Birth Weight, Maturity and Proportionality in Filipino Infants

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Abstract In order to improve assessment of risk of poor postnatal health and growth and developmental outcomes, groups of infants were defined using low birth weight status (LBW, $\leq$ 2,500 g) and an index of body proportions at birth (Rohrer's Index, RI = weight × 100/length^3). The sample, derived from a prospective study of infant-feeding practices, health and survival in the Philippines, consisted of 1971 mother-infant pairs from randomly selected urban and rural communities of metro Cebu. Multinomial logistic regressions assessed how the probability of belonging to a particular risk group was influenced by a set of maternal and infant biological and behavioral variables. Increased risk of falling into a LBW risk group was associated with low gestational age (GA), low maternal stature, and primiparity. Proportionate and disproportionately grown LBW infants could be differentiated by the magnitude of the effects of gestational age, mother's height, and primiparity (all stronger determinants of proportionate small size) and rural residence, low maternal arm fat area, and smoking during pregnancy (all of which increased risk of being proportionately small but had no effect on risk of being disproportionate). The analyses show that the determinants of weight and proportionality at birth differ markedly. RI, by capturing information about patterns of prenatal growth that contribute to proportionality, should prove to be an important predictor of postnatal outcomes when used along with birth weight.

The prevention of poor fetal outcomes requires a sophisticated understanding of factors which control fetal growth and development. It has long been recognized that babies born too soon or too small suffer significantly greater risks of neonatal mortality, morbidity and poor developmental outcomes. Traditionally, "too small" has meant a birth weight of 2500 grams or less (LBW) while "too soon" refers to completion of less than 37 weeks gestation. Yet, within these groups of LBW or preterm infants, there is a great deal of heterogeneity in etiology, actual outcome and associated risks of small size. Furthermore, birth weights associated with elevated risk of mortality may vary between populations, so that a universal cutoff may not be meaningful. Concomitant with a greater

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understanding of determinants of prenatal growth has been a growing recognition of the inadequacy of simple birth weight or maturity categories as measures of fetal growth impairment or as predictors of poor health, growth or developmental outcomes.

Recently, researchers have begun to pay more attention to body proportions at birth, particularly in the diagnosis of different types of intrauterine growth retardation (IUGR). Rosso and Winick (1974) proposed an etiological classification of IUGR based largely on body proportions. Type I IUGR infants are small but normally proportioned and usually born of mothers who were either chronically undernourished throughout pregnancy or suffered a viral infection such as rubella early in pregnancy. Type II IUGR was assumed to be the result of a vascularly deprived uterine environment, sometimes interacting synergistically with low nutrient availability to produce a small, disproportionate or "wasted" infant. Placental characteristics also differ between the two types of IUGR (Woods et al. 1982, Althabe and Labarere 1985).

Proportionality may be assessed using Rohrer's Index (RI), which is a useful indicator of ponderosity or relative fatness at birth (Gruenwald 1974). A low RI (LRI) indicates an infant who is wasted or has a low weight relative to its length, while a high RI (HRI) indicates an infant who is relatively heavy for its length. Differences in RI may therefore reflect influences on weight or length or on both simultaneously or sequentially.

RI may also reflect the timing of prenatal insults that impair fetal growth (Villar and Belizan 1982a). Factors operating early in the first trimester (e.g., genetic abnormalities or infections such as rubella) or consistently throughout pregnancy are more likely to produce an infant who is proportionately small. For example, chronic maternal undernutrition throughout pregnancy may produce well proportioned LBW infants. Alternatively, proportionate small size at birth may represent the lower limits of normal intrapopulation genetic variability. Growth retarding effects confined to the last trimester of pregnancy (when fetal weight velocity is high and subcutaneous fat is deposited), produce deficits in weight, and thus a LRI. A LRI may also be characteristic of the postmature infant who begins using its own body fat to meet energy needs in cases of placental insufficiency.

The distribution of RI within a population may differ significantly from the birth weight distribution. Because RI more accurately reflects different patterns of prenatal growth than does birth weight, it is a useful predictor of postnatal outcomes, including growth (Villar et al. 1982; Davies et al. 1979; Holmes et al. 1977), morbidity (Kishan et al. 1985; Walther and Ramaekers 1982a; 1982b), mortality (Haas et al. 1987) and responsiveness to maternal prenatal nutritional supplementation (Mueller and Pollitt 1983).

In the present study, five risk groups are identified in a randomly selected sample of Filipino infants. The risk groups differentiate normal and LBW infants by RI. Analyses focus on determinants of weight, length and RI at birth and on how variations in maternal biological characteristics affect the risk groups to which infants may belong. This study is important because to date, no other studies have systematically examined factors associated with the likelihood that an infant will fall in a particular risk group, nor has there been systematic analysis based on randomly selected births in low-income countries.

Materials and Methods

The Study Population and Design. The study site, located in Metropolitan Cebu, encompasses both urban and rural districts on the island of Cebu in the Central Philippines. Subjects were drawn from randomly selected barangays (the smallest administrative units in the Philippines, which in rural areas correspond with the village). The sample consisted of all pregnant women identified in households of the 17 urban and 16 rural selected barangays. A baseline survey was conducted among 3,327 women who subsequently gave birth between May 1, 1983 and April 30, 1984. In most cases interviews took place in the 6th to 7th month of the pregnancy. Extensive demographic, socioeconomic, time allocation, health care utilization, environmental sanitation, household, nutritional and maternal biological data were collected. Data relevant for this report include maternal anthropometry (weight, height, upper arm circumference, and triceps skinfold thickness measured using techniques standardized by the Nutrition Surveillance Section of the Centers for Disease Control [CDC]), dietary intake in the 24 hours previous to the interview, maternal age, smoking history, alcohol use, complications of the pregnancy, parity, nonpregnant intervals, and type and frequency of prenatal care. Since there was some variability in the week of gestation during which the mothers were interviewed and measured, weight, arm fat area, and number of prenatal visits were corrected to 30 weeks gestation by linear regression.

