Original Article

A prospective study of weight and height going from infancy to adolescence

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Weight and height from infancy to age 15 years was studied in the Geelong population (n = 1200 in infancy; n = 213 at adolescence), Victoria, Australia. Body mass index (BMI) increased from 3 months to 12 months and then decreased again until 80 months after which it increased to 20.5 kg/m^2 at the age of 15 years. The extent of tracking of BMI in infants classified as overweight or underweight was similar and differed from that of subjects of normal weight. Only one in four of the infants classified as overweight or underweight in infancy were still in the same category in adolescence, compared with three in four of those classified as of normal weight. Socioeconomic status has an effect on weight and height status in adolescence but not on the tracking of BMI. The age at 6–7 years is a critical age for weight and height status in adolescence. It appears that weight and height in infancy have a significant relationship with body size in adolescence but only in boys.

Key words: Australia, body mass index (BMI), children, Geelong, socioeconomic status.

Introduction

Improved nutrition, together with other environmental improvements, has resulted in an increase in the body size of children in most Western countries during the twentieth century.[1] In Australia, New South Wales schoolchildren have increased by 5–7 kg in weight and by 8–9 cm in height between 1908 and 1971.[2] There is an interest in childhood obesity for several reasons. Adult obesity is considered a health hazard, it is difficult to treat successfully and there is evidence that obese children have a strong tendency to become obese adults.[3] Detection of early deviation from the norm is therefore considered important in the search for early acting causal factors and the institution of prophylactic measures. In Australia, there have been few longitudinal studies of weight status from infancy to adolescence. In this article we therefore report a longitudinal study of weight and height from birth to adolescence at age 15 years.

Materials and methods

The study group is based on a cohort of children (n = 1200) born in the Geelong statistical district in the second half of 1972 for whom earlier data on weight and height were available.[4,5] Data collection in adolescence (n = 213) was carried out between July 1987 and March 1988. All adolescents were examined and measured by the same observer, a physician. This study was conducted in accordance with the internationally agreed ethical principles for the conduct of medical research. Weight (WT) was measured in a swimming costume or hospital gown to the nearest 0.1 kg using a digital platform scale (Soehnle). Height (HT) was measured to the nearest 0.1 cm with a Harpenden anthropometer. Weight and height in early life were obtained from the Infant Welfare Centre (IWC) at birth, 3, 6, 9 and 12 months and School Medical (SM) records at 50 and 80 months.

Data from 152 of adolescents (73 boys; 79 girls) were used to describe BMI from infancy to adolescence. Complete data on weight at birth and weight and length at 12 months, 80 months and 15 years were available for 83 adolescents (40 boys and 43 girls). Overweight and underweight were defined as a weight (at birth), or thereafter, a body mass index (BMI) more than 1 SD from the group mean for age. BMI was calculated as actual weight (kg) divided by height (m) squared.

Daniel score (DS), based on father's current occupation, was used in the present study as an indicator for socioeconomic status.[6] Daniel score was categorised into six groups, the highest SES was score 1.2 (lowest DS) and the lowest SES was score 6.7 (highest DS). The earlier available data on SES in infancy were adopted by using the Congalton

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occupational scale (class A, highest SES; class D, lowest SES) because the data were originally collected in that way.[7]

Of the approximately 1200 children who were born in the second half of 1972, a total of 580 children (271 boys; 309 girls) were followed up at the age of 6–7 years. A total of 152 children (73 boys; 79 girls) for whom birthweights were available were able to have these linked with their weights at 14–15 years of age. Of these 152, only 80 adolescents (40 boys; 43 girls) for whom completed data on weight at birth, 12 months, 80 months and at 14–15 years were available.

