Epidemiology of early and late growth in height, leg and trunk length: findings from a birth cohort of Brazilian males

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Background/Objective: To investigate socioeconomic, gestational and early life exposures as potential determinants of total height, leg and trunk length.
Subjects/Methods: Male subjects from the 1982 Pelotas Birth Cohort Study were examined in 1986 at home, and in 2000 when registering at the local army base. The follow-up rate was 79%. Standing and sitting heights were measured on both occasions. Leg length was calculated as the difference between standing and sitting heights. Outcome measures were height, leg and trunk length at 4 and 18 years and growth in this period. Complete data were obtained for 2012 participants, representing 71% of all eligible male subjects.
Results: Mean (s.d.) height, trunk length and leg length at 18 years were 173.4 (6.8), 96.0 (3.5) and 77.5 cm (4.5), respectively. The mean (s.d.) change in height from 1986 to 2000 was 75.4 cm (5.2) and for leg and trunk length 35.4 (3.9) and 40.0 cm (2.9), respectively. Of 11 independent variables analyzed, only maternal height and birthweight were associated with all three variables of growth. Gestational age showed no associations with growth or attained size.
Conclusions: Early growth plays a pivotal role in determining attained height and its components. Both biological and socioeconomic variables strongly influence determinants of height, though socioeconomic factors appear to be more important in early growth. Leg and trunk length contribute almost equally to differences in overall height, regardless of the independent variable influencing the difference. Public health strategies designed to improve chronic disease profiles should focus on the early growth period.

Keywords: body height; leg length; trunk length; cohort studies; socioeconomic factors; birth weight

Introduction

Adult height is influenced by a child's nutrition and health throughout his or her growing years. Although final height is limited by a child's genotype, environmental influences also affect his/her adult size (Silventoinen, 2003). While overall height is considered a good indicator of living conditions, the effects of environment on the components of height—leg and trunk length—are less clear.

The direct association between height and mortality from cancer has been described (Albanes *et al.*, 1988; Gunnell *et al.*, 1998b). Data from the Boyd Orr cohort showed a significant positive association between childhood leg length and mortality from cancers unrelated to smoking. There were no significant associations in relation to trunk length, with weaker associations for overall height than for leg length (Gunnell *et al.*, 1998b). These data also showed that coronary heart disease mortality increased with decreasing childhood leg length. Coronary heart disease was inversely associated with leg length in another study (Smith *et al.*, 2001) and men with shorter legs were more likely to have insulin resistance and high triglyceride levels. Height, on the other hand, was not related to these measures.

Some studies suggest that secular increases in height are due to increases in leg length rather than increased trunk length (Gerver and De Bruin, 1995; Tanner *et al.*, 1982) and the Carnegie survey data support the view that leg length is the component of childhood height most sensitive to childhood circumstances (Gunnell *et al.*, 1998b). In addition, the effects of famine exposure were most marked on the leg length of women exposed to the Dutch Hunger Winter during childhood (van Noord, 2004).

A reanalysis of the cross-sectional data on childhood height and leg length collected in the Carnegie Survey examined in more detail the associations between environmental factors and both leg and trunk length in childhood (Gunnell *et al.*, 1998b). The authors showed that socioeconomic differences in overall stature largely were due to differences in leg length rather than trunk length. Data from 1946 British Birth Cohort showed that leg length was more sensitive to childhood environmental factors and diet while trunk length was more sensitive to serious illness and possibly to emotional disturbances (Wadsworth *et al.*, 2002).

In a subset of the Carnegie children (Gunnell *et al.*, 1998a), for whom information at birth was available, similar correlations between birthweight and leg or trunk length were found, suggesting that differences in the components of stature were not related to growth during the gestational period. Results from the Avon Longitudinal Study showed that maternal diet in pregnancy was not associated with height or its components (Leary *et al.*, 2005).

