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EFFECT OF MATERNAL NUTRITION ON INFANT MORTALITY

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INTRODUCTION

High infant mortality is a major health problem in many countries of the world. In these countries the infant mortality rate (IMR) remains a major determinant of life expectancy at birth and the first year of life is the single most important risk period that a person has to face. Maternal malnutrition has been implicated as an important cause of the high IMR reported in many developing nations. The objective of this paper is to review the published data on the relationship between maternal nutrition and infant mortality.

In order to examine this relationship we will first explore the historical trends in the infant mortality rates of the developed countries. We shall then undertake cross sectional analyses relating nutrient availability to IMR. Differences in infant mortality associated with social class within countries will then be studied and finally we shall review our field results in order to document to what extent maternal nutrition is a determinant of infant mortality.

SOCIOECONOMIC DEVELOPMENT AND INFANT MORTALITY

During the last four to five centuries infant mortality rates in Europe fluctuated between 150-250/1000 live births (1-5).

reflecting the same situation seen in developing countries today (6); however, infant mortality rates began to fall dramatically in the late 19th century, first in Sweden and then in England, France, Italy and the U.S.A. (1, 7-9). This appears to have been a result of both improved sanitary practices and increased standards of living and was relatively independent of improvements in medical care (10,11). That economic factors had always played a part is evident from the study by Peller (12) on mortality in the ruling houses of Europe since 1500, which showed infant mortality comparable to modern standards as early as 1800-1899.

The same industrialized countries that decreased infant mortality rates in the twentieth century, had a simultaneous improvement in gross national product per capita. Admittedly, gross national product per capita is a very crude indicator of the nutritional condition of a population. Nonetheless, it is closely associated with food availability per capita, and although the shape and slope of this relationship varies from country to country, it appears that there is a fairly consistent fall in IMR when per capita income increases.

Figure 1, based on cross sectional data, shows that dietary energy per capita per day, a measure of food availability and IMR, are associated. Similar results have been shown previously with the proportion of low birth weight (LBW) babies (13). The threshold appears to be around 2800 calories per capita, above which IMR and the closely related LBW rates cease to decline significantly. Figure 1 reveals that for the same level of economic development there is a wide range in IMR. This variability may be partially due to variations in the efficiency of translating economic growth into improved nutrition and health. For example, in Sweden the drop in mortality occurred at a lower dietary energy per capita than in the U.S.A.

In Figure 2, 123 countries have been divided into three groups according to dietary energy per capita per day. It is clear that no country with less than 2400 calories per day has "low" IMR while most of the countries with more than 2800 calories have a "low" IMR.

Figure 3 shows the infant mortality rates for the highest and the lowest social classes in England during the last 100 years. In general, offspring of wealthier parents died less frequently in all periods (14). Death rates decreased proportionately the same amount in both social classes (9). It can also be seen that the IMR of social class I (professionals) in 1911 was not reached by social class V (manual laborers) until 1941. Similar results have been reported for France (15), the U.S.A. (16) and Finland (17).

In summary, from three independent analyses: 1) examining the historical trends of IMR within developed countries; 2) comparing different values of dietary energy per capita per day with IMR in cross sectional analyses among countries; and 3) exploring differences in IMR across socioeconomic classes within specific countries; we can deduce a clear association between socioeconomic characteristics and infant mortality rate.

It should be pointed out that poor socio-economic conditions entail economic, cultural and biological deprivation. Lower class women are shorter (18,19), work more during pregnancy (17,20)and have generally poorer health (17, 21-23). They are also more likely to have a smaller pelvis and poorer diets during pregnancy (23, 34-44). Low SES mothers are also more likely to marry young, to be multiparous and to have illegitimate births (17,23). In addition, impoverished women are likely to show less than optimal care both for themselves during pregnancy and for their children. For instance, women of low social class are more likely to delay seeking antenatal care (45,46). Each of the above named factors has been shown to be associated with a high risk of infant loss (47,48). It would appear that the relationship between increased socioeconomic status and decreased IMR is mainly effected through the general improvement in health and nutritional status of the population due to a better standard of living. Our next task is to explore to what extent specific improvements in maternal nutrition may produce a decrease in IMR.

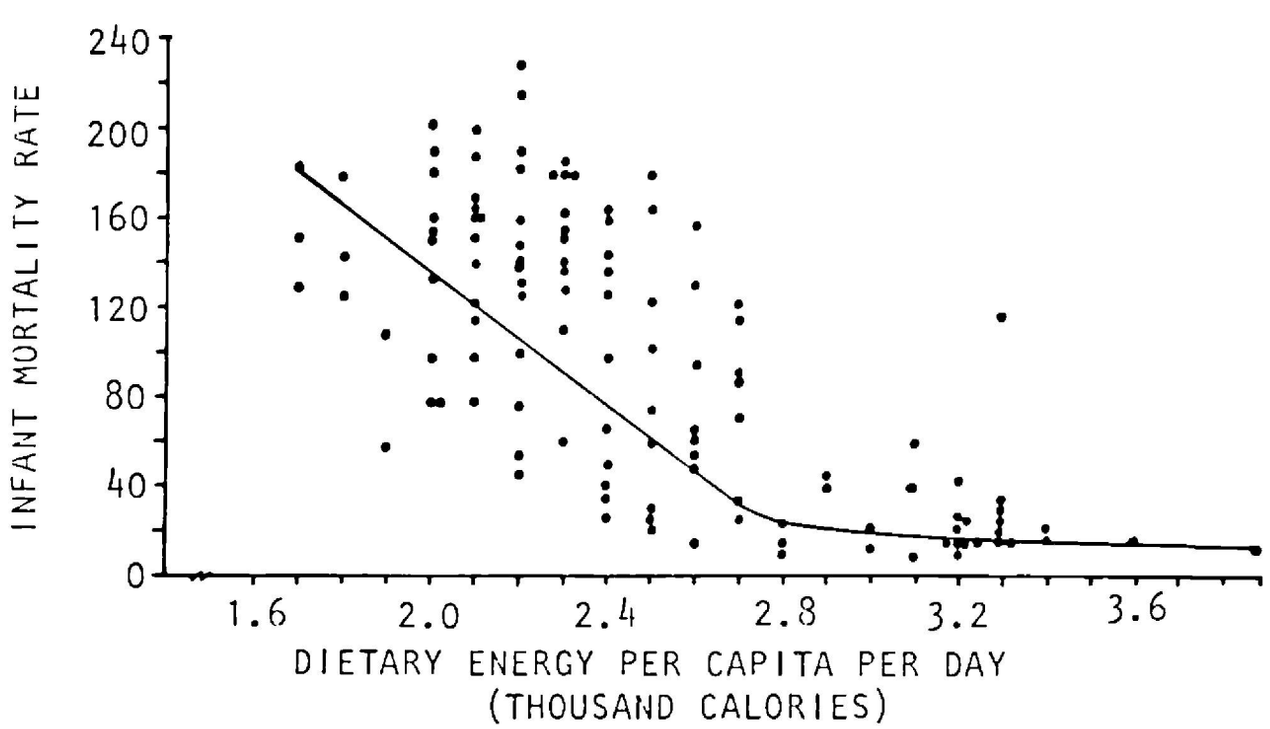

Figure 1. Relationship Between Dietary Energy per Capita and Infant Mortality Rate per 1000 Live Births. Computed from the World Population Data Sheet (Pop. Ref. Bureau Inc., 1975)

Although there is no published data on investigations to assess specifically the relationship between maternal nutrition and infant mortality, the hypothesis of an effect of maternal nutrition on infant mortality rate seems reasonable and is supported by several studies. For instance, birth weight is consistantly associated with infant mortality (49,50). The majority of the racial mortality differential in the United States can be attributed to the higher proportion of low weight at birth of the black neonates (51,52), a difference that falls within the range of the effect of maternal nutrition on birthweight demonstrated through dietary surveys (53) or nutritional supplementation (54). Thus, maternal nutrition seems to be related to infant mortality through low birth weight*.