Results

Weight, height and body mass index from infancy to adolescence

The birthweights of the adolescent boys (3517 g, SD = 559) and girls (3379 g, SD = 532) in the present study was not significantly different from the general population (boys, 3468 g, SD = 544; girls, 3366 g, SD = 494).[5] Mean weight, height and BMI of the adolescents at 3, 6, 9, 12, 50 and 80 months and 15 years are shown in Table 1. The number of adolescents at different ages varied due to missing data for some individuals. Highly significant differences were found for weight and height during infancy and 15 years between boys and girls. In contrast, no significant differences in BMI were found between boys and girls at any age. BMI increased from 3 to 12 months and then decreased again until 80 months, after which it increased to 20.5 kg/m^2 at the age of 15 years.

Growth rate (weight and height velocity) during infancy

Table 2 shows the rate of weight gain (g/month) at different time periods in infancy. Both weight and height velocity decreased throughout the first year of life. A significant difference (1% level) in the rate of weight gain between boys and girls was found only from birth to 3 months and in the rate of height gain only from 6 to 9 months of age. Data on length at birth were not available and therefore, the rate of height gain could only be calculated from 3 months.

Table 1. Weight, height and BMI of 152 study adolescents with age

	Weight (kg)			Height (cm)			BMI (kg/m^2)	
Age (months)	*n*	Mean	SD	*n*	Mean	SD	*n*	Mean	SD
Boys									
3	60	6.1**	0.67	55	61.6**	2.99	55	16.1	1.36
6	58	8.1**	0.91	54	68.1**	2.59	54	17.6	1.57
9	50	9.6**	1.05	48	72.9**	2.67	48	18.1	1.59
12	53	10.6**	1.28	46	76.8**	3.19	46	18.0	1.51
50	29	19.3	2.96	28	107.6	5.42	28	16.7	1.38
80	56	23.7	3.78	56	121.7	6.11	56	15.9	1.90
15 years	73	58.9**	11.49	73	169.3**	9.04	73	20.5	2.93
Girls									
3	71	5.7**	0.64	64	60.1**	2.24	64	15.9	1.20
6	68	7.5**	0.89	66	66.2**	2.04	66	17.2	1.49
9	61	8.9**	1.00	58	70.4**	2.07	57	18.0	1.61
12	54	10.1**	1.23	50	75.1**	3.01	50	17.8	1.40
50	39	18.7	2.08	39	106.4	4.24	39	16.5	1.15
80	63	22.3	2.59	63	119.1	4.93	63	15.7	1.33
15 years	79	54.9**	7.15	79	160.8**	5.64	79	21.2	2.67

** $P < 0.01$ between boys and girls.

Table 2. Rate of weight gain and height gain during infancy

	Boys			Girls			
Period (months)	*n*	Mean	SE	*n*	Mean	SE	*P*
Weight gain (g/month)							
Birth–3	60	858	23	71	755	21	< 0.01
3–6	57	673	25	66	627	23	NS
6–9	48	480	19	58	449	19	NS
9–12	47	345	19	52	380	37	NS
Height gain (cm/month)							
Birth–3	–	–	–	–	–	–	–
3–6	47	2.2	0.084	60	2.1	0.068	NS
6–9	44	1.6	0.079	55	1.3	0.053	< 0.01
9–12	39	1.3	0.086	45	1.4	0.105	NS

NS, not significant.

Relationship of growth rate in infancy with weight and height status in adolescence

Correlation analyses were performed between the rate of weight gain from birth to 3 months, 3–6 months, 3–9 months, 6–9 months, 9–12 months, birth to 6 months, birth to 9 months and birth to 12 months and weight, height and BMI in adolescence. Significant correlations with the rate of weight gain in infancy were found only in the adolescent boys. The strongest correlations were found with the rate of weight gain from birth to 9 months (Boys: WT, 0.60; HT, 0.42; BMI, 0.53). The relationship between rate of height gain in infancy and weight, height and BMI in adolescence was explored in a similar way to that described for rate of weight gain in infancy. No significant correlations were found between adolescents' weight, height and BMI and rate of weight gain in infancy.

Longitudinal study of weight for height status

Figure 1 indicates the number of subjects who were classified as overweight, normal and underweight at each age and the number who remained in each category for varying periods of time from birth to adolescence.

