PREDICTION OF POOR INFANT GROWTH[1]

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INTRODUCTION

There have been sustained and spectacular reductions of low birth weight, malnutrition, and infant mortality in Chile in recent times *(1, 2)*. However, deterioration of the National Supplementary Food Program in 1983, as a result of the world recession *(3, 4)*, has made it evident that this trend could change. This danger, which has also been observed in developed countries such as the United States *(5, 6)*, justifies adopting techniques that will make it possible to pinpoint the groups most exposed to malnutrition, disease, and death.

Epidemiology has provided us with new techniques for predicting harm, and both the World Health Organization (WHO—*7*) and its Regional Office for the Americas, PAHO/WHO *(8–12)*, have spearheaded utilization of the risk approach in health programs. The Inter-American Institute of the Child, in cooperation with the Latin American Center for Perinatology, has offered numerous courses on this subject *(13)*. In addition, the available medical literature includes a large number of studies and articles directed at identifying risk factors whose presence in individuals or groups provides grounds for taking preventive measures. WHO has published an annotated bibliography on this subject *(14)*, and use of the technique has recently been extended to a variety of fields *(15, 16)*.

In 1982 the Chilean Health Ministry included in its rules and standards for care of infants and adolescents *(17)* a list of risk factors and appropriate measures designed to ensure preferential care for the children or families concerned. The risk factors selected have demonstrated their value in the international literature. However, certain Chilean studies have shown that the necessary data are not always recorded in patients' clinical histories, and that the mere fact of recording them does not automatically trigger specific corrective actions *(18)*. Other Chilean authors have not found differences in the rates of malnutrition, disease, and death between groups with and without the risk factors cited *(19)*.

[1] The study reported here was begun in 1982 under an agreement between the Ministry of Health (Consejo para le Alimentación y Nutrición) and the University of Chile (Instituto de Nutrición y Tecnología de los Alimentos). Various phases of it were financed by the University of Chile Libraries and Research Unit (DIB), the World Health Organization (WHO), and the Board on Science and Technology for Development (BOSTID)/U.S. National Academy of Sciences/USAID. This article will also be published in Spanish in the *Boletín de la Oficina Sanitaria Panamericana*, vol. 104, 1988.

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These observations justify reducing the number of risk factors to those that will ensure maximum predictive value. They also justify assigning each risk factor a weight based on the strength of its association with the specific dependent variable (either malnutrition or certain morbidity or mortality deriving therefrom—*20, 21*), recognizing the possible synergism of these factors when they are combined in certain groups, and evaluating the time factor in terms of how long a particular variable needs to be present to produce its effect. (Regarding this last point, one must accept that the predictive value of the risk factors in foreseeing a particular undesirable outcome changes with the length of time that the corresponding data are recorded. It should also be noted that the failure to detect significant differences between the two above-mentioned groups could simply mean that the presence of the risk factors in one group prompted sufficient differentiated care to reduce the risk factors' impact.)

Taking account of these various considerations, an instrument was developed for predicting deterioration of infant growth using two sets of indicators. One set, termed "biomedical risk" indicators, related to susceptibilities of the infant. These indicators included birth weight, age, the number of the mother's children, maternal or newborn pathology, etc. The other set, termed "family incompetence" indicators, involved exposure to adverse conditions. These indicators included parental occupations, maternal education, housing quality and sanitation, degree of health service use, etc. *(22-29)*.

"Biomedical risk" scales and "family incompetence" scales were devised and found capable of distinguishing groups facing varying levels of malnutrition risk (Figure 1). This was done by applying the "simple relative risk" method proposed by WHO *(7, 8)* and also a logistic regression model *(30-32)* that successfully weeded out indicators with less predictive value from among a number of mutually dependent indicators.

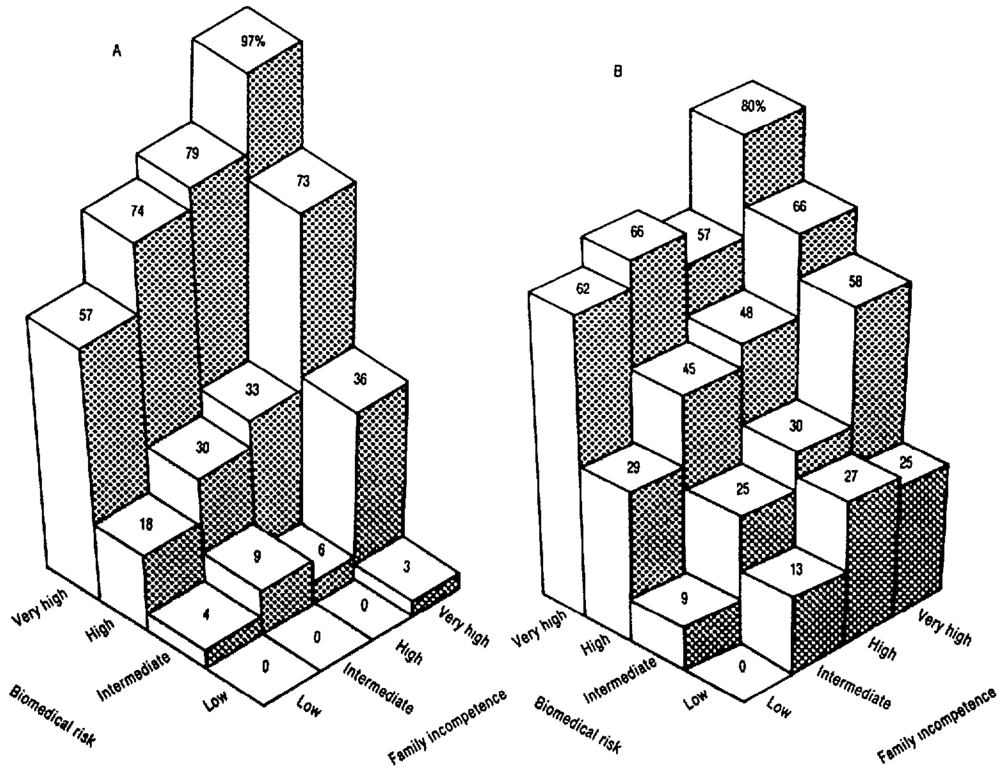
It should be noted that for more than half a century Chile's health policies have been focusing special attention on maternal and child health problems, and have been assigning high priority to the nutritional status of vulnerable populations. In this same vein, Chile's Food and Nutrition Council *(33-36)* has designed specific measures to stimulate milk production in the country and to finance the distribution of milk to those insured by the social security system.[3]

