THE JOURNAL OF PEDIATRICS • www.jpeds.com

ORIGINAL ARTICLES

Associations of Linear Growth and Relative Weight Gain in Early Life with Human Capital at 30 Years of Age

Bernardo Lessa Horta, PhD[1], Cesar G. Victora, PhD[1], Christian Loret de Mola, PhD[1], Luciana Quevedo, PhD[2], Ricardo Tavares Pinheiro, PhD[2], Denise P. Gigante, PhD[1], Janaina Vieira dos Santos Motta, PhD[2], and Fernando C. Barros, PhD[2]

Objective To assess the associations of birthweight, nutritional status and growth in childhood with IQ, years of schooling, and monthly income at 30 years of age.

Study design In 1982, the 5 maternity hospitals in Pelotas, Brazil, were visited daily and 5914 live births were identified. At 30 years of age, 3701 subjects were interviewed. IQ, years of schooling, and income were measured.

Results On average, their IQ was 98 points, they had 11.4 years of schooling, and the mean income was 1593 reais. After controlling for several confounders, birthweight and attained weight and length/height for age at 2 and 4 years of age were associated positively with IQ, years of years of schooling, and income, except for the association between length at 2 years of age and income. Conditional growth analyses were used to disentangle linear growth from relative weight gain. Conditional length at 2 years of age ≥1 SD score above the expected value, compared with ≥1 SD below the expected, was associated with an increase in IQ (4.28 points; 95% CI, 2.66-5.90), years of schooling (1.58 years; 95% CI, 1.08-2.08), and monthly income (303 Brazilian reais; 95% CI, 44-563). Relative weight gain, above what would be expected from linear growth, was not associated with the outcomes.

Conclusion In a middle-income setting, promotion of linear growth in the first 1000 days of life is likely to increase adult IQ, years of schooling, and income. Weight gain in excess of what is expected from linear growth does not seem to improve human capital. *(J Pediatr 2017;182:85-91).*

In low- and middle-income countries, rapid weight gain in early childhood has clear short-term benefits, including the reduction of morbidity and mortality owing to infectious diseases.[1] In contrast, the evidence on the long-term consequences of rapid weight gain in childhood are not as clearcut. Several studies, mostly from high-income countries, reported that rapid weight gain in childhood is associated with a greater risk of obesity[2-5] and hypertriglyceridemic waist phenotype.[6]

The associations of weight gain in childhood and metabolic cardiovascular risk factors in low- and middle-income countries seem to be different. In a pooled analysis of data from 5 birth cohorts, weight gain in the first 2 years of life was associated with higher fat-free mass in adulthood, whereas weight gain after the first 2 years of life was associated with higher fat and fat-free mass.[7] Norris et al[8] used data from the same 5 cohorts and found that impaired fasting glucose and type 2 diabetes were not associated with weight gain in the first 4 years of life, whereas weight gain from 48 months increased the risk. These and other studies[9-11] stressed that the long-term consequences of weight gain in childhood depend on timing, with negative consequences being particularly associated with late weight gain rather than gain in the first 1000 days.

With respect to human capital, different indicators of malnutrition (wasting, underweight, and stunting) in early childhood are associated negatively with performance on cognitive tests and years of schooling completed later in childhood and adolescence.[12-17] Furthermore, children who recovered from stunting performed slightly better on cognition tests than those who remained stunted, but less well than those who did not experience stunting.[18,19] Additionally, Hoddinott et al[20] reported that the height-for-age *z*-score at 2 years of age was positively associated with years of schooling, performance on cognitive testing, and socioeconomic status in adulthood.

With respect to growth in childhood, school achievement and IQ are associated more strongly with early than with later growth in childhood.[21-26] In contrast, Krishnaveni et al[27] did not observe an association between linear growth in childhood and early adolescence and IQ in adolescence. Most of these studies relied on weight gain as the exposure variable, and until recently there was no attempt to disentangle the consequences of weight gain from those of linear growth. It is important to disentangle the effect of weight from that of linear growth because they may have different consequences. In 2013, in a pooled analysis of 5 cohort studies from low- and middle-income countries (including data from the 23-year follow-up visit to the 1982 Pelotas cohort), Adair et al[9] reported that linear growth in the first 2 years of life was associated more strongly with years

From the [1]Postgraduate Programme in Epidemiology, Universidade Federal de Pelotas, Brazil; and [2]Postgraduate Program in Health and Behavior, Universidade Católica de Pelotas, Brazil

Funded by Wellcome Trust (086974/Z/08/Z), International Development Research Center (Canada), CNPq, FAPERGS, and the Brazilian Ministry of Health. The authors declare no conflicts of interest.

http://dx.doi.org10.1016/j.jpeds.2016.12.020

of schooling than weight gain, suggesting therefore that nutritional interventions in childhood should be focused in promoting linear growth instead of weight gain. Moreover, growth monitoring programs should also incorporate length/height measurements.