Of the 21 individuals classified as overweight either at birth or at 12 months, 19% were still overweight at 80 months and 24% at 15 years (Table 3). In contrast, half of the 12 adolescents classified as overweight at 15 years had been overweight at some time during childhood while the remainder were first classified as overweight at this age.

Of the 76 individuals classified as being of normal weight at birth or at 12 months, 84% were still in this category at 80 months and 71% at 15 years (Table 3). Of the 60 adolescents classified as being of normal weight at 15 years, almost all (97%) had been in this category at some time previously in childhood and only 3% were classified as normal weight for the first time in adolescence.

Of the 23 individuals classified as underweight at birth or at 12 months, 26% were underweight at 80 months and 17% at 15 years (Table 3). Forty five per cent of the 11 adolescents classified as underweight at 15 years had been underweight at some time in early childhood and the majority first became underweight at this age. These proportions are similar to those of individuals classified as overweight in the first year of life and at 15 years, but quite different from those of individuals classified as being of normal weight.

Socioeconomic influences on weight, height and body mass index in adolescence

Sociodemographic information available for this study included parents' country of birth, occupation and education, family size and types of school attended by adolescents. Parents' country of birth and educational level were not associated with weight, height or BMI in adolescence. However, girls, but not boys, who attended non-government schools had a tendency to be taller (162.3 (0.78) cm *vs* 160.0 (0.73) cm; $P < 0.05$) and heavier (56.6 kg, SD = 1.19 *vs* 53.7 kg, SD = 0.86; $P < 0.05$) than their peers who attended government schools, despite a similar BMI. When adolescents were grouped according to family sizes, significant differences of height at 5% level were found between girls from families of four or less (162.4 cm, SD = 0.85) and those from families of six or more (159.5 cm, SD = 0.91).

Significant differences in Daniel scores (DS), based on father's occupation, were only observed in girls. Girls with

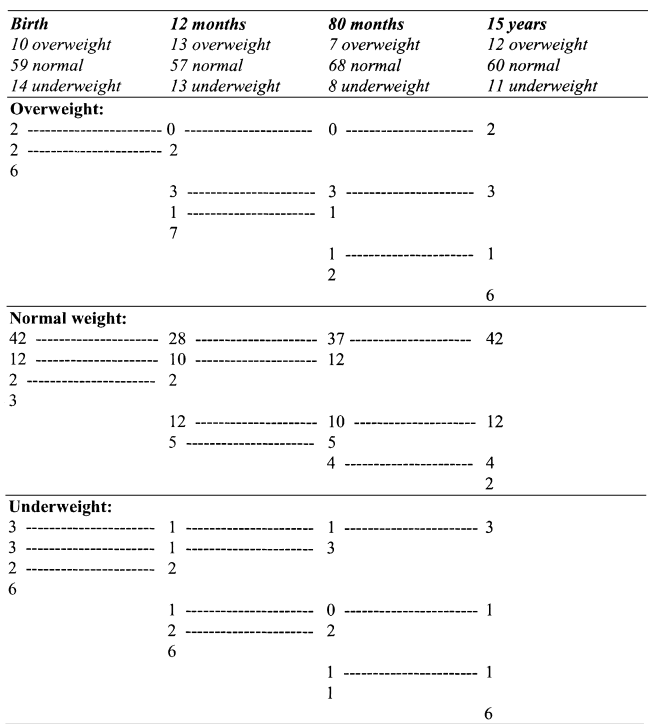

Figure 1. Prospective study of body mass index of 83 Geelong adolescents.

Table 3. Percentage of subjects categorised as overweight/normal weight/underweight either at birth or at 12 months remaining in the same category at a later age

Body image category	% subjects at infancy at 80 months	% subjects at infancy at 15 years	% subjects at 6–7 years at 15 years	% O/N/U subjects at 15 years who had been in the same category at some time during childhood
Overweight	19	24	57	50
Normal weight	84	71	85	97
Underweight	26	17	63	45

N, normal weight; O, overweight; U, underweight.

fathers in occupations of higher socioeconomic status (SES) (DS < 3.8) were significantly taller (162.7 (0.92) cm *vs* 158.5 (1.06) cm; $P < 0.01$) than those whose fathers were in occupations with lower SES (DS > 5.4). There was also a trend for girls with higher SES fathers to be heavier than those with lower SES fathers (55.7 (1.28) kg *vs* 51.9 (1.07) kg; $P < 0.05$).