Following establishment of the National Health Services in 1952, these programs were expanded with additional funding derived from Social Security contributions and the Worker's Family Allowance *(2)*.

Since 1975, the Chilean Health Ministry has been publishing the nutrition status (age:weight ratio) of children below age six who are under National Health Service supervision *(37, 38)*. But this universal procedure only makes it possible to tell when a child ceases to grow at the expected rate, and so only serves as a signal for starting or reinforcing preventive measures of a secondary nature—those taken after harm has already become evident.

[3] In addition, since 1942 the Ministry of Health has been providing milk to indigent families; and since 1952 the National Health Service has been providing milk to families registered at local health centers, whether or not they are within the social security system.

FIGURE 1. Estimated probabilities of inadequate weight gains among infants, based on their "biomedical risk" and "family incompetence" scores. (A) shows probabilities for the 0–90 day period and (B) shows probabilities for the 90–360 day period. (N = 876 infants in both cases.)



According to current health ministry standards, a nursing child (under two years old) is classified as being at risk of biomedical malnutrition when its weight gain at two consecutive checkups is less than 75% of what it should be (600 g per month in the first year) *(17)*. Also, anthropometric evaluation according to the reference pattern selected *(39)* has lost sensitivity because of changes in anthropometric patterns. Thus, in 1975 15.4% of the Chilean infant population under observation was below one standard deviation from the Sempe average, while in 1984 the figure was 8.4%. This indicates that the Chilean child population is above the Sempe average by almost three-quarters of a standard deviation. These two situations justify adoption of a reference standard stricter than Sempe and also efforts to identify children likely to deviate from the normal growth trend in the future, using a prediction instrument that selects variables associated with this likelihood.

WHO has proposed universal application of the standard devised in the United States by the National Center for Health Statistics after an extensive study headed by Morley that was carried out over more than a decade *(40, 41)*. A large number of countries, including Chile, participated in that study. The work reported here makes use of this latter standard, converting it to a unisex basis in accordance with a proposal by one of the authors (F.M-R.) (see Figure 2). Reports submitted to the Ministry of Health by Habicht *(42)* and Horwitz *(43, 44)* concerning the Food and Nutrition Council and development of a food and nutrition surveillance system have considered this modified standard very useful.

MATERIALS AND METHODS

Data were gathered on a cohort of children born in January 1982 at five Santiago maternity hospitals,[4] and follow-up work was performed at 11 of the city's district clinics,[5] all of which provided helpful collaboration in developing the investigation. The population studied, which was representative of the clientele of the National Health Services, included families protected by the Social Security System as well as indigent families that received the benefits of an integral health program free of charge. (Care given under this program was provided by a multiprofessional health team and consisted of immunizations, provision of food from the prenatal period through six years of age, in-hospital delivery services, and hospitalization as needed.) The cohort of all children born in January 1982 numbered 1,151. Of these, 876 were followed until they reached one year of age. The remaining 275 were successfully monitored only through the ninety-day checkup, mainly because their families tended to move around a lot. (Many of these frequently moving families belonged to certain subgroups of families whose children were especially apt to have development problems.)

Prenatal information about the cohort members was obtained retrospectively from the children's clinical histories. All the information was entered on precoded forms, using data normally gathered in the health establishments, and professional visits were made to the children's families—especially to determine the mother's acceptance of the pregnancy, her interest in the child after its birth, and the family's current socioeconomic status.

The risk that a cohort member would not achieve normal growth was studied in terms of the previously mentioned "biomedical risk" and "family incompetence" variables listed in Table 1. Each infant's weight gain was determined by measurements taken at least three times during the first 90 days following delivery and at least three times from 90 to 360 days of age. All infants that were above 90% of the standard weight for 30, 60, and 90 days in the first case and for 120, 240, and 360 days in the second were deemed to exhibit satisfactory growth. In addition, all infants who were below the 90% limit at their first checkup but above it at the other two checkups were considered to show satisfactory growth. However, those whose weight for their age was found to be below the 90% limit at each of the checkups, or at two of the three checkups, or at one if it was the last one, were