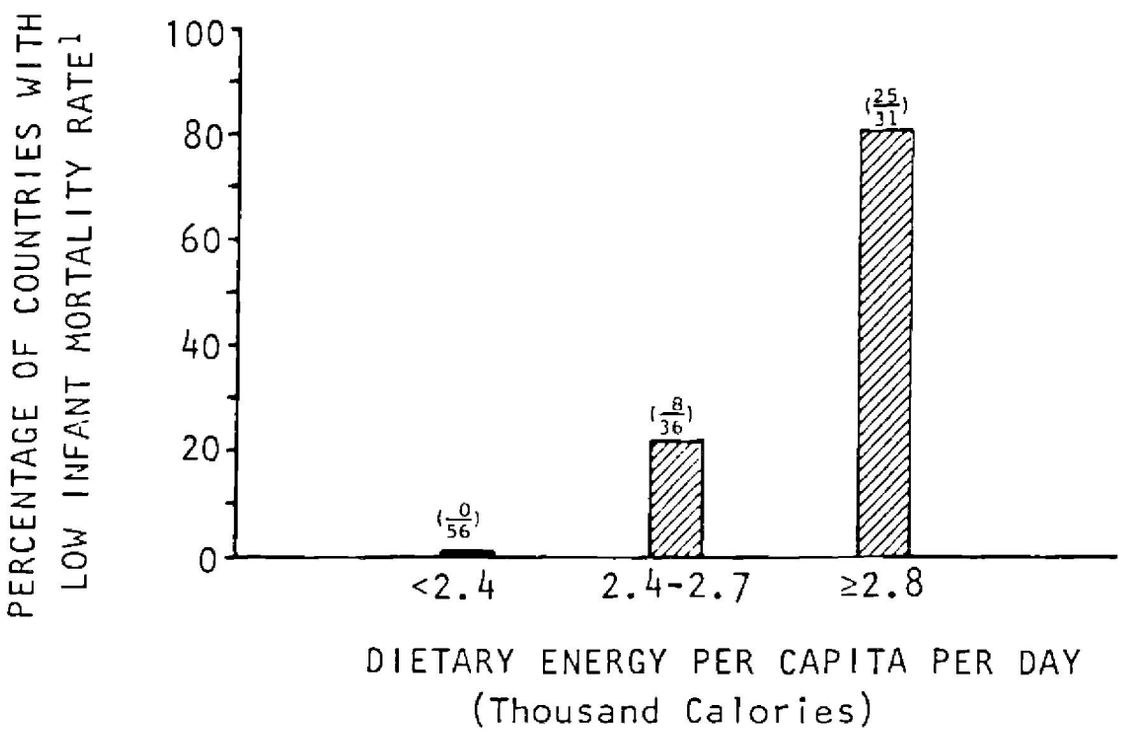

Figure 2. Relationship Between Dietary Energy per Capita and Percentage of Countries with Low Infant Mortality Rate. Low Infant Mortality Rate: ∠40/1000 Live Births. Computed from the World Population Data Sheet (Pop. Ref. Bureau, Inc., 1975). In parenthesis the numerator is the number of countries with low IMR and the denominator is the number of countries with available information.

*Low birth weight is defined as less than 2.5 kg.

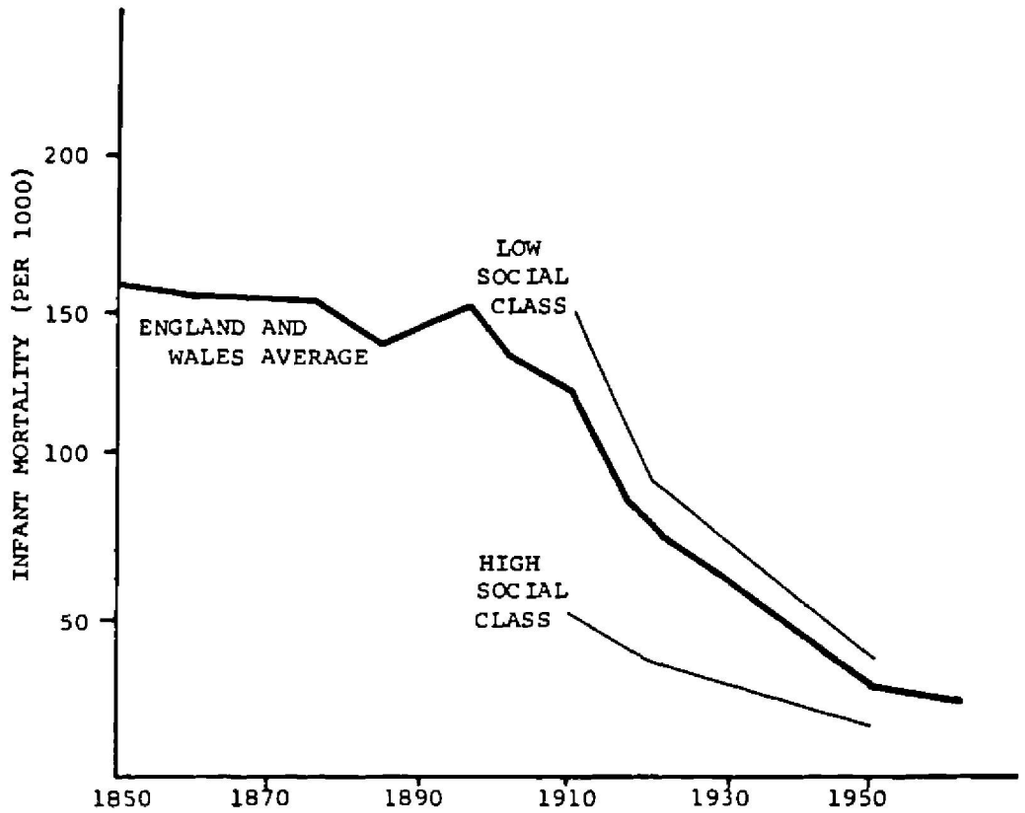

Figure 3. Trends in Infant Mortality by Social Class in England and Wales 1910-1950. Adapted from Morris and Heady 1955.

The next part of the hypothesis, that lower SES women have poorer diets during pregnancy has been demonstrated in developing nations where the social class gap is wide (19,53,55-59). In addition, placental size is smaller in low SES women, a factor that may contribute to fetal malnutrition (60-62). In other words, low socioeconomic status may lead to poor maternal nutrition, high prevalence of LBW babies and consequently high IMR. It has been argued that the accelerated drop in infant mortality rates which occurred during World War II could only be attributed to the war-time food distribution program which favored pregnant mothers (18). Further, maternal malnutrition during the mother's infancy and childhood could also produce an effect on infant mortality perpetuated through generations.

OBSERVATIONS IN GUATEMALA

We have explored the interrelationship between maternal nutrition and infant mortality in two different studies; the first one in a urban population of low social class from Guatemala City and the second one in four rural villages from eastern Guatemala.

Urban Study

In this study the design corresponded to a case-control retrospective study with the main purpose of identifying simple risk indicators of infant death. For this purpose we studied the records of 101 consecutive infant deaths from low social class during 1975 in a hospital of Guatemala City. These were compared with 199 children (control group) who survived the first year of life, were also of low social class and were being followed in the same hospital. From 42 variables examined 14 showed significant differences between the study and the control groups.

Table 1 presents the relative risk associated with these variables as well as their sensitivity and specificity as indicators of risk of infant death. Of the 14 risk indicators, 6 concern the nutritional status of either the infant or the mother. These are: weight for age ($\leq$ 80%), breast feeding ($\leq$ 6 months), weight for height ($\leq$ 90%), height for age ($\leq$ 87%), low birthweight ($\leq$ 2.5 Kg), and maternal arm perimeter ($\leq$ 24 cm). Two additional indicators probably affect infant survival by means of impaired maternal nutritional status. These are birth interval ($\leq$ 30 months) and maternal age ($\leq$ 19 years).

A risk scale was built on the basis of 7 of these indicators presented in Table 1, the possible score ranging between 0 and 7. The high risk population group, composed of those children with high score (from 5 to 7) in this scale, comprised 86 percent of the infant deaths and had a relative risk of dying during the first year of life 85 times higher than children with low score (from 0 to 4). Of the 7 components of this risk scale, 5 (weight for age, breast feeding, birth weight, birth interval and maternal age) concern the nutritional status of the baby, the mother or both. In conclusion, the results of the urban study bring support to the hypothesis that maternal nutrition is related to infant survival.

Rural Study

We have explored the interrelationship among these variables as part of a study in four villages of Guatemala (63). These are communities where chronic malnutrition and infectious diseases are highly prevalent, a situation unfortunately common to most of the rural populations of the third world. The economy is based on subsistence agriculture and corn and beans form basis of the local diet. Pregnant mothers, who average 149 cms. in height and 49 Kg in first trimester weight, have average daily dietary intakes of 1500 calories and 40 gms of protein. They deliver newborns weighing around 3 kg. and they breastfeed these children for a median of 17 months.

Until 1969, no "modern" medical services existed in these communities. Pregnancy and birth were supervised by midwives, home remedies were used for minor illnesses, and serious medical problems required transporting the patient to larger communities.

In 1969 INCAP provided a system of curative medical care in these communities. Each village now has a clinic, staffed by an auxiliary nurse, with weekly supervision by two physicians. Most of the diagnosis and treatment is performed by a nurse who remains in the community throughout the week. The doctors see patients on a random basis as well as review the medical workups performed by the nurses.

These clinics have cooperated fully with various national vaccination campaigns against measles, polio, diphteria, whooping cough and tetanos. The out-patient problems today mainly encompass diarrheal, respiratory and dermatological conditions. The infant mortality rates have been reduced from 160 per 1,000 in 1968 to about 50 per 1,000 in 1975.

The acceptance of our contemporary medical approach has been very good. The villagers have expressed considerable confidence in both the personnel and system of treatment. Midwives continue to assist at childbirth in collaboration with the clinic. Thus, the communities essentially have and use a system of medicine which integrates the most favorable aspects of both traditional and modern curative practices.

The study design and the principal examinations made in mothers and preschool children are presented in Table 2. Two types of food supplements are provided: atole* and fresco**. Two villages receive atole while the other two receive fresco. Attendance at the supplementation center is voluntary and consequently a wide range of supplement intake is observed. Table 3 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.

As the home diet is more limiting in calories than in proteins (12), ingestion of supplemented calories was selected as the criteria to assess supplement intake. We stress that while

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* The name of a gruel, commonly made with corn.
** Spanish for a refreshing, cool drink.