The present study aimed to evaluate how birthweight, nutritional status, linear growth, and relative weight gain in childhood are associated with performance in intelligence tests, years of schooling, and monthly income at 30 years of age.

Methods

In 1982, the maternity hospitals in Pelotas, a southern Brazilian city, were visited daily and all in-hospital births were identified. The 5914 liveborns whose families lived in the urban area of city were examined and their mothers interviewed. In 1984 and 1986, all households located in urban areas of the city were visited in search of cohort members; 5161 and 4979 individuals were evaluated in 1984 and 1986, respectively. From June 2012 to February 2013, cohort members were invited to visit the research clinic to be interviewed and examined. We interviewed 3701 subjects, which added to the 325 known to have died, for a follow-up rate of 68.1%. Concerning the losses to follow-up, we were unable to locate 1055 participants from the original cohort, 467 were living far from Pelotas, 86 refused to take part in this follow-up, and 280 did not attend the clinic despite repeated invitations. Further details on the study methodology have been published elsewhere.[28,29] The Ethical Review Board of the Faculty of Medicine of the Federal University of Pelotas approved the study, and written informed consent was obtained from all participants.

Birthweight was assessed by the hospital staff using pediatric scales that were calibrated weekly by the research team. Gestational age estimate was based on the mother's recall of the date of her last menstrual period. Preterm birth was defined by a gestational age of <37 weeks. In the 1984 and 1986 visits, children were weighed using calibrated scales and their length and height were assessed with portable stadiometers. Weight and height *z*-scores, according to age and sex, were estimated using the 2006 World Health Organization growth standards.[30] Birthweight for gestational age *z*-scores were calculated using the Williams reference population.[31]

Outcomes

Performance in intelligence tests was evaluated in the 2012-2013 visit, at a mean of 30.2 years of age. Four psychologists who were unaware of participant intrauterine growth and nutritional status in childhood administered the Wechsler Adult Intelligence Scale, third version, which has been validated for the Brazilian population.[32] The following subtests were used: arithmetic, digit symbol, similarities, and picture completion.

Subjects were asked about the highest grade completed successfully at school, as well as their income in the previous month in Brazilian reais.

Conditional Growth

Conditional growth modeling was used in the analyses on the effect of weight and height gain.[33] Conditional variables were obtained by regressing current size (weight or length/height) on birthweight and earlier measures of weight and length/height, and standardized residuals were derived. Conditional variables express how a child deviates from its expected height or weight, based on its previous measures and the growth of the studied population. At each time point, the conditional variable represents growth during a time interval, and a positive value represents a weight gain or linear growth faster than predicted in that period. For example, conditional relative weight gain at 2 years of age represents the relative weight from birth to 2 years of age. The conditional variable at 4 years of age represents height or relative weight gain from 2 to 4 years of age. To estimate conditional height, current length or height was regressed on previous weight and length. Therefore, conditional length at 2 years of age was estimated by regressing length-for-age *z*-scores at 2 years of age on birthweight. In contrast, conditional relative weight was estimated from length/height at that age and previous measures of length/height and weight. Therefore, conditional relative weight at 2 years of age was derived by regressing weight at 2 years of age on birthweight and length at 2 years of age.

Confounding Variables

Family income at birth was defined as total income earned by the family members in the month before the interview. Maternal and paternal years of schooling at birth was defined as years of schooling successfully completed. Household assets index in childhood was defined as based on the ownership of household goods and estimated using factor analysis.[34] Maternal skin color was rated by the interviewer during the perinatal study. Maternal smoking during pregnancy was defined as those mothers with a history of smoking in the pregnancy being considered smokers. Breastfeeding duration was based on information on breastfeeding duration was collected in 1984 and 1986, and we used the information closest to the age of weaning to minimize recall bias.

Data Analyses

ANOVA was used to compare means and multiple linear regression to obtain estimates that were adjusted for the following confounders: family income at birth, maternal years of schooling at birth, paternal years of schooling in childhood, household assets index, maternal skin color, and maternal smoking during pregnancy. Estimates on the effect of nutritional status in childhood and conditional growth were further adjusted to breastfeeding duration. Furthermore, for conditional length gain from birth to 2 years of age, estimates were also adjusted for birthweight according to gestational age *z*-score, whereas for conditional relative weight gain from birth to 2 years of age, analyses also controlled for conditional length gain from 0 to 2 years of age, for conditional length gain from 2 to 4 years of age, birthweight and conditional variables from 0 to 2 years of age were also controlled for, and for relative weight gain from 2 to 4 years of age, length gain from 2 to 4 years of age was also included in the model. Statistical comparisons between groups were based on tests of heterogeneity and linear trend in the case of ordinal variables, and the