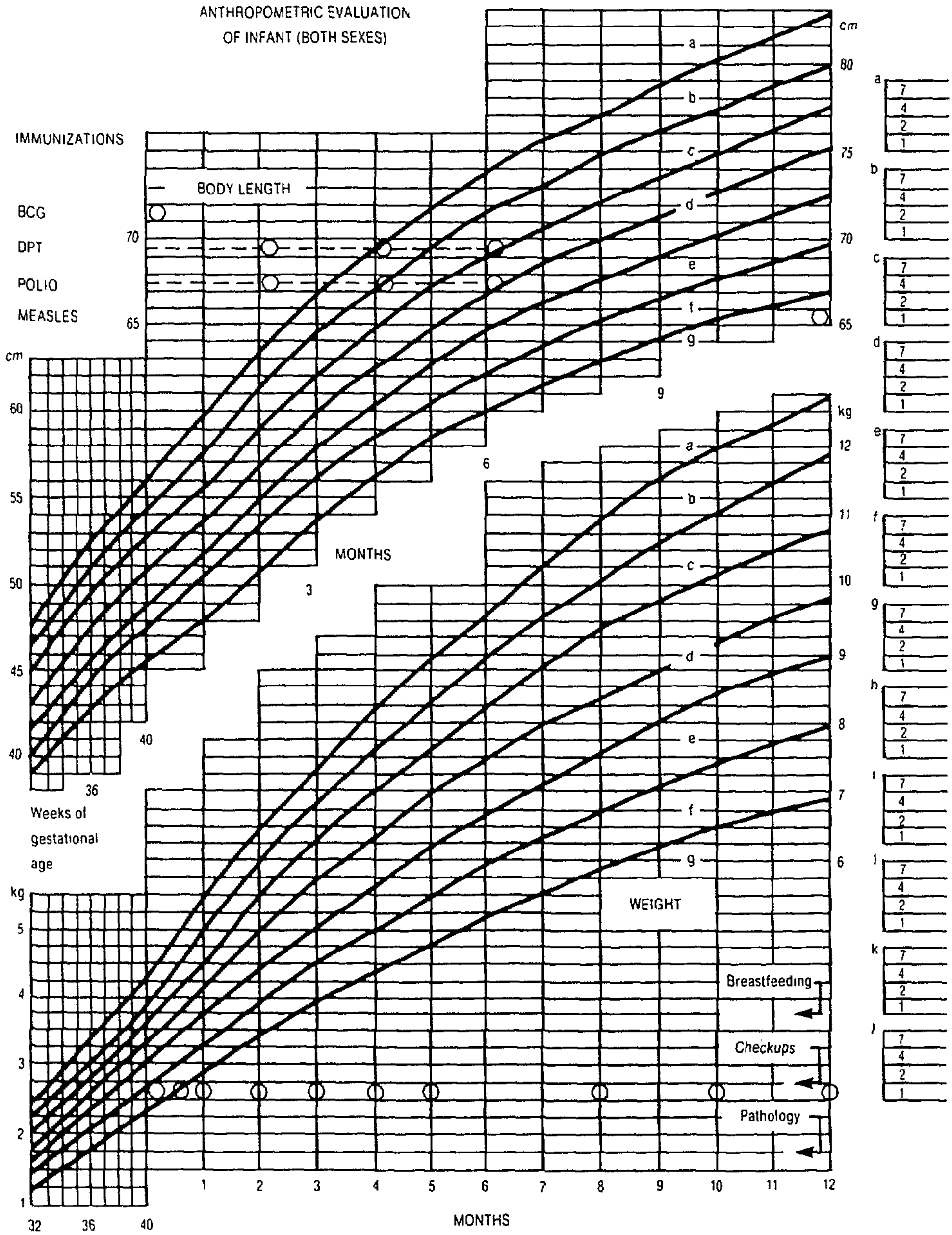
[4] El Salvador, Barros Luco, San José, San Juan de Dios, and Sótero del Rio.

[5] Dr. Albertz, Independencia, Julio Acuña, La Bandera, La Faena, Lucas Sierra, Peñalolén, República del Uruguay, Rosita Renard, Salvador Bustos, and Santa Julia.

FIGURE 2. A unisex version of the WHO growth charts (1978), as modified by one of the authors (F.M-R.).

NAME OF CHILD ______________________ CARD NO ______________

NAME OF MOTHER ______________________ CARD NO ______________



WHO Reference Growth Charts (1978) modified by F Mardones-Restat

Establishment ______________________

Service ______________________

TABLE 1. Risk factors selected for use in seeking to find infants at high risk of inadequate weight gains by the simple relative risk method. The figures shown are derived from histories and interview data and from weighings of children in the cohort studied during two periods—newborn to 90 days and 90 to 360 days.

		Development, 0–90 days					Development, 90–360 days				
Risk factors	High risk/low risk	Relative risk (RR)	95% confidence interval	% population with factor	Chi^2	Score	Relative risk (RR)	95% confidence interval	% population with factor	Chi^2	Score
Family data:											
Father's occupation[a]	0–4, 17/5–16	1.81	1.5/2.2	42.0	39.95	6	1.30	1.1/1.5	42.7	8.40	3
Parental alcoholism	Yes/no	1.36	1.0/1.9	13.8	3.32	3	1.04	0.8/1.4	13.8	0.05	1
Connections (nonpaying relatives or friends) residing in the home	Yes/no	1.35	1.1/1.7	52.2	8.44	3					
No. of persons in household	2, ≥5/3 or 4	1.34	1.1/1.6	28.9	8.3	3	1.28	1.1/1.5	38.8	7.9	2
No. of persons per bed	≥3/1 or 2	1.41	1.1/1.8	22.0	9.19	3	1.29	1.1/1.6	38.2	7.99	3
No. of persons per bedroom	≥5/1-4	1.41	1.6/2.6	12.2	10.6	3	1.69	1.4/2.1	12.0	23.0	5
Bedroom floor	Earthen/other	2.14	1.7/2.7	14.6	45.5	8	1.68	1.3/2.0	14.8	26.4	5
Fuel for cooking	Other/gas	2.24	1.8/2.8	10.7	43.9	8	1.6	1.2/2.1	9.3	13.4	5
Potable water	Other/in the home	1.55	1.3/1.9	33.4	18.5	4	1.4	1.1/1.6	33.2	14.8	3
Excreta disposal	Inadequate/adequate	1.52	1.2/1.9	31.4	16.7	4	1.4	1.2/1.7	31.3	14.7	3
Type of housing	Inadequate/adequate	1.82	1.5/2.3	43.3	31.07	6	1.43	1.2/1.7	42.9	15.63	4