Table 1

Urban Study - Risk Indicators of Infant Mortality

Indicator	Number of Cases		Relative[1] Risk
	Deaths	Control	
1. Hemorrhage during pregnancy[4]	101	199	23.2**
2. Weight for age $\leq$ 80% [4]	101	197	21.1**
3. Breast feeding $\leq$ 6 months[4]	101	199	19.6**
4. Weight for height $\leq$ 90%	31	191	13.9**
5. Umbilical cord rolled in neck	101	199	12.6**
6. Height for age $\leq$ 87%	70	191	7.6**
7. Birth weight $\leq$ 2.5 kg.[4]	101	199	6.9**
8. Gestational age $\leq$ 37 weeks[4]	101	199	6.0**
9. Preceding Child dead	64	147	3.7*
10. Birth interval $\leq$ months[4]	64	147	3.0*
11. Arm perimeter $\leq$ 24 cm.	101	199	3.0*
12. Absence of perinatal medical care	101	199	2.9
13. Maternal age $\leq$ 19 years[4]	101	199	2.6*
14. Age of menarche $\leq$ 13 years	101	199	1.9*
Score of 5-7 in risk scale[5]	64	147	25.2**

* $p < .05$; ** $p < .01$

1. Computed increment of probability of death in high risk group
2. Percentage of deaths accurately predicted
3. Percentage of children alive accurately predicted
4. Components of risk scale
5. Score range: 0-7; high risk score: 5-7

calories are the main limiting nutrient in this population, other populations may present very different nutritional situations. Three additional independent variables were also included in the present analysis: maternal height (an indicator of the nutritional history of the mother during the age of growth); socioeconomic score of the family; and birthweight (an indicator of fetal growth). The socioeconomic score is a composite indicator reflecting the physical conditions of the family house, the mother's clothing and the reported extent of teaching various skills and tasks to preschool children by family members. The principal outcome variable was IMR in the cohort of children born from January 1, 1969 to February 28, 1975.

Table 2

Study Design for Four Villages*

Information+	When Collected
Obstetrical history	Once
Clinical examination[1]	Quarterly
Anthropometry[1]	Quarterly
Surveys[1]	
Diet	Quarterly
Morbidity	Fortnightly
Attendance at feeding center[1]	Daily
Amount of supplement ingested[1]	Daily
Socioeconomic status[1]	Annually
Birthweight	At delivery
Infant death	First year age

* Two villages received atole, a protein-calorie supplement, and two fesco, a calorie supplement.

+ Pregnancy was diagnosed by absence of menstruation; these surveys were made fortnightly.

[1] In mothers and preschool children.

Table 3

Nutrient Content per Cup*
(180 ml)

	Atole	Fresco
Total calories (Kcal)	163	59
Protein (g)	11	--
Fats (g)	.7	--
Carbohydrates (g)	27	15.3
Ascorbic acid (mg)	4.0	4.0
Calcium (g)	.4	--
Phosphorus (g)	.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
Fluor (mg)	.2	.2

For the purpose of doing discrete variable analyses and due to the relatively small sample size, we will present analyses with dichotomous variables (categories "low" and "high"). Table 4 presents the limits for partition of each variable in two categories. These limits were defined on basis of reported literature (i.e. low birthweight $\leq$ 2.5 Kg) or were based on results of prior analyses predicting birthweight.

Figure 4 explores the relationship between socioeconomic score (SES) maternal height, caloric supplementation during pregnancy and birthweight with the proportion of infant deaths in the four villages combined. In all four groups there is a lower proportion of infant deaths in the "high" category of each variable. However, the difference in the proportion of infant deaths in the "high" and "low" categories is statistically significant only with maternal height and birthweight.

Next, we studied to what extent each of these apparent associations with infant mortality held after controlling for the remaining three independent variables. Given the small sample size, we might not be able to measure the magnitude of the relationship between each of the variables presented in Figure 4 and proportion of infant deaths. In consequence, we explored mainly the consistency or replicability of the direction of these relationships across eight mutually independent comparisons.

Figure 5 shows the percentage of infant deaths for low and high categories of socioeconomic score within categories of birthweight, height and food supplementation. This analysis shows that once these last variables are controlled, there is no consistent association between socioeconomic score and infant death. This suggests that the original trend observed in Figure 4 may be due to the association between SES and the other three variables, maternal height, food supplementation, and birthweight.

Figure 6 presents a similar analysis comparing low and high categories of maternal height within categories of socioeconomic score, caloric supplementation during pregnancy and birthweight. It is evident that in all the eight comparisons the proportion of infant deaths is consistently lower in the groups with high maternal height than in those with low height. For instance, within the low birthweight category, the mothers with high height presented a lower proportion of infant deaths.

Women from poor populations are generally shorter in stature, mainly because of long-term malnutrition during the growth years (23,45,64,65). The inference is that in these populations height represents to some extent the nutritional history over the growth years, and that it is this which affects capacity of the offspring

Table 4

Limits Used to Form Dichotomous Variables

Variable	Category	
	Low	High
1- Supplemented calories during pregnancy	< 20,000	≥ 20,000
2- Maternal height (cm)	≤ 149	> 149
3- Socioeconomic Score	< mean + 1SD of four villages	> mean + 1SD of four villages
4- Birth weight	≤ 2.5 Kg.	> 2.5 Kg.

to survive. This gives rise to the idea of a generational mortality, determined during the mother's childhood.

The mechanisms through which short maternal stature are associated with poorer offspring survival remain obscure and may range from greater susceptibility of the fetus to infection to adequacy of the maternal nutrient supply to the placenta. In addition, smaller, stunted women are more likely to have contracted a pelvis, difficult labor and birth trauma (23). Whatever the mechanisms may be, it is evident that maternal height is, at least in these populations, a risk indicator of infant mortality.

Figure 7 shows a comparison between two categories of caloric supplementation during pregnancy within each category of socioeconomic score, maternal height and birthweight. This reveals that infant mortality was lower in the high supplemented group than in the low supplemented group in six of the eight independent comparisons. Of the remaining two comparisons in one there was no difference and in the other infant mortality behaved in the opposite direction.

In order to control for constant maternal factors, either measured or not measured, we explored the relationship between caloric supplementation during pregnancy and infant death within pairs of siblings of the same mother (see Figure 8). For this purpose the pairs of siblings were grouped according to the status of the preceding infant: alive or dead and then, substratified according to the status of the later infant (alive or dead). For each of these sub-groups we computed the proportion of mothers

who decreased their caloric supplementation during the later pregnancy (vertical line of Figure 8). In the two independent comparisons presented in Figure 8 the proportion of mothers with decreased caloric supplementation during the latter pregnancy was higher in the groups in which the latter child died than in those in which the latter child survived.

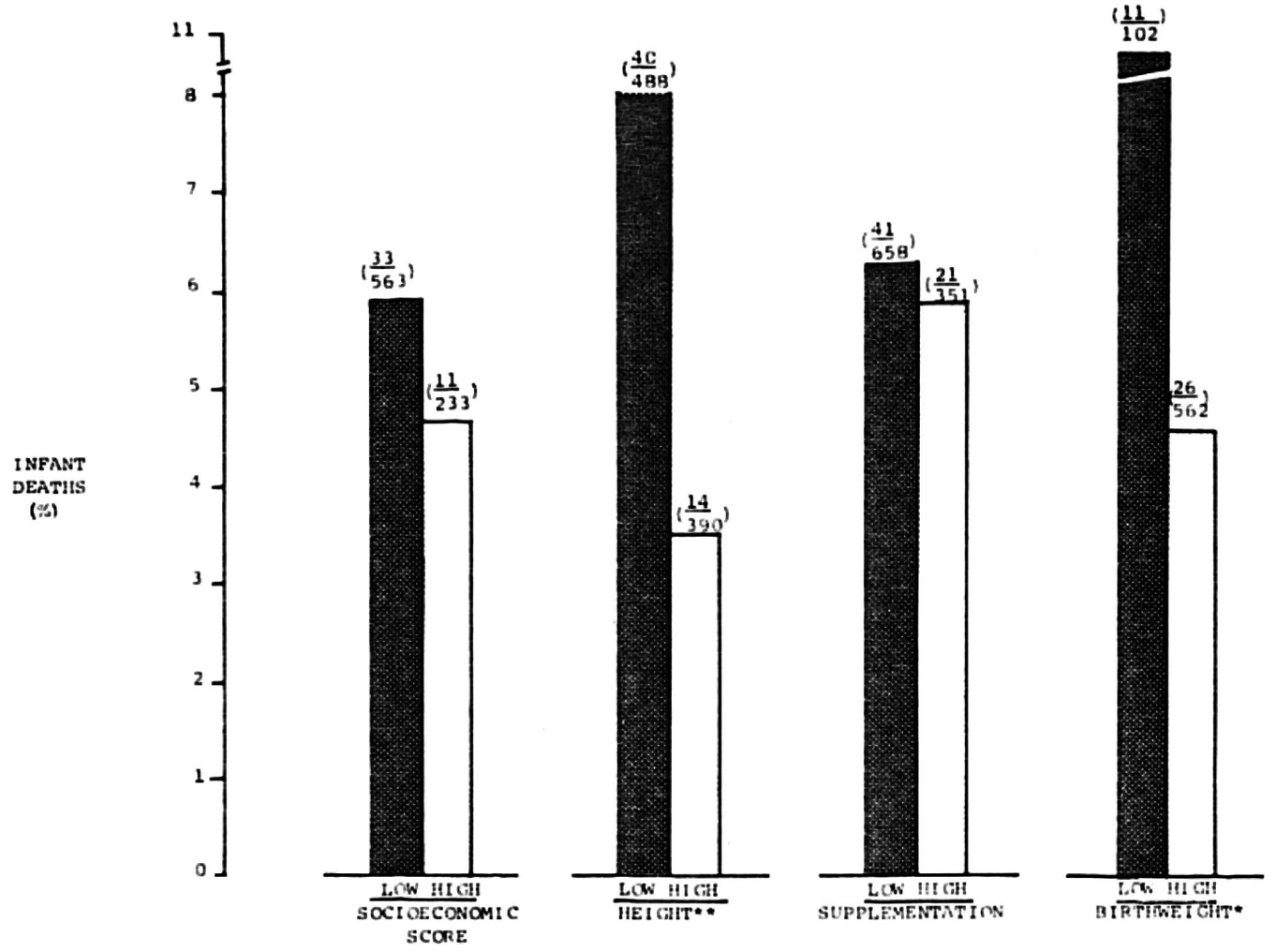

Figure 4. Percentage of Infant Deaths by Levels of Socioeconomic Score, Maternal Height, Food Supplementation During Pregnancy, and Birth Weight. In parenthesis the numerator is the number of infant deaths and the denominator is the total number of live births.

