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RELATIONSHIP BETWEEN MATERNAL NUTRITION AND INFANT MORTALITY

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INTRODUCTION

High infant mortality rates (IMR) are a major health problem in many countries of the world. Maternal malnutrition has been implicated as an important cause of the high IMR reported in many developing nations. The objetive of this paper is to explore the relationship between maternal nutrition and infant mortality.

For this purpose we will first explore the historical trends in the infant mortality rates of the developed countries. We shall then undertake cross-sectional analysis 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.

RELATIONSHIP BETWEEN SOCIOECONOMIC DEVELOPMENT AND INFANT MORTALITY RATES

During the last four to five centuries, infant mortality rates in Europe fluctuated between 150-250/1,000 live births[1], reflecting the same situation seen in developing countries today.

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. This appears to have been the result of both improved sanitary practices and increased standards of living, and it was relatively independent of improvements in medical care.

the same industrialized countries where infant mortality rates decreased in the twentieth century had a simultaneous improvement in gross national product per capita.

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[2]. The threshold appears to be around 2,800 calories per capita, above which IMR and the closely related LBW rates cease to decline significantly. For the same level of economic developement 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.

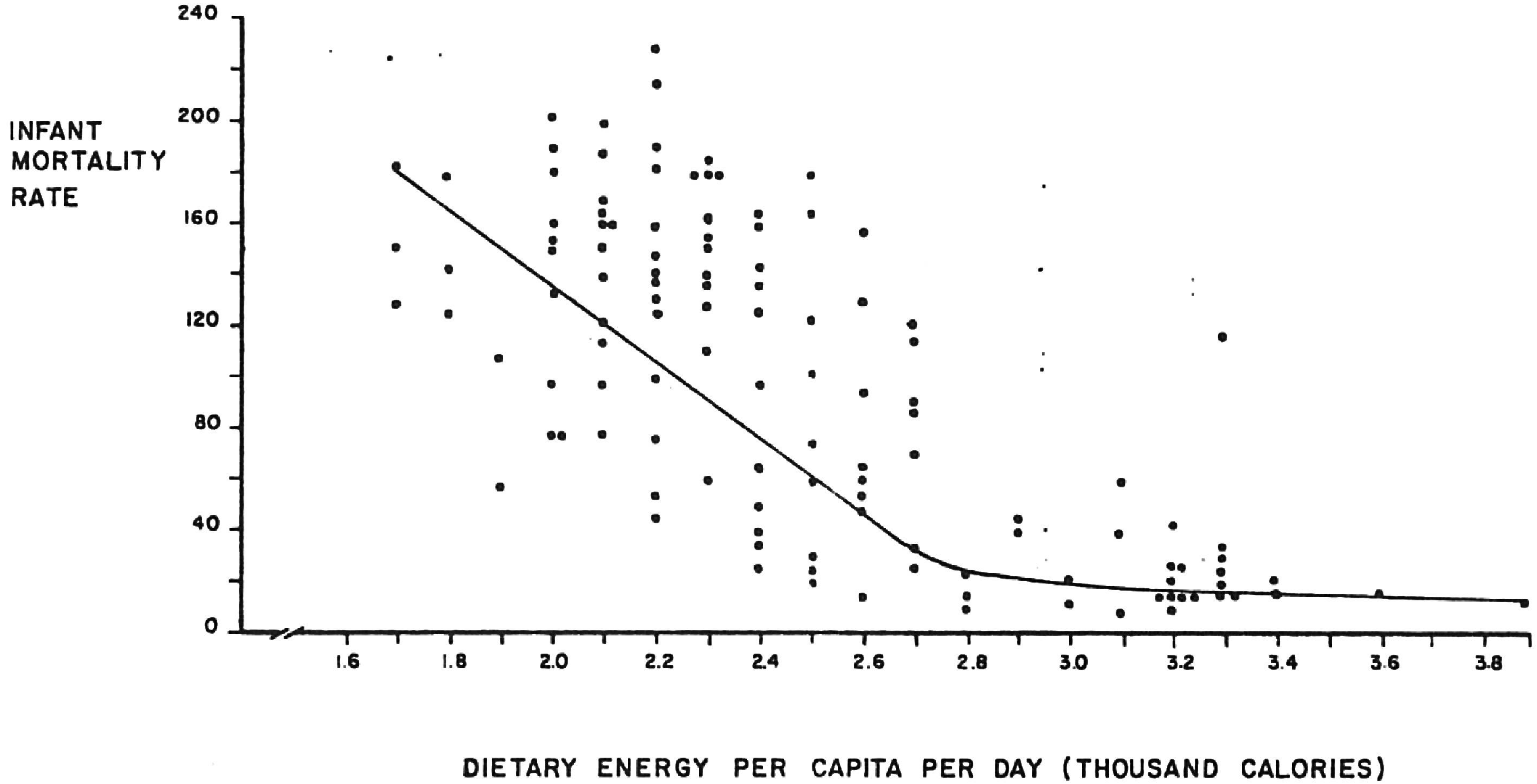
In Figure 2, 123 countries have been divided into three groups according to dietary energy per capita per day. It is clear that no country with less than 2,400 calories per day has "low" IMR while most of the countries with more than 2,800 calories presented "low" IMR.