Data on mother:											
Age (years)	<19, >35/19-35	1.26	1.0/1.6	18.1	3.6	2	1.0	0.9/1.4	18.1	1.73	1
Civil status	Unmarried/married	1.50	1.2/1.9	21.1	13.15	4	1.2	1.0/1.4	20.8	2.51	2
Years of education	0-6/≥7	1.7	1.4/2.0	33.5	24.9	5	1.35	1.1/1.6	33.4	11.9	3
Employed[a]	No/yes	1.89	1.3/2.6	85.4	10.20	6	1.71	1.3/2.3	86.4	11.81	5
Age (years) at first pregnancy	<17 and >30/17-30	1.64	1.1/2.4	7.5	7.3	5	1.10	0.9/1.4	17.4	1.10	1
Outcome of last pregnancy	Stillbirth/live birth	1.43	0.7/2.9	3.9	1.01	4	1.08	0.6/1.9	3.8	1.08	1
Week of first prenatal visit	≥17/<17						1.37	1.2/1.6	65.5	12.34	3
Weight (kg) at first prenatal visit	<55/≥55	1.34	1.1/1.6	30.9	13.90	3	1.19	1.0/1.4	39.4	3.59	2
Week of last prenatal visit	<39/≥39	2.27	1.7/2.7	53.7	42.9	8	1.54	1.3/1.8	42.9	21.76	4
Weight (kg) at last prenatal visit	<65/≥65	1.99	1.6/2.6	48.9	37.31	7	1.39	1.2/1.7	48.9	13.15	3
Weight increase (g/wk)	<200, >700/200-700	1.75	1.3/2.4	21.0	19.52	6	1.14	0.9/1.4	27.9	1.79	1
No. of prenatal visits	0-5 and ≥13/6-12	1.46	1.2/1.8	30.0	13.16	4					
Pathology of pregnancy[a]	1,4,7,11,13,15/others and 0	1.74	1.4/2.1	40.8	28.97	6	1.11	0.9/1.4	17.5	0.85	1
Intrapartum pathology[a]	2,8,14/others and 0	1.60	1.2/1.9	23.9	13.42	4					
Puerperal pathology[a]	7,8/others and 0	1.51	0.6/2.0	2.5	0.08	1	1.29	1.0/2.2	2.7	0.22	3
Height (meters)	<1.52/≥1.52	1.43	1.1/1.8	34.2	10.2	4	1.40	1.2/1.7	34.8	13.48	3
Interested in child	No/yes	3.28	2.3/4.7	3.2	42.8	12	2.23	1.5/3.2	3.7	17.9	8
Weight (kg) at puerperium	<55/≥55	1.34	0.9/2.1	33.6	1.64	3	1.25	1.0/1.8	33.9	3.73	3
Data on newborn:											
Birth order	≥5/1-4	1.6	1.2/2.2	9.2	8.7	5	1.44	1.1/1.9	0.2	6.3	4
Sex	F/M	1.24	1.6/1.5	52.7	4.2	2	1.54	1.4/1.9	52.9	30.1	5
Gestational age (weeks)	<39/≥39	4.3	3.5/5.2	30.0	214.1	15	1.57	1.3/1.9	24.9	23.7	5
Birth weight (g)	<2,901/≥2,901	2.15	1.7/2.6	29.0	53.6	8	2.04	1.7/2.4	29.1	70.9	7
Pathologies[a]	By codes/none	1.87	1.5/2.3	21.7	33.71	6	1.11	0.9/1.4	21.6	1.0	1

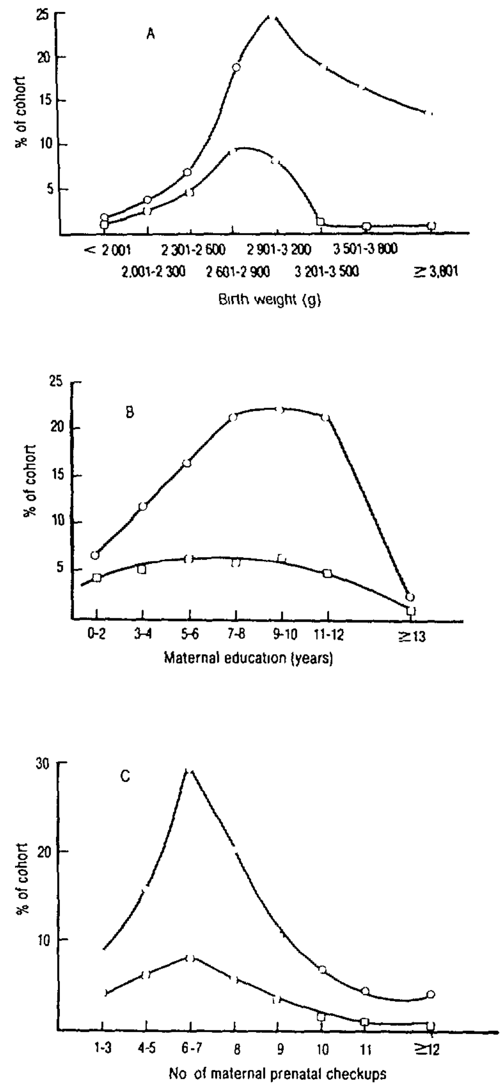
[a] By codes.

classified as having inadequate development.