During a birth information survey 3 to 6 days after birth, data were gathered on the birth and immediate postpartum period, and mothers and infants were measured. Birth information data are available for 3,080 single live births. Cases lost between the baseline and birth information surveys were due to migration out of the study area, refusal to participate, and miscarriages.

Birth weight was measured and recorded by the person who assisted in the delivery of the infant. All birth attendants in the selected barangays were provided with Salter scales (which measure weight to the nearest 50 g) and instructed in their use. At the time of the birth information survey, project interviewers obtained the recorded information from the mothers. If infants were delivered in hospitals, weight was verified from hospital records. Birth weight data were obtained on 2,632 infants. Length was determined by trained project interviewers using custom-made length measuring boards and measurement techniques which followed procedures standardized by the CDC. Interviewer reliability was assessed twice during the course of the study. Gestational age was determined from the mother's last menstrual period (LMP) date. In cases where LMP data were missing or obviously inaccurate (e.g., cases where conception occurred during postpartum or post-pill amenorrhea) or if infants were LBW, the Ballard method was used to assess gestational age (Ballard et al. 1979). Only those Ballard scores determined within 120 hours of birth were considered acceptable.

From the sample of 2,632 births with available birth weight data, a subset was selected based on the following criteria:

1. Birth weight was measured within 1 hour of birth.
2. Birth weight data are reasonable as determined by a comparison of weights taken by birth attendants with interviewer's measurements taken during the birth information survey.
3. Reliable gestational age data are available.
4. Length was measured by project interviewers within 10 days of birth.

These selection criteria resulted in a final sample size of 1,971. A multivariate analysis of selectivity bias indicated that the selection criteria do not bias an analysis of determinants of birth weight (Heckman 1976, Guilkey et al. 1987).

LBW is defined as birth weight of 2,500 grams or less.[1] Infants are considered preterm if they completed less than 37 weeks of gestation. Disproportionality is defined relative to the Cebu sample of 1,971 births. A (LRI) is below the 10th percentile (2.18), and a (HRI) is above the 90th percentile (2.91) at birth. An adequate RI (ARI) is between 2.17 and 2.91. RI standards used by other investigators (e.g., Lubchenco et al. 1966, Miller and Hassanein 1971) are gestational age-specific. To avoid difficulties in interpreting the effects of gestational age in our models and to select those infants who clearly represent the extremes of the RI distribution, we have chosen not to use gestational age-specific cutoffs.

Model Specification. All available maternal biological variables and behavioral variables (such as smoking or prenatal care) postulated to have a direct biological effect on intrauterine growth were evaluated for their contribution to the variability in weight, length and RI at birth and for problems of collinearity

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[1] The WHO definition of LBW excludes infants who weigh 2,500 g. We chose to include these infants to maximize cell sizes for risk group analyses. Infants who weigh exactly 2,500 g are overrepresented due to rounding bias, but they do not differ biologically from those weighing a few grams more or less.

in a regression model. Eleven variables were selected to enter into an ordinary least squares (OLS) regression. These included sex and gestational age of the infant, place of residence (urban or rural) and mothers' smoking habits, number of prenatal visits to private, public and traditional practitioners[2] at 30 weeks of pregnancy, primiparity (i.e., was this the first baby or not?), caloric intake per/kg pregnant body weight (cal/kg), height, arm muscle area, and arm fat area (calculated according to the formula in Frisancho et al. 1977) at 30 weeks of pregnancy. Variables examined but excluded from further analyses included maternal age, season of birth, altitude and mother's weight, protein and alcohol consumption during pregnancy. When rainfall is used to define seasons, no significant effects of wet versus dry season births on outcomes were observed. It is possible that a more careful analysis of other aspects of seasonality will reveal significant effects on birth outcomes, but such analyses are beyond the scope of this report. Altitude and alcohol consumption during pregnancy do not show sufficient variation within the population to be included as independent variables. Protein intake was eliminated because of its high correlation with caloric intake. Maternal age is highly correlated with parity, and as a continuous variable, has no significant effects independent of parity.

Mothers's weight during pregnancy was eliminated as an independent variable for two reasons. First, it is highly correlated with height (r = 0.51) and arm fat area (r = 0.73) and shares joint determinants with these variables as well. Second, there is no information from the Cebu study on prepregnant weight or weight gain during pregnancy. Interpretation of maternal weight at 30 weeks gestation is therefore problematic, particularly since it includes weight of the developing fetus as well as maternal body tissues. Furthermore, when mother's weight is included in the birth weight regression along with height and arm fat area, it significantly alters the relationships of these two variables to birth weight. When maternal weight is accounted for, the effect of fat area on birth weight is negative, and the effect of height is nonsignificant. These paradoxical findings are best explained as a problem of endogeneity. To test for the effects of endogeneity, instrumental variables (predicted values for mother's weight and arm fat that are purged of joint determinants effects) were entered into a birth weight regression (cf Guilkey et al. 1987). No sign change of the fat area instrument was observed when it was included in the same equation with

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[2] Prenatal care has been grouped into three different types. Providers of modern prenatal care include physicians, nurses, and trained midwives offering services in both private and public settings. Traditional care is provided by mananambangs (traditional midwives). Several alternate measures of prenatal care were considered. These include most frequently used type, number of visits, and month of pregnancy when the first visit occurred. The number of visits to traditional and modern (public plus private) practitioners was selected because these had the most statistically significant effects on a wide variety of health related factors (cf. Guilkey et al. 1987). The content of care differs most widely between traditional and modern practitioners. This is why the latter were grouped for analytic purposes.

weight. Accordingly, only maternal height, arm fat and arm muscle area were retained for subsequent analyses since each measures a different component of maternal weight.

