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ANTENATAL EVENTS AND POSTNATAL GROWTH AND SURVIVAL OF CHILDREN —PROSPECTIVE OBSERVATION IN A RURAL GUATEMALAN VILLAGE*

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The relation of size and maturity of the newborn infant to survival, growth, and development has been recognized in industrial nations.[1,2] Pre-term and small-for-gestational age as well as postmature infants have an increased risk of disease, death, and abnormal behavior.[3-6] The magnitude of the problem in preindustrial regions has not been measured, nor has it received the consideration that it deserves in activities directed toward public health and national development. Failure to recognize the importance of fetal growth retardation in preindustrial nations is due, in part, to inadequate information on the characteristics of the newborn infant in those regions. In an effort to focus attention on the matter, two decades ago WHO initiated a series of group discussions on the need for better definitions and statistics on birth weight and fetal development.[7,8] Nevertheless, most data for developing nations continue to be from hospital records, in themselves generally inadequate and not representative of the predominantly rural populations where fetal growth retardation is expectedly most prevalent. Only a small proportion of the lower socioeconomic strata of that group can afford hospital services. Furthermore, the usual methodology in hospitals in recording birth weight and gestational age is often unsatisfactory.

This paper summarizes observations of a long-term prospective field study in a typical Mayan Indian village in the Guatemalan highlands. The study began in 1963 by recruiting all pregnant women into annual cohorts and by observing the health and growth of the infants born to those women. The data to be presented refer to liveborn infants delivered in the village between February 1964 and January 1972,[9,10] although observations still continue.

MATERIALS AND METHODS

The study population included 203 women and their infants provided they were delivered in the village; they contributed 465 pregnancies terminating in either a living infant or a stillbirth. In the beginning most women were recruited into the study in the second or third trimesters of pregnancy; as the study progressed, however, the greater proportion were examined in the first trimester. Observations included birth interval, age, mid-pregnancy weight, height, obstetrical experience, and socioeconomic condition.

Deliveries resulted in 470 newborns of whom 460 (97.9%) were singletons and 10 (2.1%) were twins. Among the singletons, 446 (97%) were liveborn and 14 (3%) stillborn; all twins were liveborn. Of the singletons, 47% were male and 53% female. Pregnancy is de-

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fined as the presence of a developing embryo as evidenced by cessation of the menses. *Duration of pregnancy*—a term equivalent to *gestational age*—is the elapsed time in weeks between the last observed menstrual period and the termination of pregnancy. *Abortion* is a pregnancy terminating at less than 20 weeks of gestation. After 20 weeks the pregnancy results in a delivery of a *liveborn* or a *stillborn*. *Age* of the gravida is the number of years at the initial visit to the clinic because of a current pregnancy. *Parity* is the number of previous pregnancies terminating in delivery. *Birth order* is the number of live births.

As for the newborns, a *live birth* is defined as the expulsion or complete extraction from the mother (delivery) of an infant of more than 20 weeks of gestation who breathes or gives other signs of life such as pulsation of the umbilical cord. *Gestational age* is the time, in weeks, between the date of the last menstruation and the date of birth. *Low birth weight* (lbw) is less than 2,501 gm; *pre-term* infant is one born at less than 37 weeks of gestation; *term-small-for-gestational age* infant (TSGA) is a child of less than 2,501 gm birth weight but of 37 weeks or more of gestation; a *term* infant is one whose birth weight was 2,501 gm or more with a gestational age of 37 weeks or more.

This sample represents virtually the village entirety of pregnant women and newborns. Two village women, non-Indian, were excluded because their deliveries were at city clinics. Birth weight was obtained with a Seca balance within one hour of birth for 430 (97%) of the liveborns and for 8 of the twins. Other measurements were body length at birth (birth length), and head and thorax circumferences. Gestational age was assessed for 416 (93%) liveborns and 8 twins, by date of last menstruation, uterine height, or the two methods combined. Thus birth weight and gestational age were available for most infants, permitting characterization of fetal maturity by combined variables.

