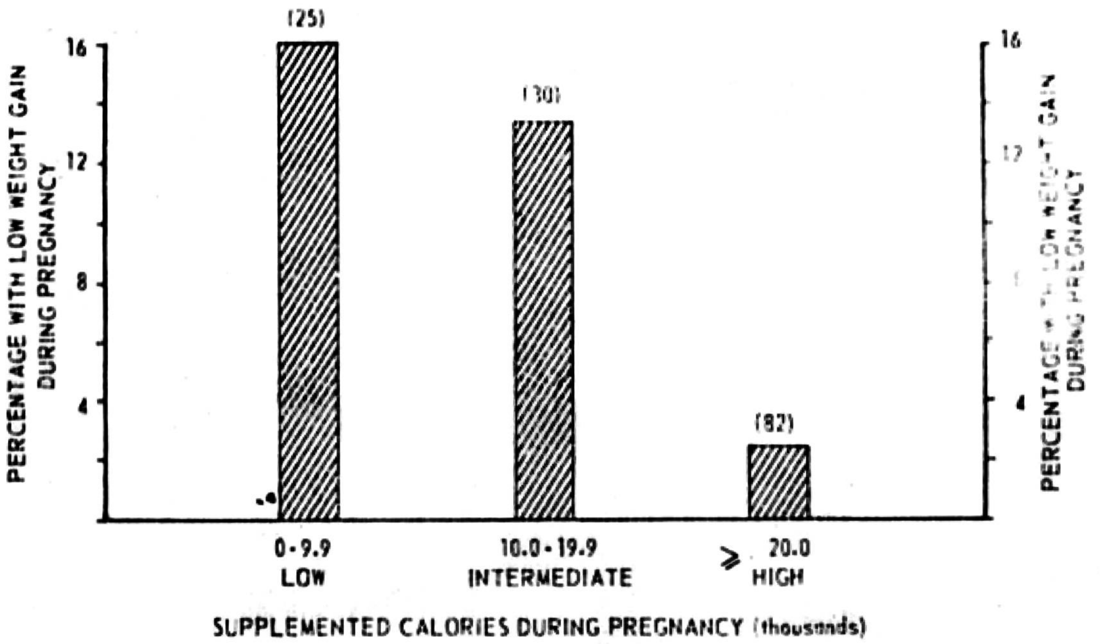

Fig. 2. Effect of supplemented calories during pregnancy on the proportion of mothers with low weight gain during pregnancy. Less than 0.5 kg per month of pregnancy. Number of cases in parentheses. $p < 0.10$.

Maternal Anthropometry and Birthweight

Figures 4 and 5 show that maternal head circumference and height are associated with birthweight. Figure 6 shows that in a sample of urban mother's arm circumference was also significantly associated with birthweight. We believe that this association may reflect the influence of recent maternal nutritional status on fetal growth. In addition, the maternal weight at 36 weeks of pregnancy was associated with birthweight. In fact, we have found that almost all the parameters of maternal size are associated with birthweight (30). Thus, smaller mothers tend to have smaller babies. Since the bulk of the retardation in head circumference and height in the adult is a consequence of events occurring during the first few years of life, their relationship with birthweight may reflect the effect of early maternal nutrition on subsequent fetal nutrition (21, 23).