Finally, separate analyses on multiparae are required to test the effects of the nonpregnant interval (NPI). NPI was entered alternatively as a continuous variable and as a dichotomous variable indicating NPI of greater or less than 12 months. Initial tests of a set of NPI dichotomous variables showed that only the 12 month cutoff had a significant effect.

Z-scores of weight, length and RI were used as dependent variables so that comparisons could be made of the parameters across the three different regression equations.

Hypotheses and Rationale for Analyses. Our primary goal is the development of meaningful neonatal risk categories that include RI and birth weight. A variable which influences RI has differential effects on prenatal linear growth compared to growth in soft tissues (weight). A variable with no effect on RI either influences weight and length to an equal degree or influences neither weight nor length. Parameter values from separate regressions on weight, length, and RI equations were compared to see how RI is affected. In addition, by looking at determinants of birth weight alone relative to determinants of risk groups, we can more clearly assess what is gained by refinement of our notions of what constitutes risk.

For a second set of analyses, risk groups were defined using LBW status and RI centiles. A decision was made to use categories of low or normal birth weight, rather than small- or adequate-for-gestational-age (SGA or AGA). The rationale for this decision is twofold. First, in many Third World settings, gestational age data are either unavailable or inadequate, even when birth weight data are available. Thus, for epidemiological studies of risk, the usefulness of categories based on an accurate determination of GA is limited. Second, basing categories on LBW results in a more conservative assessment of risk, since in the Cebu sample, only 39.1% of SGA infants are LBW (when SGA is defined using the sex-specific birth-weight-for-gestational-age standards published by Hoffman et al. [1971]). Three normal weight (> 2,500 g) and two LBW groups form the risk groups. The LBW-HRI group was eliminated from analyses because only one infant fell into this group.

Essentially, we wish to examine the likelihood that an infant will fall into one of the five mutually exclusive unordered categories or risk groups. For estimation purposes, this results in a system of five equations (one for each risk group), each of which is specified with a value of 0 or 1 for the dependent variable. OLS procedures are inappropriate for this type of estimation. The multinomial logit technique is the appropriate estimation system for this objective (Schmidt and Strauss 1975). The MLOGIT procedure supported by SAS provided maximum likelihood solutions for the estimations (Salford System 1985). Because the coefficients from the logit are mutually dependent and difficult to interpret, we also calculate odds ratios and changes in predicted probabilities of falling into each risk group given specified changes in the independent variables (for example, a 0 to 1 change in a dichotomous variable, or an increase of one standard deviation in a continuous variable) (Molyneaux and Stone 1986).[3]

We expect to find several variables which have the power to differentiate proportionate versus disproportionately grown infants both within and between the LBW and normal BW categories. The LBW groups are of particular interest because they are thought to represent the highest risk of poor postnatal outcomes. Some factors traditionally thought to contribute to an increased risk of LBW may be expected to play a role as determinants of both ARI and LRI risk groups. These variables are likely to be stronger determinants of birth weight than of RI. A second group of variables is more likely to influence RI than birth weight and thus differentiate the two LBW risk groups. These distinctions are important since the underlying hypothesis guiding our analyses is that postnatal outcomes will vary between risk groups.

Results

Descriptive Statistics on the Population. Characteristics of mothers and infants in the Cebu sample at birth are presented in Table 1. Short stature and low energy reserves indicated by triceps skinfold thickness and arm fat area are typical of this population. Mean daily caloric intake during pregnancy (1,560 kcal) is substantially below WHO (1985) recommendations. In general, these statistics suggest a moderate degree of malnutrition and an increased risk of poor reproductive outcomes. It should be noted however, that there is a great deal of variability in maternal nutritional status within the population.

Relative to NCHS standards (NCHS 1977), Cebuano infants are shorter and lighter. Twenty-seven percent of Cebuano male infants and 14% of females fall below the U.S. 10th centile for weight while only 28% (males and females combined) are above the 50th. For length, 15% of males and 10.5% of females fall below the U.S. 10th centile, but only 28.2% of males and 34% of females are above the 50th U.S. centile. Twelve and one tenth percent of infants

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[3] A variable may be statistically significant in a logistic regression but do little to drive the overall model. Simulations give an idea of the relative effects a variable may have on the probability of falling into a particular risk group. For each simulation, one specified independent variable is changed at a time, while the values for all other independent variables are held constant at their means. Thus, simulations apply only to the theoretical case where a woman and her infant have mean values for all independent variables except the one in question.

Table 1. **Characteristics of Mothers and Infants at Birth**

Mothers (N = 1,971)	*Mean*	*S.D.*	*Range*
Age (years)	25.8	5.8	14.0– 47.0
Parity	2.1	2.1	0.0– 14.0
Weight (kg)[1]	50.50	7.07	30.0– 84.0
Height (cm)	150.7	5.0	136.0– 169.2
Triceps skinfold (mm)[1]	12.4	3.9	4.1– 34.0
Arm fat area (cm^2)[1]	14.3	5.5	3.8– 50.6
Arm muscle area	34.7	6.0	15.2– 83.7
(mm^2)[1]	1,560	744.	247. –6,360.
Caloric intake (kcal)[2]	29.9	14.4	5.5– 126.1
(kcal/kg)			

	Males (N = 1,042)		*Females (N = 929)*		*All (N = 1,971)*	
Infants	*Mean*	*S.D.*	*Mean*	*S.D.*	*Mean*	*S.D.*
Birth weight	3,028.	409.	3,001.	425.	3,014.	417.
Length	49.3	1.96	48.9	1.96[3]	49.2	1.97
RI	2.52	0.28	2.56	0.29[3]	2.54	0.29
Gestational age	38.8	2.4	39.2	2.5[3]	39.0	2.5

[1] Measured 2–10 days after birth.

