SHORT REPORT

Pre-pubertal growth and cognitive function

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British longitudinal data were used to investigate the association of heights at 22 months and 5 years with a digit recall test at age 10 years. Greater height, particularly at 5 years, was associated with higher scores, suggesting that some exposures influence both growth and capability for cognitive function.

An association has been reported of infant growth in the first year with adult income, while subsequent growth to age 12 years was not a significant additional predictor.[1] Short childhood stature has been associated with educational failure,[2] so slower growth may indicate poorer cognitive function as well as other disadvantages,[2] adversely influencing educational attainment and, ultimately, occupation and income.

This study investigated associations of infant growth with a measure of cognitive function, a digit recall test at age 10 years, using longitudinal British data. As digit recall tests are less influenced by cultural factors than tests of word recognition or knowledge, this is a good indicator of cognitive function. Our study focused on growth to age 5 years, avoiding any potential masking effect of puberty.

METHODS AND RESULTS

The 1970 British Cohort Study (BCS70) follows the lives of everyone born between 5 and 11 April 1970 living in Great Britain, comprising approximately 16 500 members.[3] This study is limited to a sub-sample for whom additional information was collected at age 22 months, when a 10% random sample was combined with an over-sampled group of infants who were small for gestational age, post mature, or multiple births. Some 2296 infants had a measured height at 22 months and of these, this study used information from 1643 (72%) who also had valid test score data at age 10 years.

Health visitors with training for this study measured height in centimetres at ages 22 months and 5 years. Around the time of delivery, midwives recorded sex, birth weight in grams, gestational age in days, and multiple births. They also recorded father's occupation, which was used to assign Registrar General's social class, divided here into manual, non-manual, and other (no assigned class, for example, if the father is absent). At age 10 years an assessment of digit recall was administered under test conditions at school, producing a normally distributed score with range from 7 to 34.

The digit recall test score was the dependent variable in linear regression analysis. The independent variables were heights for ages 22 months and 5 years (converted into standard deviation units, calculated separately for males and females). The potential confounding factors included in the model were social class, multiple births, and gestational age (dummy variables), and birth weight.

The association with digit recall score for *change* in height z-score from age 22 months to age 5 years was also modelled, with adjustment for the potential confounding factors.

Among 1444 subjects with complete data for all variables, greater heights at ages 22 months and 5 years are both associated with higher digit recall test scores, independent of each other and potential confounding factors (table 1). None of the other measures, except social class, were statistically significantly associated with the test score in the adjusted model. Exclusion of subjects with missing data did not notably influence the association: the unadjusted estimate for height at age 22 months with the test score using all subjects ($n = 1643$) produced a coefficient of 0.50 (95% CI 0.28 to 0.70), almost identical to the unadjusted estimate produced by the main analysis, suggesting absence of selection bias. The difference in z-scores between ages 22 months and 5 years is statistically significantly associated with the digit recall test after adjustment for height at 22 months, and all of the other potential confounding factors excluding height at 5 years: 0.35 (95% CI 0.10 to 0.61, $p = 0.007$).

To confirm that our results are not specific to numeric tests, associations were investigated for height with a test at age 10 years ("similar"[3]) where the child identifies and names groups. After adjustment for the potential confounding factors, the B coefficient for the association of height at age 22 months is 0.20 (95% CI 0.05 to 0.35, $p = 0.01$); at 5 years, the association is greater: 0.26 (95% CI 0.11 to 0.42, $p = 0.001$).

DISCUSSION

A previous study found that slower infant growth (height) to 1 year predicted subsequent lower income, but later childhood growth to age 12 years provided no additional predictive power.[1] The authors hypothesised mediation through lower cognitive function. Our study investigated cognitive function using a test score and found associations with infant growth to 22 months, but also subsequent growth to 5 years, even after adjustment for earlier height and potential confounding factors. Possible explanations for apparent discrepancy between the studies are: the earlier study included growth to age 12 years, while our study considered growth to 5 years, eliminating a potential masking effect of pubertal growth; or the association of later childhood height with adult outcomes is not mediated through cognitive function.

The positive association of higher parental social class with cognitive function indicates the importance of environmental factors in cognitive development. The disadvantages associated with lower social class and factors such as psychosocial stress may slow both growth[4] and cognitive development. Birth weight was associated with cognitive function, but not independently of the other measures, while height at 5 years was more predictive of cognitive function than height at 22 months. A possible explanation is that adverse exposures in early life may have a cumulative impact, restricting both growth and cognitive development. Other research suggests that adult adversity associated with slowed childhood growth is not mediated through short adult stature,[5] and it is more likely that the

Table 1 Growth to age 5 years and cognitive function at age 10 years indicated by digit recall test score

	n (%)	Unadjusted B	Unadjusted 95% CI	Unadjusted p value	Adjusted B	Adjusted 95% CI	Adjusted p value
Height at 22 months z-score	1444 (100)	0.53	0.31 to 0.75	<0.001	0.28	0.02 to 0.53	0.04
Height at 5 years z-score	1444 (100)	0.56	0.35 to 0.78	<0.001	0.35	0.09 to 0.60	0.008
Birth weight z-score	1444 (100)	0.36	0.14 to 0.57	0.001	0.12	−0.14 to 0.38	0.4
Sex							
Male	777 (54)	Ref			Ref		
Female	667 (46)	0.30	−0.14 to 0.73	0.2	0.28	−0.15 to 0.71	0.2
Multiple birth							
Yes	125 (9)	−0.47	−1.24 to 0.30	0.2	0.01	−0.84 to 0.85	1.0
No	1319 (91)	Ref			Ref		
Social class							
Non-manual	379 (26)	0.82	0.32 to 1.31	0.001	0.62	0.13 to 1.11	0.01
Manual	1044 (72)	Ref			Ref		
Not assigned	21 (2)	−0.74	−2.56 to 1.08	0.4	−0.85	−2.65 to 0.95	0.4

Digit recall test score at age 10 years was the dependent variable in a linear regression analysis. The table shows the regression (B) coefficients with 95% confidence intervals.
The two heights and birth weight were modelled using standard deviation units (z-scores) for comparability.
Adjustment was for all the variables shown, as well as gestational age in fifths of its distribution.
Ref indicates the reference category for categorical variables.

cognitive and other developmental disadvantages associated with slowed growth[2] have life-long consequences. An alternative, but not mutually exclusive, explanation is that those taller at age 5 years also experience earlier puberty (growth tempo) and have a cognitive advantage at age 10 years that is lost subsequently. However, as adverse economic outcomes in adult life are independently associated with slow childhood growth,[1 5] some persisting association with poor cognitive function is plausible, so exposures associated with good growth in infancy and prepubertal childhood may impart capability relevant to cognitive function.

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