About 2250 male subjects in the 1982 Pelotas Birth Cohort have been prospectively followed since birth. Height and sitting height were measured in 1986 and 2000. In addition, information about the biological and social background of individuals, including environmental factors, has been collected since birth. The aim of this study was to determine which socioeconomic and perinatal factors were associated with height or its components. The determinants of changes in height, leg and trunk length between 1986 and 2000 were also analyzed.

Methods

The Pelotas Birth Cohort recruited 5914 live-born infants in 1982 from the city's three maternity hospitals. These births represented more than 99% of all births in Pelotas that year. The children and their mothers were visited several times after birth. The methods utilized in 1982 Pelotas Birth Cohort have been described in detail (Barros *et al.*, 1990; Victora *et al.*, 2003a). In 2000, men from the cohort who were registering at the local army base were interviewed and included in this phase of the study.

All male members of the cohort were visited in 1982, 1984, 1986 and 2000. In 1982, infants were examined and weighed, and their mothers were interviewed on demographic and socioeconomic variables in the maternity hospitals, as described in Victora *et al.* (2003a). In 1984 and 1986, we performed a house-to-house census of the 70 000 urban households in the city, looking for children born in 1982. Children who still had not been located were searched for at their last known address. This approach resulted in locating 87.2 and 84.1% of the original cohort in 1984 and 1986, respectively. In these visits children were weighed with portable scales with 10 g precision (CMS, UK) and were measured for height using locally made stadiometers to AHRTAG (Healthlink Worldwide) standards to a precision of 1 mm. In 1986, sitting height was also measured. Interviewers were thoroughly trained according to standardized anthropometric techniques before undertaking fieldwork. Quality control measures included repeating 5% of the interviews and repeat measurements by a fieldwork supervisor, standardization sessions and double data entry.

From January to April 2000, all male subjects born in 1982 were legally required to enlist in the Army. Army registration is mandatory only for men. A research assistant was deployed at the recruitment office to interview all enlisters in an effort to locate members of the original cohort. Of the 3037 boys in the cohort, 2890 were presumed to be alive and 2047 were identified when enlisting. The 843 individuals not identified when enlisting were searched for at their last known address, and an additional 216 individuals were located, of whom 13 declined to participate, leaving 203 who were measured and interviewed. Thus, 2250 male members of the cohort were interviewed. Added to the 147 who were known to have died; they comprised 78.9% of the 3037 men in the cohort.

Outcome measures were height, trunk and leg length at 4 and 18 years and growth in height, leg and trunk length between 1986 and 2000 derived from standing and sitting heights measured on all participants. Measures obtained in 2000 were considered as attained height, trunk and leg length. Standing and sitting heights were measured to the nearest millimeter using locally manufactured boards according to international specifications (Healthlink Worldwide). No shoes or socks were worn during these measurements. Leg length was calculated as the difference between standing and sitting heights, and trunk length was represented by sitting height.

Explanatory variables included in present analysis were obtained in the perinatal study. In the maternity hospital questionnaire, information was collected on family income (minimum wages per month); maternal education (years of schooling); maternal age at birth (<20; 20–29; $\geqslant 30$); skin color (white or non-white, defined by the interviewer by observation); maternal pregestational weight (kg); maternal height (m); weight gain during pregnancy (kg); gestational age (<37; 37–39; 39–41 and $\geqslant 42$ weeks); maternal smoking during pregnancy (at least one cigarette per day at any time during pregnancy); and birthweight (measured by the research team with regularly calibrated pediatric scales (Filizolla, Brazil) immediately after birth to the nearest 10 g).

Analysis of variance was used to compare means. Linear regression models were used in the crude and adjusted

First level	Socio-economic variables	Family income
		Maternal schooling
		Skin colour
		Household crowding
Second level	Maternal characteristics before pregnancy	Age
		Weight
		Height
Third level	Maternal characteristics during pregnancy	Weight gain
		Gestational age
		Smoking
Fourth level	Child characteristic	Birth weight

Figure 1 Hierarchical conceptual model of the determinants associated with height, leg and trunk length (Pelotas, 1982–2000).