For 99 of the adolescents, data were also available on father's occupation at the time of the child's birth, classified according to the Congalton scale.[7] The fathers' Congalton occupational scale rankings at birth were essentially maintained in adolescence, for example, adolescents in Congalton scale groups A and B, C and D at birth had fathers with DS of 3.3, 4.6 and 5.7, respectively, in adolescence. Using the father's Congalton classification at birth in place of DS at adolescence to assess the influence of SES on weight and height in adolescence gave essentially similar results.

Relationship between socioeconomic status and tracking of body mass index

Tracking of body mass index in the present study applied to individuals who maintained their BMI in the same category from infancy to adolescence.

Father's current occupational level (Daniel score). Father's occupation based on Daniel score was categorised into quartiles (Table 4). There were no significant differences in tracking of BMI of the study subjects between the low, middle and high quartile groups ($\chi^2 = 1.01$, d.f. = 2). However, more than half (59%, $n = 48$) of the study groups had BMI tracked from infancy to adolescence.

Parent's educational level. About half of the study subjects were found to have BMI tracked according to their parental educational level ($n = 35$, father's education; $n = 48$, mother's education; Table 5). However, current parental educational levels were not associated with tracking of BMI from infancy to adolescence (fathers' education: $\chi^2 = 1.19$, d.f. = 2; mothers' education: $\chi^2 = 0.868$, d.f. = 2).

Table 4. Tracking of BMI of the study subjects ($n = 81$) from infancy to adolescence according to father's occupation

Daniel score (DS)	Tracking (*n*)	Not tracking (*n*)
< 3.8	12	9
3.8–5.3	21	17
> 5.4	15	7
Total	48	33

$\chi^2 = 1.01$, d.f. = 2. Two subjects gave no information on their fathers' Daniel scores. BMI, body mass index.

Discussion

A relation between socioeconomic status (SES) and health status has been observed and systematically assessed in France and England since the 19th century.[8,9] In the present study, SES had a significant influence on height in adolescents aged 14–15 years. Adolescent girls whose fathers were of higher SES were 4–5 cm taller than their peers with fathers of lower SES. These findings are in general agreement with other studies.[10,11] In the present study, neither level of father's current occupational level by Daniel score (low, middle, high) nor parent's educational levels (low, middle, high) affected tracking of BMI. Therefore, tracking of BMI from infancy to adolescence was not related to the parent's socioeconomic status.

It is well known that weight and weight gain during infancy are important in neonatal and paediatric care because of their relationships to infant mortality and morbidity and to developmental deficits. Environmental influences that impair growth and development in early life may also be risk factors for ischaemic heart disease.[12] A number of studies have reported a relationship between weight in infancy and subsequent weight gain in early childhood.[13–15] Others have studied the effect of birthweight doubling and tripling time on later weight.[16] Heald and Hollander reported that children who were obese (meaning not defined by the authors) in adolescence had gained weight more rapidly in infancy than those who were of normal weight at adolescence.[17] In the present study, the rate of height gain in infancy did not have as much influence on body size in adolescence as did the rate of weight gain. The rate of weight gain from birth to 9 months was a significant predictor of anthropometric measures for adolescent boys, but not girls. Literature for comparison with the present study is scanty. Mellbin and Vuille, in a Swedish study, reported that the correlation coefficient between the rate of weight gain from birth to 9 months or from birth to 12 months and height at 7 years was approximately 0.4 ($P < 0.01$), which was similar to the present study at age 15 years.[18] Similar to the present study, the Swedish study also found that the relationship between early growth pattern (rate of weight and height gain in infancy, weight and height at 1 year) and anthropometric status (weight, height, skinfolds) at 7 years of age was