[2] 24-hour recall during pregnancy.

[3] Male-female differences, t-value significant at $p < 0.01$.

weighed 2,500 grams or less. The incidence of disproportionality indicated by a LRI is much higher among LBW (36.7%) than normal weight (6.2%) infants.

Determinants of Weight, Length and RI at Birth. Together, the 11 selected independent variables account for 13% of the variability in birth weight, 14% of the variability in length, and 6% of the variability in RI (Table 2). Several of the variables were significant determinants of weight, length and RI, while others show differential effects on these outcomes at birth.

Gestational age is the strongest determinant of size at birth. Regression coefficients show that longer gestation influences weight more than length, resulting in a higher RI at birth.

Multiparae tend to give birth to infants who are longer and heavier than firstborns, but since multiparity has a stronger effect on weight than length, it also increases RI. Prenatal visits to traditional health practitioners show no significant effects on length, but significant positive effects on weight and thus RI.

Table 2. **Determinants of Weight, Length and Rohrer's Index at Birth**[1]

	Regression Coefficients		
	Weight	*Length*	*Rohrer's Index*
Gestational age (weeks)	0.079***	0.065***	0.031***
Parity > 1	0.433***	0.146***	0.382***
Prenatal visits (trad)[2]	0.049***	0.012	0.045***
Sex (1 = male)	0.074*	0.192***	−0.108**
Urban-rural (1 = urban)	0.132**	0.267***	−0.126**
Prenatal visits (modern)[3]	0.108	0.052***	−0.031***
Mother's height (cm)	0.028***	0.040***	−0.007*
Caloric intake (cal/kg)	−0.004**	−0.00006	−0.004***
Mother's arm fat area (cm2)	0.018***	0.017***	0.004
Mother's arm muscle area (cm2)	0.007*	0.005	0.004
Mother's smoking (1 = yes)	−0.142**	−0.088	−0.079
NPI[4] (1 = < 12 months)	−0.087*	−0.088*	−0.015
F	27.6***	28.5***	11.47***
R^2	0.13	0.14	0.06
Intercept	−8.23***	−9.59***	−0.247

*$p < 0.10$
**$p < 0.05$
***$p < 0.01$

[1] OLS regressions on Z-scores of weight, length and Rohrer's index; N = 1,971.

[2] Visits to traditional care providers.

[3] Sum of visits to public and private care providers.

[4] Based on separate regressions on multiparae only. NPI was added and multiparity removed from the model specification.

Sex of the infant, urban residence, prenatal visits to modern health practitioners, and mother's height each have a stronger positive effect on length than on weight and thus a negative effect on RI. Since males are significantly longer, but not significantly heavier than females, they tend to have a lower RI.

The remaining variables (mothers' arm fat and muscle area and smoking during pregnancy) have effects of nearly equal magnitude on weight and length and are therefore not significant determinants of RI. Although the effects of smoking on birth weight are slightly stronger than on length, this difference is insufficient to significantly alter RI.

One paradoxical finding in this set of regressions is the effect of caloric intake on birth weight. Since the relationships of this variable to weight and length are both negative, but the length effect is smaller, an increase in caloric intake during pregnancy appears to produce relatively thinner babies.

Among multiparae, the same set of independent variables (with the exception of parity) were regressors in separate equations that included NPI. NPI as a continuous variable was not a statistically significant determinant of weight, length or RI. As a dichotomous variable (greater than or less than 12 months) NPI was a significant determinant of weight and length, but not RI. Although the actual values of the coefficients of the other independent variables differed slightly, significance patterns were the same for multiparae and for the entire sample.

Risk Groups Based on Birth Weight and RI. First, a description of infant characteristics in the 5 risk groups is presented to facilitate interpretation of determinants of risk group membership. Table 3 includes mean values for birth weight, length, gestational age and RI for the 5 risk groups. Disproportionality in the normal BW-HRI group is due to higher than average weight coupled with lower than average length. In the normal BW-LRI group, infants are lighter but longer than average. In the LBW groups, ARI infants are lighter and shorter than average, and are more likely to be preterm. They fit the traditional description of stunted infants, and are similar to type I or proportionate-IUGR infants.[4] LBW-LRI infants have the lowest mean birth weight of any of the risk groups, but are closer to average in length than are other disproportionate infants. They are wasted or similar to infants with type II or disproportionate IUGR.

Results from the multinomial regression (means, parameter coefficients and T-statistics for each of the independent variables) are presented in Table 4. Normal BW-ARI infants form the group to which each of the other risk groups is compared. Thus, a coefficient indicates that, relative to the normal group, an increase in the value of an independent variable contributes to a decreased probability of belonging to a particular risk group. The changes in predicted probabilities of falling into a particular risk group based on simulated changes in the independent variables are presented in Table 5. Odds ratios for paired comparisons of each risk group to the reference group are presented in Appendix 1.

Factors which contribute to an increased risk of having a HRI relative to the reference group (i.e., variables with T-values > 1.65) include female sex of the infant, short maternal stature, multiparity, and rural residence. Parity is the strongest determinant of membership in the HRI risk group, 91% of which is composed of second or later born infants. The effects of maternal stature are

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[4] These infants do not conform precisely to standard definitions of IUGR which use the 10th centile sex-specific cutoff of weight for gestational age.