Table 1 Characteristics of the original 1982 Pelotas birth cohort andadolescents included in the analysis

Variable	*Original cohort (n = 3037, %)*	*Included in the analysis (n = 2012, %)*
Family income (minimum wage units)		
⩽1	21.9	17.9
1.1–3	48.2	49.7
3.1–6	17.9	20.3
6.1–10	6.1	6.6
>10	5.5	5.5
Maternal schooling (years)		
0–4	33.2	30.6
5–8	42.5	44.4
9–11	10.9	10.9
⩾12	13.4	14.2
Maternal skin color		
White	81.7	82.3
Nonwhite	18.3	17.7
Maternal age in 1982 (years)		
< 20	15.5	13.5
20–29	59.1	58.1
⩾30	25.4	28.4
Birth weight (g)		
< 2500	8.0	5.8
2500–2999	20.6	20.0
3000–3499	37.3	38.2
3500–3999	26.6	27.9
⩾4000	7.5	8.1
Total	100%	100%

Pelotas, 1982–2001.

Table 2 Height, trunk and leg length at 4 and 18 years and change in height, leg and trunk length between 1986 and 2000

Measurements (cm)	n	*Mean*	*s.d.*	*Minimum*	*Maximum*
Height at 4 years	2428	97.8	5.1	71.9	113.7
Height at 18 years	2229	173.4	6.8	150.2	194.7
Change in height	2012	75.4	5.2	52.4	98.3
Leg length at 4 years	2419	42.0	3.1	29.0	54.8
Leg length at 18 years	2224	77.5	4.5	60.0	93.6
Change in leg length	2000	35.4	3.9	20.1	53.2
Trunk length at 4 years	2419	55.8	2.9	42.9	70.0
Trunk length at 18 years	2225	96.0	3.5	84.1	107.7
Change in trunk length	2001	40.0	2.9	24.6	51.0

analyses. The determinants associated with height, leg and trunk length were studied via a hierarchical conceptual model (Victora *et al.*, 1997). This approach takes into account the effect of a risk factor after controlling for confounding factors. The choice of factors to be included in the adjusted analysis is not based purely on statistical associations, as is the more conventional approach, but is based on a conceptual framework describing the hierarchical relationships between risk factors included in the crude analysis. One regression equation was fitted in each hierarchical level. The first level included family income, maternal education, skin color and household crowding. All variables associated with each outcome (P-value $\leqslant 0.2$) were included in the next level of analysis. The variables of the next levels were adjusted for others in the same or higher levels of the hierarchical model. Maternal age, pregestational weight and height were in the second level and variables describing conditions during pregnancy (weight gain, gestational age and smoking) were included in the third level of analysis. Birthweight was included in the last level. The hierarchical conceptual model is shown in Figure 1.

The Ethical Research Committee of the Federal University of Pelotas approved the study. Written informed consent was obtained from all participants.

Results

The follow-up rates for the 3037 men born in 1982 were 87.5% in 1986 and 78.2% in 2000. A total of 2012 (70.6%) subjects were measured in both 1986 and 2000. A comparison of the socioeconomic and maternal characteristics of boys included in this analysis and those of the original cohort showed that the lowest income group—which included subjects with low birthweight—were less likely to have been included in the analysis. However, differences were small—three percentage points or less. These differences were due to the fact that adolescents who were lost or deceased belonged to the lower income group and were low birthweight (Table 1).

Mean height, leg length and trunk length in 1986 were 97.8 (s.d. 5.1), 42.0 (s.d. 3.1) and 55.8 cm (s.d. 2.9), respectively; and 173.4 (s.d. 6.8), 77.5 (s.d. 4.5) and 96.0 cm (s.d. 3.5) in 2000. The mean change in height during this period was 75.4 cm (s.d. 5.2) and changes in leg and trunk length were 35.4 (s.d. 3.9) and 40.0 cm (s.d. 2.9), respectively (Table 2).

