Childhood cognitive ability and deaths up until middle age: a post-war birth cohort study

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Background Childhood IQ has been related to mortality in later life in four studies. Cognitive ability may be a mediator between early disadvantage and mortality, a marker of the efficiency of information processing in the central nervous system, or predict entry to safe adult environments or healthy behaviours. We examined mortality in relation to cognitive ability at age 8 years in a birth cohort and investigated these possible reasons.

Methods Cox’s proportional hazards models were used to investigate the effect of early cognitive ability on all-cause mortality in 2057 women and 2192 men born in England, Scotland, and Wales in March 1946 and followed until age 54 years. We tested whether the relationship was accounted for by childhood socioeconomic conditions or serious illness, education, adult socioeconomic conditions, or smoking.

Results Cognitive ability was related to mortality in men but not women. The excess mortality rate in men was concentrated in the bottom quarter of the cognitive score (hazard ratio [HR] for bottom versus top quarter 1.8, 95% CI: 1.0, 3.0) and there was no gradient across the range of ability. Adjustment for childhood socioeconomic conditions and serious illness had a small effect on the HR for deaths between 9 and 54 years while adjustment for education or early adult socioeconomic conditions halved the HR for deaths from age 26 years. Smoking was not a mediator of the effect of early ability on adult mortality.

Conclusions Greater cumulative exposure to poor lifetime socioeconomic conditions is the most likely explanation for the observed relationship between low cognitive ability in childhood and mortality. This relationship may therefore be elucidated further by studying the causes of lifelong socioeconomic inequalities in health.

Keywords Birth cohort, IQ, mortality, life course, socioeconomic conditions

Several studies report that cognitive impairment and decline are associated with mortality. Most measured cognitive function in older people and followed subjects for between 3 and 20 years.1–4 One study reports an association between poor performance on an IQ test given to Australian army recruits and deaths after discharge up to age 40 years.5 More recently, scores on mental ability tests taken in childhood were shown to be associated with survival into midlife and old age in three Scottish cohorts6–8 and into midlife in a cohort of Danish boys.9 An important question is whether this effect of cognition is explained by lifetime socioeconomic status. However, three of these studies6,7,9 had no information on adult socioeconomic conditions or lifestyle for the deceased. Information on childhood social conditions was absent in one Scottish study8 and limited in another.7 We examine the relationship between childhood cognitive ability and mortality in a nationally representative cohort followed since their birth in March 1946 until age 54 years, taking into account prospective measures of childhood illness and adult smoking, and lifetime socioeconomic conditions previously shown to be related to mortality in this cohort.10
Methods

The Medical Research Council's National Survey of Health and Development is a prospective national birth cohort of 2547 women and 2815 men, a socially stratified sample of all the births that took place in England, Scotland and Wales during 3–9 March 1946. At age 8 years, 79.2% (2057 women and 2192 men) took tests of reading comprehension (sentence completion), pronunciation, vocabulary, and non-verbal reasoning (picture intelligence) designed specially for the study by the National Foundation for Educational Research in England and Wales. Unavoidable reasons for not taking these tests were death (236 = 4.4%) and living abroad (299 = 5.6%) before age 8 years (Figure 1). Avoidable losses (10.8%), discussed elsewhere, were due to study members being untraced, absent from school, not mentally able to take the tests, having parents who refused to let them take the tests, or attending schools which did not set aside time for testing.

All but eight men and three women who took the tests at age 8 years and had not died or emigrated by 1971 (at age 25 years) were flagged for death on the National Health Service (NHS) Central Register. Sufficient deaths have now accrued to provide 90% power at the 5% significance level to detect a doubling of all-cause mortality at any age in those in the bottom quarter of the cognitive score compared with those in the top quarter.

Possible confounders or mediators

We used a record of hospital admissions for more than 28 days from birth to 9 years to test whether any effect of cognitive ability on mortality was due to a common risk factor of serious illness, already manifest by the start of follow-up. Socioeconomic indicators in childhood, based on information from interviews of the mother at home by health visitors when the study member was aged 4 years, included father's social class (manual or non-manual) and a score derived from health visitor reports on the care of the home and child. The score which allocated one point for each of very clean house, very clean child, at least adequate shoes, at least adequate clothes, and mother coped well was dichotomized into the bottom third and the top two-thirds. Those with educational qualifications by age 26 years were distinguished from those with none. Indicators of socioeconomic conditions and lifestyle at age 26 years were household social class (based on study member's occupation if male or the occupation of their partner if female), home ownership (yes or no), and cigarette smoking (current smoker, ex-smoker, and non-smoker).