Table 3. **Characteristics of Infants in 5 Risk Groups**

Birth weight status	*Normal*	*Normal*	*Normal*	*Low*	*Low*
RI[1]	*Normal*	*High*	*Low*	*Normal*	*Low*
N	1,423	197	110	146	95
Weight (g)	3,097. ± 313.	3,397. ± 344.	2,842 ± 238.	2,330. ± 174.	2,246. ± 196.
Length (cm)	49.6 ± 1.6	47.9 ± 1.7	51.5 ± 1.6	45.9 ± 1.4	48.0 ± 1.8
RI ($g/cm^3 \times 100$)	2.54 ± 0.19	3.08 ± 0.15	2.08 ± 0.09	2.41 ± 0.17	2.03 ± 0.14
GA (weeks)	39.1 ± 2.4	39.5 ± 2.5	39.0 ± 2.5	38.0 ± 2.4	38.3 ± 2.4

[1] Low = < 10th centile, Cebu sample; normal = 10th to 90th centile; high = > 90th centile.

Table 4. **Risk Group Determination by Multinomial Logit Analyses**[1]

	Normal Birth Weight							*Low Birth Weight*					
	Ref.	*Disproportionate (HRI)*			*Disproportionate (LRI)*			*Proportionate (ARI)*			*Disproportionate (LRI)*		
	N = 1423	*(197)*			*(109)*			*(146)*			*(95)*		
	Mean	*Mean*	*Coef*	*T*	*Mean*	*Coef*	*T*	*Mean*	*Coef*	*T*	*Mean*	*Coef*	*T*
Constant	1.0	1.0	0.661	0.24	1.0	−7.24	−2.04	−1.0	22.5	6.87	1.0	12.79	3.39
Gestational age (weeks)	39.1	39.5	0.043	1.32	39.0	−0.013	−0.31	38.0	−0.188	−5.30	38.3	−0.141	−3.38
Sex (male = 1)	0.55	0.41	−0.53	−3.35	0.64	0.413	1.97	0.48	−0.241	−1.32	0.46	−0.342	−1.59
Smoking during pregnancy (= 1)	0.11	0.10	−0.291	−1.13	0.14	0.418	1.40	0.18	0.447	1.79	0.13	0.099	0.30
Multiparity (= 1)	0.77	0.90	0.98	3.87	0.68	−0.492	−2.21	0.66	−0.740	−3.69	0.65	−0.662	−2.83
Prenatal visits (public + private)	1.87	1.57	−0.038	−0.84	2.10	0.016	0.30	1.50	−0.064	−1.12	1.5	−0.138	−1.97

Prenatal visits (traditional)	0.94	0.98	0.034	0.59	0.837	−0.048	−0.64	0.80	−0.178	−2.22	0.90	−0.079	−0.92
Caloric intake/kg body wt	30.0	28.0	−0.006	−1.07	32.9	0.011	1.67	30.1	0.006	0.87	29.4	−0.004	−0.47
Mother's:													
height (cm)	151.0	150.2	−0.031	−1.91	151.8	0.026	1.30	148.3	−0.102	−5.20	149.5	−0.054	−2.40
arm fat (cm2)	15.3	15.12	−0.001	−0.09	15.8	0.002	0.13	12.4	−0.105	−4.20	14.1	−0.019	−0.79
arm muscle (cm2)	34.32	34.71	0.008	0.55	34.75	0.016	1.81	32.76	0.009	0.47	33.16	−0.019	−0.78
Urban-rural (urban = 1)	0.81	0.74	−0.348	−1.87	0.87	0.372	1.23	0.68	−0.554	−2.64	0.80	0.056	0.20
NPI[2] (>12 vs. <12 months)	0.36	0.31	−0.187	−1.06	0.31	−0.232	−0.875	0.40	0.321	1.39	0.26	−0.412	−1.36

Log likelihood value = −1,784; χ^2 = 232 with 44 df

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[1] Reference group = normal birth weight, ARI.

[2] Based on a separate multinomial logit on multiparae only. NPI was added, multiparity removed from specification. Coefficients for other values change slightly, but patterns of significance remain the same.

Table 5. **The Likelihood of Risk: Simulation of the Changes in Predicted Probabilities**

	Normal BW			*Low BW*	
	HRI	*ARI*	*LRI*	*ARI*	*LRI*
N	197	1,423	109	146	95
Simulation:					
GA: 36 to 40 weeks	+2.0	+4.7	0.0	−4.2	−2.5
Sex: female to male	−4.4	+4.2	+2.4	−1.0	−1.3
Smoke: no to yes	−2.6	−2.5	+2.3	+2.5	+0.3
First baby?: no to yes	−7.3	−2.9	+2.7	+4.3	+3.2
Prenatal visits pub + prv: 0 to 5	−1.2	+4.4	+0.7	−1.3	−2.6
Prenatal visits trad: 0 to 5	+2.1	+3.6	−0.9	−3.4	−1.4
Residence: urban to rural	+3.0	−3.6	−2.0	+3.0	−0.4
Mother's:					
Height (+ 1 S.D.)	+0.4	−1.7	−0.3	−0.5	+1.1
Arm fat (+ 1 S.D.)	+0.2	+2.1	+0.2	−2.2	−0.3
Arm muscle (+ 1 S.D.)	+0.2	−0.4	+0.3	+0.2	−0.3
Cal/kg (+ 1 S.D.)	−0.6	−0.1	+0.6	+0.2	−0.2
NPI[1] (<12 to >12 months)	+2.3	−1.8	−0.8	+1.6	−1.3

[1] Based on a separate multinomial logit on multiparae only. NPI was added, multiparity removed from specification.

relatively small. It is interesting that HRI infants who are relatively fatter than any other infants are not differentiated from the reference group by arm fat area of the mother.

