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Newborn length predicts early infant linear growth retardation and disproportionately high weight gain in a low-income population☆,☆☆

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ABSTRACT

Background: Stunting is prevalent by the age of 6 months in the indigenous population of the Western Highlands of Guatemala.
Aim: The objective of this study was to determine the time course and predictors of linear growth failure and weight-for-age in early infancy.
Study design and subjects: One hundred and forty eight term newborns had measurements of length and weight in their homes, repeated at 3 and 6 months. Maternal measurements were also obtained.
Results: Mean ± SD length-for-age Z-score (LAZ) declined from newborn −1.0 ± 1.01 to −2.20 ± 1.05 and −2.26 ± 1.01 at 3 and 6 months respectively. Stunting rates for newborn, 3 and 6 months were 47%, 53% and 56% respectively. A multiple regression model ($R^2 = 0.64$) demonstrated that the major predictor of LAZ at 3 months was newborn LAZ with the other predictors being newborn weight-for-age Z-score (WAZ), gender and maternal education * maternal age interaction. Because WAZ remained essentially constant and LAZ declined during the same period, weight-for-length Z-score (WLZ) increased from −0.44 to +1.28 from birth to 3 months. The more severe the linear growth failure, the greater WAZ was in proportion to the LAZ.
Conclusion: The primary conclusion is that impaired fetal linear growth is the major predictor of early infant linear growth failure indicating that prevention needs to start with maternal interventions.

1. Introduction

The association between impaired linear growth and enhanced risks of morbidity and mortality in infants and children under the age of five years from resource poor communities has been well established [1–4]. Survivors are at risk for impaired brain function, loss of economic productivity, and greater reproductive risks to adult women and their offspring [5]. The community as a whole suffers from loss of human capital [5]. Except in circumstances of acute under-nutrition, inadequate growth is typically manifested by linear growth failure with low length-for-age Z-scores (LAZ). According to the World Health Organization (WHO) data [6], linear growth failure in low resource communities typically starts in early to mid-infancy with progressive deterioration in linear growth rates reaching a plateau at a low level at approximately two years of age. Though considered to result primarily from under-nutrition, further aggravated by infection, infant–toddler nutrition interventions designed to reverse this progressive linear growth failure have had only limited success [3] in what is regarded as the "window of opportunity" to prevent or/and treat growth failure.

Our own recent experience with the indigenous post-Mayan population in Chimaltenango in the Western Highlands of Guatemala has documented a very high incidence of stunting, approximately 60%, by as early as 6 months of age [7,8]. The precise timing of the early growth failure and its predictors has not been explored.

Guatemala, as is typical of resource poor countries in transition, is faced with the dual challenges of growth failure and a rapidly increasing prevalence of overweight [9]. There is increasing evidence that excessive weight gain in infancy is a predictor of overweight in later childhood [10].

The objectives of this project were: [1] to characterize the linear growth of the indigenous population in Chimaltenango from the

Abbreviations: AIC, Akaike Information Criterion; IUGR, intra-uterine growth retardation; IFS, iron folate supplement; LMP, last menstrual period; LAZ, length-for-age Z-score; SES, socio-economic status; VIF, variance inflation factor; WAZ, weight-for-age Z-score; WLZ, weight-for-length Z-score.

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newborn to 6 months of postnatal age; [2] to identify the predictors of linear growth failure in early infancy; and [3] to determine the relationship between weight-for-age Z-score (WAZ) and low LAZ in early infancy.

2. Experimental design and methods

2.1. Study design

This was an observational longitudinal anthropometric study of newborns and infants from birth until 6 months of age in a population known to have linear growth retardation by the age of 6 months [7]. Maternal, paternal, family, home and infant feeding data were also collected. Basic cross-sectional statistics were calculated and LAZ at 3 and 6 months were modeled as functions of the measured variables using multiple linear regression analysis.