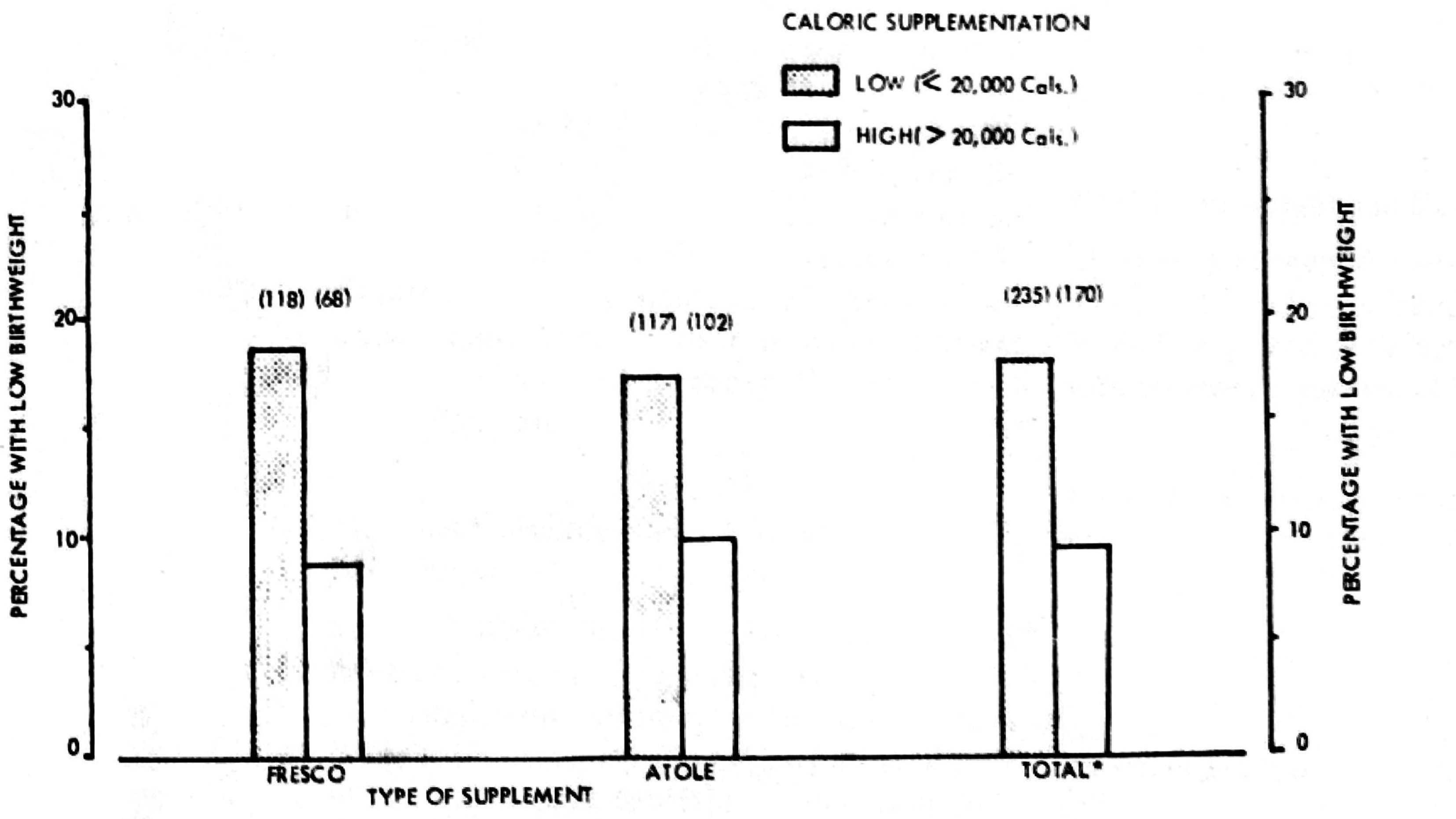

Fig. 3. Relationship between supplemented calories during pregnancy and proportion of babies with low birthweight (≤2.5 kg). Number of cases in parentheses. $^*p < 0.05$.

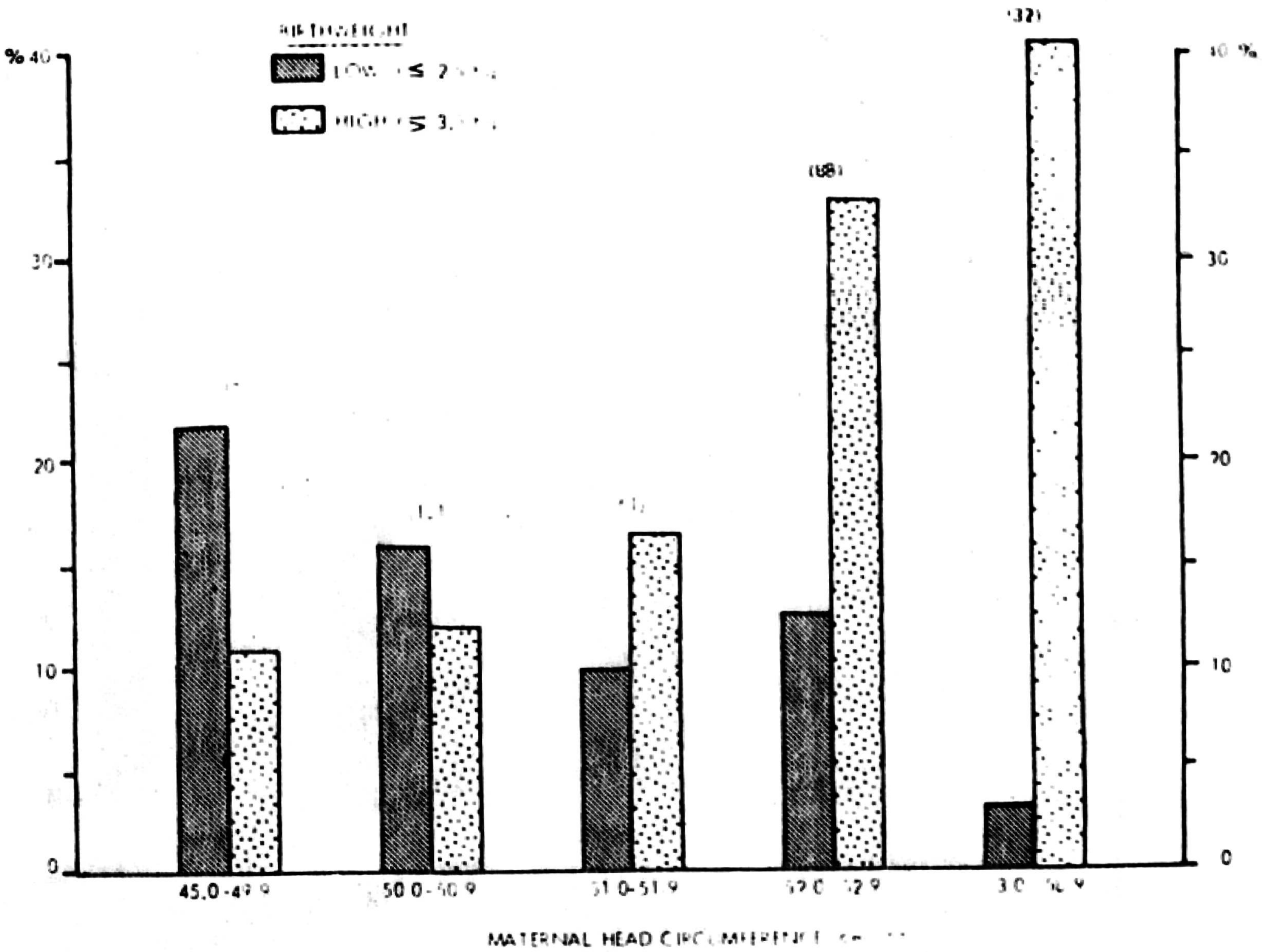

Fig. 4. Relationship between head circumference of the mother and the proportion of babies with low and high birthweight. Number of cases in parentheses. **$p<0.01$.

Obstetric Characteristics and Birthweight

Table 4 shows that all of these obstetric characteristics studied (age of the mother, number of gestations, parity and gestational age) were positively associated with birthweight (18).

In addition, studying differences between siblings, birth interval showed a positive correlation with birthweight. Of the two components of birth interval, the period of lactation and non-lactation, the latter was the primary determinant of the association between birth interval and birthweight (5).