Measurements of weight and height at frequent intervals were programmed for every newborn. Each child had as many as 40 measurements in the first 3 years of life. To accomplish this, every house with a newborn was visited at least once a week, a practice that also permitted an identification of illnesses and the death of children. Circumferences of head and thorax were obtained with lesser frequency and only for representative cohorts. The techniques and methods used in the field, and the analytical procedures employed are described in detail elsewhere.[11]

RESULTS

Maternal characteristics The village mother is stoic, dedicated, and hard working; she arrives at motherhood after a long traditional preparation that begins in childhood. Her training emphasizes domestic chores and the role of a housewife but neglects sexual education and childbirth. Experience in these matters and in motherhood is gained through a succession of pregnancies spaced by 2 to 4 years within a span of 20 to 25 years. Certain prenatal obstetric characteristics are presented in Table 1 to illustrate the prevailing early age of first conception, a high parity, and a high rate of abortion and of deceased children, all increasing with maternal age.

Detailed observations on the diet and infectious processes of this population during infancy and childhood have demonstrated that malnutrition-infection interactions begin *in utero* and extend into the whole childhood period.[9,10] It thus is anticipated that the growth deficits manifest in infancy and childhood extend as a consequence into adolescence and adulthood. To illustrate, Table 2 summarizes anthropometric characteristics of pregnant village women, their short stature, low weight, and minimal subcutaneous fat, all indicative of a background of nutritional deprivation and recurring infection.

Women not only had a history of poor diets and excessive infection, but those stresses continued through pregnancy. For instance, Table 3 shows the degree of adequacy of diets of 50 women in the third trimester of pregnancy, expressed as a percent of the requirements established by INCAP[12] for women of similar age, weight, and habitat. Most consumed deficient amounts of vitamin A, riboflavin, iron, and niacin. While some women have a low intake of dietary calories and proteins, more than a half

Table 1
Prenatal Obstetrical Characteristics, Mean Values and Standard Deviations, 458 Pregnancies, by Maternal Age, Santa Maria Cauqué, 1964–1972

Age, Years	Number of Cases	Previous Deliveries	Abortions	Deceased Children at Time of Current Pregnancy
14	2	0	0	0
15–19	107	0.57(0.73)	0.10(0.39)	0.22(0.54)
20–24	124	2.10(1.21)	0.20(0.46)	0.57(0.85)
25–29	70	4.21(1.44)	0.54(1.13)	1.17(0.71)
30–34	86	6.18(1.58)	0.64(0.77)	1.67(1.36)
35–39	52	7.63(1.72)	0.73(1.05)	2.31(1.46)
40–44	17	9.12(1.76)	2.12(2.26)	2.94(1.71)

Table 2
Maternal Anthropometry, 410 Pregnancies, by Maternal Age, Santa Maria Cauqué, 1964–1971

Age, Years	Number of Cases	Weight (kg)	Height (cm)	Tricipital Skinfold (mm)
14	1	58.4	142.2	14.0
15–19	80	52.2 ± 0.7*	142.5 ± 0.5	10.7 ± 0.4
20–24	117	52.7 ± 0.6	143.5 ± 0.4	9.5 ± 0.3
25–29	66	52.8 ± 0.7	144.0 ± 0.6	8.5 ± 0.4
30–34	75	52.8 ± 0.8	142.0 ± 0.5	9.4 ± 0.4
35–39	50	53.1 ± 0.9	141.0 ± 0.6	10.0 ± 0.5
40–44	21	56.8 ± 1.6	143.0 ± 0.6	9.6 ± 0.8
Mean		52.9	143.1	9.6

*Mean ± S.E.

Table 3
Adequacy of Diets of 50 Women in the Third Trimester of Pregnancy, by Percent of INCAP Recommendation, Santa Maria Cauqué, 1971

	Percent Nutrient Adequacy,* Percent of Women		
	≤50	51–100	>100
Calories	6**	74	20
Total protein	4	47	49
Calcium	10	53	37
Iron	26	60	14
Retinol	100	0	0
Thiamin	2	33	65
Riboflavin	61	39	0
Niacin	10	86	4
Ascorbic acid	37	47	16

*Adequacy as percent of requirement for pregnant women, 2nd and 3rd trimester, 53 kg, 20+ years old.
**Percent women in category.