x^2 test: * $p < .05$
** $p < .01$

In consequence, in spite of the small sample size of the study groups, at present we believe that these results are compatible with the hypothesis that maternal nutrition is causally related to infant mortality. This conclusion arises from the following facts: 1) the results of Figure 6 suggested that maternal height, an indicator of nutritional history of the mother during ages of growth, is consistently associated with infant mortality, and 2) the results presented on Figures 7 and 8 suggest that caloric supplementation during pregnancy, an indication of maternal nutritional status during intrauterine life of the baby, is also associated with infant mortality in these populations.

The causal chain leading from maternal malnutrition to infant mortality may be composed by the following steps: 1) Maternal malnutrition may lead to smaller placental size and decreased

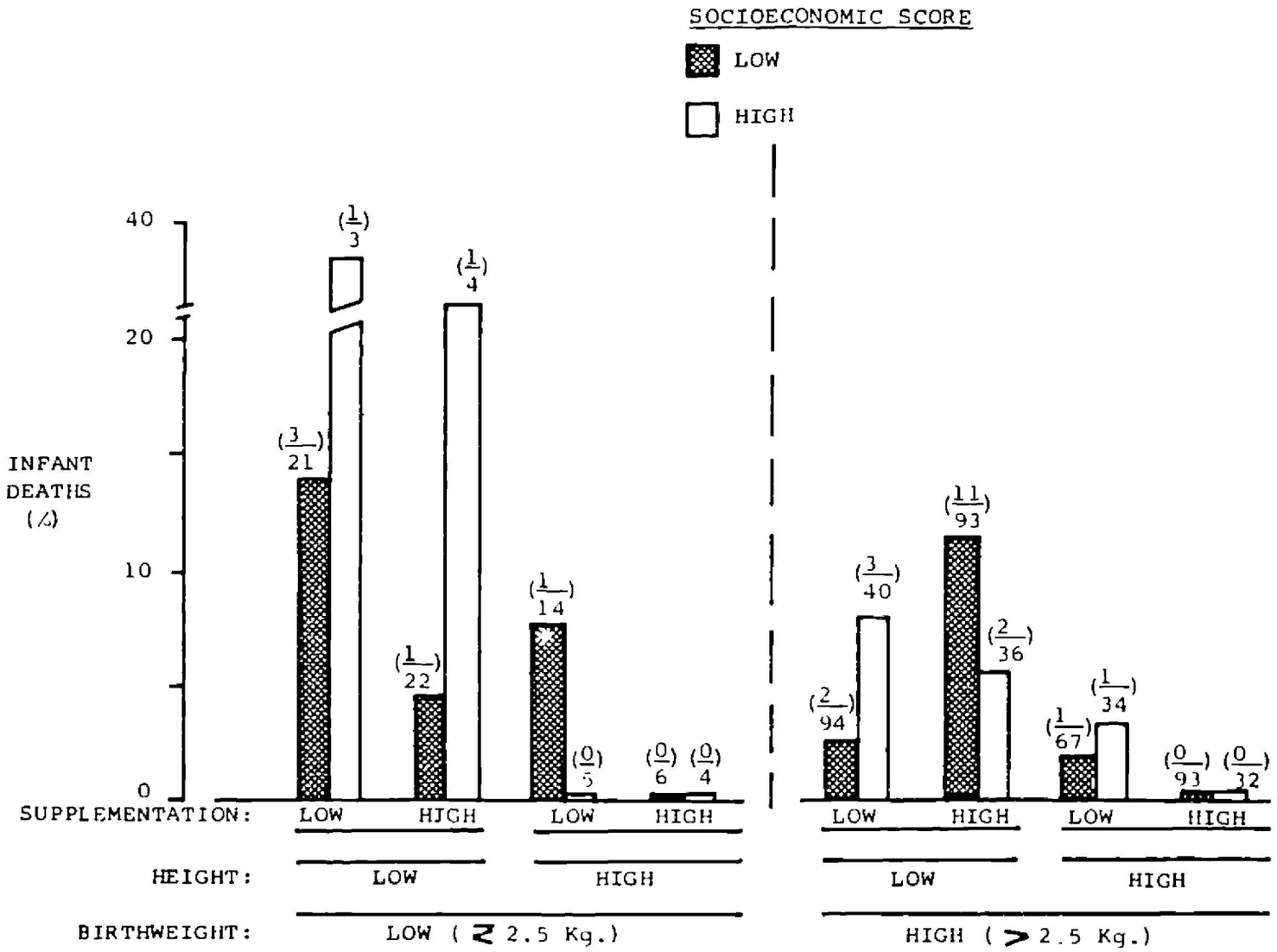

Figure 5. Relationship Between Socioeconomic Score and Infant Mortality After Controlling for Food Supplementation During Pregnancy, Maternal Height and Birthweight.

nutrient supply from the mother to the fetus. This would result in developmental retardation during intrauterine life and therefore in decreased ability to survive during post natal life. 2) Maternal malnutrition may also produce sub-optimal lactation performance which will contribute to the infant malnutrition, growth retardation and, in consequence, may limit the infant's potential to survive in its environment. Usually, this gradual deterioration of the child's development may increase susceptibility to infections of the gastrointestinal and respiratory tracts which in turn would worsen the health status of the baby and end up as the "final" cause of death. There is available evidence supporting the plausibility of several parts of this hypothesis.

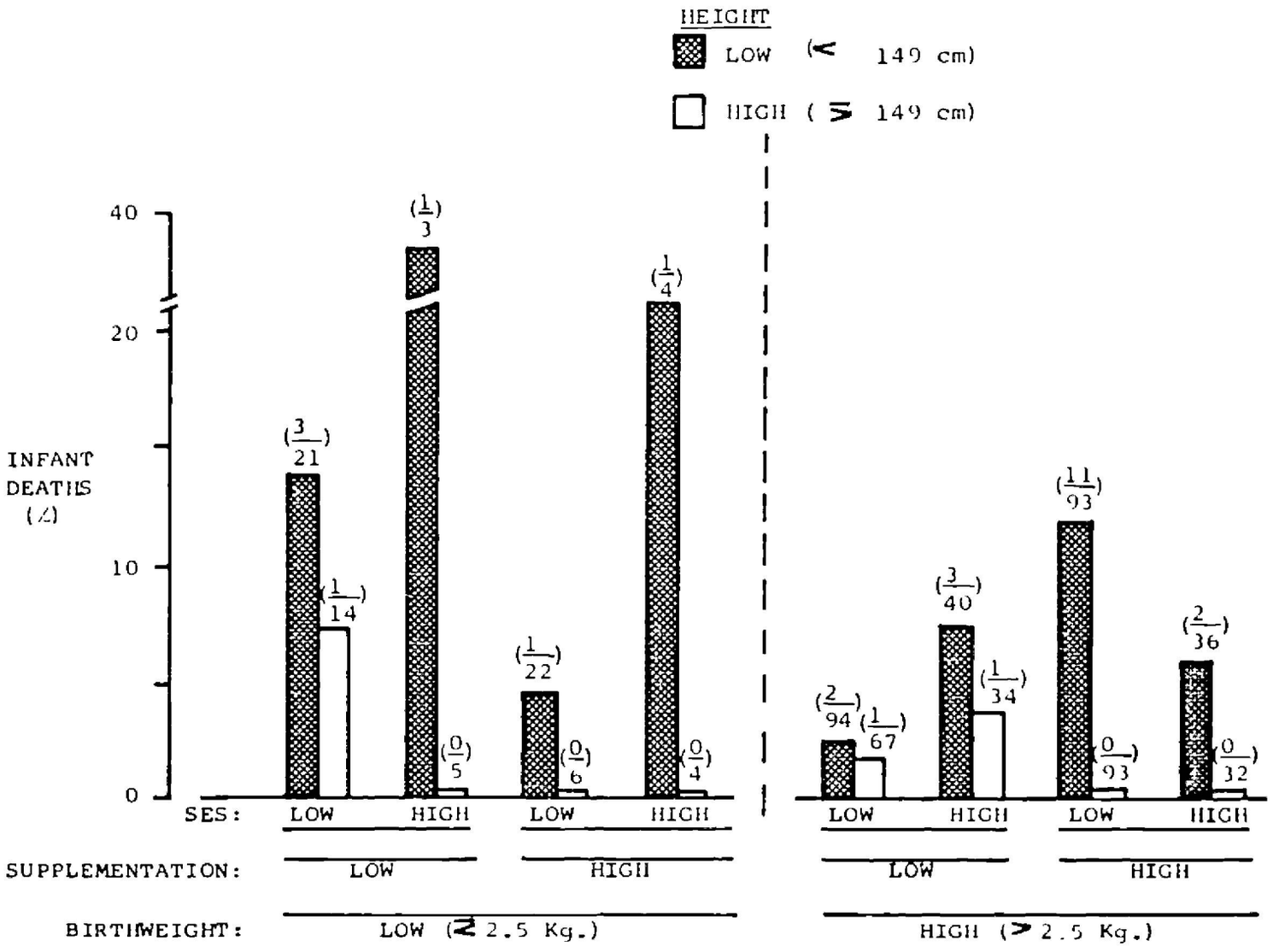

Figure 6. Relationship Between Maternal Height and Infant Mortality After Controlling for Socioeconomic Score, Food Supplementation During Pregnancy and Birthweight.