Maternal Morbidity during Pregnancy and Birthweight

Figure 7 shows that a composite indicator of morbidity during pregnancy was negatively associated with birthweight. In fact, mothers with the lowest levels of morbidity showed 10% of low birthweight babies compared with 26% among the mothers with the highest levels of morbidity. Our interpretation of these results is that morbidity during pregnancy leads to lower dietary intake which, in turn, results in fetal growth retardation (17, 29).

Cord Levels of IgM and Birthweight

There is evidence that both high cord IgM levels reflect intrauterine infection and that at least several intrauterine infections are associated with greater prevalence of low birthweight (25).

Table 4. *Relationship between maternal obstetric characteristics and birthweight*

	Correlation value	Number of cases	Probability value<
Age	0.11	405	0.01
Number of gestation	0.15	405	0.01
Parity	0.15	405	0.01
Gestational age	0.22	396	0.01

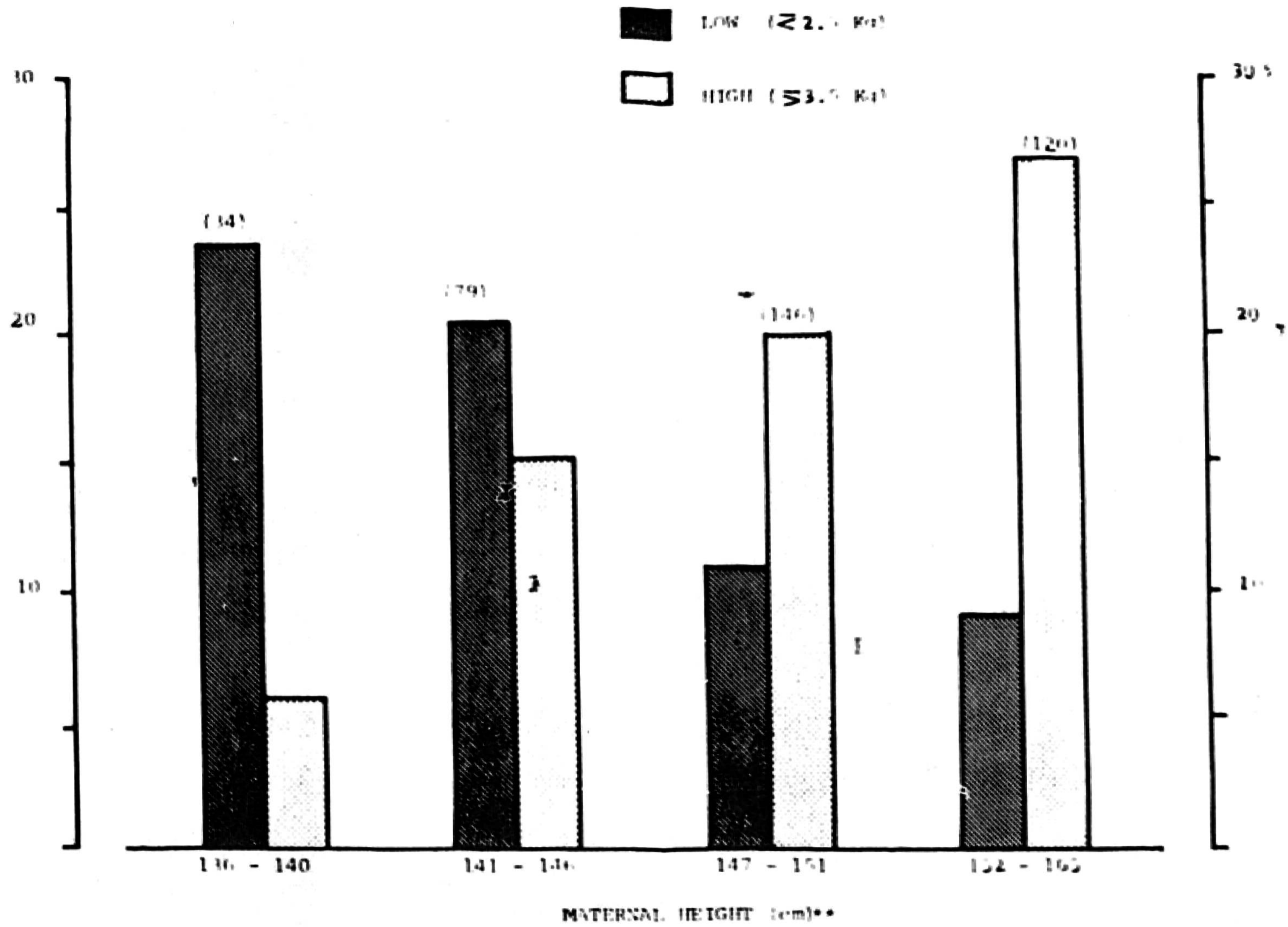

Fig. 5. Relationship between maternal height and the proportion of babies with low and high birthweight. Number of cases in parentheses. $^{**}p<0.01$.

In our study population, there was a negative trend between cord IgM levels and birthweight. However, within the group with low IgM values (<20 mg%) the correlation was positive ($r=0.16$, $N=101$, $p<0.10$) whereas in the group with high IgM values (≥20 mg%) the correlation was negative ($r=0.21$, $N=74$, $p<0.05$). These results suggest that there are at least two factors contributing to the relationship between cord IgM levels and birthweight. The first is, that apart from infection, heavier babies produce greater quantities of IgM, and the second is that intra-uterine infection produces both increased levels of IgM and lower birthweight (19, 25).