have diets contributing at least 75% of the prescribed nutrient levels. Furthermore, the mean percent of calories derived from net dietary protein was approximately 6% after correcting for a net protein utilization of 50%, an adequate figure according to the ICMR recommendations.[13]

Infection and infectious disease present a problem more serious than usually recognized because rural women tend only to report a fraction of their illnesses, and because infectious disease has a debilitating effect measurably enhanced in chronically malnourished women. To illustrate that magnitude, Table 4 gives the frequency of infectious diseases in a series of 365 pregnancies; more than two-thirds had an associated infectious process. As many as 40% of pregnant women had two episodes, and 20% experienced at least three. Most illnesses were of the upper respiratory tract; diarrheal disease was less frequent. However, diseases such as

Table 4
Infectious Diseases, 365 Pregnancies, Santa Maria Cauqué, 1964–1971

Number of Episodes	Number of Pregnancies	Attack per 100 Pregnancies	Cumulative Attack per 100
0	106	29.0	
1	114	31.2	70.9
2	80	21.9	39.7
3	58	15.9	17.8
4	6	1.6	1.9
5	1	0.3	0.3
Total	365	99.9	

diarrhea, dysentery, laryngotracheobronchitis, pneumonia, otitis media, hepatitis, and pyelonephritis occurred in the third trimester in as many as 14.5% of all pregnancies.

It is not surprising that weight gained during gestation averaged no more than 7 kg, a finding reflected in the low birth weights so characteristic of this population.

Such conditions as eclampsia, toxemia, vascular problems, hypertension, diabetes, and obesity, which outnumber infectious diseases in industrial societies, are minor problems in the village. Death during the puerperium was not recorded among 465 deliveries.

Obstetrical practices follow tradition and custom. Women kneel on the floor or on a palm mat; the traditional midwife is the sole assistance to the mother during labor; there is no preparation of the mother, no administration of drugs; rupture of the membranes is spontaneous and leads to a relatively rapid delivery, regularly with cephalic presentation.[11]

Newborn characteristics Preliminary analyses of the newborn in Santa María Cauqué[14,15] established that village infants are small compared with those of the upper socioeconomic strata of Guatemala or of industrial societies (Table 5); 7.2% were pre-term, and 34.3% were term-small-for-gestational age. No infants were born post-term. The low weight of village infants is evident when the values are plotted in a standard graph and compared with infants born at a similar altitude,[16] as that of Santa María Cauqué (Figure 1). Almost half of the Cauqué newborns were below the 10th percentile, whether pre-term or term, and only a few term infants had weight above the 50th percentile.