For instance, there is increasing information supporting the hypothesis that maternal nutrition affects the materno-fetal nutrient supply (60), and that fetal growth retardation is accompanied by suboptimal immune response to some infectious agents (69). It is becoming evident that the nutritional status of lactating mothers may affect breast milk output (70-72) and infant growth, at least during the first 3 to 6 months of age (72,73). Finally, data on the literature (reviewed in 74) as well as our own data (see Table 1), suggest that in poor populations the duration of breast feeding may be truly associated with the probability of survival.

The finding (see Figure 7) that the association between

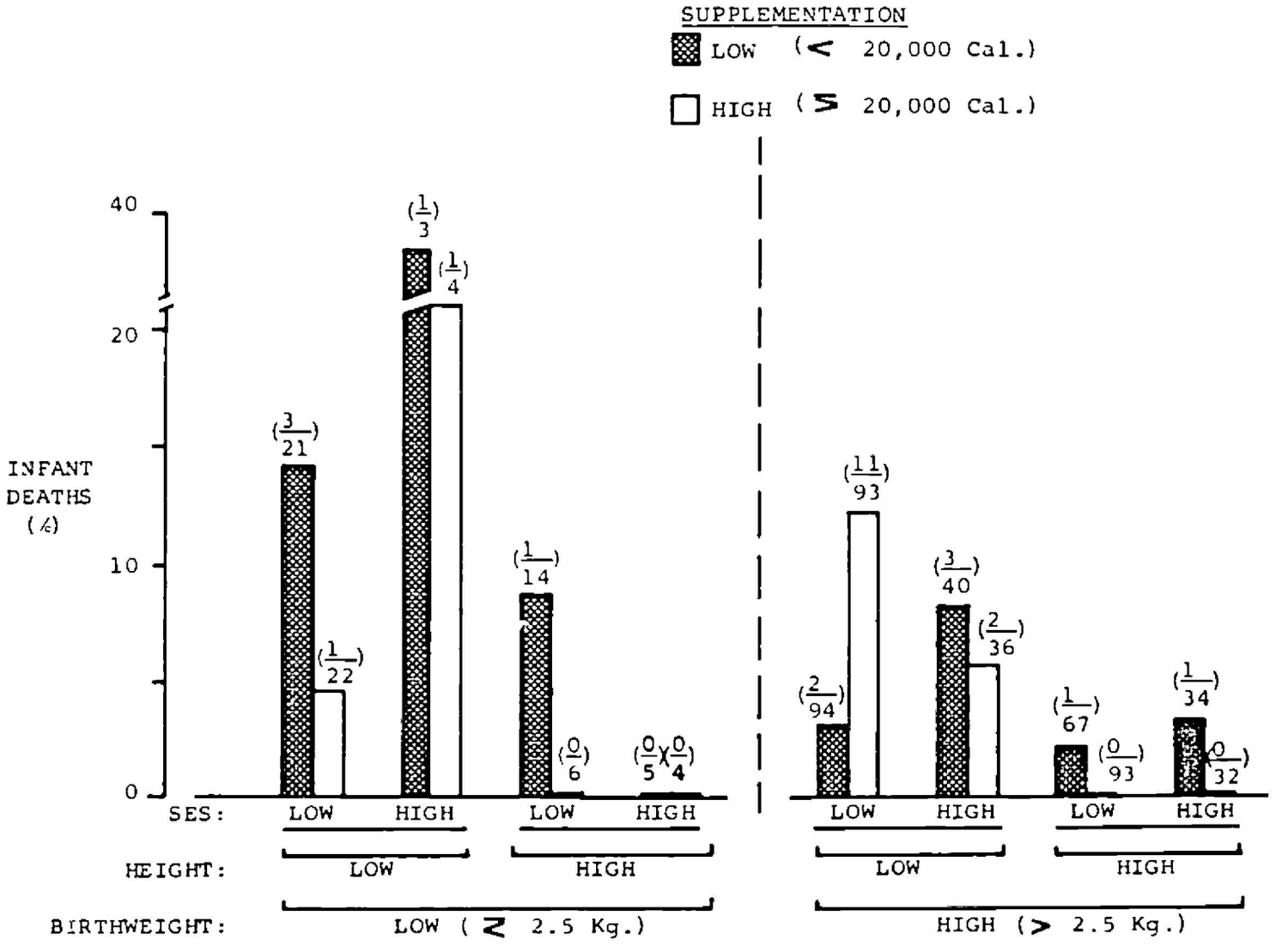

Figure 7. Relationship Between Food Supplementation During Pregnancy and Infant Mortality After Controlling for Maternal Height, Socioeconomic Score and Birthweight.

caloric supplementation and infant mortality does not disappear after controlling for birthweight suggests that birthweight does not contain all the prenatal information associated with infant survival. An alternative explanation is that caloric supplementation during pregnancy not only affects birthweight but also post natal maternal and infant nutritional status.

Finally, Figure 9 presents the relationship between two categories of birthweight and proportion of infant deaths within categories of socioeconomic score, caloric supplementation during pregnancy and maternal height. It is clear that low birthweight babies presented higher mortality rates in only four of the eight comparisons presented in Figure 9. Of the remaining four, in two there was no difference and in the other two the trend was to higher mortality in the high birthweight group.

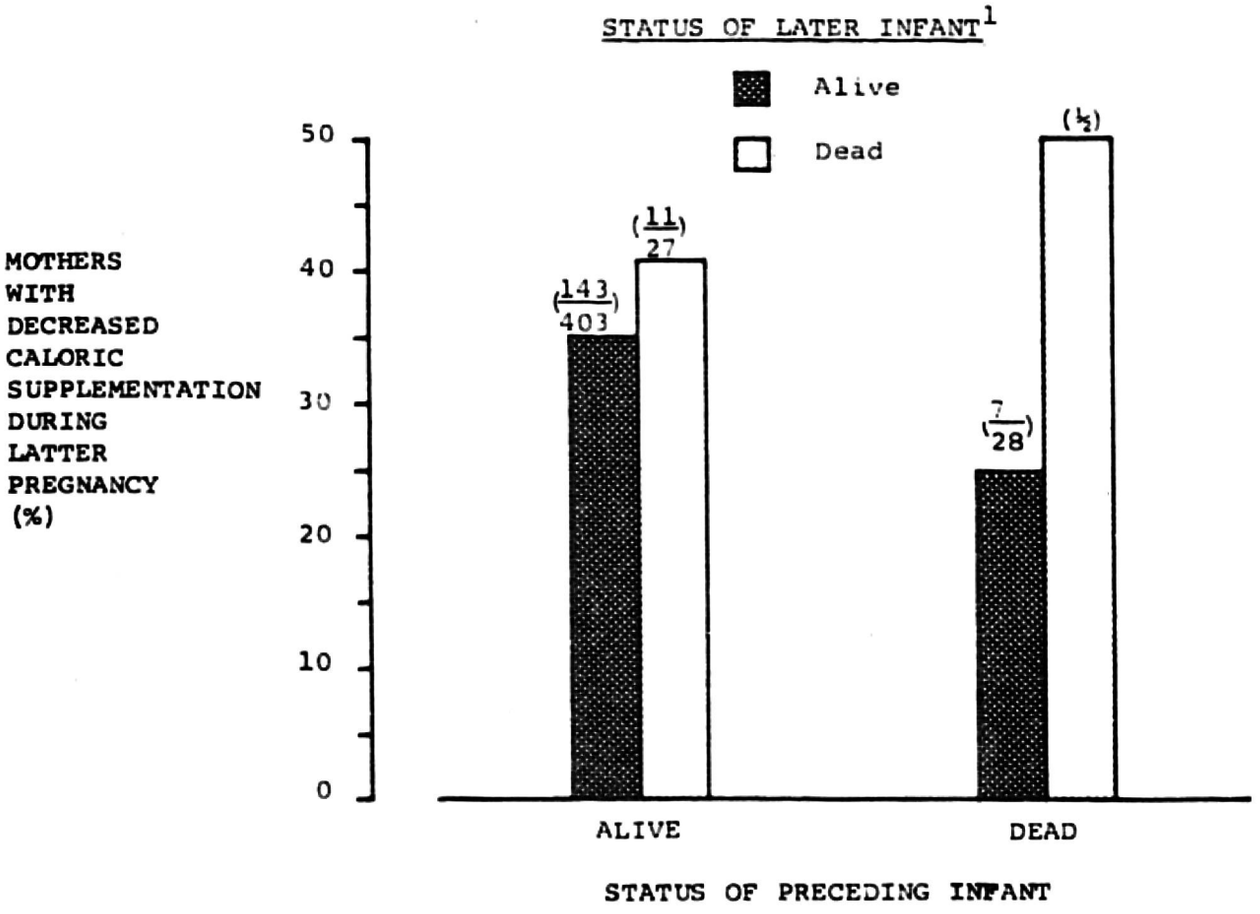

Figure 8. Relationship Between Percentage of Mothers with Decreased Caloric Supplementation During the Later Pregnancy and Death of the Later Infant During the First Year of Age.
In parenthesis the numerator is the number of mothers with decreased caloric supplementation during the later pregnancy as compared with the preceding pregnancy and the denominator is the total number of pairs of siblings in the group.