Table 5. Tracking of BMI of the study subjects ($n = 81$) from infancy to adolescence according to parents' education

	Father's education		Mother's education	
Education level	Tracking (*n*)	Not tracking (*n*)	Tracking (*n*)	Not tracking (*n*)
School	22	34	32	25
TAFE	6	5	11	6
University	7	7	5	2
Total	35	46	48	33

Two subjects gave no information on their parents' educations. Father's occupation, $\chi^2 = 1.19$, d.f. = 2. Mother's occupation, $\chi^2 = 0.868$, d.f. = 2. BMI, body mass index.

stronger in boys than in girls. The rate of weight gain in infancy was also more highly correlated with height at 7 years of age than was the rate of height gain in infancy.[18]

Most studies of the relationship between body fatness and age during childhood have limitations. Many have been retrospective, documenting the level of body fatness at earlier ages by recall[19,20] or from available medical records.[21,22] Most retrospective studies have been restricted to short periods in childhood, usually of five years or less,[23,24] while in the present study, data for weight and height were available over a period of 15 years. Prospective studies of overweight, underweight and normal weight individuals in the same cohort are scanty. The pattern of BMI from infancy to adolescence in the present study was similar to that observed in other studies.[25,26]

Subjects who were classified as overweight and underweight in infancy differed from the subjects who were classified as being of normal weight. For example, of the subjects classified as overweight or underweight during the first year of life, only a quarter were still in the same category at 15 years while in contrast, 71% of the infants classified as being of normal weight were still in this category at adolescence. In a study of US children aged from birth to 9 years, Shapiro *et al*. reported that of 26 boys obese at 6 months, only half were obese for varying periods of time, either continuously or in any interval, until 9 years of age and half were not obese at any subsequent age.[27] Cronk *et al.* found that, in general, the BMI in the immediate preceding period is the best predictor of the percentile in any subsequent age period.[28] Continuity of the percentile level of BMI from infancy (3 months–3 years) to childhood (3–9 years) was found to be less than from childhood to adolescence (10–17 years). Continuity from infancy to adolescence was very low. Girls appear to show more stability in BMI than boys, both within and between the age periods considered. These findings are based on data from a general population and may not apply to individuals at the extremes of the distribution. Sorensen and Sonne-Holm found that, using logistic regression analysis, 13-year-old overweight children who had either decreased or increased in percentile level since age 7 years had a higher risk of developing severe adult obesity than did 13-year-old children who had maintained their percentile level.[29]

In conclusion, socioeconomic status has an effect on weight and height status in adolescence, but not on the tracking of BMI. The age at 6–7 years is a critical age for weight and height status in adolescence. It appears that weight and height in infancy have a significant relationship with body size in adolescence, but only in boys. This is in accord with the finding that a high weight gain in the first year is a factor in increased height during childhood and adolescence, regardless of whether or not the excess weight is later lost or retained.[30]