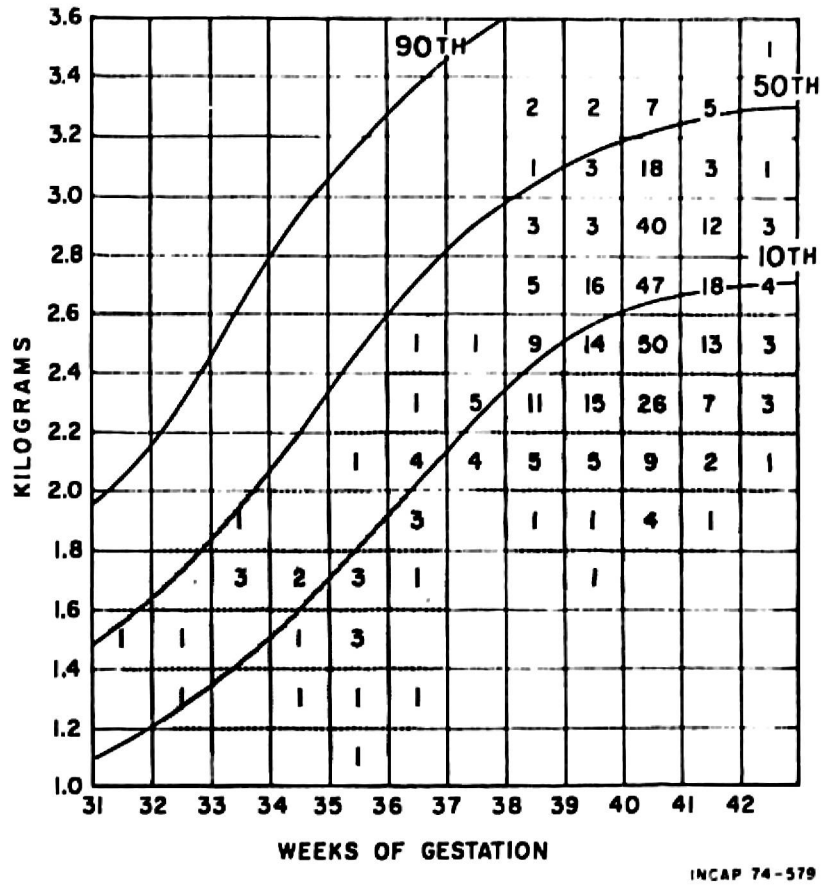

Figure 1. Birth weights and gestational ages, 430 live singletons according to the Denver scale.[16] The numbers are cases in each compartment. Santa Maria Cauqué, 1964–1972.

Taking into consideration birth weight and gestational age, the population of singleton newborns distributed as in Table 6. Term infants (58.1%) were subdivided arbitrarily into two groups, those with high birth weight (> 3,000 gm) and with moderate birth weight (2,501 to 3,000 gm). Pre-term infants (7.2%) were grouped as of moderate low birth weight (2,001 to 2,500 gm) and severe low birth weight

Table 5
Newborn Infants, Santa Maria Cauqué (1964–1972) and Guatemala City (1960)

	Santa Maria Cauqué	Guatemala City*
Birth weight, grams	2533(398)**	3261(417)
Birth length, cm	45.6(1.8)	49.9(1.1)
Head circumference, cm	32.0(1.5)	34.2(0.9)
Thorax circumference, cm	29.9(1.8)	

*Hurtado[25]
**Mean (S.D.)

Table 6
Infants by Birth Weight and Gestational Age, 415 Liveborn Singletons, Santa Maria Cauquė, 1964–1972

Class	Number (%)	Birth Weight Range (gm)	Gestational Age Range (weeks)
Term high bw	43(10.3)	>3000	37–42
Term moderate bw	199(47.8)	2,501–3,000	37–42
Term-small-for-gestational age	143(34.4)	<2501	37–42
Pre-term moderate lbw	6(1.4)*	2,001–2,500	35–37
Pre-term severe lbw	24(5.8)	<2001	31–36

*One pre-term infant, not in the table, had a birth weight slightly above 2500 grams.

(< 2001 gm). The term-small-for-gestational-age infants (34.4%) were treated as a single group. This classification shows a ratio of pre-term to small-for-gestational-age infants of 1:4.7, the reverse of the observed 2:1 in industrial societies.

Survival of infants and preschool children A direct relationship between birth weight and survival has been noted in village infants,[10] and a similar correlation exists for gestational age.[17] Infants with the greater birth weights and longer gestational ages showed the best survival; the apparent safety level for neonatal survival was around 2,300 gm and 37 weeks of gestation.

Survival in neonatal and post-neonatal infancy as a function of combined birth weight and gestational age (fetal maturity) is depicted in Table 7. Survival was poorest for pre-term babies; half died in the first year of life. Small-for-gestational age infants also had low survival; one-fifth died in infancy. Term babies performed best but infant mortality, nevertheless, was 90 per 1,000 term livebirths.

Fetal maturity also correlates with survival in the second year. All pre-term infants who survived the first year also survived the second. However, mortality was high among term and term-small-for-gestational age infants (Table 8); they also had a high risk of death in the third and fourth years.

Physical growth Retrospective and prospective studies conducted mainly in industrial societies[1] have established a correlation between fetal maturity and physical growth. Village children also tend to remain in growth tracks defined either by birth weight or by gestational age.[11,17]

The following analysis was based on measurements of the 416 children for whom data on birth weight and gestational age had been collected. Attrition in numbers was due to deaths; to the fact that some children belonged to cohorts recruited after 1964 and had varying ages; and to an occasional migration or failure to collect the measurement.[11] A useful separation was observed when cohorts of infants were defined by differences of 500 gm in weight

Table 7
Infant Survival by Birth Weight and Gestational Age, 416 Cases with Complete Data, Santa Maria Cauquė, 1964–1972

Type of Newborn	Number of Newborn**	Survivors		
		Neonatal	Postneonatal	Total
Pre-term*	31	21(67.7)***	15(71.4)***	15(48.4)
Term-SGA	143	139(97.2)	131(94.2)	119(82.2)
Term	242	240(99.2)	232(96.7)	220(90.9)
Total	416	400(96.2)	376(94.0)	336(80.8)

*One newborn weighed 2,565 grams.
**Beginning the period.
***Infants alive as the period ended; percent in parentheses.