The crude analysis shows that nearly all of the explanatory variables were associated with total height, leg length and trunk length. Socioeconomic variables, including family income, maternal schooling and household crowding were associated with all outcomes, except for growth in trunk length. Gestational age was not associated with any outcomes. Skin color was associated with all outcomes, with the exceptions of height in 2000 and leg length in 1986. Household crowding was associated with all outcomes except for leg length in 2000. Maternal age, maternal weight gain and smoking during pregnancy were associated with nearly all outcomes in 1986 and in 2000, but with no outcomes reflecting growth in that period.

Because several of the associations between variables changed after adjustment for confounding, the presentation of results will concentrate on the latter analyses, presented in Tables 3–5.

Variables related to socioeconomic conditions—family income and maternal education—were positively associated with height both in 1986 and in 2000, but not with growth within the period (Table 3). The same results were observed both for leg (Table 4) and trunk length (Table 5).

Skin color was not significantly associated with any total height indicators (Table 3). Non-whites had longer leg length (Table 4) in both 1986 and in 2000 and faster growth within that period, but length of the trunk at both points and growth in the trunk was faster for whites (Table 5).

Crowding showed a unique pattern. It had a negative effect on height and its components at the age of 4 years, but was associated with faster growth in the trunk (Table 5) and in total height thereafter (Table 3).

Because the association between maternal age and the outcomes was not linear, it was included in the adjusted model as two dummy variables, with mothers aged 20–29 years as the reference category. Subjects born to teenage

Table 3 Multiple linear regression analysis[a] for height in 1986 and 2000, and height change between 1986 and 2000 (cm)

Variable	*Height in 1986*			*Height in 2000*			*Height change*		
	β	*95% CI*	P-*value*	β	*95% CI*	P-*value*	β	*95% CI*	P-*value*
Family income (groups)	0.86	0.62 to 1.10	<0.001	0.78	0.42 to 1.14	<0.001	−0.11	−0.39 to 0.19	0.5
Maternal schooling (years)	0.26	0.20 to 0.32	<0.001	0.16	0.07 to 0.25	<0.001	−0.04	−0.11 to 0.03	0.3
Maternal skin color (nonwhite)	−0.13	−0.64 to 0.39	0.6	0.28	−0.49 to 1.06	0.5	0.53	−0.10 to 1.16	0.10
Household crowding	−0.25	−0.36 to −0.14	<0.001	−0.11	−0.28 to 0.05	0.19	0.15	0.01 to 0.28	0.04
Maternal age in 1982 (<20 years)	−0.40	−0.99 to 0.20	0.19	−1.08	−1.91 to −0.25	0.01	−0.21	−0.95 to 0.52	0.6
Maternal age in 1982 (⩾30 years)	−0.12	−0.62 to 0.38	0.6	0.23	−0.89 to 0.43	0.5	−0.29	−0.87 to 0.28	0.3
Maternal pregestational weight (kg)	0.08	0.06 to 0.10	<0.001	0.06	0.03 to 0.09	<0.001	0.01	−0.02 to 0.04	0.4
Maternal height (cm)	0.22	0.18 to 0.26	<0.001	0.52	0.47 to 0.57	<0.001	0.25	0.21 to 0.30	<0.001
Smoking during pregnancy	−0.49	−0.97 to 0.00	0.05	−0.36	−1.05 to 0.33	0.3	−0.02	−0.61 to 0.58	0.9
Maternal weight gain (kg)	0.04	−0.01 to 0.08	0.06	0.07	0.01 to 0.13	0.02	0.04	−0.01 to 0.09	0.14
Gestational age (weeks)	0.01	−0.12 to 0.15	0.8	−0.05	−0.24 to 0.14	0.6	−0.05	−0.22 to 0.11	0.5
Birth weight (kg)	1.50	1.07 to 1.93	<0.001	2.54	1.95 to 3.14	<0.001	1.03	0.50 to 1.55	<0.001

[a]Adjusted according to conceptual model presented in Figure 1.