Analysis

A sex-standardized score, based on the average of the four cognitive tests and grouped into four equal groups, was used in

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**Figure 1** Flow diagram indicating losses from the original cohort and the reason for censored observations
the analysis. We used Kaplan Meier plots to compare the cumulative death rate between ages 9 and 54 years for those in each quarter of the 8-year-old cognitive score. We used Cox’s proportional hazards models to investigate the relationship between quarters of the cognitive score and subsequent mortality and checked the proportional hazards assumption. Follow-up time (in months) was from the cohort’s ninth birthday until the first of death, emigration, or the end of February 2001, just before the cohort’s 55th birthday (Figure 1). If death had not occurred, follow-up was treated as censored at this age. The small number who were not flagged for follow-up (n = 11) were censored at the age flagging started. To test whether small sex differences in the variance of the cognitive score influenced our findings, we repeated the analysis using the same cutpoints for women as for men.

We investigated the effect of cognitive score (lowest quarter versus top three-quarters) on mortality before and after adjusting for childhood socioeconomic conditions and serious illness in separate models based on 3733 men and women with complete information (Figure 1). We undertook a similar analysis for mortality between 26 and 54 years, adjusting for educational qualifications, adult conditions, and cigarette smoking at age 26 years. These models were based on 3184 men and women. A further analysis simultaneously adjusted for all childhood and adult confounders or mediators.

We present weighted hazard ratios (HR) that account for the initial sampling procedure, with correctly adjusted CI and P-values, obtained using Software for the Statistical Analysis of Correlated Data (SUDAAN, Research Triangle Institute, NC). Tests of interaction were conducted to assess whether the effects of the cognitive score varied by sex or socioeconomic conditions.

Results

Between age 9 and 54 years, 96 women and 133 men died. The death rate was lower for women compared with men (HR = 0.82, 95% CI: 0.61, 1.1) but not significantly so with this small number of deaths.

Mortality 9–54 years and childhood cognitive ability

Compared with the death rate for men in the top quarter of the cognitive score at age 8 years, the death rate for men in the bottom quarter of the cognitive score was almost double (HR = 1.8, 95% CI: 1.0, 3.0) but there were no differences in the rates for men in the middle two quarters of the score (Table 1). By age 54 years, 10.4% of men in the lowest quarter of the cognitive score at age 8 years had died compared with 5.5% of those in the top quarter of the score (Figure 2). Childhood cognitive ability was not associated with mortality in women (Table 1). Tests for interaction between the cognitive score (split into the top three and bottom quarters) and sex showed that the effects for men and women were significantly different (P = 0.03). The variance in the cognitive score was slightly greater for men than for women (range [standard deviation] for men, −3.04 to 3.12 [1.01] and for women, −3.04 to 2.94 [0.98]). Using the same cutpoints for women as for men made no difference to the HR. The death rates of those who had or had not taken the cognitive tests did not differ.

<table>
<thead>
<tr>
<th>Cognitive score</th>
<th>Samplea</th>
<th>P-value (trend)</th>
<th>Womenb</th>
<th>Menb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top quarter</td>
<td>1.0</td>
<td>0.055</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Second quarter</td>
<td>0.83 (0.52, 1.3)</td>
<td>1.1 (0.58, 2.2)</td>
<td>0.59 (0.30, 1.2)</td>
<td></td>
</tr>
<tr>
<td>Third quarter</td>
<td>1.0 (0.64, 1.6)</td>
<td>1.0 (0.49, 1.9)</td>
<td>1.0 (0.56, 1.9)</td>
<td></td>
</tr>
<tr>
<td>Bottom quarter</td>
<td>1.4 (0.94, 2.2)</td>
<td>1.0 (0.54, 2.0)</td>
<td>1.8 (1.0, 3.0)</td>
<td></td>
</tr>
</tbody>
</table>

Hazard ratios obtained from Cox’s proportional hazards models.

a Hazard ratio adjusted for sex only.
b Hazard ratio unadjusted.
remained significantly associated with mortality (Table 2). Similarly, the effects of childhood socioeconomic conditions and illness on mortality were slightly reduced after adjusting for cognitive ability (not shown). In women, there was still no evidence of a relationship between childhood cognitive function and mortality after these adjustments.

Is the relationship between low cognitive ability and mortality (26–54 years) accounted for by educational attainment, adult socioeconomic conditions, or smoking?

Those with the lowest cognitive ability were more likely to have achieved no educational qualifications, become a smoker, and be living in less advantaged socioeconomic conditions at age 26. These factors were all associated with about a doubling of the adult death rate in this cohort (not shown). In women, there was still no evidence of a relationship between childhood cognitive function and mortality after these adjustments.