The variables which differentiate normal BW-LRI infants from the reference group are sex of the infant, parity and mothers' caloric intake during pregnancy. Being male or firstborn increases the probability of falling into this risk group, which is composed of infants who are long but light. Caloric intake per kilogram of body weight (measured at about 30 weeks gestation in most subjects) is significant as a determinant of this risk group, but a simulated increase of 10 kcal/kg or about 500 kcal/day has little effect when all other variables are evaluated at their means.

The LBW risk groups share several determinants which distinguish them from the reference group. Still other factors differentiate proportionate from disproportionate LBW infants.

Low gestational age, short maternal stature, and primiparity each increase an infant's chances of falling into a LBW risk group. Gestational age is the most highly significant determinant of both LBW groups. Increasing gestational age from 36 to 40 weeks decreases the probability of falling into the LBW-ARI group by over 4%. An increase in gestational age has a slightly smaller impact on the LBW-LRI group. The lowest mean maternal height is found in the ARI group, but while height is a statistically significant determinant of both LBW risk groups, the effects of simulated increases in mother's height are small. If an infant is a firstborn, its chances of being in either LBW group are increased. This effect is stronger for the ARI group than for the LRI group as shown by the coefficients and the simulations.

Factors which clearly differentiate the proportionate and disproportionate risk groups (i.e., factors that are statistically significant determinants of the ARI group but not the LRI group) include mothers' smoking during pregnancy, prenatal care, mother's arm fat area and place of residence. A low number of visits to traditional prenatal care providers, low maternal fat reserves (indicated by arm fat area), and rural residence each increase the probability of falling into the LBW-ARI risk group.

Finally, although the largest number of women with NPIs less than 12 months are mothers of infants in the LBW-ARI risk group, NPI was not found to be a statistically significant determinant of any of the risk groups relative to normal BW-ARI infants.[5] However, in the simulations, lengthening the NPI increases the probability of falling into a proportionate group (either low or normal birthweight), and decreases the probability of falling into a group characterized by disproportionality. It should be noted, however, that sample sizes for the LBW groups are small. Exclusion of primiparae reduces the sample sizes in normal BW-LRI, LBW-ARI and LBW-LRI groups by 30%, but reduces the sample of normal BW-HRI cases by only 8%.

Discussion

We are ultimately interested in determining how size at birth influences risk of poor postnatal growth, morbidity and mortality. Most Cebuano infants are smaller at birth than infants in developed countries of the world. A number of previous studies have linked small size at birth with high morbidity and mortality rates, poor postnatal development and increased risk of postnatal growth abnormalities. Yet, these risks are not evenly distributed across all infants who are small. Rohrer's Index, when considered along with birthweight, provides information about patterns of prenatal growth and thus may help ex-

[5] The effects of NPI were tested using a set of dichotomous variables indicating relatively short or relatively long intervals. Logits were run both with one or combinations of these NPI variables alone and with all other independent variables (specified in the text). NPI was not a statistically significant risk group determinant in any of these analyses.

plain why an infant is small and in turn, why there are differences in risk among groups of small infants.

Nearly two-thirds of infants in the Cebu sample weighing 2,500 g or less at birth are proportionately grown, while the remaining one-third show weight deficits relative to their lengths. While there is a fairly extensive literature on the determinants of LBW (cf. Institute of Medicine 1985, Kramer 1985, Dougherty and Jones 1981), relatively little attention has been paid to the determinants of proportionality. A key contribution of the present study is to show that some risk factors associated with LBW can also be used to differentiate proportionate from disproportionately grown infants. Differentiating determinants of proportionality is particularly important in light of literature which associates disproportionate growth retardation with an increased risk of neonatal morbidity (Kishan et al. 1985, Walther and Ramaekers 1982b), and mortality (Haas et al. 1987), but also a better potential for catch-up growth (Davies et al. 1979). Proportionate growth retardation, according to Villar et al. 1986, is associated with long term deficits in postnatal physical growth and mental development.

Gestational age is clearly an important determinant of birth weight. Prematurity occurs in 13% of proportionate and 17% of disproportionate (LRI) LBW infants. OLS regressions show that longer gestational age is associated with increased RI. This would be expected since most surviving preterm infants will have had the opportunity to grow adequately in length, but are born before they have had the opportunity to lay down significant amounts of subcutaneous fat. Simulations are also consistent with this explanation in showing that as gestational age is increased from 36 to 40 weeks, there is an increased probability that an infant will be of normal weight and normal or above normal RI.

A second set of risk group determinants reflect maternal nutritional status. Previous studies have documented a relationship between poor pregnancy outcome and low maternal prepregnant weight and inadequate weight gain during pregnancy (see Institute of Medicine 1985 for a review). These variables are not available from the Cebu study, but arm fat area at 30 weeks of gestation provides important information about maternal energy reserves that can help support the third trimester of pregnancy. OLS regressions show that arm fat area of the mother is a significant determinant of both weight and length of the infant. Furthermore, the multinomial logit shows that low fat reserves contribute significantly to the risk of being a proportionate LBW infant. Recently, the role played by maternal fat stores as a determinant of birth weight has been questioned. Briend (1985) reported that for a given weight, fatter women in his periurban African sample had smaller babies. We found a similar effect when weight of the mother was included in the same regression with height and arm fat area. However, this effect disappeared when we used analytic techniques which control for the effects of codeterminants of weight, height and fat area.