Table 4 Multiple linear regression analysis[a] for leg length in 1986 and 2000, and leg length change between 1986 and 2000 (cm)

Variable	*Leg length in 1986*			*Leg length in 2000*			*Leg length change*		
	β	*95% CI*	P-*value*	β	*95% CI*	P-*value*	β	*95% CI*	P-*value*
Family income (groups)	0.51	0.36 to 0.67	<0.001	0.45	0.21 to 0.69	<0.001	−0.07	−0.29 to 0.15	0.5
Maternal schooling (years)	0.13	0.10 to 0.17	<0.001	0.07	0.01 to 0.13	0.02	−0.04	−0.09 to 0.02	0.19
Maternal skin color (nonwhite)	0.65	0.33 to 0.98	<0.001	1.63	1.12 to 2.15	<0.001	0.99	0.53 to 1.46	<0.001
Household crowding	−0.11	−0.18 to −0.04	<0.001	−0.02	−0.19 to 0.15	0.8	0.13	−0.02 to 0.29	0.10
Maternal age in 1982 (<20 years)	−0.34	−0.73 to 0.04	0.08	−0.68	−1.22 to −0.14	0.01	−0.26	−0.81 to 0.28	0.3
Maternal age in 1982 (⩾30 years)	−0.75	−0.45 to 0.16	0.3	−0.13	−0.55 to 0.30	0.6	−0.03	−0.45 to 0.40	0.9
Maternal pregestational weight (kg)	0.04	0.02 to 0.05	<0.001	0.03	0.01 to 0.05	0.001	0.01	−0.01 to 0.03	0.6
Maternal height (cm)	0.12	0.10 to 0.14	<0.001	0.31	0.28 to 0.35	<0.001	0.18	0.15 to 0.22	<0.001
Smoking during pregnancy	−0.19	−0.51 to 0.13	0.3	−0.23	−0.57 to 0.11	0.18	−0.03	−0.38 to 0.31	0.8
Maternal weight gain (kg)	−0.01	−0.03 to 0.03	0.9	0.02	−0.02 to 0.06	0.2	0.02	−0.02 to 0.06	0.3
Gestational age (weeks)	0.01	−0.08 to 0.10	0.9	−0.07	−0.19 to 0.06	0.3	−0.08	−0.20 to 0.05	0.23
Birth weight (kg)	0.76	0.51 to 1.01	<0.001	1.11	0.76 to 1.46	<0.001	0.55	0.22 to 0.87	0.001

[a]Adjusted according to conceptual model presented in Figure 1.

Table 5 Multiple linear regression analysis* for trunk length in 1986 and 2000, and trunk length change between 1986 and 2000 (cm)

Variable	*Trunk length in 1986*			*Trunk length in 2000*			*Trunk length change*		
	β	*95% CI*	P-*value*	β	*95% CI*	P-*value*	β	*95% CI*	P-*value*
Family income (groups)	0.34	0.20 to 0.48	<0.001	0.33	0.24 to 0.51	0.001	−0.02	−0.18 to 0.15	0.8
Maternal schooling (years)	0.12	0.09 to 0.16	<0.001	0.10	0.05 to 0.14	<0.001	0.01	−0.04 to 0.04	0.9
Maternal skin color (nonwhite)	−0.81	−1.11 to −0.51	<0.001	−1.38	−1.78 to −0.99	<0.001	−0.50	−0.85 to −0.15	0.005
Household crowding	−0.15	−0.21 to −0.08	<0.001	−0.07	−0.15 to 0.02	0.12	0.08	0.01 to 0.16	0.03
Maternal age in 1982 (<20 years)	−0.08	−0.43 to 0.28	0.7	−0.25	−0.70 to 0.20	0.3	−0.18	−0.61 to 0.25	0.4
Maternal age in 1982 (⩾30 years)	0.01	−0.27 to 0.29	0.9	−0.12	−0.48 to 0.23	0.5	−0.24	−0.57 to 0.09	0.15
Maternal pregestational weight (kg)	0.04	0.03 to 0.06	<0.001	0.03	0.01 to 0.05	0.001	−0.01	−0.02 to 0.01	0.9
Maternal height (cm)	0.10	0.08 to 0.12	<0.001	0.21	0.18 to 0.24	<0.001	0.10	0.07 to 0.12	<0.001
Smoking during pregnancy	−0.31	−0.61 to −0.02	0.04	−0.14	−0.51 to 0.23	0.5	0.03	−0.31 to 0.38	0.8
Maternal weight gain (kg)	0.04	0.02 to 0.07	0.001	0.05	0.02 to 0.08	0.002	0.03	−0.01 to 0.05	0.09
Gestational age (weeks)	−0.01	−0.08 to 0.07	0.9	0.01	−0.10 to 0.11	0.9	0.02	−0.07 to 0.12	0.6
Birth weight (kg)	0.76	0.50 to 1.02	<0.001	1.19	0.87 to 1.52	<0.001	0.39	0.09 to 0.69	0.01