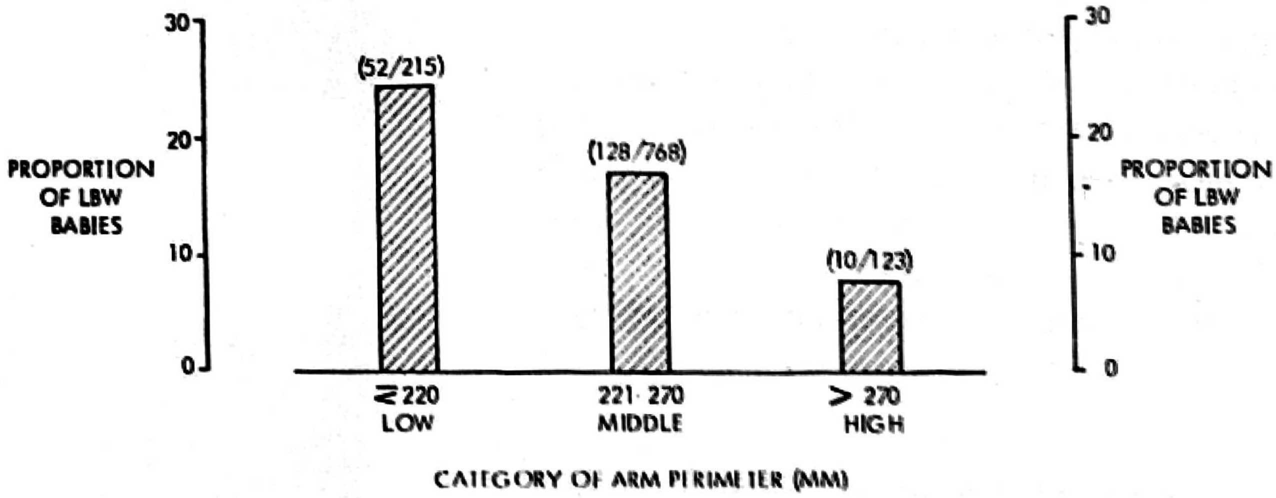

Fig. 6. Proportion of low birthweight (LBW<2.5 kg) babies per category of maternal arm circumference ($p<0.01$). In parentheses: numerator is number of LBW babies and denominator is number of cases in each category.

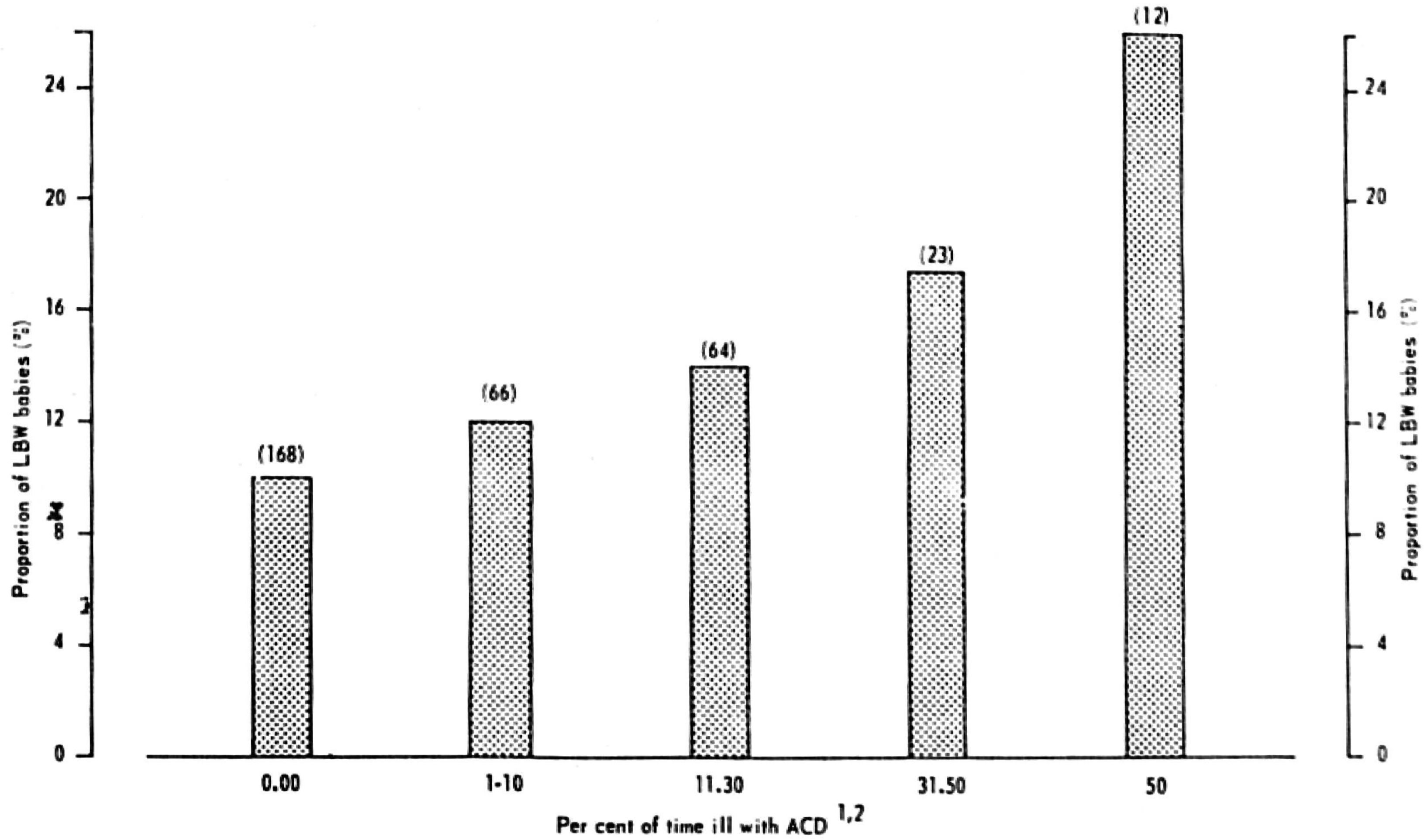

Fig. 7. Relationship between per cent of time ill with ACD during pregnancy and proportion of low birthweight (LBW≤2.5 kg) babies (four rural Guatemalan villages (N=334). 1. Per cent of pregnancy days ill with diarrhea and/or anorexia and/or cephalgia (Composite Indicator ACD). 2. Sign test for direction: $(\frac{1}{2})^5$; p=0.03. Number of cases in parentheses.