In the third world context where chronic malnutrition is present, maternal stature reflects nutritional history as well as genetic factors. Previous studies have shown that the risk of LBW is reduced among tall women (Frisancho et al. 1977, Thomson 1959). The Cebu study confirms that effect, but in addition, shows a negative relationship between maternal height and RI of the infant. Among the LBW risk groups, maternal height is a more highly significant determinant of the ARI risk group than of the LRI risk group. LBW proportionate infants have mothers who are the shortest and thinnest in the sample. Infants in this group also have the lowest mean length at birth, but weigh slightly more than their LBW-LRI counterparts. Mothers of disproportionate LBW infants are short relative to the sample mean, but they are taller than mothers of proportionate LBW infants. Disproportionate LBW infants are close to average in length, but have weight deficits. These effects are most probably attributable to a strong genetic effect on length coupled with a nutritional effect on weight.

Smoking during pregnancy is another risk factor known to be associated with LBW. The number of Cebuano mothers who smoke is quite small, yet the negative effects of smoking on birth weight could still be detected. The logistic regressions show that smoking during pregnancy tends to produce a proportionate growth retardation.

In most populations, females are shorter than males at birth. Rural infants in Cebu are shorter than urban infants. Thus it is not surprising that female sex and rural residence increase the probability of membership in risk groups characterized by lower than average infant length.

Primiparity is a significant risk factor for LBW, and in the Cebu study, it is a significant determinant of both LBW risk groups. Based on the magnitude of the parity coefficient and the simulation results, primiparity is a stronger determinant of the proportionate LBW group than of the disproportionate LBW group. It is also interesting to note that HRI infants are rarely firstborns. The biological basis of increases in birthweight associated with parity greater than one is not fully understood. Hypertension and preeclampsia, both of which represent significant risk factors for LBW, are more frequent in primiparae (Institute of Medicine 1985).

Although NPI was a significant determinant of weight and length in OLS regressions, it was not a statistically significant determinant of any risk group. The theoretical basis for an NPI effect is unclear. In other studies, where an effect of short NPI is found, it is usually attributed to depletion of maternal energy reserves. Depletion may be accentuated if an undernourished woman continues to lactate during a subsequent pregnancy. In our logistic regression equations, we tested for the effects of maternal nutrition by examining effects of NPI alone and along with anthropometric indicators by nutritional status. No significant effects of NPI were found in either instance. In some cases, lack of consistency between studies can be attributed to differences in the interval variable used. Studies that show an increased risk of LBW with short birth intervals are difficult to interpret because when birth interval rather than pregnancy interval is used, an artifact of preterm births is introduced (see Kramer 1985 for a comprehensive review). In the Cebu study, pregnancy interval was used. This may be an important factor in accounting for the lack of a significant NPI effect on risk group membership.

Few of the direct effects of prenatal care on birth outcomes are significant in these models. This is not surprising, since we expect most of the impact of prenatal care to appear through maternal biological and behavioral factors. Issues related to prenatal care are more fully addressed in another paper (Guilkey et al. 1987).

In conclusion, these analyses have clearly illustrated the degree of heterogeneity characteristic of groups of normal or low BW infants. An important aspect of this heterogeneity is reflected in body proportions, which capture some important information about patterns of prenatal growth. Our analyses have shown differences in determinants of weight versus length at birth and in determinants of weight and RI-based risk categories. RI and weight-based risk groups at birth represent an outcome of numerous interacting influences on growth. As such, they also represent different biological potentials that should bear significantly on important postnatal health, growth and developmental outcomes.

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Appendix 1. **Determinants of Risk Group Membership: Odds Ratios and 95% Confidence Intervals.[1]**

	Normal Birth Weight				*Low Birth Weight*			
	HRI		*LRI*		*ARI*		*LRI*	
	OR	*95% CI*	*OR*	*95% CI*	*OR*	*95% CI*	*OR*	*95% CI*
Gestational age (weeks)	1.04	0.97–1.11	0.98	0.90–1.07	0.82	0.77–0.88	0.86	0.80–0.94
Sex (male = 1)	0.59	0.43–0.80	1.51	1.00–2.27	0.78	0.54–1.12	0.71	0.46–1.08
Smoking during pregnancy (= 1)	0.74	0.45–1.23	1.51	0.84–2.72	1.56	0.95–2.54	1.10	0.57–2.11
Multiparity (= 1)	2.67	1.62–4.39	0.61	0.39–0.94	0.47	0.32–0.70	0.51	0.32–0.81
Prenatal visits (public + private)	0.96	0.88–1.05	1.01	0.91–1.12	0.93	0.83–1.04	0.87	0.75–0.99
Prenatal visits (traditional)	1.03	0.92–1.15	0.95	0.82–1.10	0.83	0.71–0.97	0.92	0.77–1.09
Caloric intake/kg body wt	0.99	0.98–1.00	1.01	0.99–1.02	1.00	0.99–1.01	0.99	0.98–1.01
Mother's:								
height (cm)	0.96	0.93–1.00	1.02	0.98–1.06	0.90	0.86–0.93	0.94	0.90–0.99
arm fat (cm2)	0.99	0.96–1.02	1.00	0.96–1.04	0.89	0.85–0.94	0.98	0.93–1.02
arm muscle (cm2)	1.00	0.97–1.03	1.01	0.97--1.05	1.00	0.97–1.05	0.98	0.93–1.02
Urban-rural (urban = 1)	0.70	0.49–1.01	1.45	0.80–2.63	0.57	0.38–0.86	1.05	0.61–1.82
NPI	0.83	0.58–1.17	0.79	0.47–1.33	1.38	0.88–2.17	0.66	0.36–1.20

[1] Reference group = normal birth weight, ARI.

Literature Cited

ALTHABE, O. AND C. LABARERE 1985 Chronic villitis of unknown etiology and intrauterine growth retarded infants of normal and low ponderal index. Placenta 6:369-373.

BALLARD, J.L., K.K. NOVAK AND M. DRIVER 1979 A simplified score for assessment of fetal maturation in newly born infants. J. Ped. 95:769-774.