[a]Adjusted according to conceptual model presented in Figure 1.

mothers were shorter at age 18 years (Table 3), the difference being due to leg length (Table 4); no difference was observed for trunk length (Table 5). Height and its components were similar between subjects whose mothers were 30 years or older and those in their 20s.

Maternal height and birthweight were strongly associated with all outcomes. Maternal pregestational weight showed positive effects on height and its components measured at age 4 and 18 years, but no effect on growth between these ages. The negative effect of smoking during pregnancy on height (Table 3) and trunk length at age 4 years (Table 5) was quite significant. Maternal weight gain in pregnancy was associated with height in 2000 and trunk length in 1986 and 2000 but not with growth in this period. As in the crude analyses, gestational age was not associated with any of the height outcomes in the adjusted models.

Discussion

This study identified several early life variables associated with height and its components. Of the 11 independent variables analyzed, only gestational age failed to be associated with any of the outcomes. Most associations were highly significant.

We identified three general patterns of association, and will refer to growth up to 4 years as 'early growth' and to that between 4 and 18 years as 'late growth'. Karlberg (1989) had proposed an 'infancy–childhood–puberty' growth model; the infancy–childhood growth spurt is completed around the age of 3 years, roughly the first component of the present study that includes growth up to 4 years.

Pattern 1: variables positively associated with both early and late growth

Maternal height and birthweight were strongly and positively associated with all three height outcomes in 1986 and 2000, as well as with growth between these periods. We found an extra kg of birthweight to be associated with an increase of 2.54 cm in adult height, a finding similar to a previous study (Li *et al.*, 2004). Non-white maternal skin color was associated with growth in the legs but not in the trunk. Individuals of African descent are known to have relatively longer legs and shorter trunks than Europeans and Asians (Eveleth and Tanner, 1976). These differences have been attributed to genetic variation. Our findings confirm that whites have relatively longer trunks, while non-whites have relatively longer legs, with no significant differences in total height between the two groups. These variables largely reflect genetic characteristics.

Pattern 2: variables positively associated with early growth but not with late growth

Two socioeconomic indicators, family income and maternal education, were strongly and positively associated with early but not with late growth. This led to greater attained height and its components in 2000. Maternal pregestational weight showed the same pattern. Increases of 0.45 and 0.33 cm in leg and trunk length, respectively, for each family income category led to nearly a 2 cm difference both in leg and trunk length between the highest and lowest family income groups. Socioeconomic factors were associated only with early growth in this study, suggesting that the effects of these variables were more important in early life than after 4 years of age. Maternal weight gain had similar effects, except for leg length indicators. Environmental influences, especially during periods of rapid growth, are known to affect leg length and are considered as a useful indicator of socioeconomic status (Gunnell *et al.*, 1998b; Wadsworth *et al.*, 2002). In our results, the effect of income on leg length was slightly greater than that on trunk length, but this pattern was not observed for maternal schooling.