Socio-economic Factors and Birthweight

So far, we have presented data to argue that factors such as socio-economic status do not confound the findings reported. We should note, however, that this does not mean that socio-economic status is not important. In fact, the reverse is true.

Figure 8 shows that in our study population, a socio-economic scale (SES) mainly based in house characteristics was associated with birthweight. The association between the socio-economic score and birthweight disappeared after controlling for maternal height and supplementation during pregnancy. Our interpretation of these results is that the socio-economic score indicates environmental conditions which in turn will lead to a lower birthweight. This hypothesis is supported by the observation that food supplementation produced the greatest effects in the low socio-economic score group (20).

Effect of Nutrition on Post-natal Growth

Maternal nutrition during pregnancy and lactation may also determine breast milk output which in turn influences early postnatal growth in breastfed infants.

The existence of a consistent trend for well-supplemented children to be heavier and taller than the poorly supplemented children is apparent in Table 6 which shows mean attained growth up to 6 months of age for three categories of caloric supplementation since conception. A similar trend was also observed within siblings of the same mother. We have thus concluded that a suitable interpretation of these results is

Table 5. *Relationship between maternal morbidity during pregnancy and birthweight*

	Correlation value	No. of cases	Probability value≤
Composite maternal morbidity scale			
Composed of no. of days with diarrhea, anorexia and in bed due to illness	0.15	249	0.05
Cord IgM levels	0.10	170	0.10

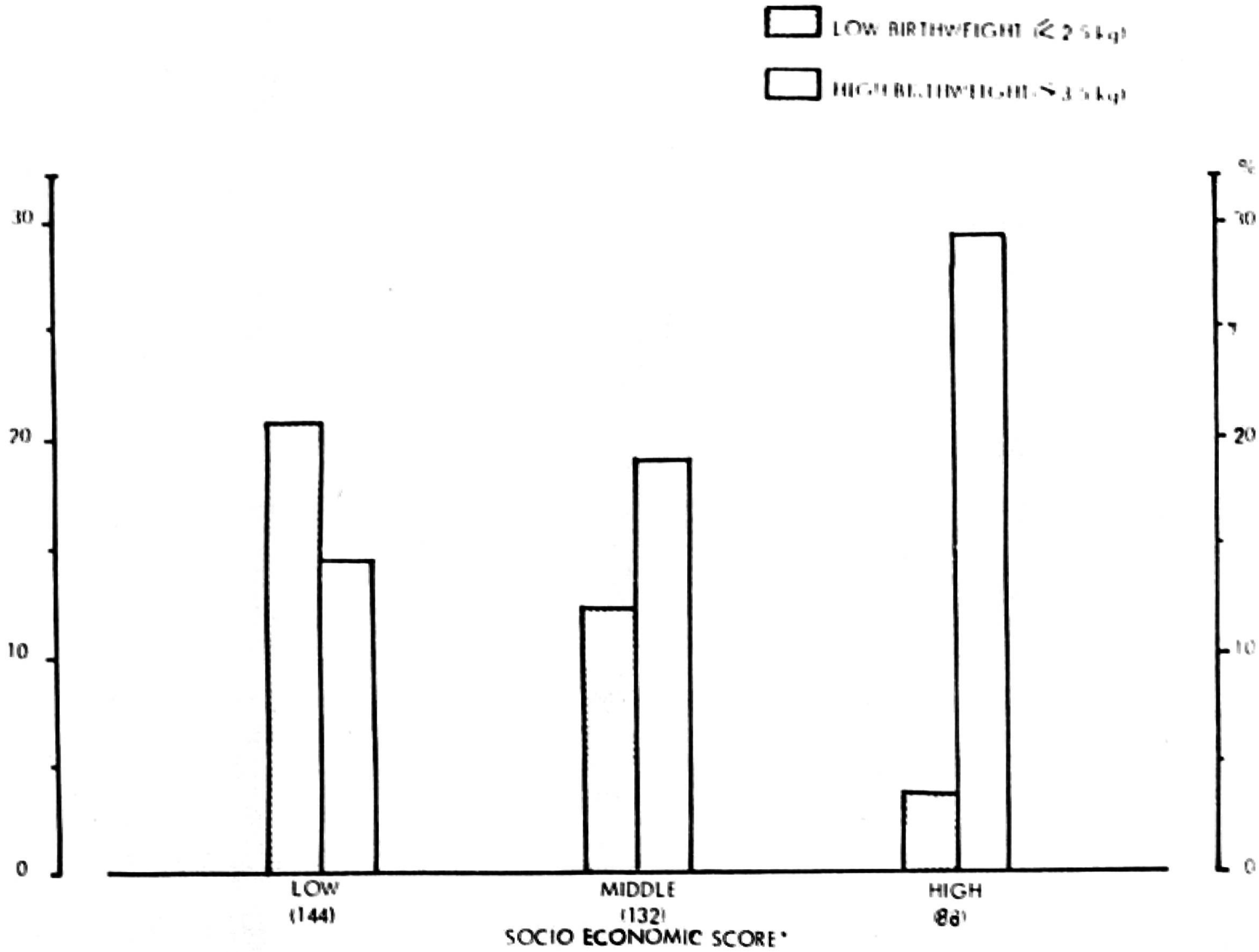

Fig. 8. Relationship between socio-economic score and the proportion of children with low and high birthweight in four rural Guatemalan villages ($N=304$). Number of cases in parentheses. *$p<0.01$.

that food supplementation during pregnancy and lactation caused an improvement of the infant's growth up to 6 months of age, in our study population (7).