Low birthweight (LBW) is considered the major predisposing factor of infant death in both developed and developing countries. Low birthweight infants who survive the first week remain at higher risk, being especially more susceptible to infection and severe malnutrition in developing countries. Even in developed countries where such factors play a lesser role, LBW survivors are 3-4 times more likely to die in the subsequent 11 months (49). It is recognized that the major factors influencing birth weight are of social, economic and biological origin, and that incidence of LBW may be a very sensitive indicator of social change (13,67, 68). The results presented in Figure 9 suggest that the association between birthweight and infant mortality may be explained, at least in part, by maternal characteristics such as height, socioeconomic score and food supplementation during pregnancy.

It should be noted in Figure 9 that the children with lower infant mortality were those delivered from mothers with high height and high supplement intake during pregnancy (deaths: 0;

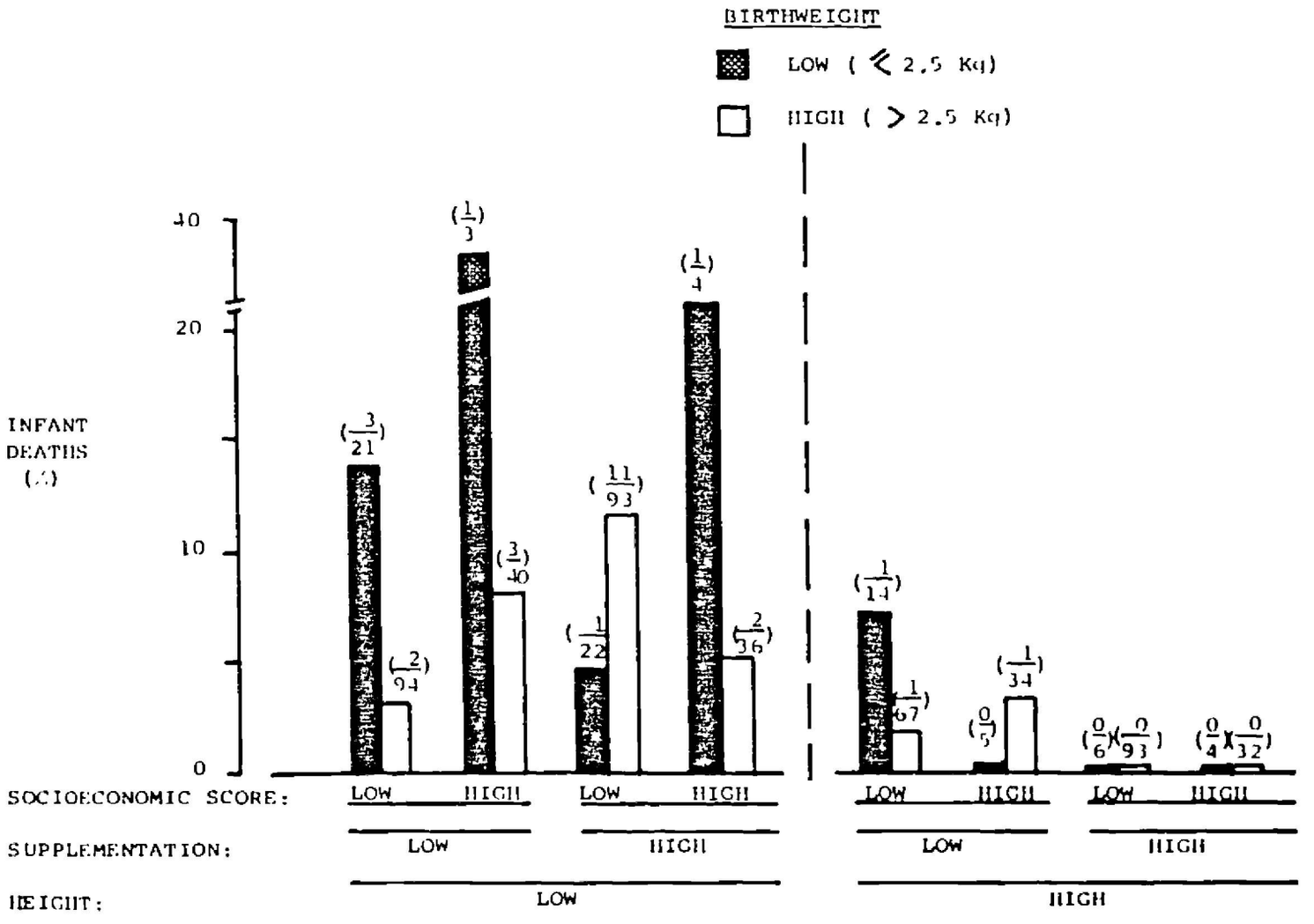

Figure 9. Relationship Between Birthweight and Infant Mortality After Controlling for Socioeconomic Score, Food Supplementation During Pregnancy and Maternal Height.

n = 135). In contrast, there were 9 deaths in the group of children delivered by mothers with low height and low supplement intake (n = 158; t-test with arcsine transformation: $t = 4.7$; $p < 0.001$).

Conclusions

Our conclusion from these findings is that both short and long term maternal nutrition status may be causally related to infant mortality.

It should be pointed out that this conclusion does not mean that other factors namely medical care and environmental sanitation are not important determinants of infant mortality in these populations. Actually, it is probable that in these rural populations in which medical care is available, infant mortality is the end result of a complex interaction among several factors including maternal nutrition. For instance, we have estimated that in the four study villages the medical care system using paramedical personnel and strict quality control systems is mainly responsible for a decrement in IMR from 160/1000 in 1968 to about 85/1000 in 1969. The rest, from 85/1000 to 47/1000 may be ascribed to the program of food supplementation or, in other words, to the improvement of maternal and infant nutrition and to improved medical care.

Some interactions are also probably occurring between both programs, food supplementation and medical care. Several studies have shown higher infant survival from mothers who have had more antenatal visits when compared to those who have had less, or none (16,25,26,27,32,74,75; see Table 1). If the mother's use of medical care facilities is associated with maternal height or supplement intake, this could explain differences in survival associated with maternal height or caloric supplementation (75, 76). However, the present sample size does not permit us to solve this problem and there is no study available that has placed an answer to these questions (77). Further analyses are planned when data collection of the present study is completed in order to solve this problem. This lack of information may explain the widely discrepant opinions as to the value of medical care and maternal nutrition as determinants of infant mortality (20).

In conclusion, mechanisms for translating SES into variations in infant mortality exist at several levels. The main maternal factors are malnutrition and illness which lead to delivery of poorly viable infants. These effects, aggravated by poor medical care, lead to infant death.

These factors are heavily affected by access and utilization;

diet is affected by food availability, including food costs and individual purchasing capacity. The same holds for medical care, and home sanitary practices. Finally, each of these factors is influenced by socioeconomic status which affects income and attitudes and thus ability to afford medical care, adequate diet, and housing and sanitation. The relative contribution of each particular factor in a specific population and the variations among populations must be taken into account in program planning and study design. From this point we will turn our attention to the consideration of possible interventions.

RECOMMENDATIONS TO DECREASE INFANT MORTALITY

In the following paragraphs we will discuss the main aspects of action programs designed to decrease infant mortality in developing nations. We will mention the social, political and economic limitations to action; the need to implement immediate action programs and the main characteristics that these programs should have in poor populations.

Clearly, the nutrition and health problems in low income populations lie in the framework of the political, social and economical system. For example, poor communications, inadequate transportation, low availability of potable water, low purchasing power for basic foods are important nutritional determinants. Most intervention programs are dominated by political and financial considerations, and the scope of planning must necessarily work within (or against) these constraints since they affect the basic questions of what population is to be served, where, by by what method of intervention, and at what level of funding.

In some countries important improvements in socioeconomic conditions may not occur within the next one or two decades. Even in such cases action should not be delayed: the link between health services and political structure may be flexible enough to allow for an independent limited improvement of health. This is possible through integrated health care programs using paramedical personnel strongly emphasizing nutrition and preventive medicine and assigning first priority to high risk population groups.

Most efforts to reduce IMR are directed towards the mother during pregnancy. The data herein presented point out that in addition to these efforts, a long-term orientation is necessary for the malnourished girls of today may be the high risk mothers of tomorrow. In consequence, we believe that there is already sufficient knowledge in this field to justify planned action and evaluation. Based on both the literature reports and our own findings we believe it reasonable to assume that both short and

long-term maternal nutritional status are important determinants of infant survival, growth and development. Waiting for firm results and conclusions before acting will mean waiting for a long time, sometimes longer than the life of the funding government.