In this way a more dynamic evaluation of the growth process was achieved. The 90% weight limit corresponds to the level of the eighteenth to twentieth percentile of infants used to establish the reference standard (in Figure 2 this limit is the lower limit of "d"). The joint evaluation of biomedical factors and those of an economic, social, and cultural nature with respect to the dependent weight variable, as reported in various publications *(22, 45–47)*, provides guidance for the appropriate selection of interventions that can be used to strengthen primary prevention.

The data obtained in the study reported here were processed on the INTA2 terminal of the computer belonging to the University of Chile's Service for Computational and Information Systems (SECI). The packages used were the SPSS (statistical package for the social sciences) and SAS (statistical analysis system), preferentially employing a "logistic regression" procedure that permits construction of models wherein variables are selected according to their degree of independence, thereby optimizing predictability.

FIGURE 3. Charts showing the distribution of the whole study cohort and cohort members with inadequate weight gains in terms of (A) birth weight (in grams), (B) maternal education (in years), and (C) maternal prenatal checkups. (○-○ = whole cohort; □-□ = cohort members with inadequate weight gains.)



Results

Analysis of the data gathered from the Santiago cohort made it possible to devise simple instruments for predicting unfavorable growth—both in the 0 to 90 day period and the 90 to 360 day period. This analysis was performed as follows:

The "simple relative risk" method proposed by WHO was used first *(7, 8)*. All the risk factors that were clearly and accurately recorded for over 90% of the study subjects, and that placed at least 5% of the study population at risk, were selected (see Table 1). Since this method requires "dichotomized" variables (each risk factor is deemed either present or absent), selection of the cutoff point for variables such as birth weight that have a continuous range of values provided grounds for concern.

Figure 3 illustrates the problem. Figure 3A charts the entire study population and the children with inadequate weight gains, showing the percentages in different birth weight ranges. Figure 3B does the same but substitutes years of maternal education for the birth weight variable; and Figure 3C does the same but substitutes the number of prenatal checkups. As the Figure 3A data clearly show, selecting a birth weight risk factor cutoff point of 2,900 g creates two subgroups confronting appreciably different risks of inadequate weight gain: it also leaves nearly 30% of the study subjects in the high-risk group, a proportion close to that with inadequate weight gain. Similarly, selecting a cutoff point for maternal education of 7–8 years (see Figure 3B) creates two groups facing notably different risks of inadequate weight gain while leaving a large percentage of subjects in the high-risk group. And, as the Figure 3C data show, lumping those whose mothers had 0–5 and over 12 prenatal checkups into a single high-risk category creates two groups having markedly different risks of inadequate weight gain and places nearly 30% of the subjects in the high-risk group.

One risk factor that affected only 3.5% of the mothers surveyed in the hospital had the highest predictive value; that is, its presence was associated with the highest probability of failure to attain normal growth. This indicator, designated "lack of maternal interest in the child," was observed and recorded by the sociologist or social worker during the interview, at which the newborn was always present. When the mother expressed a desire to get rid of the child, this was taken to indicate "extreme lack of interest." (Mothers who spoke this way were generally single women without family support who were therefore unable to care for their children.) Also, some children were placed in this category because they were abandoned at the hospital. In other cases, lack of interest was discerned from observation of the mother's behavior—such as rough handling of the newborn; inability to comfort it; and (particularly) insensitivity to crying, at times accompanied by refusal to nurse the child.

In general, it is felt that the mere presence of this risk factor alone justifies immediate interventions to educate the mother (behavior modification) in conjunction with efforts to interest the family in caring for the child. This means efforts to interest the couple involved if the man has not abandoned the mother, or else (especially) efforts to interest the grandmother. In this regard, it has been found that care by the grandmother will significantly improve the probability of normal growth.

Table 1 lists the risk factors examined that met the foregoing requirements and also had a lower confidence interval corresponding to a relative risk that was equal to or greater than one. This table also shows the cutoff points for each factor, the relative risk (RR) involved, the extreme values of the 95% confidence interval in accordance with the formula 95% confidence interval = $RR^{[1 \pm 1.96/\sqrt{Chi^2}]}$ *(47)*, the percentage of the study population with each risk factor, the value of Chi^2, and the score assigned to the risk. The latter score was calculated for each factor by multiplying the natural logarithm of the relative risk (RR) times 10 and rounding to the nearest whole number *(8)*.

The prediction instrument derived by the simple relative risk method is simply the total of all the scores corresponding to the risk factors present in each child, these being used to establish scales of (1) biomedical risk and (2) family incompetence. This latter designation is intended to emphasize the role of the family as the first, principal, and permanent provider of care for each child *(48)*. It also encourages recognition of the need to have the health team ensure that parents receive proper guidance and training, and that effective means of communication are used to attain adequate health standards.

The prediction instrument derived by the logistic regression procedure involves applying this regression to the relevant data *(32)*. Like discrimination analysis, logistic regression makes it possible to select those indicators that have the greatest predictive value or association with the dependent variable from among a larger set of indicators *(24, 25)*. For our purposes it is preferred over discrimination analysis, which requires a normal curve of values, because many of the biological and social factors studied do not produce values following such a curve.