Discussion

In this post-war birth cohort childhood cognitive ability was related to mortality in men but not women up to age 54 years. The excess mortality rate was concentrated in the bottom quarter of the cognitive score distribution rather than a gradient in mortality rates across the four cognitive groups, suggesting the possibility of a threshold effect. The different results for men and women were not due to differing cognitive score distributions. The high trace rate for those who sat the cognitive tests lends weight to our findings.

In a final model adjusting for all childhood and adult confounders and mediators in those with complete data (1404 men and 1430 women), the HR in men was reduced by 63% (unadjusted HR = 2.06 [95% CI: 1.14, 3.73] and adjusted HR = 1.29 [95% CI: 0.67, 2.49]). In women, death rates remained unrelated to early ability.

Hazard ratios obtained from Cox’s proportional hazards model.

### Table 2

<table>
<thead>
<tr>
<th></th>
<th>Unadjusted</th>
<th>P-value</th>
<th>Adjusted for serious illness 0–9 years</th>
<th>P-value</th>
<th>Adjusted for childhood socioeconomic conditions</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cognitive score (at 8 years)</td>
<td>2.1 (1.4, 3.2)</td>
<td>&lt;0.001</td>
<td>1.9 (1.2, 2.9)</td>
<td>0.004</td>
<td>1.8 (1.1, 2.7)</td>
<td>0.013</td>
</tr>
<tr>
<td><strong>Women</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cognitive score (at 8 years)</td>
<td>1.1 (0.66, 1.8)</td>
<td>0.743</td>
<td>1.1 (0.64, 1.8)</td>
<td>0.826</td>
<td>0.90 (0.52, 1.6)</td>
<td>0.703</td>
</tr>
</tbody>
</table>

### Table 3

<table>
<thead>
<tr>
<th></th>
<th>Unadjusted</th>
<th>P-value</th>
<th>Adjusted for educational qualifications</th>
<th>P-value</th>
<th>Adjusted for adult socioeconomic conditions</th>
<th>P-value</th>
<th>Adjusted for smoking</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cognitive score (at 8 years)</td>
<td>2.0 (1.2, 3.4)</td>
<td>0.014</td>
<td>1.5 (0.90, 2.7)</td>
<td>0.121</td>
<td>1.5 (0.88, 2.7)</td>
<td>0.139</td>
<td>2.0 (1.1, 3.4)</td>
<td>0.016</td>
</tr>
<tr>
<td><strong>Women</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cognitive score (at 8 years)</td>
<td>1.1 (0.67, 2.1)</td>
<td>0.679</td>
<td>1.1 (0.57, 2.1)</td>
<td>0.791</td>
<td>0.89 (0.46, 1.7)</td>
<td>0.962</td>
<td>0.98 (0.53, 1.8)</td>
<td>0.961</td>
</tr>
</tbody>
</table>

Hazard ratios obtained from Cox’s proportional hazards model.
rate of all-cause mortality, similar to our own study. One of these studies followed up participants from childhood,\textsuperscript{7} the other from middle life.\textsuperscript{8} The results from the Danish cohort of just under 7500 boys born in 1953 and followed until age 49 years showed a gradient in mortality risk across all four cognitive groups.\textsuperscript{9}

Three studies included women as well as men,\textsuperscript{6–8} but two of these\textsuperscript{6,8} have not published sex-specific associations. In contrast to our findings, the Scottish cohort of just over 2000 men and women born in Aberdeen in 1921 and followed to age 76 years found a stronger association between cognitive ability at age 11 years and mortality up to 76 years in women than in men.\textsuperscript{7} This may have been because men with higher ability in that cohort were more likely to die during the World War II. Thus the reasons for the relationship between early cognitive ability and later mortality may be cohort and place specific. It is possible, for example, that the introduction of the British NHS in 1948 may have contributed to the absence of an association for women in our younger cohort; the older Aberdeen cohort, which showed an inverse association for women, did not benefit from the NHS during their childhood.