As implied above, actions to decrease IMR must be specifically adapted to the needs of each population group. For instance, in many developed countries IMR has begun a leveling trend as it approaches a purely perinatal component. It seems that further improvement in developed countries depends on advances in medical science, whereas in the lesser developed countries it depends on better nutrition and sanitation, and improved delivery of present medical knowledge.

Projects to decrease infant mortality rates must be run by local people, giving them confidence and a real awareness of their usefulness in dealing with the prevailing conditions of their societies. Although international coordinated effort is required; this may be limited to promotion and technology. Local, national personnel should establish their needs and programs and be in charge of program implementation and evaluation.

SUMMARY

In summary, results of different analytic approaches indicate a clear association between socioeconomic characteristics of the mother and infant mortality rates. The reports available and our own data support the hypothesis that short and long-term nutritional status of the mother are causally related to infant mortality and are in part responsible for the association between socioeconomic status and infant mortality.

The actions to decrease infant mortality rates should be specifically adapted to the needs of each population group, and planners should take account of the socio-political constraints that influence maternal nutritional status. As immediate actions simplified health care programs with a strong nutritional component and using paramedical personnel may be very effective. In the long-term, the most effective actions in developing countries will be those oriented to a comprehensive attack of the causes of underdevelopment. To be successful, this approach will require positive socio-political changes focused on social objectives and rational economic methods. The social changes are justified not only because the ultimate goal of development is to improve the quality of human existence but also because the quality of human life is the key to development.

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References

1. Cipolla, C. M. Four Centuries of Italian Demographic Development. In: Population in History: Essays in Historical Demography, 570-587. D. V. Glass and D.E.C. Eversley (eds.). London: Edward Arnold Publishers Ltd., 1965.

2. Aykryod, W. R. Nutrition and Mortality in Infancy and Early Childhood: Past and Present Relationships. Am. J. Clin. Nutr. 24: 480-487, 1971.

3. Deprez, P. The Demographic Development of Flanders in the 18th Century. In: Population in History: Essays in Historical Demography, 608-630. D. V. Glass and D.E.C. Eversley (eds.). London: Edward Arnold Publishers Ltd., 1965.

4. Gille, H. The Demographic History of the Northern European Countries in the Eighteenth Century. Pop. Studies 3: 3-65, 1949-50.

5. Henry, L. The Population of France in the 18th Century. In: Population in History: Essays in Historical Demography. D. V. Glass and D.E.C. Eversley (eds.), 445-448. London: Edward Arnold Publishers Ltd., 1965.

6. Verhoestraete, L. J. and Puffer, R. R. Challenge of Fetal Loss, Prematurity and Infant Mortality: A World View. J. Am. Med. Assoc. 167: 951-959, 1958.

7. Bourgeois-Pichat, J. The General Development of the Population of France since the Eighteenth Century. Population 6: 635-662, 1951 and Population 7: 319-329, 1952.

8. McCarthy, M. Infant, Fetal and Maternal Mortality USA 1963. Vital and Health Statistics, NCHS Series 20, No.3, 1966.

9. Morris, J. N. and Heady, J. A. Social and Biological Factors in Infant Mortality. V. Mortality in Relation to the Father's Occupation, 1911-1950. Lancet 1: 554-560, 1955.

10. McKewon, T. and Brown, R. G. Medical Evidence Related to English Population Changes in the Eighteenth Century. Population Studies 9: 119-141, 1955.

11. Hoffman, E. The Sources of the Italian Mortality Decline. California Institute of Technology Division of Humanities and Social Sciences, Working Paper No. 88, Pasadena, California, July 1975.

12. Peller, S. Mortality, Past and Future. Population Studies 1: 405-456, 1948.

13. Lechtig, A., Margen, S., Farrell, T., Delgado, H., Yarbrough, C., Martorell, R., and Klein, R. E. Low Birth Weight Babies: World Wide Incidence, Economic Cost and Program Needs. Paper submitted for publication to World Health Organization, Special Supplement, 1976.

14. Morrison, J. N., Heady, J. A. and Morris, J. N. Social and Biological Factors in Infant Mortality. VIII. Mortality in the Post-neonatal Period. Arch. Dis. Childh. 34: 101-113,

15. Croze, M. La Mortalité Infantile en France Suivant Le Milieu Social. International Population Conference (Ottowa 1963), 263-285. Liege: International Union for the Scientific Study of Population, 1964.

16. Kovar, M. G. Variations in Birth Weight - 1963 Legitimate Live Births. Vital and Health Statistics, NCHS Series 20, No. 8, 1966.

17. Rantakallio, P. Groups at Risk in Low Birth Weight Infants and Perinatal Mortality. Acta Paediat. Scand. 193: 1-93, Suppl. 1969.

18. Baird, D. Environmental and Obstetrical Factors in Prematurity, with Special Reference to Experience in Aberdeen. Bull. WHO 26: 291-295, 1962.

19. Lechtig, A., Delgado, H., Lasky, R. E., Klein, R. E. Engle, P. L., Yarbrough, C., Habicht, J-P. Maternal Nutrition and Fetal Growth in Developing Societies: Socioeconomic factors. Am. J. Dis. Child. 129: 434-437, 1975.

20. Abramowicz, M. and Kass, E. H. Pathogenesis and Prognosis of Prematurity. New Engl. J. Med. 275: 878-885, 938-943, 1001-1006, 1053-1059, 1966.

21. Abernathy, J. R., Greenberg, B. G., Donnelly, J. F. Applica-

tion of Discriminant Functions in Perinatal Death and Survival. Am. J. Obst. Gyn., 95: 860-867, 1966.

22. Anderson, U. M., Jenss, R., Mosher, W. E., Randall, C. L. and Marra, E. High Risk Groups - Definition and Identification. New Engl. J. Med., 273: 308-313, 1965.

23. Baird, D. Social Class and Foetal Mortality. Lancet 253: 531-535, 1947.

24. Bedger, J. E., Gelperin, A. and Jacobs, E. E. Socioeconomic Characteristics in Relation to Maternal and Child Health. Pub. Hlth. Rep. 81: 829-833, 1966.

25. Chase, H. C. and Nelson, F. G. Education of Mother, Medical Care and Condition of the Infant. Am. J. Pub. Hlth., (Supplement) 63: 27-40, 1973.

26. Erhardt, C. L., Abramson, H., Pakter, J. and Nelson, F. An Epidemiological Approach to Infant Mortality. Arch. Environ. Hlth. 20: 743-757, 1970.

27. Erhardt, C. L. and Chase, H. C. Ethnic Group, Education of Mother and Birth Weight. Am. J. Pub. Hlth. 63: 17-26, 1973.

28. Donabedian, A., Rosenfeld, L. S. and Souther, E. M. Infant Mortality and Socioeconomic Status in a Metropolitan Community. Pub. Hlth. Rep., 80: 1083-1094, 1965.

29. Greenberg, B. G. and Wells, H. B. Linear Discriminant Analysis in Perinatal Mortality. Am. J. Pub. Hlth. 53: 594-602, 1963.

30. Rider, R. V., Taback, M. and Knobloch, H. Associations between Premature Birth and SES. Am. J. Pub. Hlth. 45: 1022-1028, 1955.

31. Thompson, J. F. Some Observations on the Geographic Distribution of Premature Births and Perinatal Deaths in Indiana. Am. J. Obst. Gyn. 101: 43-52, 1968.

32. Wiener, G. and Milton, T. The Demographic Correlates of Low Birth Weight. Am. J. Epidemiol. 91: 260-272, 1970.

33. Willie, C., Rothney, W. Racial, Ethnic and Income Factors in the Epidemiology of Neonatal Mortality. Am. Sociol. Rev., 27: 522-526, 1962.

34. Chandrasekhar, S. Infant Mortality in India 1901-1935.

London: George Allen & Unwin Ltd., 1959.

35. Hedayat, S. H., Koohestani, P. A. and Kamali, P. Influences of Economic Status and Certain Maternal Factors on Birth-Weight. J. Trop. Ped. 17: 158-162, 1971.

36. Infante-Roldan, S., Puentes-Rojas, R., Rivera-Marfan, F., Gray-Gray, J., Maulen-Piña, J., Morales-Aedo, J., Zenteno-Travisany, M., Díaz-Zepeda, D., and Vargas-Jarmel, S. Epidemiología de la mortalidad infantil. Extudio comparativo con grupo control, area hospitalaria Vallenar, ãno 1967. Rev. Chilena Ped. 42: 281-292.

37. Jansen, A. A. Birthweight, Birthlength, Prematurity and Neonatal Mortality in New Guineans. Trop. Geogr. Med. 14: 341-349, 1962.

38. Jain, V. C. Some Social Components of Infant Mortality in India. Indian J. Ped. 35: 109-112, 1968.

39. Moodie, A. D., Hansen, J.D.L., Jordaan, H.V.F., Malan, A. F. and Davy, D. Low Weight Cape Coloured Mothers and Their Infants. South Afr. Med. J. 44: 1400-1408, 1970.

40. Rahimtoola, R. J., Mir, S. and Baloch, S. Low Birthweight, the "small for dates" Syndrome and Perinatal Mortality in a Low Family Income Group. Acta Paed. Scand. 57: 534-536, 1968.