Table 2 lists the variables selected by the logistic regression method for the two age ranges studied (0 to 90 days and 90 to 360 days). It also shows the values of the logistic regression coef-

TABLE 2. Independent variables selected for use in seeking to find infants at high risk of inadequate weight gains by the logistic regression method. Beta is the natural logarithm of the relative risk, SE is the standard error, and p is the level of significance of the logistic regression.

	Values for variables measured at:							
	0–90 days (N=789)				90–360 days (N=786)			
Variables	Beta	SE	Chi^2	p	Beta	SE	Chi^2	p
Family data:								
Father's occupation	0.6654	0.2379	7.82	0.0052	—	—	—	—
No. of persons in household[a]	0.4116	0.1703	5.84	0.0157	—	—	—	—
Bedroom floor quality	1.5145	0.3456	19.19	0.0000	0.5949	0.2460	5.85	0.0156
Fuel for cooking	1.1622	0.3830	9.20	0.0024	—	—	—	—
Data on mother:								
Civil status	0.7293	0.2973	6.02	0.0142	—	—	—	—
Years of education	—	—	—	—	0.0433	0.0284	2.32	0.1277
Employed	0.8437	0.3622	5.42	0.0199	0.4392	0.2602	2.85	0.0914
No. of prenatal visits[a]	0.0185	0.0482	4.80	0.0284	0.0592	0.0347	2.91	0.0878
Intrapartum pathology	0.6062	0.2643	5.26	0.0218	—	—	—	—
Data on newborn:								
Birth order	—	—	—	—	0.1731	0.0665	6.83	0.0090
Birth weight	0.0042	0.003	122.50	0.0000	0.0009	0.0002	16.16	0.0001
Data at three months:								
Height	—	—	—	—	0.1318	0.0277	22.51	0.0000

[a] Continuous variable, score assigned in accordance with the unit used for measuring the variables

ficients corresponding to each selected variable. In this regard, it should be noted that Beta represents the natural logarithm of the relative risk (RR); SE is the standard error of the preceding value; and p is the level of significance of the logistic regression. Each instrument derived in this manner could also include one or two additional indicators which, while they may not add much to the total predictability index, can serve to remind the health team of the importance of certain prevention programs—such as those encouraging breast-feeding—and thereby help to improve local acceptance of such programs.

For both age ranges (0–90 days and 90–360 days) the overall value of p is less than 0.0001; the probability of predicting concordant pairs is 89.7% for the first period and 75.7% for the second.

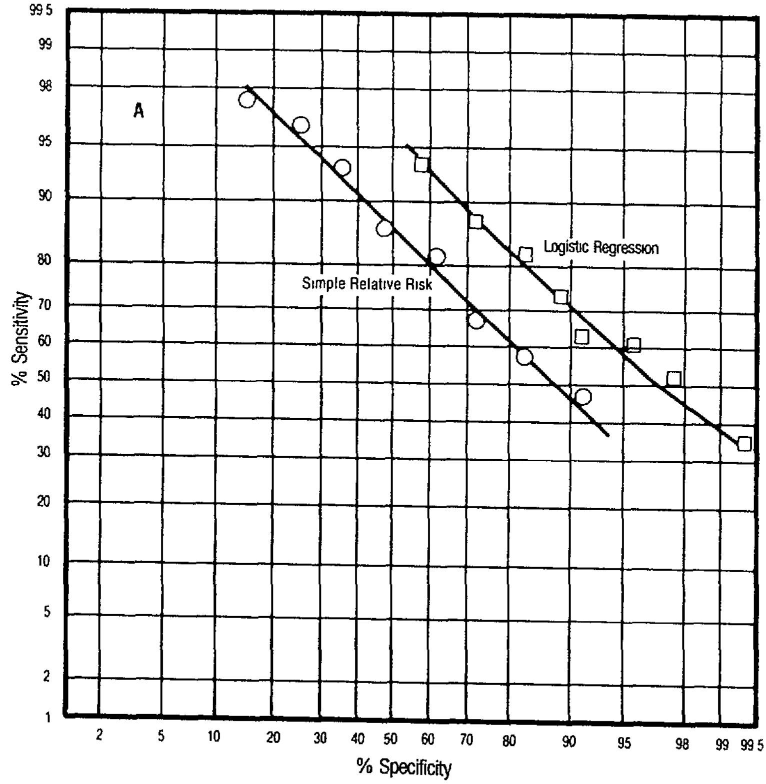
The prediction instrument shown for the first period includes nine selected indicators, seven of which can be obtained in the clinic during prenatal visits, to which should be added the scores for birth weight and newborn pathology. The prediction instrument for the second period (90–360 days) includes fewer indicators.

Figure 4 indicates the sensitivity and specificity relationships found by the simple relative risk and logistic regression methods for both periods of development studied. These results clearly indicate that the logistic regression method provides a better basis for prediction, despite the fact that the simple relative risk method uses many more indicators, because the former attains a higher degree of sensitivity at any given level of specificity and a higher degree of specificity at any given level of sensitivity.

It is also interesting to observe the behavior of certain continuous variables such as birth weight (Figure 5A), maternal education (Figure 5B), and prenatal consultations (Figure 5C). Each of these graphs charts the variable in question against the percentage of the study cohort failing to show an adequate weight gain during each of the two development periods covered. For each age range, a line representing the association between the variable and inadequate weight gain was calculated by means of a quadratic regression. It is noteworthy that the logistic regression method can use the data provided on these continuous variables directly, while the simple relative risk method requires that the data be used to indicate merely whether the risk factor in question was present or absent.