Pattern 3: variables negatively associated with early growth but not associated with attained size

Household crowding showed significant negative associations with all early growth indicators, but positive associations with late growth, except for leg length. Maternal smoking also showed negative associations with early growth in trunk and total height, but no association with later growth. Neither household crowding nor maternal smoking was associated with attained size in 2000, and thus seems to represent environmental factors constraining early, but not later growth. Smoking during pregnancy is known to be a risk factor for being born small and for infant mortality (Horta *et al.*, 1997; Zambonato *et al.*, 2004). This study indicates this 'catch-up' growth after 4 years of age does not occur in the case of maternal smoking. On the other hand, this does seem to occur for household crowding, in terms of trunk length and total height.

The effect of maternal age on growth did not fit any of the above patterns. Children born to teenage mothers were shorter, with the difference being due to leg length.

It has been suggested that differences in height and its components are mainly a result of differences in leg length, with little sign of significant intrapopulational variation in trunk length (Gunnell *et al.*, 1998b). In this study, of the six variables strongly associated with height, trunk and leg length (family income, maternal schooling, skin color, pregestational weight, maternal height and birthweight), the regression coefficients for leg and trunk length were nearly equally responsible for the difference in overall height. This suggests that leg and trunk length are both associated with overall height difference in this population, contributing almost equally, and that biological and socioeconomic factors can influence trunk as well as leg growth.

Some studies indicate that leg length, as an important marker of early nutritional deprivation, is associated with the occurrence of adult chronic diseases (Smith *et al.*, 2001; Gunnell *et al.*, 2003; Lawlor *et al.*, 2004). Other analyses from our cohort confirmed the association between early growth and risk factors for the metabolic syndrome (Barros and Victora, 1999; Nazmi *et al.*, 2007).

Different studies have highlighted the positive socioeconomic influences on leg and, to a lesser degree, trunk length, reporting that individuals with longer legs or taller stature have lower risk of chronic diseases (Gunnell *et al.*, 1998b; Smith *et al.*, 2001; Langenberg *et al.*, 2003; Lawlor *et al.*, 2004). Further research will be needed to explore these issues as the members of this cohort age.

A major strength to the design of this study is the longitudinal nature of the data collection. The same methods and training techniques were used for obtaining total height, trunk and leg length at age 4 and 18 years. General standardization procedures ensure uniformity and consistency in data collection (Barros *et al.*, 1990; Victora *et al.*, 2003a). Since total height and sitting height measurements are each associated with error, one drawback of obtaining leg lengths by subtraction is increased overall error (Wadsworth *et al.*, 2002). Nevertheless, the strong associations observed between this derived variable and several explanatory factors shows that measurement error did not eliminate these associations. Although height at age 18 years was considered attained height; these boys have not stopped growing. In 2004–2005 follow-up, when these boys were 23 years old, mean height increased 0.3 cm (data not yet published). Unfortunately, leg and trunk lengths were not measured at age 23 years.

Among explanatory variables, one possible limitation in the current analysis could be measurement error in maternal prepregnancy weight and weight gain, However, self-reported prepregnancy weight has been used in several studies and a study from Brazil showed good agreement between self-reported and measured information for pregestational weight (Oliveira *et al.*, 2004). Finally, another limitation of this study is that only male subjects were included and further analyses should be conducted including components of height in female subjects. The effects of early life factors on adult height were studied in a subsample of female participants of this cohort (Gigante *et al.*, 2006).

The importance of early growth is evident, albeit the effect of breastfeeding is unclear—in another analysis of these data the association between breastfeeding and height was almost significant ($P = 0.06$) but no association with leg length was observed (Victora *et al.*, 2003b). In the present analysis, six variables were found to be associated exclusively with early growth, whereas none of the eleven variables under study had an effect that was restricted to the late period. Family income, maternal education, pregestational weight and maternal weight gain were positively associated with growth in the early period. Smoking and household crowding were negatively associated with early growth. The importance of investigating the factors influencing early growth is therefore highlighted. The early period was also a stronger predictor of attained height components. Given the possible links between early growth and disease in later life, further research should focus on the factors influencing early growth, and on potential strategies for public health interventions.

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