Table 8
Second Year Deaths and Death Rates, by Birth Weight and Gestational Age, Santa Maria Cauqué, 1964–1972

Type of Newborn	Number of Infants*	Deaths in Second Year of Life	Deaths per 1,000 Children
Pre-term	15	0	0
Term-SGA	105	8	76
Term	204	9	44
Total	324	17	52

*Alive as the second year begins.

at birth. Gestational age appeared to have a lesser predictive capacity since only two cohorts separated by the dividing line of 37 weeks were distinctly different.[17]

Infants classed by fetal maturity as described in Table 6 and Figure 1 exhibited individual growth patterns, evident in the first week of life. Term infants with moderate birth weight or small-for-gestational age infants lost less weight in the first week of life than the other two groups and also showed the greatest weight gain in that week.[11] The mean growth curves for weight are compared in Figure 2 with the INCAP standard for Central American children.[18] The differences became well established within the first three months and were still more evident toward the end of the first year, and thereafter for as long as observations were made (6 years). There was some tendency for the differences between groups to become more distinct with time. Children with better fetal maturity showed the best absolute weight values, and were followed by the term-small-for-gestational age and the prematures. However, one group behaved individually, the preterm babies with adequate weight for gestational age. Although they had a high infant mortality, survivors showed a high growth velocity in the first 6 months of life, and attained weights approximating those of term infants with adequate weight-for-gestational age (Fig-