Discussion

The results presented here show that the instruments devised were able to perform the required function successfully while remaining simple and easy to use. Evaluation of their acceptability by local health personnel—and of the time needed to apply them—has begun. It should be noted, of course, that our work has only shown these instruments to provide reliable results for clients of the National Health Service in Santiago. This is a population that receives a package of health services (immunizations, health team checkups, health education, food distribution, etc.), and also has a particular pattern of living standards that the health services have sought to evaluate with a social stratification instrument applied by social action committees at the municipal level.



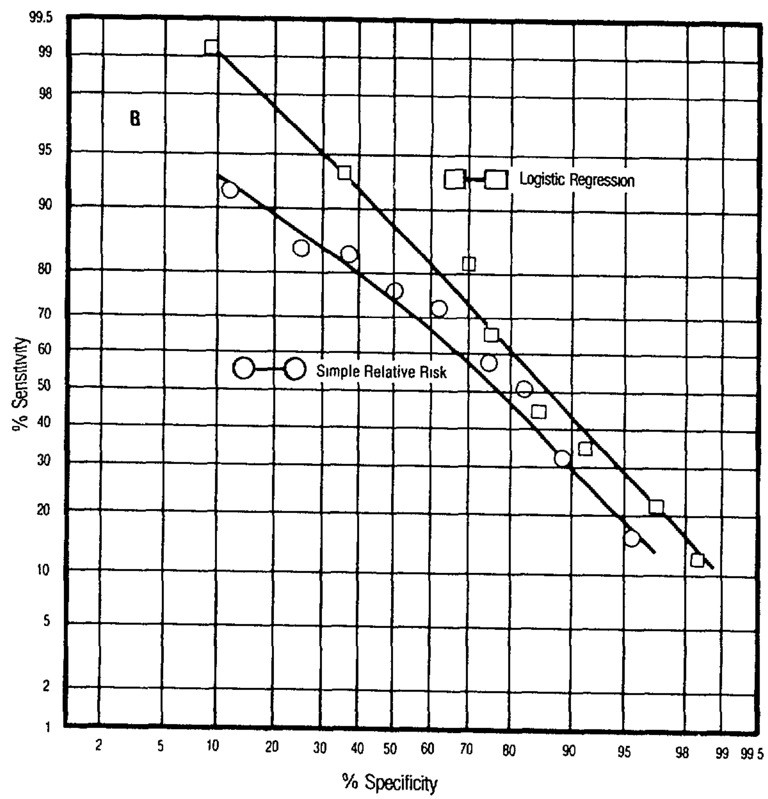
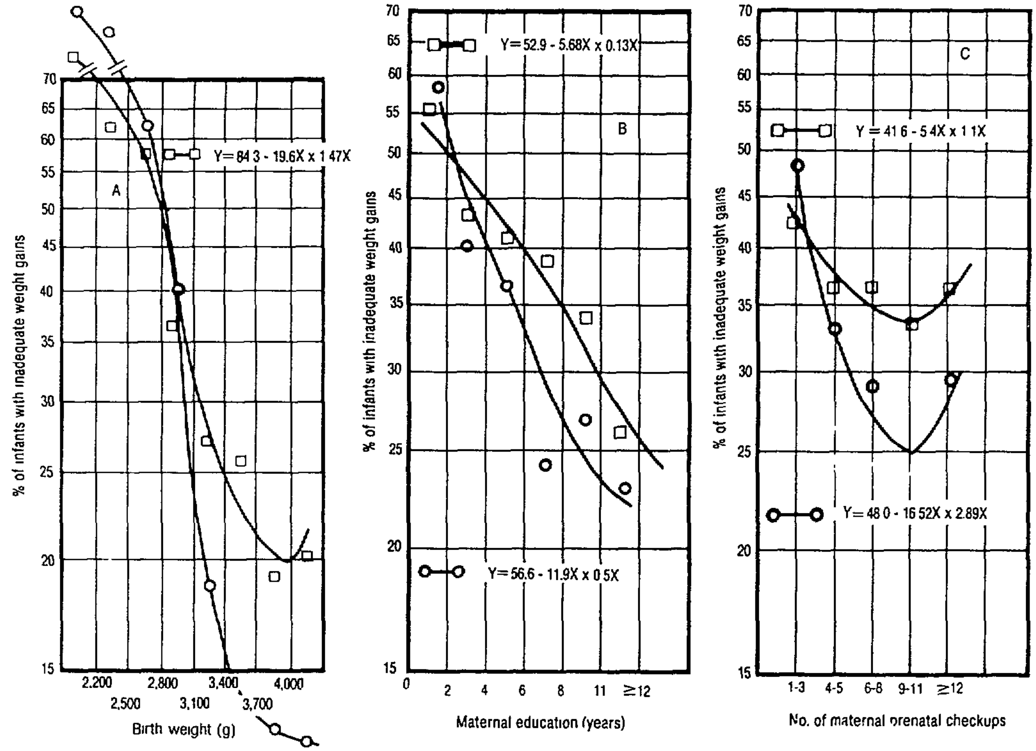


FIGURE 4. Sensitivity and specificity of the simple relative risk (○-○) and logistic regression (□-□) methods for detecting inadequate weight gain, as applied to 876 members of the study cohort. The data shown are for inadequate weight gains over the two periods covered, these being (A) 0–90 days and (B) 90–360 days.

FIGURE 5. Charts showing rates of inadequate weight gain among 876 members of the study cohort over 0-90 days (O-O) and 90-360 days (□-□) relative to three continuous variables, these being (A) birth weight in grams, (B) maternal education in years, and (C) the number of maternal prenatal checkups.