For the analyses at 36 months of age, we defined retardation in growth, whether in weight, height or head circumference, as being below the 30th percentile of the study population distribution. These limits are below the 10th percentile of Denver standards (10). For weight, this limit was equivalent to 78% of the mean weight of the Denver standard. Since we do not believe these populations differ in genetic potential (9, 32), we regard this deficit as true retardation.

Figure 9 shows the proportion of children with retardation in weight, height and head circumference at 36 months of age for the low middle and high supplemented groups. The groups with low and high supplementation were formed of those children who ingested either directly or

Table 6. *Attained weight and height for three categories of cumulative caloric supplementation since conception*

Age (months)		Weight Low	Weight Intermediate	Weight High	Weight *t*-test High-Low	Height (cm) Low	Height (cm) Intermediate	Height (cm) High	Height (cm) *t*-test High-Low
3	Mean	5.21	5.29	5.41	2.46**	56.5	56.6	57.4	3.14**
	N	155	168	105		155	169	105	
6	Mean	6.58	6.61	6.81	1.99*	62.1	62.1	62.7	1.92
	N	133	217	97		134	217	96	

* $p<0.05$; ** $p<0.01$.

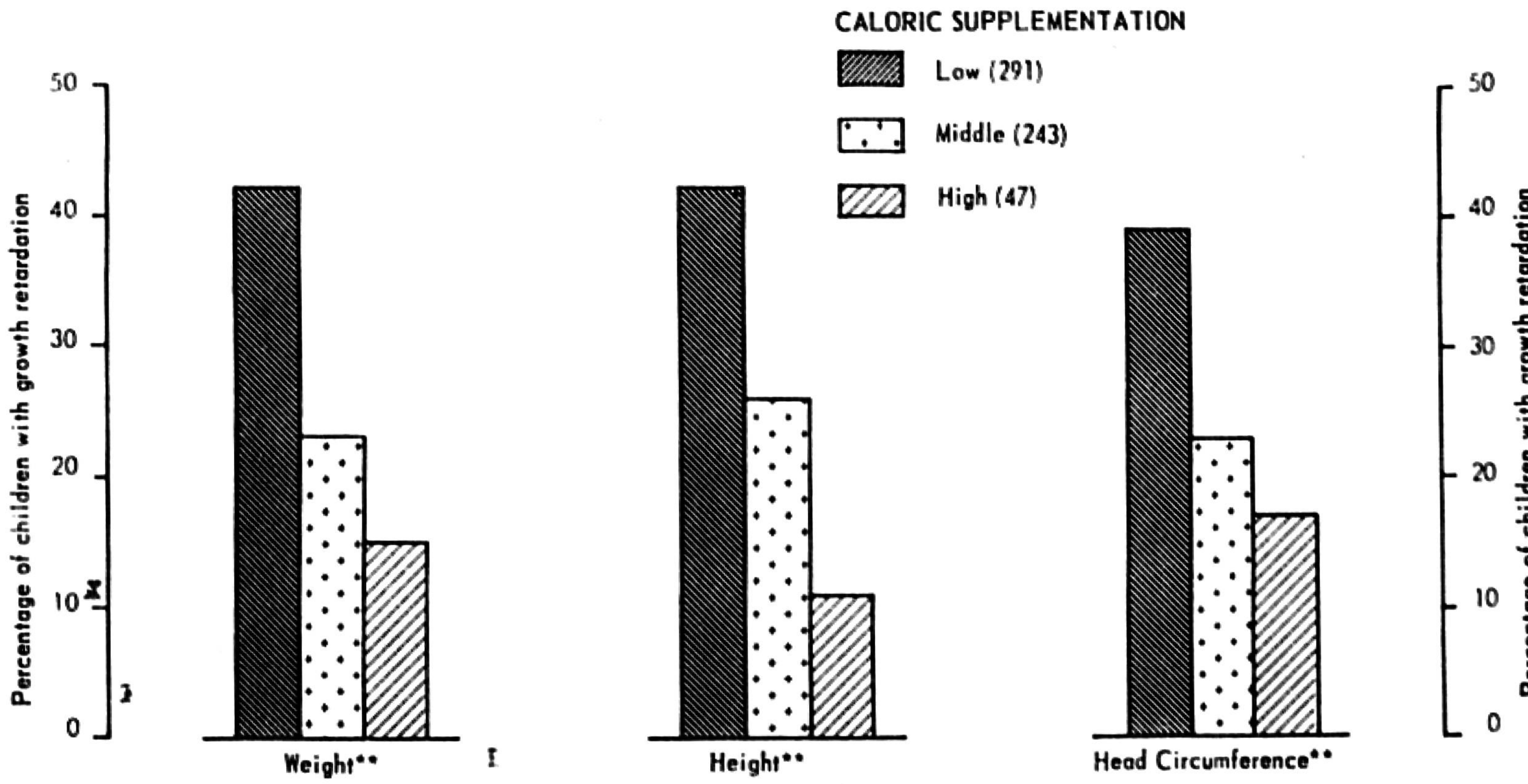

Fig. 9. Relationship between categories of caloric supplementation since conception and percentage of children with growth retardation in weight, height and head circumference at 36 months of age. ($N=581$, Fresco and Atole combined.) Number of cases in parentheses. See text for definition of growth retardation. $^{**}p<0.001$.

through their mothers less than 5000 or more than 10000 supplemented calories per quarter, during at least 14 quarters. The group with middle supplementation was formed by children who did not fall in either the low or the high groups. There is a strong relationship between level of supplementation and physical growth retardation. It should be stressed that within each of the four villages, the proportion of children showing growth retardation (see Figure 10); was consistently greater in the low supplemented group than in the middle or in the high group. In the total sample, the risk of growth retardation was almost three times greater in the low supplement group than in the high group.

At present, we consider that this relationship is causal, since it was not explained by maternal size, home diet, morbidity, obstetrical characteristics and socio-economic status. We estimate that the final result of food supplementation up to seven years of age will be a reduction of about 50% of the original deficit in height between this population and the Denver standards (4). This seems to be a reasonable estimation: results of preliminary analysis indicate that at five years of age well-supplemented children since conception were in the average 5 cm taller than the low-supplemented children.