BRIEND, A. 1985 Do maternal energy reserves limit fetal growth? Lancet, I. (No. 8419):38-40.

DAVIES, D.P., P. PLATTS, J.M. PRITCHARD, AND P.W. WILKINSON 1979 The nutritional status of "light-for-dates" infants at birth and its influence on early postnatal growth. Arch. Dis. Child 54:703-706.

DOUGHERTY, C.R.S. AND A.D. JONES 1981 The determinants of birth weight. Obstet. 3:190-200.

FRISANCHO, A.R., J.E. KLAYMAN AND J. MATOS 1977 Influence of maternal nutritional status on prenatal growth in a Peruvian population. Am. J. Phys. Anthropol. 46:265-274.

GRUENWALD, P. 1974 Pathology of the deprived fetus and its supply line. *In:* Size at birth. 27th Ciba Foundation Symposium. Amsterdam, Elsevier.

GUILKEY, D.K., B.M. POPKIN, J.S. AKIN AND E. WONG 1987 Prenatal care and pregnancy outcome in the Philippines. Unpublished manuscript, Carolina Population Center. University of North Carolina, Chapel Hill.

HAAS, J.D., H. BALCAZAR AND L. CAULFIELD 1987 Variation in early mortality for different types of fetal growth retardation. Am. J. Phys. Anthro., in press.

HECKMAN, J.J. 1976 The common structure of statistical models of truncation, sample selection and limited dependent variables and a simple estimator for such models. Annals of Economic and Social Measurement, 5:475-492.

HOFFMAN, H.J., C.R. STARK, F.E. LUNDIN AND J.D. ASHBROOK 1971 Analysis of birth weight, gestational age, and fetal viability. U.S. births, 1968. Obstet. and Gyn. Survey 29:651-81.

HOLMES, G.E., H.C. MILLER, K. HASSANEIN, S.B. LANSKY AND J.E. GOGGIN 1977 Postnatal somatic growth in infants with atypical fetal growth patterns. Am. J. Dis. Child. 131:1078-1083.

INSTITUTE OF MEDICINE 1985 Preventing Low Birthweight. National Academy Press, Washington.

KISHAN, J., A.Y. ELZOUKI, N.A. MIR AND A.M. FAQUIH 1985 Ponderal index as a predictor of neonatal morbidity in small for gestational age infants. Indian J. Ped. 52:133-137.

KRAMER, M.S. 1985 Determinants of intrauterine growth and gestation duration. A methodological assessment and synthesis. WHO Prepublication Document.

LUBCHENCO, L., C.H. HAUSMAN AND C. BOYD 1966 Intrauterine growth in length and head circumference as estimated from live births at gestational ages from 26 to 42 weeks. Peds. 37:403.

MILLER, H.C. AND K. HASSANEIN 1971 Diagnosis of impaired fetal growth in newborn infants. Peds. 48:511-522.

MOLYNEAUX, J.W. AND E.M. STONE 1986 SAS macros to calculate the full set of coefficients and predicted outcome probabilities for a polytomous logit model. Paper presented at the SAS Users Group International Conference, February 1986, Atlanta, GA.

MUELLER, W.H. AND E. POLLITT 1983 The Bacon Chow Study: Effects of nutrition supplementation on sibling-sibling anthropometric correlations. Human Biology, 54:455-460.

NATIONAL CENTER FOR HEALTH STATISTICS 1977 NCHS growth curves for children 0-18 years. *In:* U.S. Vital and Health Statistics, Series 11, No. 165. U.S. Government Printing Office, Washington.

ROSSO, P. AND M. WINICK 1974 Intrauterine growth retardation: A new systematic approach based on the clinical and biochemical characteristics of this condition. J. Perinat. Med. 2:147-160.

SALFORD SYSTEM 1985 The MLOGIT procedure. Salford Systems, 2214 El Amigo Road, Del Mar, CA.

SCHMIDT, P. AND R.P. STRAUSS 1975 Estimation of models with jointly dependent qualitative variables: A simultaneous logit approach. Econometrica, 43:745-755.

THOMSON, A.M. 1959 Maternal stature and reproductive efficiency. Eugenics Review 51:157-162.

VILLAR, J. AND J. BELIZAN 1982a The timing factor in the pathophysiology of the intrauterine growth retardation syndrome. Obstet. Gynec. Survey, 37:499-506.

VILLAR, J. AND J. BELIZAN 1982b The relative contribution of prematurity and fetal growth retardation to low birth weight in developing countries. Am. J. Obstet. Gynec. 143:793-798.

VILLAR, J., J.M. BELIZAN, J. SPALDING AND R.E. KLEIN 1982 Postnatal growth of intrauterine growth retarded infants. Early Hum. Dev. 6:265-271.

VILLAR, J., L. ALTOBELLI, E. KESTLER AND J. BELIZAN 1986 A health priority for developing countries: The prevention of chronic fetal malnutrition. Bul. WHO 64:847-851.

WALTHER, F.J. AND L.H.J. RAEMAEKERS 1982a Neonatal morbidity of SGA infants in relation to their nutritional status at birth. Acta Ped. Scand. 71:437-440.

WALTHER, F.J. AND L.H.J. RAEMAEKERS 1982b The ponderal index as a measure of the nutritional status at birth and its relation to some aspects of neonatal morbidity. J. Perinat. Med. 10:42-47.

WOODS, D.L., A.F. MALAN AND H. DE V. HEESE 1982 Placental size for small-for-gestational-age infants at term. Early Hum. Dev. 7:11-15.

WORLD HEALTH ORGANIZATION 1985 Energy and Protein Requirements: Report of a Joint FAO/WHO/UNU Expert Consultation. Technical report series, no. 724. World Health Organization, Geneva.