In sumary, from these independent analysis we can deduce a clear association between socioeconomic characteristics and infant mortality rate.

It should be pointed out that poor socieconomic conditions entail economic, cultural and biological deprivation. Lower class women are shorter, work more during pregnancy and have generally poorer health. They are also more likely to have smaller pelves, and poorer diets during pregnancy. Low SES mothers are also more likely to marry young, to be multiparous and to have illegitimate births. In addition, impoverished women are likely to show less than optimal care both for themselves during pregnancy and for their children. Each of the above-named factors has been shown to be associated with a high risk of infant loss. Our next task is to explore to what extent specific improvement in maternal nutrition may produce a decrease in IMR.

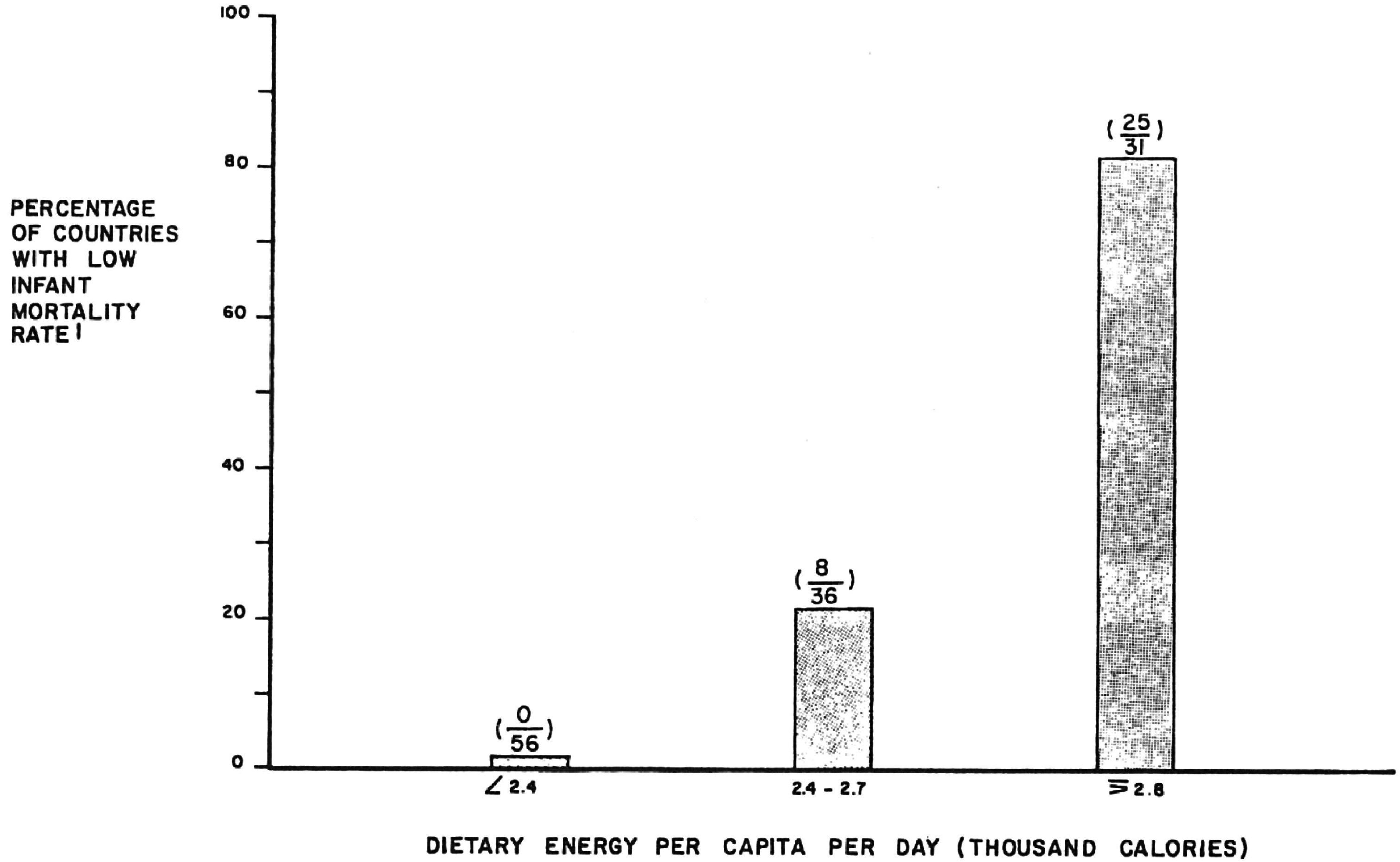
EFFECT OF MATERNAL NUTRITION ON INFANT SURVIVAL

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 consistently associated with infant mortality[4,5]. 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[6,7], a difference that falls



1 IMR = infant deaths/1000 live births. Computed from the world population data sheet (Pop. Ref. Bureau Inc., 1975)

Fig. 1 - Relationship between dietary energy *per capita* and infant mortality rate[1].



1- LOW Infant Mortality Rate: ∠ 40/1000 Live Births

2- 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

Fig. 2 - Relationship between dietary energy _per capita_ and percentage of countries with low infant mortality rate[1, 2] ($p < 0.001$).

within the range of the effect of maternal nutrition on birthweight demonstrated through dietary surveys[8] or nutritional supplementation[9]. Thus, maternal nutrition seems to be related to infant mortality through low birth weight (LBW≤ 2.5 kg). 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[10]. In addition, placental size is smaller in low SES women, a factor that may contribute to fetal malnutrition[11]. 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 occured in England during World War II could only be attributed to the wartime food distribution program which favored pregnant mothers[12]. Further, maternal malnutrition during the mother's infancy and childhood could also produce an effect on infant mortality perpetuated through generations.