Effect of Food Supplementation during Pregnancy and Lactation on Infant Mortality

The association described above between maternal characteristics and birthweight has important public health implications. Low birthweight babies have higher rates of infant mortality (2, 35). Therefore, efficiency of programs aimed at decreasing infant mortality will be enhanced if these programs were focused on mothers at high risk of delivering low birthweight babies. Some of the maternal characteristics mentioned above may become useful risk instruments, feasible

Table 7. *Relationship between difference in cumulative maternal caloric supplementation since conception and differences in attained weight at 6 months of age for two consecutive siblings. (Latter minus preceding child)*

Differences in caloric supplementation	Differences in infant weight (g)		
	Mean	S.D.	*N*
−40 000 to 0 cal.	−247	788	39
100 to 20 000 cal.	−107	861	34
20 100 to 120 000 cal.	280	920	38

t-test High-Low = 2.70; $p<0.01$.

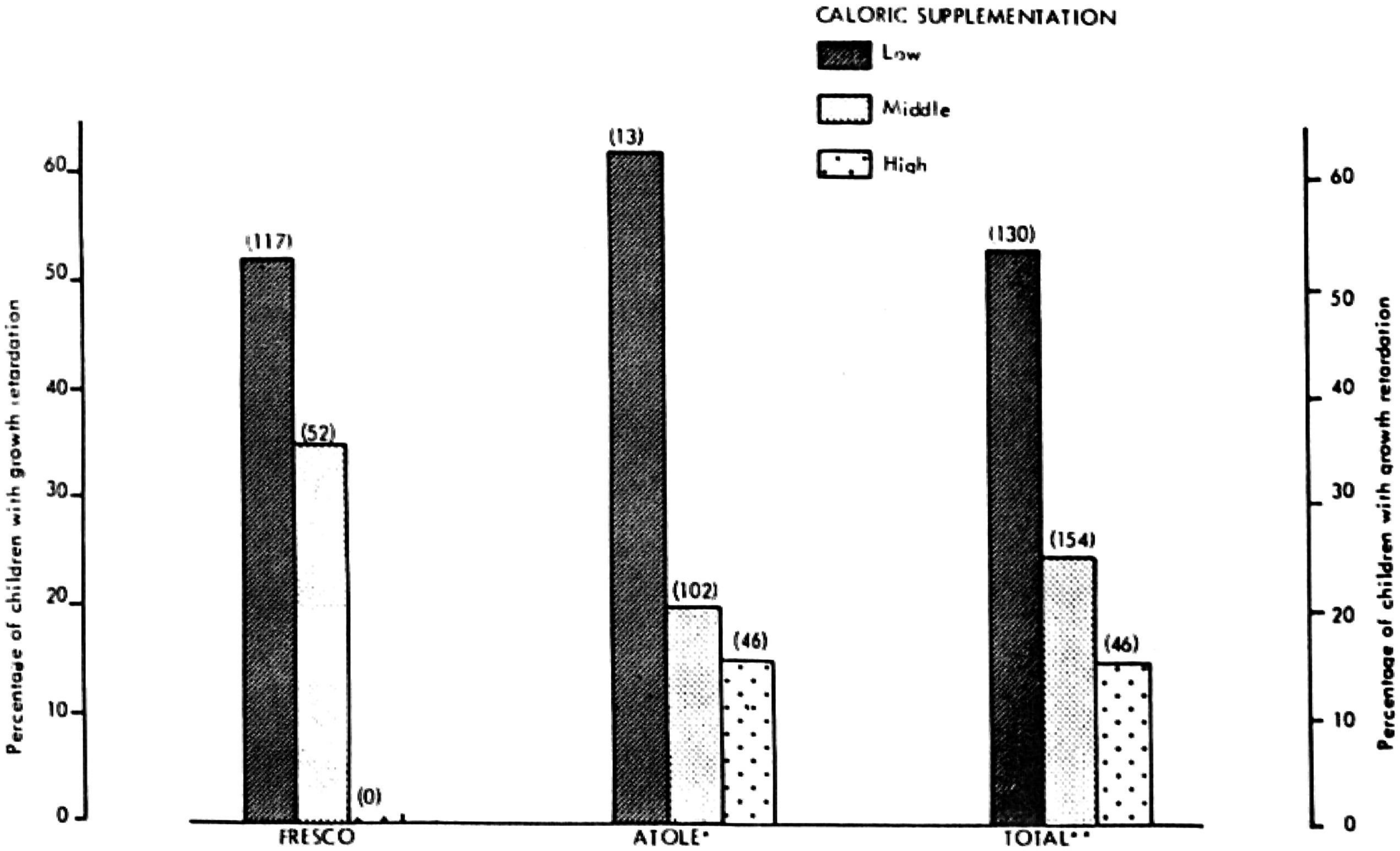

Fig. 10. Relationship between categories of caloric supplementation since conception and the proportion of children with growth retardation in weight at 36 months of age. Number of cases in parentheses. See text for definition of growth retardation. $*p<0.05$; $**p<0.01$.

for use in populations with scarce health resources (27).

Figure 11 reports the association between caloric supplementation during both pregnancy and lactation, and mortality during the first year of life. In all five comparisons made, the proportion of deaths in the lower supplement groups was about twice that observed in the higher supplemented group. In other words, the risk of dying during the first year of life in the high supplemented groups was half of that observed in the low supplemented group.

The observation that improved nutrition during pregnancy and lactation decreases infant mortality by nearly half, deserves consideration. Intervention programmes designed to reduce infant mortality have generally focused on the control of infectious diseases through provision of adequate health services. This was, in fact, our experience as well: the introduction of preventive and curative medical care reduced infant mortality from a rate of over 200/1 000 to somewhat less than 80/1 000. We believe that improved maternal nutrition may have accounted for a further reduction to a rate of 55/1 000 (22). These results demonstrate that nutritional interventions may be important components of medical interventions designed to reduce infant mortality in poor rural populations.