41. Richardson, B. D. Studies on South African Bantu and Caucasian Pre-school Children: Mortality Rates in Urban and Rural Areas. Trans. Roy. Soc. Trop. Med. Hyg. 64: 921-926, 1970.

42. Shah, P. M., Udani, P.M. and Shah, K. P. Analysis of the Vital Statistics from the Rural Community Palghar. I: Foetal Wastage and Maternal Mortality. Indian Ped. 6: 595-607, 1969.

43. Shah, P. M., and Udani, P. M. Analysis of the Vital Statistics from the Rural Community, Palghar. II: Perinatal, Neonatal and Infant Mortalities. Indian Ped. 6: 651-668, 1969.

44. Timmer, M. Prosperity and Birthweight in Javanese Infants. Trop. Geogr. Med. 13: 316-320, 1961.

45. Baird, D. and Thomson, A. M. The Survey Perinatal Deaths Reclassified by Special Clinicopathological Assessment. In: Butler and Alberman, op.cit., Chapters 2,11,13,14, 1969.

46. Kincaid, J. C. Social Pathology of Foetal and Infant Loss. Brit. Med. J. 1: 1057-1060, 1965.

47. Butler, N. R. and Bonham, D. G. Perinatal Mortality: The First Report of the 1958 British Perinatal Mortality Survey. London: E.& S. Livingston, Ltd., 1963.

48. Butler, N. R. and Alberman, E. D. (eds.): Perinatal Problems: The Second Report of the 1958 British Perinatal Mortality Survey. London: E. & S. Livingston, Ltd., 1969.

49. Chase, H. C. Infant Mortality and Weight at Birth: 1960 United States Birth Cohort. Am. J. Pub. Hlth. 59: 1618-1628, 1969.

50. Lechtig, A., Delgado, H., Martorell, R., Richardson, D., Yarbrough, C. and Klein, R. E. Socioeconomic Factors, Maternal Nutrition and Infant Mortality in Developing Countries Paper presented at the VII World Congress of Gynecology and Obstetrics, Mexico, D.F., October 17-24, 1976.

51. Bergner, L. and Susser, M. W. Low Birth Weight and Prenatal Nutrition: An Interpretative Review. Pediatrics 46: 946-966, 1970.

52. Habicht, J-P., Lechtig, A., Yarbrough, C. and Klein, R. E. Maternal Nutrition, Birth Weight, and Infant Mortality. In: K. Elliott and J. Knight (eds.): Size at Birth (Ciba Foundation Symposium 27), Amsterdam: Associated Scientific Publishers.

53. Lechtig, A., Habicht, J-P., DeLeón, E., Guzmán, G., and Flores, M. Influencia de la nutrición sobre el crecimiento fetal en poblaciones rurales de Guatemala: Aspectos dietéticos. Arch. Latinoamer. Nutr., 22: 101-115, 1972.

54. Lechtig, A., Habicht, J-P., Delgado, H., Klein, R. E., Yarbrough, C. and Martorell, R. Effect of Food Supplementation during Pregnancy on Birth Weight. Pediatrics 56: 508-520, 1975.

55. Arroyave, G., Hicks, W. H., King, D. L., Guzmán, M. A., Flores, M., and Scrimshaw, N. S. Comparación de algunos datos bioquímico-nutricionales obtenidos de mujeres embarazadas procedentes de dos niveles socio-económicos de Guatemala. Rev. Col. Med. Guate. 11: 80-87, 1960.

56. Arroyave, G., De Moscoso, Y., and Lechtig, A. Vitamina A en sangre de embarazados y sus recién nacidos de dos grupos socioeconómicos. Arch. Latinoamer, Nutr. 25: 283-290, 1975.

57. Institute of Nutrition of Central América and Panamá and Nutrition Program, Center for Disease Control (USPHS).

Nutritional Evaluation of the Population of Central America and Panama, 1965-1967. DHEW Publication No. (HSM) 72-8120.

58. Sebrell, W. H., King, K. W., Webb, R. E., Daza, C. H., Franco, R. A., Smith, S. C., Severinghaus, E. L., Pi-Sunyer, F. X., Underwood, B. A., Flores, M., Conner, M. C., Townsend, C. T., Pezzotti, J. M., and Castillo, B. Nutritional Status of Middle and Low Income Groups in the Dominican Republic. Arch. Latinoamer. Nutr. 22 (Supplement 1-190) 1972.

59. Venkatachalam, P. S. Maternal Nutritional Status and Its Effects on the Newborn. Bull WHO 26: 193-201, 1962.

60. Lechtig, A., Yarbrough, C., Delgado, H., Martorell, R., Klein, R. E., and Béhar, M. Effect of Moderate Maternal Malnutrition on the Placenta. Am. J. Obst. Gyn. 123: 191-201, 1975.

61. Naeye, P. L. and Blanc, W. Poverty and Race: Effects on Prenatal Nutrition. Pediatric Res. 4: 473, 1970.

62. Naeye, R. L., Diener, M. M., Horcke, H. T. and Blanc, W. A. Relation of Poverty and Race to Birth Weight and Organ and Cell Structure in the Newborn. Pediatric Res. 5: 17-22, 1971.

63. Klein, R. E., Habicht, J-P. and Yarbrough, C. Some Methodological Problems in Field Studies of Nutrition and Intelligence. In: D. J. Kallen (ed.), Nutrition, Development and Social Behavior, 61-75. Washington, D.C.: U.S. Government Printing Office, DHEW Publication No. (NIH) 73-242, 1973.

64. Thomson, A. M. Technique and Perspective in Clinical and Dietary Studies of Human Pregnancy. Proc. Nutr. Soc. 16: 45-51, 1957.

65. Lechtig, A., Delgado, H., Lasky, R., Yarbrough, C., Klein, R. E., Habicht, J-P. and Béhar, M. Maternal Nutrition and Fetal Growth in Developing Countries. Am. J. Dis. Child. 129: 553-556, 1975.

66. Illsley, R. Social Class Selection and Differences in Relation to Stillbirths and Infant Deaths. Brit. Med. J. 2: 1520-1524, 1955.

67. Gruenwald, P., Funakawa, H., Mitani, S., Nichimura, T. and Takeuchi, S. Influence of Environmental Factors on Foetal Growth in Man. Lancet 1: 1026-1028, 1967.

68. Gruenwald, P. Fetal Growth as an Indicator of Socioeconomic Change. Pub. Hlth. Rep. 83: 867-872, 1968.

69. Chandra, R. K. Fetal Malnutrition and Postnatal Immunocompetence. Amer. J. Dis. Child. 129: 450-454, 1975.

70. Lechtig, A., Martorell, R., Yarbrough, C., Delgado, H., and Klein, R. E. Influence of Food Supplementation on the Urinary urea/creatinine (U/C) Ratio of the Child. Submitted to J. Trop. Ped., 1976.

71. INCAP/DDH, unpublished data, 1976.

72. Lechtig, A., Delgado, H., Martorell, R., Yarbrough, C. and Klein, R. E. Maternal-feto Nutrition. In: D. B. Jelliffe and E. F. P. Jellife (eds.), Nutrition and Growth, New York: Plenum Press, in press.

73. Lechtig, A., Martorell, R., Delgado, H., Yarbrough, C. and Klein, R. E. Nutrition and Growth: Pre and Post-natal. In: M. Winick (ed.), Nutrition and Development: Pre-and Post-Natal. New York: Plenum Press, 1976, in press.

74. Lechtig, A., Delgado, H., Lasky, R., Yarbrough, C., Martorell, R., and Klein, R. E. Influencia de la nutrición materna sobre el crecimiento y desarrollo del niño hasto los 15 meses de edad. Paper presented at the X Congreso Centroamericano de Gineco-Obstetricia, Symposium on "Factors ambientales que afectan la salud de la madre y del niño en Centro América y sus implicaciones para la formulación de un programa materno-infantil." Guatemala, Nov. 27 - Dec. 2, 1974.

75. Levy, B. S., Wilkinson, F. S., Marina, W. M. Reducing Neonatal Mortality with Nurse-midwives. Am. J. Obst. Gyn. 109: 50, 1971.

76. Nold, B., Stallones, R. A. and Raynolds, W. E. The Social Class Gradient of Perinatal Mortality in Dependents of Military Personnel. Am. J. Epidemiol. 83: 481-488, 1966.

77. Yankauer, A., Goss, K. G. and Romeo, S. M. An Evaluation of Prenatal Care and Its Relationship to Social Class and Social Disorganization. Am. J. Pub. Hlth. 43: 1003-1010, 1953.

78. Richards, I.D.G. and Lowe, C. E. Changes in the Stillbirth Rate in England and Wales. Lancet 1: 1169-1173, 1966.

79. Parmlee, A. H. Prematurity and Illegitimacy. Am. J. Obst. Gyn. 81: 81-94, 1961.

80. Lechtig, A., Delgado, H., Yarbrough, C., Habicht, J. P., Martorell, R. and Klein, R. D. A Simple Assessment of the

Risk of Low Birthweight to Select Women for Nutritional Intervention. Am. J. Obst. Gyn. 125: 25-34, 1976.

81. INCAP/DDH Publication/Working Group on Rural Medical Care: Delivery of Primary Care by Medical Auxiliaries: Techniques of Use and Analysis of Benefits Achieved in Some Rural Villages in Guatemala, 24-37. Washington, D. C.: PAHO/WHO Scientific Publication No. 278, Medical Care Auxiliaries, 1973.