We have explored the interrelationship between maternal nutrition and infant mortality in two different studies: the first one in an urban population of low social class from Guatemala City and the second one in four rural villages of 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. Of 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 (≤ 80%), breast feeding (≤ 6 months), weight for height (≤ 90%), height for age (≤ 87%), low birth weight (≤ 2.5kg), and maternal arm perimeter (≤ 24cm). Two additional indicators probably affect infant survival by means of impaired maternal nutritional status. These are birth interval (≤ 30 months) and maternal age (≤ 19 years).

A risk scale was built on the basis of 7 of the 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 per cent of the

TABLE 1

URBAN STUDY — RISK INDICATORS OF INFANT MORTALITY

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

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

1 Computed increment of probability of death in high risk group.

2 Components of risk scale

3 Score range: 0-7; high risk score: 5-7.

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[9]. 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.

In 1969 INCAP provided a system of curative medical care in these comunities. The infant mortality rates have been reduced from 160 per 1,000 in 1968 to about 50 per 1,000 in 1975.

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. Atendance 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.

As the home diet is more limiting in energy than in proteins[9], ingestion of supplmented calories was selected as the criteria to assess supplement intake. We stress that while energy is 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 birth weight (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 4 presents the limits were defined on the basis of reported literature (i.e. low birth < 2.5 kf) or were based on results of prior analyses predicting birth weight.

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

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
Socieconomic status[1]	Annually
Birth weight	At delivery
Infant death	First year age

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

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

1 In mothers and preschool children

Figure 3 explores the relationship between socieconomic score (SES), maternal height, caloric supplementation during pregnancy and birth weight 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 between the proportion of infant deaths in teh "high" and "low" categories is statistically significant only with maternal height and with birth weight.