The prospective measures of childhood serious illness, educational achievement, lifetime socioeconomic conditions, and smoking available for this cohort allowed us to explore four possible mechanisms for the observed relationship between childhood cognitive ability and mortality raised by Whalley and Deary.\textsuperscript{7} First, cognitive ability could be a mediator between physical and social disadvantage in childhood and survival. The evidence from our study was that childhood socioeconomic conditions, serious illness, and low cognitive ability independently raised mortality risk and ability was not an important mediator of these other factors. In the younger Aberdeen cohort study\textsuperscript{6} and the Danish cohort study,\textsuperscript{9} father’s social class did not explain the association between IQ and mortality. In the older Aberdeen cohort study, father’s social class in the deceased was not correlated with age at death but could not be compared with father’s social class for survivors for whom this information was not available. In this context we should note that birth order, another early variable, is inversely related to childhood cognitive ability,\textsuperscript{12} and positively related to mortality.\textsuperscript{13} However, further analyses (not shown) showed that the inverse relationship between childhood ability and mortality was not explained by birth order.

Second, early cognitive ability might predict entry to safe adult environments. The evidence presented here showing that educational achievement or adult socioeconomic conditions halved the effect of cognitive ability on mortality, supports this mechanism. Similarly, in one of the Scottish cohorts,\textsuperscript{8} socioeconomic conditions at the time of screening (when participants were aged 45–64 years) almost halved the excess risk of death in the lowest group over the 25-year follow-up period. Additional analyses on our study (not shown) revealed that survivors of low cognitive ability in a manual occupation at age 26 years were more likely to have remained in the manual class (80.8\%) compared with other manual class men of higher cognitive ability (61.2\%). Similarly, they were twice as likely as others not to own their own homes (27.1\% versus 14.5\%) by age 43 years. Thus the low ability group was probably exposed to persisting disadvantage in adult life. The strong attenuation of the excess risk of death for the lower cognitive group when childhood and adult factors were simultaneously taken into account supports this conclusion.

Third, early cognitive ability might be a predictor of healthy behaviours. Smoking is the biggest single cause of premature death in the developed world.\textsuperscript{16} We found that the increased death rate between 26 and 54 years in men with the lowest cognitive ability was not explained by smoking behaviour at 26 years. We cannot rule out that smoking was implicated in the excess risk of death of low ability men because smoking at that age may not characterize very well lifetime smoking behaviour. Among survivors, those of low cognitive ability were less likely to report quitting smoking in the intervening years compared with those of higher cognitive ability.

The fourth mechanism proposed by Whalley and Deary was that early cognitive ability could be an indicator of ‘system integrity’, by which they meant the efficiency of information processing in the central nervous system. If the inverse of ‘system integrity’ is ‘system degradation’ then there may be a clinical threshold for this, which could explain why excess mortality risk in our cohort was carried by those of lowest cognitive ability. Given the strong attenuation of the effect of cognitive ability on mortality after allowing for adult educational and social factors, any effect on mortality of system integrity, as reflected by the cognitive score at age 8 years, would seem to be small or operate on mortality indirectly. The lack of any relationship between ability and mortality in women also mitigates against this explanation. It is possible that the effect of cognitive ability would be stronger for particular causes of death or will strengthen as the central nervous system ages. The main limitation of our study is that follow-up of the cohort so far is only to age 54 and there are insufficient deaths to investigate the relationship of cognitive ability to specific causes of death.

If low childhood cognitive ability reflects early damage to the nervous system that has a direct effect on mortality risk, then a similar relationship between cognitive ability and mortality ought to be present whatever the quality of the later social environment. We found that among men with educational qualifications or men in the non-manual class at age 26, those of low cognitive ability had a lower rather than a higher rate of death compared with those of higher ability. The inverse relationship between ability and mortality was only present in those with no qualifications or who were in the manual social class. This suggests that ability may represent a rather different set of mechanisms than early damage to the nervous system. For example, high achieving men of lower mental ability may have individual characteristics such as attitudes and motivation, or sources of social or financial support, that promote healthy living as well as socioeconomic success.

In conclusion, this study has shown that low cognitive ability in childhood was related to a higher mortality rate in men up until midlife. Greater cumulative exposure to poor lifetime socioeconomic conditions was the most likely explanation of this observed relationship. There was less evidence that low cognitive ability was an important mediator of the effect of early physical and social disadvantage or reflected an effect of early physiological damage to the nervous system on later risk of mortality. The relationship between early cognitive ability and later mortality may be elucidated further by studying the causes of lifelong socioeconomic inequalities in health.
KEY MESSAGES

- Childhood IQ has been related to mortality in later life but previous studies have been unable to control for lifetime socioeconomic conditions and most studies have not included women.
- This prospective study of a representative British birth cohort shows that boys in the lowest quarter of cognitive ability at age 8 were twice as likely to die by age 54 years than boys in the highest quarter.
- There was no graded effect on mortality across the ability range in men.
- Lower educational achievement and more disadvantaged social circumstances accounted for at least half of this excess risk.
- Death rates in women were not related to early ability.

References