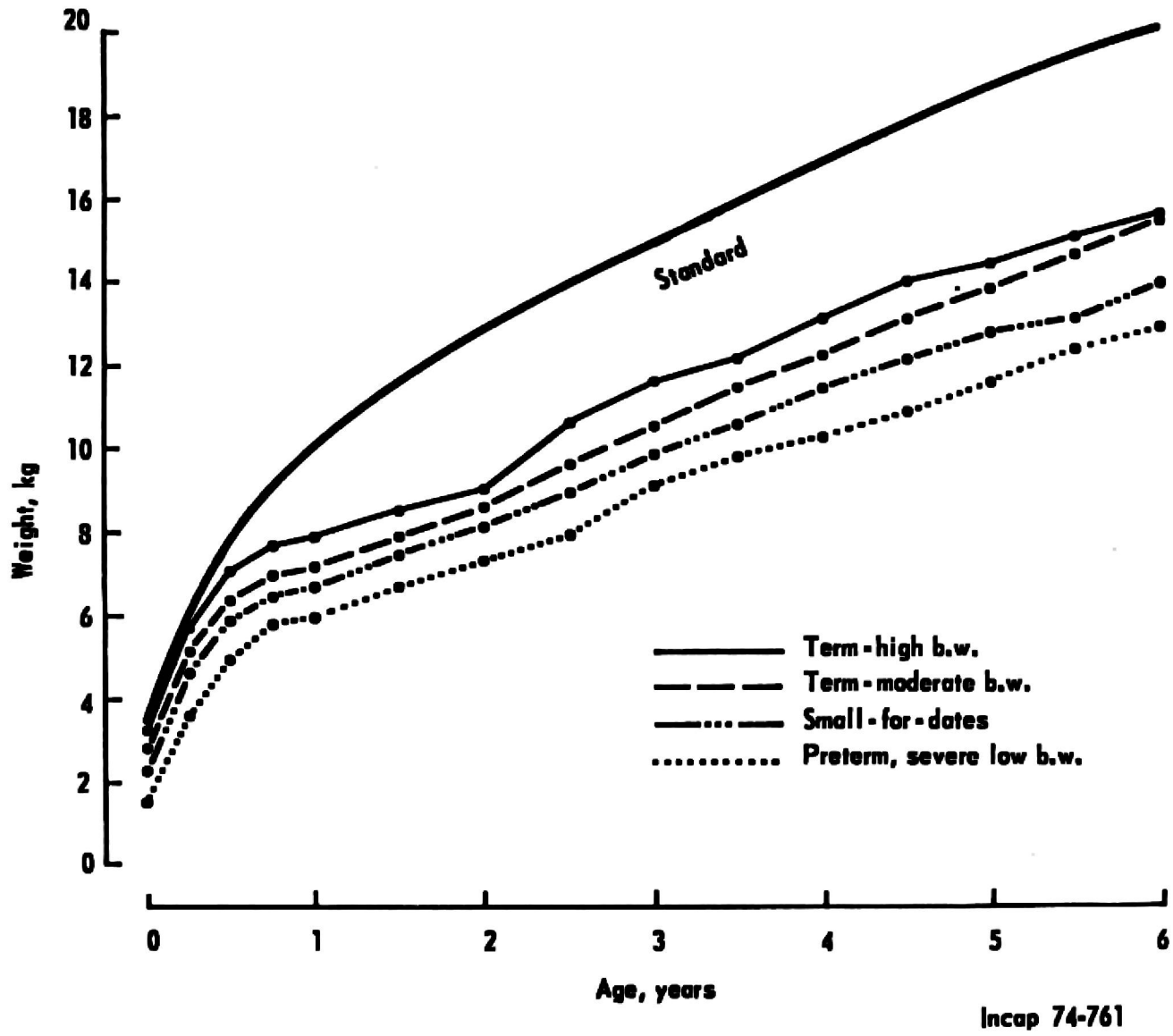

Figure 2. Mean weight curves, cohorts of children by maturity at birth, birth to 6 years of age. Santa Maria Cauqué, 1964–1972.