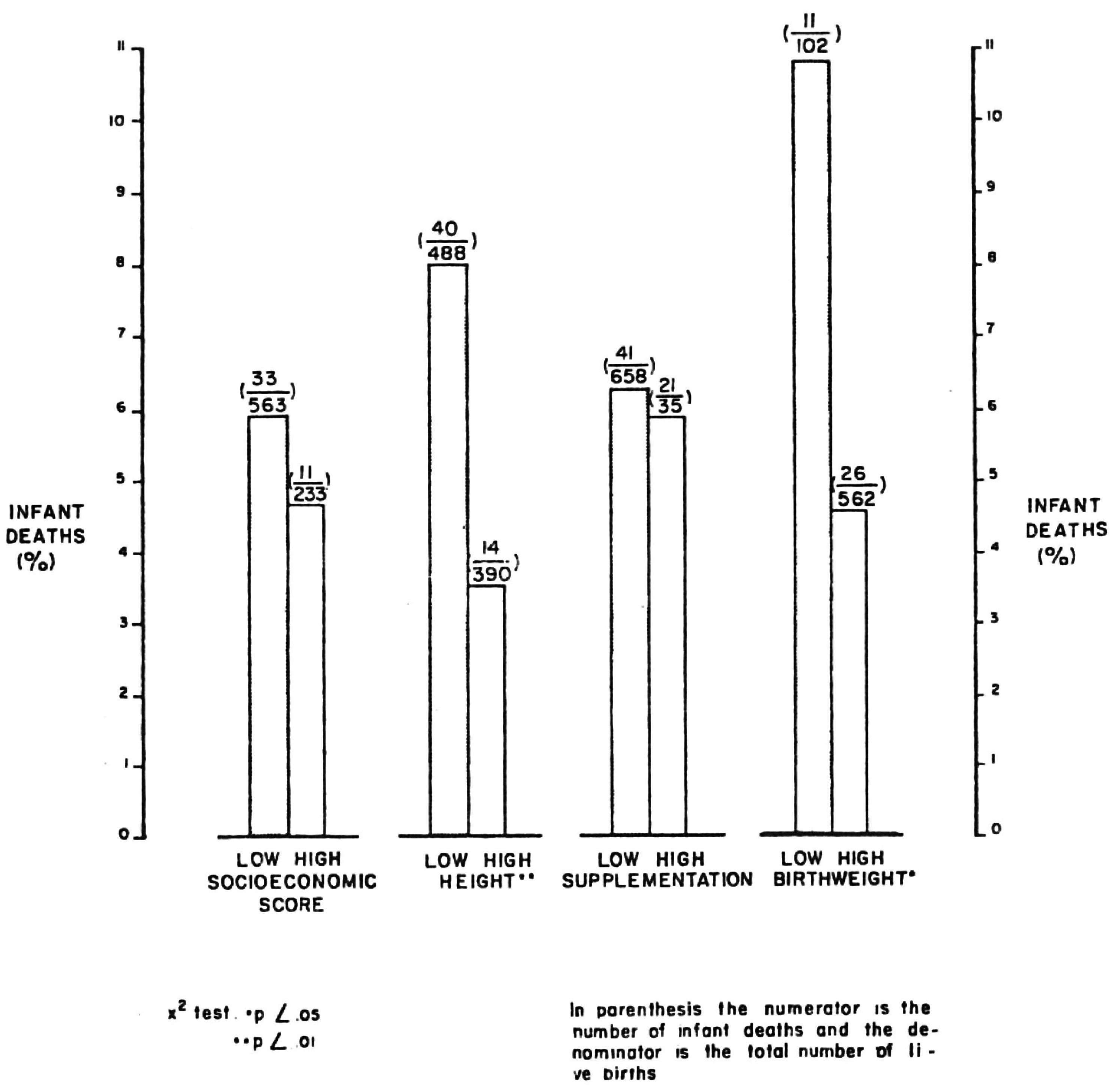

Fig. 3 - Percentage of infant deaths by levels of socioeconomic score, maternal height and food supplementation during pregnancy.

TABLE 3

NUTRIENT CONTENT PER CUP

(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
Fluor (mg)	0.2	0.2

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 cosequence, we explored mainly the consistency or replicability of the direction of these relationships across eight mutually independent comparisons.

Figure 4 shows a comparison between two categories of caloric supplementation during pregnancy within each category of socioeconomic score, maternal height and birth weight. It can be seen in this Figure that in six of the eight independent comparisons infant mortality was lower in the high supplemented group than in the low supplemented group.