Other variables were also associated with infant mortality: low socio-economic status, low maternal height, low gestational age, severe hypoxia at birth and low birthweight (22). These five variables, either alone or combined, can be useful as early indicators of children who need special medical care.

Conclusions

In these rural populations, improved nutrition since conception was associated with an important decrease of the prevalence of physical growth retardation up to 36 months of age and of infant mortality. Maternal height, head and arm circumference, and a simple house score predict risk of delivering low birthweight babies. Use of these indicators to select women at higher risk could greatly enhance the efficiency of nutritional programmes in decreasing both prevalence of growth-retarded children and infant mortality.

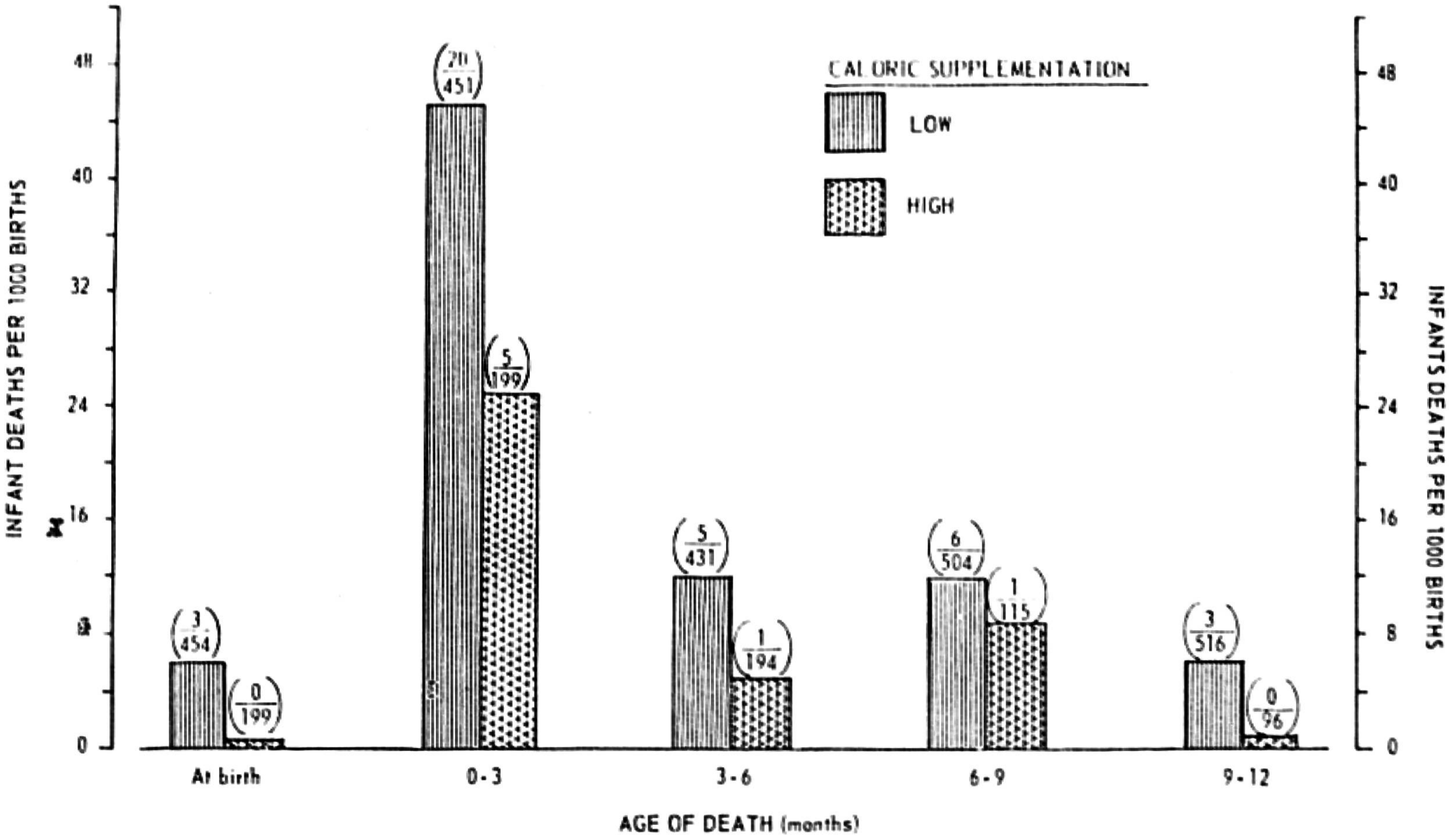

Fig. 11. Effect of caloric supplementation during pregnancy and lactation of infant deaths. In parentheses: the numerator is number of deaths and the denominator population at risk. *P*-value=0.06 (Cox-test).

In recent papers we have shown that nutritional supplementation is also associated with improved placental weight (24), lower levels of placental RNAse (31), decreased diastolic blood pressure and increased prevalence of lower limbs oedema during pregnancy (26), improved physical growth of pre-school children (33), better psychological test performance (13, 14), and with shorter postpartum amenorrhea and shorter birth interval (6, 7).

Final Remarks

The issue of calories requires a comment. In the study population the home diet protein-caloric ratio is 11.5%. Thus, we believe it feasible to improve the total diet of mothers by adding more calories. In other populations with different diets the situation could be quite different. The best supplement for one population need not be the best and indeed may even be harmful for another population.

It should be emphasized that the technique of food supplementation as employed in this investigation was primarily a research tool and that programmes of this type are inappropriate for large populations over long periods of time. In many pre-industrial societies, the ultimate solution will be the elimination of poverty. However, in the meantime, public health programmes with strong nutritional components can do much to reduce growth retardation, infant mortality, and reduce the risk of less than optimum mental development.

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