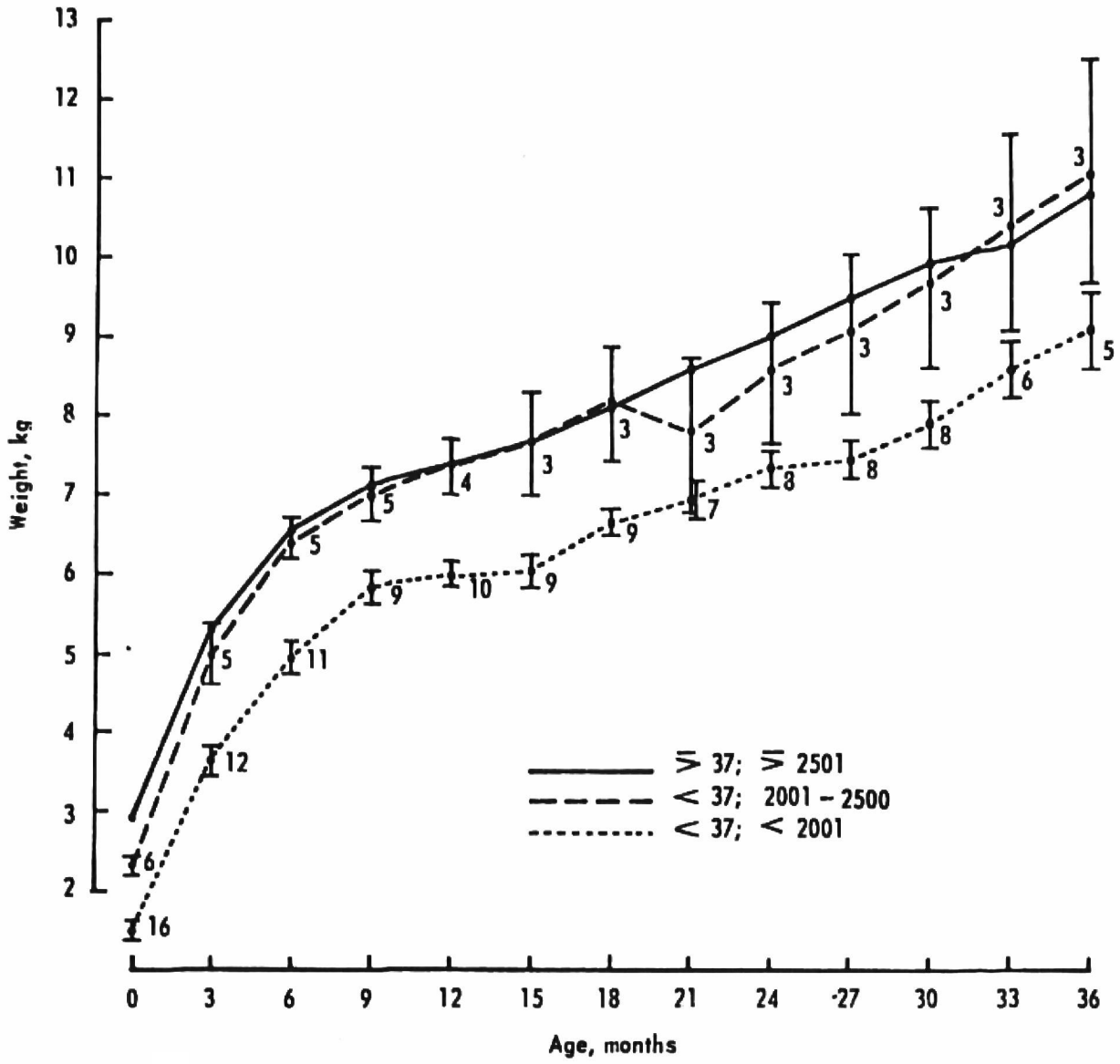

Figure 3. Weight curves of three groups of children, by age, birth to three years of age, Means ± 2 S.E. Figures near means are numbers of children measured.

ure 3). After the third year of life these infants grew similarly to children who were term with adequate weight.

Maternal factors and survival and growth Despite the strong correlation between weight, gestational age, and the survival and growth of children, antenatal events explain only a relatively small part of the variance of growth. Unpublished observations indicate that birth interval, infection, weaning age, and other factors directly related to the maternal environment and immediate surroundings after birth are the more distinctive determinants of survival and growth following the neonatal period. For instance, survival in the first 6 months of life is highly correlated with a long interval between births. Also, weaning age and infection account for a large proportion of the variance of physical growth in a multiple regression analysis.[11]

Antenatal factors of the maternal environment expressed in the birth weight and gestational age attained by the fetus relate not only to fetal growth, but to postnatal survival and physical growth as well. The relationship with fetal growth is discussed first.

Maternal variables such as height, mid-pregnancy weight, age, parity, protein and calorie intake, and morbidity correlate with fetal growth by use of either parametric or non-parametric statistics. In step-wise regression analyses for 4 anthropometric infant variables, each handled as a dependent variable against 14 maternal variables, as much as 37% of the variance of birth weight and 39% of the variance of birth length could be accounted for by such variables as duration of pregnancy, weight, height, age, and illnesses in the third trimester of pregnancy (Table 9). Sex of the infant was among the independent variables. If gestational age is removed from the equation, a significant part of the variance still can be accounted for. Birth order, maternal age, infant sex, and maternal height accounted

Table 9
Step-Wise Regression Analysis for Birth Length,* 325 Newborns, Santa Maria Cauqué, 1964–1972

Variable in Order of Entry**	Regression Coefficient (B)	Standard Error of B	F Value***	% RSQ	Δ % RSQ
With duration of pregnancy					
DPREG	7.07	.58	146.74	29.8	29.8
SEX	−10.41	1.87	30.89	35.6	5.8
MHT	.93	.21	18.14	39.0	3.4
Without duration of pregnancy					
BORDER	3.26	.37	77.78	9.9	9.9
MAGE	− .08	.01	35.05	18.4	8.4
SEX	−9.35	2.25	17.30	22.3	3.9
MHT	1.06	.26	16.40	26.1	3.7

*Dependent variable.
**The other variables did not add significantly to the regression (tested at the 1% level).
***$P < .01$

for 26% of the variance of birth length, and a good proportion of variance of head and thorax circumferences. However, the prediction of birth weight was less strong.

