Introduction

The relationship between height and intelligence has long been subject to investigation [1–5]. Life-long levels for both height and intelligence emerge during childhood development. Although both height and IQ are highly heritable with demonstrable genetic associations [6, 7], distinct environmental contributions are also evident [8, 9]. Early studies considered both height and IQ to be outcomes of social disadvantage in [10]; however, the relationship between height and IQ in childhood is not fully explained by shared effects of social class or putative in utero programming [11]. Height in middle age predicts cognitive performance in old age [12] when not controlled for the direct influence of childhood IQ on later life cognition [13]. Hitherto, relationships between height and intelligence have focussed on height as a developmental outcome. However, with the advent of mass population ageing, a new cause of changes in height becomes of increasing importance: changes occurring secondary to degenerative diseases of old age [14]. There is a paucity of evidence on factors influencing change in height in old age [15, 16], and relationships to intelligence fall under the emerging discipline of cognitive epidemiology [17, 18] including, as noted above, height in middle age [5].

Longitudinal studies are necessary to investigate the relationship between height and intelligence in older adults because age differences in height derived from cross-sectional studies can be the result of differential secular influences among cohorts [19–21]. Using such a longitudinal design across seven decades, we studied the associations of IQ, height and life-time IQ change in a sample first assessed for IQ at age 11.

Methods

Sample

The sample comprised Lothian Birth Cohort 1921 (LBC1921) participants with unique IQ data collected at age 11 [18] who were seen at 79 and 87 years of age.

[22]. Full details of recruitment to the LBC1921 cohort are available [18]. Briefly, potential participants were identified from the local Community Health Index. Consent, in accordance with permission from the Multicentre Research Ethics Committee for Scotland, was sought from those who positively responded. Some participants were directly recruited following local publicity of the study. Participants (n = 550) were seen at age 79 and all those who were still alive and not terminally ill were invited again at age 87. All were community residents and those with a known diagnosis of dementia or scoring <24 on the Mini-Mental State Examination [23] at either visit were excluded from analyses.

**Measures**

Assessments were performed at 79 and 87 years. Standing height was measured to the nearest millimetre by a SECA stadiometer. Some participants attended in the morning and others in the afternoon: there was no systematic selection of which participants attended when during the day. On each occasion, participants completed the Moray House Test (MHT), a validated measure of general intelligence [18]. All but one participant fell in social classes I–IIIM. Also recorded were full-time education and main occupation: I (professional) to V (unskilled) divided into IIIN (non-manual) and IIIM (manual). All but one participant fell in social classes I–IIIM.

**Statistical analyses**

All analyses were performed using SPSS 14.0. After initial descriptive statistics, univariate analysis of variance was performed with height at age 87 years as the primary outcome. Sex was entered a priori as a factor in all analyses and height age 79 years entered a priori as a covariate. Significance was set at $P = 0.05$ and statistical trend at $P = 0.1$.

**Results**

One hundred and ninety-one (87 male, 104 female) participants were seen at both a mean age of 79.0 (SD 0.59) and 86.6 (SD 0.42) years. There was no significant attrition by sex ($P = 0.13$) or height ($P = 0.073$), but participants with lower age 79 MHT scores were less likely to be seen at age 87 ($P < 0.001$). Men had a mean of 11.3 (SD 2.9) years of full-time education and women a mean of 11.2 (SD 2.4) years. Nine (4.7%) participants were current smokers, 87 (45.5%) ex-smokers and 95 (49.7%) had never smoked. Mean age 79 MHT score was 62.7 ($n = 190$, SD 8.8) out of a maximum of 76 points: 177 participants had both MHT and height age 11 and MHT age 79 scores into the model produced a significant positive effect for MHT age 79 on height at age 87, of a similar magnitude to that of sex ($P < 0.001$, partial $\eta^2 = 0.094$) and a statistical trend for a negative effect for MHT age 11 ($P = 0.053$, partial $\eta^2 = 0.024$), indicating that loss of height between 79 and 87 years was greatest in those whose MHT scores had increased least between age 11 and 79 years. Adding MHT at age 87 into this model had no significant effect ($P = 0.93$, partial $\eta^2 < 0.001$). Similarly, no additional significant effects were found for weekly alcohol consumption ($P = 0.30$, partial $\eta^2 = 0.003$), education ($P = 0.99$, partial $\eta^2 < 0.001$) or social class ($P = 0.52$, partial $\eta^2 = 0.009$). There was a trend for current smokers to have lost more height ($P = 0.084$, partial $\eta^2 = 0.032$) with a significant interaction of smoking with sex ($P = 0.002$, partial $\eta^2 = 0.078$). Women who smoked lost a mean 4.5 cm more height than non-smokers; there was no significant difference between women non-smokers and ex-smokers. After adjusting for MHT age 79, height at age 79 did not predict MHT age 87 years ($P = 0.57$, partial $\eta^2 = 0.002$).