2.2. Participants

Participants were identified through the Eunice Kennedy Shriver National Institute of Child Health and Human Development Global Network Maternal and Newborn Health Registry. They were consecutive deliveries from four control clusters for the series of research projects being undertaken by this Global Network site in the Department of Chimaltenango in the Western Highlands of Guatemala. The population was indigenous, primarily post-Mayan, with a long history of deprivation and poverty. The participants were primarily resident in small rural towns, with men typically working on subsistence farms but progressively changing to laborers on larger farms or to other low to low-medium income jobs. Maize remains the dominant crop and food staple. Homes generally have a primitive electrical supply, television but no refrigerator. The water supply is variable; the majority having a running water supply of variable consistency and purity. Typically, wood fires are still used in part or whole for cooking, either in a kitchen or sometimes in the same room as the sleeping quarters. The majority of deliveries were in the home, most frequently attended by a local traditional birth attendant. All final participants were apparently healthy term or near-term neonates, based on history of last menstrual period (LMP) obtained through the Registry records. They had no acute illnesses during the six month study and 82% of the participants were exclusively breast fed at 3 months according to maternal history. Approval for this study was provided by the Comite de Etica Independente and by the University of Colorado Multiple Institutional Review Board.

2.3. Anthropometry

Crown–heel and crown–rump lengths were obtained in the recumbent position per World Health Organization (WHO) guidelines [11] by a specially trained pair of the research team. Two measurements were taken using a calibrated Harpenden infantometer (Crymych, Pembs, UK) and recorded to the nearest 0.1 cm. A third measurement was made if the difference was >0.4 cm and the mean of the two closest measurements calculated. Duplicate newborn and infant naked weights were obtained with calibrated Salter scales and recorded to the nearest 4 g. Newborn measurements were obtained as soon after birth as possible. Infant measurements were made at the age of 3 and 6 months. All measurements were made in the home.

Maternal height and weight were measured at 6 months postpartum in the local health clinic. Barefoot height was obtained using a calibrated mechanical column scale with a measuring rod at the project headquarters and recorded to the nearest 0.5 cm. Maternal weight was obtained from a calibrated digital scale and recorded to the nearest 0.2 kg.

2.4. Data management and analyses

Data were recorded by two of the authors (JBB & SCB) in the participants' homes with pencil/paper and entered into an electronic excel database after verification of data accuracy. These data included socio-economic status assessed using World Bank guidelines [12](Table 1); maternal and parental education and work; parity; obstetric history; exclusive breast feeding at 3 months, infant and child feeding index at 6 months; use of iron/folate supplements (IFS) or mineral/vitamin supplements, and other demographic information. Initial processing included final cleaning and conversion of infant anthropometric data to Z-scores (WHO Anthro, version 3.2.2, World Health Organization). Cross-sectional statistical measures including correlation were calculated for all the variables of interest, notably LAZ, WAZ and WLZ. These statistics and plots of selected data were used to examine longitudinal characteristics and inter-variable relationships.

Multiple linear regression analysis was used to model LAZ at 3 and 6 months as functions of 23 quantitative and categorical variables (Table 2). Stepwise and best subset model selection methods were used in multiple phases of the analyses to determine the best candidates for the final models. After elimination of the explanatory variables for which there was no evidence of a relationship to the response variables, all two-way interactions between the remaining explanatory variables were added to the models being investigated. Final model selections were performed manually taking into consideration the statistical significance of the parameter estimates, Akaike Information Criterion (AIC) values, and model parsimony. Throughout the analyses regression residuals were examined to check for deviations from regression assumptions. Multicollinearity of variables was assessed using variance inflation factors (VIF) and apparent outliers were evaluated.

Because missing data entailed the use of subsets of the complete dataset for certain analyses, a sensitivity analysis, using t-tests, ANOVA and chi-squared tests, was performed to determine whether the datasets were statistically similar.

Regression analyses were accomplished using the R statistical computing language, version 2.14 [13]. Other statistical analyses were performed with GraphPad Prism (version 5, GraphPad Software, Inc. San Diego, CA) and Microsoft Excel (version 2003). Data are presented as mean ± SD unless otherwise noted. The level of significance used was 0.05.

3. Results

Two hundred apparently healthy newborns (108 males, 92 females) were enrolled in this project. Some did not participate through the end of the study; the total numbers of participants were 200 at birth, 176 at 3 months and 157 at 6 months. Six participants who completed all measurements, but were born prematurely (gestational age <37 weeks from the last menstrual period reported by mother), were excluded. In addition, three participants whose data were anomalous and could not

Table 1
Data used in computing SES score.

Electricity, Y/N
Radio, Y/N
Television, Y/N
Refrigerator, Y/N
Telephone, Y/N
Work own or family's land, Y/N
Principal source of drinking water
Principal type of toilet facility
Natural or man-made material used for floors in home
Natural or man-made material used for walls in home
Natural or man-made material used for roof of home
Type of home tenancy
Number of people for each sleeping room in home