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

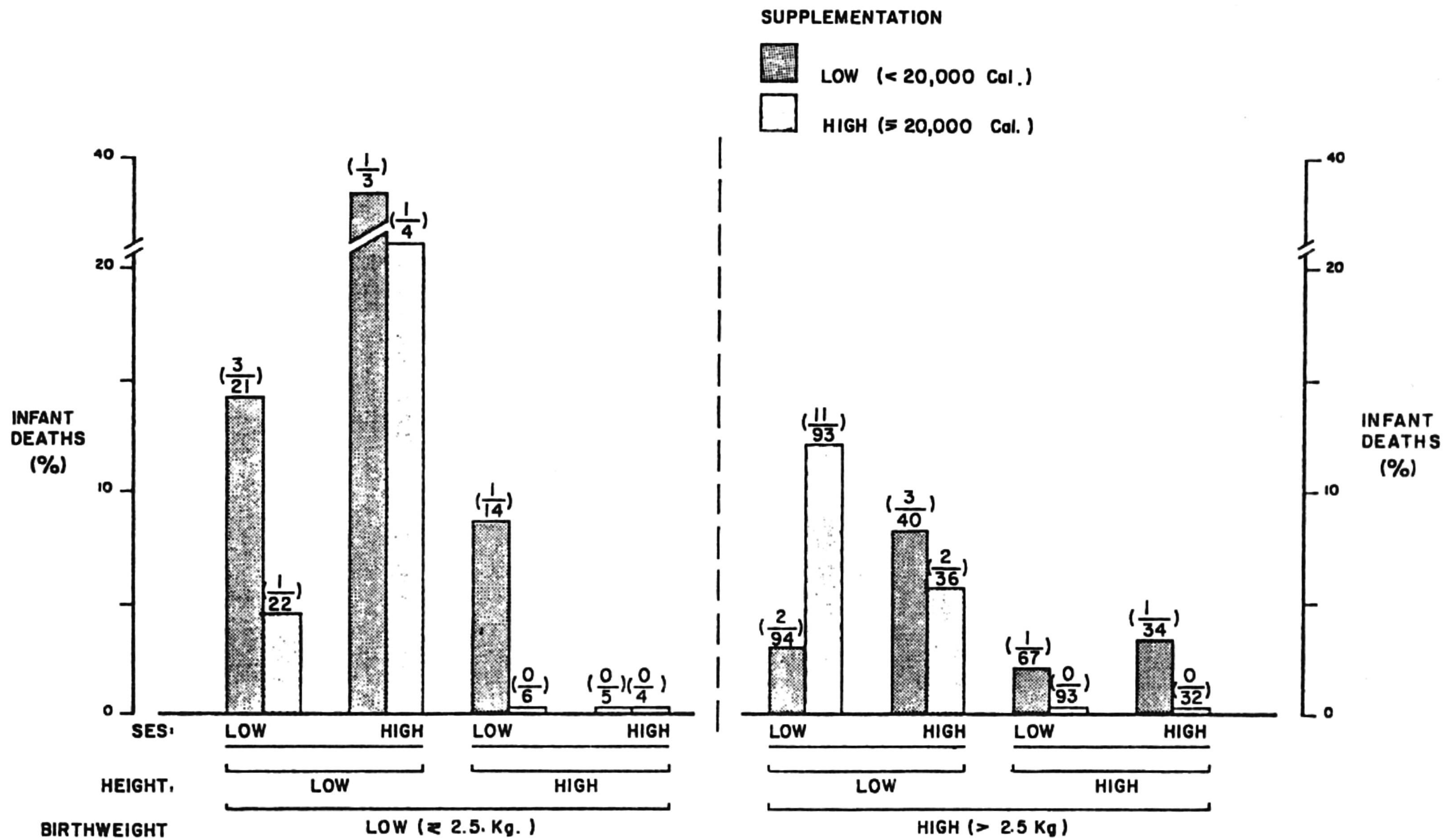

Fig. 4 - Relationship between food supplementation during pregnancy and infant mortality after controlling for maternal height, socioeconomic score and birthweight.

TABLE 4

LIMITS USED TO FORM DICTOMOUS 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

siblings of the same mother. In this analysis, 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.

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) maternal height, an indicator of nutritional history of the mother during ages of growth, is consistently associated with infant mortality, and 2) caloric supplementation during pregnancy, an indicator of maternal nutritional status during intrauterine life of the baby, is also associated with infant mortality in these populations.

The causal may be composed by the following steps: 1) maternal malnutrition may lead to smaller placental size and decreased 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 postnatal life. 2) maternal malnutrition may also produce suboptimal 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.

Our conclusion from these findings is that both short-and long--term maternal nutrition status may be causally related to infant mortality, This does not mean that other factors, namely medical care and environmental sanitation are not important determinants or 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 medicl care. Some interactions are also probably occuring 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 (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. However, the present sample size does not permit us to solve this problem and there is no study available that provides an answer to these questions.

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. Based on both the literature reports and our own findings we believe it reasonable to assume that both and short and long-term maternal nutritional status are important determinants of infant survival, growth and development.

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 porgrams with a strong nutritional component and using paremedical personnel may be very effective. However, 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 approcah will require positive socio-political changes, focused on social objectives and rational economic methods. The social changes mentioned above 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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