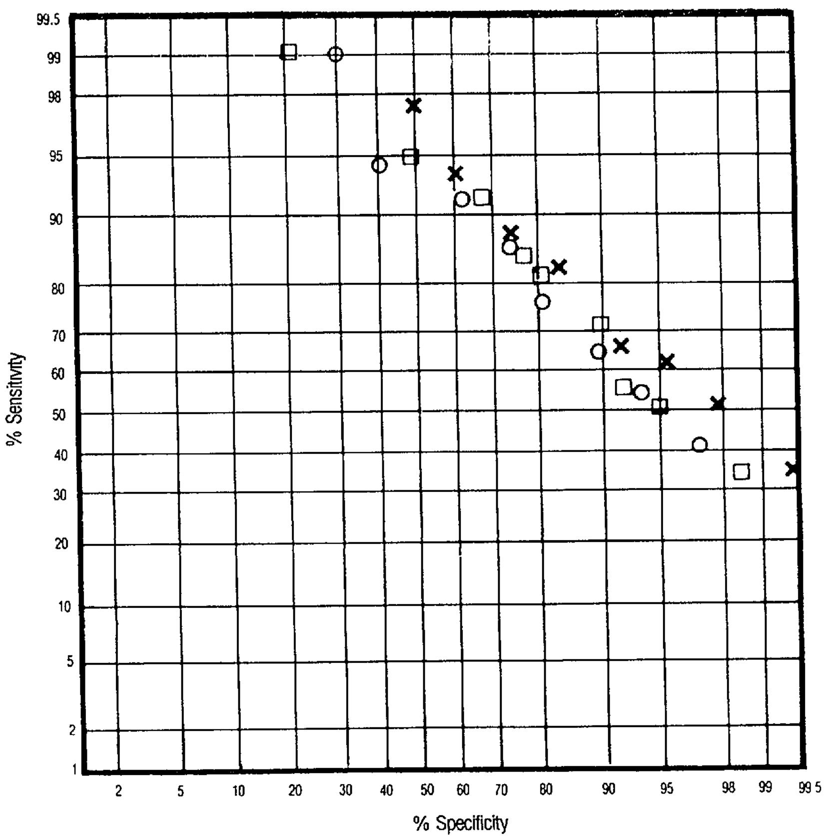
These growth prediction instruments thus need to be validated for heterogeneous populations, a process that will require monitoring cohorts of children similar to the one studied. The same biomedical risk and family incompetence indicators will need to be recorded for these children, together with any other indicators having a significant bearing on inadequate growth that may be identified by ad hoc socioanthropologic studies.

This validation process needs to be applied in parts of the country where health indicators (based on Health Ministry data—*17*) and living standards exhibit substantial differences. Regions selected for this purpose include regions II (Antofagasta), V (Valparaíso), VII (Talca), VIII (Los Angeles and Chillán), and IX (Temuco).

Without detracting from the real need for these studies, it is noteworthy that the work reported here did validate the logistic regression instrument (developed for 876 infants followed for a year) by applying it to 275 cohort members who were only monitored for the first three months after delivery. Those latter 275 children, who proved hard to monitor because of their families' frequent movements, exhibited a higher rate of unfavorable physical development than the other 876, and were also differentiated from the others by several variables—including birth weight, gestational age, and the mother's civil status. However, as Figure 6 shows, a satisfactory degree of prediction was attained by applying the logistic regression model for the 876 children to the 275, and also by applying a model developed especially for the 275. This can be accounted for by the similar associations existing between the dependent variable and the risk factors employed in both cases—as indicated by the very similar relationships found between sensitivity and specificity in these cases.

If these associations are generally similar, it should prove possible to devise a single prediction instrument valid for the entire country, and for both of the development periods studied, by making certain adjustments to the model developed in Santiago. Of course, some loss of predictive ability would be assumed in making broad application of

FIGURE 6. Sensitivity and specificity of the logistic regression method—as indicated by applying the model developed for the 876 cohort members followed 360 days to those 876 infants for the 0–90 day period (×-×); by applying this model to 275 cohort members who were followed only 90 days for this 0–90 day period (○-○); and by applying the model developed for these 275 cohort members to those same members for the same 0–90 day period (□-□).



such an instrument; and if this loss proved significant, it would then be preferable to develop two or three predictive models applicable to segments of the population with different living standards.

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Summary

The investigation reported here sought to develop a statistical instrument capable of identifying infants at high risk of failing to achieve adequate growth. Accordingly, factors associated with inadequate weight gains were studied in a cohort of 1,151 infants born during January 1982 at five National Health Service maternity hospitals in Santiago, Chile. Data were obtained from the children's medical histories, visits to their families, and follow-up assessments. Most of the children (876) were followed for a year, the remaining 275 being followed for 90 days.

Each study infant was weighed at least three times during the first 90 days following delivery and (if possible) at least three times during 90 to 360 days. All the infants who were below 90% of the standard weight for age at the last of the three weighings in a set, or at two out of the three, or at all three were classified as having inadequate development.

To devise instruments capable of predicting inadequate development, a series of risk factors were examined. The ones selected had to be clearly and accurately recorded for over 90% of the cohort infants and had to affect at least 5% of the study group. In this way 35 risk factors were selected.

Prediction instruments were then developed using two methods, the "simple relative risk" method and the "logistic regression" method. The simple relative risk method was applied by assigning each risk factor a score based on relative risk, determining which factors were present or absent in each case, and adding up the scores. The logistic regression method was applied by determining which factors appeared to have the greatest predictive value and using them to make the determination.

The results of these applications indicated that both instruments were able to perform the required function while remaining simple and easy to use. Evaluation of their acceptability by local health personnel is now in progress.

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