Antenatal events have a definite relation to survival in the neonatal period because they depend strongly on birth weight and gestational age. While neonatal mortality in the village is much beyond usual rates for any industrial society, differences are erased once birth weight is taken into account.[11]

With respect to physical growth, in a regression equation antenatal events explain a small part of the variance of growth. Maternal factors such as height and age have the greater capacity, accounting for as much as 7% to 8% of the variance.[11]

Summary and discussion This report describes biological features of the pregnant woman and newborn infant in a typical rural village of Guatemala. Most women have a background of chronic malnutrition and recurring infections, which relate to the short stature, relatively small muscle mass, and small fat deposit noted during childbearing age. Malnutrition and infection continue throughout pregnancy and are responsible for the small weight gain observed during pregnancy, of itself common to many developing regions of the world.

The newborn population has a low mean birth weight and a high incidence of prematurity and fetal growth retardation. As much as 30% of infants can be classed as term-small-for-gestational age and an additional 7% as pre-term or premature, percentages much in excess of those for well nourished populations living at similar altitudes.

This finding is in agreement with the high neonatal mortality in the village. Survival correlated strongly with birth weight and gestational age[17] and with fetal maturity. Pre-term infants had the poorest survival rates in neonatal and postneonatal infancy but improved thereafter. The term-small-for-gestational age infants had poor survival in infancy but, more importantly, deaths were also more frequent in the second and thrid years of life. Term infants with adequate weight-for-gestational age had the best survival.

Postnatal physical growth also correlated with antenatal events, as expressed in birth weight, gestational age, or the two variables combined. Pre-term small-for-gestational age infants grew more slowly; the pre-term adequate-for-gestational age infants, however, showed a rate of growth as good as that of term infants. The term small-for-gestational age infants (small-for-dates) also had deficient growth as compared to term infants. The differences in growth ascribed to fetal maturity became established shortly after birth and persisted through childhood.

While all children had a marked deficit in

growth after the first 6 months of life, those of adequate birth weight and gestational age fared better than the others. Evidently, environmental factors (deficient supplementary feeding and recurring infection) are responsible for a goodly part of growth deficit, and the prescribed intervention is a better quality of living conditions, biological and social.

On the other hand, antenatal events are related to survival and growth, and specific public health action could lead to definite improvement. If mean birth weight were raised by 200 grams, a reduction in infant mortality and better growth curves would be expected. However, the peculiar distribution of birth weight values in the population indicates that more action is needed, and the difficulties in modifying birth weights of a population are well known.

Furthermore, the strong correlation observed between maternal size and birth weight suggests that a substantial improvement in birth weight cannot be anticipated promptly. Observations over a long time in Japan[19] and experiments in animals[20,21] suggest that a secular change in fetal growth requires first an improvement in nutrition, hygiene, and physical growth of the general population, in order that women reach reproductive ages in better condition to sustain fetal growth and development. This is not incompatible with the knowledge that an improved caloric and protein intake results in moderately higher birth weights.[22,23] Data from England show convincingly that increased size of the mother is associated with improved fetal growth;[24] conceivably, tall women in that population are the result of better environmental conditions during childhood and adolescence. There are no data for European villages 200 years ago with which to compare the data from Santa María Cauqué; neonatal and post-neonatal infant mortality figures, however, suggest that in such regions the situation of fetal growth likely was similar to that of the present day Guatemalan village.

The general consideration is that an intergenerational effect on birth weight can be anticipated if living conditions improve, a matter of importance in the planning of public health action. Without entering into details of logistics and feasibility of public health measures, it is evident that for the immediate situation much could be gained by delaying marriage, encouraging breast feeding, spacing children, improving the socioeconomic status of women, and strengthening prenatal care. For the long range, the improved nutritional status of the infant, child, and adolescent is a continuum that will result in greater societal benefit, because it will lead to a better maternal environment, improved fetal growth and the associated improvement in survival and growth and development. While such long range measures involve at least one generation of effort, the result should be outstanding.

In reality, public health action aims at both targets: a better social condition of the family favors both maternal health and fetal growth. The effects extend to infant nursing, child care, and growth in adolescence. The social contribution has a cumulative effect. Girls affected in this way will deliver larger and healthier infants than did their mothers. The intergenerational effect should bring the society to a level close to that of the more developed nations.

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