References

1. Leitch I, Boyne AW. Recent changes in the height and weight of adolescents. Nutr Abstract Rev 1960; 30: 1173–1186.
2. Jones DL, Hemphill W, Meyers ESA. Height, weight and others physical characteristics of New South Wales children. Part 1. Children aged five years and over. Special Report. Sydney: New South Wales Department of Health, 1973.
3. Charney E, Goodman HC, McBridge M, Lyon B, Pratt R. Childhood antecedents of adult obesity. Do chubby infants become obese adults? N Engl J Med 1976; 295: 6–9.
4. Rutishauser IHE, Hunter S. The Geelong study. Proc Nutr Soc Aust 1980; 5: 79–87.
5. Rutishauser IHE. Weight, height and weight for height in 6–7-year-old children. 1. Relationship with demographic variables. Aust Paediatr J 1984; 20: 35–38.
6. Daniel A. Australian studies. Power, privilege and prestige. Occupations in Australia. Melbourne: Longman Cheshire, 1983.
7. Congalton AA. Status and prestige in Australia. Melbourne: Cheshire, 1969.
8. Graham S, Reeder LG. Social epidemiology of chronic disease. In: Freeman H, Levine S, Reeder LG, eds. Handbook of Medical Sociology. Englewood Cliffs, NJ: Prentice Hall, 1979.
9. Susser M, Watson W, Hopper K. Sociology in Medicine. New York: Oxford University Press, 1985.
10. Goldstein H. Factors influencing the height of seven year old children – results from the national child development study. Hum Biol 1971; 43: 92–111.
11. Goldstein H, Peckham C. Birthweight, gestation, neonatal mortality and child development. In: Roberts DF, Thomson, AM, eds. The Biology of Human Growth. London: Taylor and Francis, 1976.
12. Barker DJP, Osmond C, Golding J, Kuh D, Wadsworth MEJ. Growth in utero, blood pressure in childhood and adult life, and mortality from cardiovascular disease. BMJ 1989; 298: 564–567.
13. Thomson J. Observations on weight gain in infants. Arch Dis Child 1955; 30: 322–327.
14. Drillien CM. A longitudinal study of the growth and development of prematurely and maturely born children. Part II. Physical development. Arch Dis Child 1958; 33: 423–431.
15. Pomerance HH, Krall JM. The relationship of birth size to the rate of growth in infancy and childhood. Am J Clin Nutr 1984; 39: 95–99.
16. Neumann CB, Alpaugh M. Birthweight doubling time: a fresh look. Pediatrics 1976; 57: 469–473.
17. Heald FP, Hollander RJ. The relationship between obesity in adolescence and early growth. J Pediatr 1965; 67: 35–38.
18. Mellbin T, Vuille JC. Physical development at 7 years of age in relation to velocity of weight gain in infancy with special reference to incidence of overweight. Br J Prev Soc Medical 1973; 27: 225–235.
19. Mullins AG. The prognosis in juvenile obesity. Arch Dis Child 1958; 33: 307–314.
20. Asher P. Fat babies and fat children. The prognosis of obesity in the very young. Arch Dis Child 1966; 41: 672–673.
21. Johnson ML, Burke BS, Mayer J. Relative importance of inactivity and overeating in the energy balance of obese high school girls. Am J Clin Nutr 1956; 4: 37–44.
22. Ratten GC, Targett C, Drew J, Beischer N. The effect of fetal and placental weight at birth on weight during childhood. Med J Aust 1975; 2: 735–736.
23. Hampton MC, Huenemann RL, Shapiro LR, Mitchell BW. Caloric and nutrient intakes of teenagers. J Am Diet Assoc 1966; 50: 385–396.
24. Poskitt EM, Cole J. Nature, nurture, and childhood overweight. BMJ 1978; 1: 603–605.
25. Hitchcock NE, Maller RA, Gilmour AI. Body size of young Australians aged five to 16 years. Med J Aust 1986; 145: 368–372.
26. Rolland-Cachera MF, Sempe M, Guilloud-Bataille M, Patois E, Peguignot-Guggenbuhl F, Fautrad V. Adiposity indices in children. Am J Clin Nutr 1982; 36: 178–184.

27. Shapiro LR, Crawford PB, Clarke MJ, Pearson DL, Raz J, Huenemann RL. Obesity prognosis. A longitudinal study of children from the age of 6 months to 9 years. Am J Public Health 1984; 74: 968–972.
28. Cronk CE, Roche AF, Chumlea WC, Kent R. Longitudinal trends of weight/status squared in childhood in relationship to adulthood body fat measures. Hum Biol 1982; 54: 751–764.
29. Sorensen TI, Sonne-Holm S. Risk in childhood of development of severe adult obesity: retrospective, population-based case-cohort study. Am J Epidemiol 1988; 127: 104–113.
30. Johnson FE, Mack RW. Obesity in urban Black adolescents of high and low relative weight at 1 year of age. Am J Dis Child 1978; 132: 862–864.