**Table 1.** Mean heights with standard deviations for LBC1921 participants measured at both 79 and 87 years

<table>
<thead>
<tr>
<th>Height (cm)</th>
<th>Men ($n = 71$)</th>
<th>Women ($n = 85$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age 79 years, mean (SD)</td>
<td>171.6 (7.0)</td>
<td>157.9 (5.9)</td>
</tr>
<tr>
<td>Age 87 years, mean (SD)</td>
<td>169.3 (6.9)</td>
<td>154.3 (5.9)</td>
</tr>
</tbody>
</table>

**Table 2.** Spearman correlation coefficients ($P$ value) for the 177 LBC1921 participants with complete MHT and height data

<table>
<thead>
<tr>
<th></th>
<th>Height age 79</th>
<th>MHT age 87</th>
<th>Height age 87</th>
</tr>
</thead>
<tbody>
<tr>
<td>MHT age 79</td>
<td>0.15 (0.050)</td>
<td>0.75 (&lt;0.001)</td>
<td>0.15 (0.042)</td>
</tr>
<tr>
<td>Height age 79</td>
<td>0.15 (0.044)</td>
<td>0.96 (&lt;0.001)</td>
<td>0.15 (0.040)</td>
</tr>
</tbody>
</table>

Height at either age 79 or age 87 years. There were significant correlations of small effect size between height and MHT scores at both age 79 and 87 years (Table 2).

The baseline analysis of variance model with height at age 87 years set as the dependent variable showed significant effects for height at age 79 (partial $\eta^2 = 0.768$) and sex (partial $\eta^2 = 0.095$). Adding MHT at age 11 did not significantly improve the model ($P = 0.62$, partial $\eta^2 = 0.002$). There was a statistical trend for MHT age 79 to improve the baseline model ($P = 0.086$, partial $\eta^2 = 0.017$). Entering both MHT age 11 and MHT age 79 scores into the model produced a significant positive effect for MHT age 79 on height at age 87, of a similar magnitude to that of sex ($P < 0.001$, partial $\eta^2 = 0.094$) and a statistical trend for a negative effect for MHT age 11 ($P = 0.053$, partial $\eta^2 = 0.024$), indicating that loss of height between 79 and 87 years was greatest in those whose MHT scores had increased least between age 11 and 79 years. Adding MHT at age 87 into this model had no significant effect ($P = 0.93$, partial $\eta^2 < 0.001$). Similarly, no additional significant effects were found for weekly alcohol consumption ($P = 0.30$, partial $\eta^2 = 0.003$), education ($P = 0.99$, partial $\eta^2 < 0.001$) or social class ($P = 0.52$, partial $\eta^2 = 0.009$). There was a trend for current smokers to have lost more height ($P = 0.084$, partial $\eta^2 = 0.032$) with a significant interaction of smoking with sex ($P = 0.002$, partial $\eta^2 = 0.078$). Women who smoked lost a mean 4.5 cm more height than non-smokers; there was no significant difference between women non-smokers and ex-smokers. After adjusting for MHT age 79, height at age 79 did not predict MHT age 87 years ($P = 0.57$, partial $\eta^2 = 0.002$).

**Discussion**

Both men and women lost height between 79 and 87 years, with women losing significantly more. Height and intelligence correlated at both age 79 and 87 years. While intelligence at
age 79 did not predict change in height over the 8-year period, loss in ability from age 11 indicated that those participants who had relatively cognitively declined by age 79 were more likely to lose height thereafter. This association was not explained by education, social class, alcohol consumption or smoking habit, though continuing to smoke was found to be deleterious for women. No significant effect was found for height at age 79 on the change in IQ from age 79 to 87 years. Absolute height and height loss in the LBC1921 was comparable to that of similarly aged participants in other studies [16, 19], with the effects of height on survival [24, 25] balanced by the greater age of the cohort.

Intelligence, per se, was not a good predictor of height loss; it was change in IQ between ages 11 and 79 years that significantly contributed to individual differences in height loss. Whilst height and intelligence correlate at both age 79 and 87, the trajectory of change in height after 79 years strongly relates to the trajectory of cognitive change before age 79. The cohort lacked data on childhood height, so testing the hypothesis that change in height had a similar lagged effect on intelligence was not possible.

It is possible that the effect of loss of IQ on subsequent loss of height is mediated by lifestyle factors (e.g., smoking cessation [26]). As controlling such factors did not affect the result, a more plausible explanation is that a common factor drives cognitive decline measured at 79 (and subsequently) and also loss in height. The fact that fluid cognitive abilities start to decline as early as age 25 [27] whilst bone loss starts around 40 [28] is consistent with this model. There are many plausible candidates for this pleiotropic process influencing both cognitive decline and bone loss. One such is renal function that, like cognition, starts to decline from 20 to 29 years of age and relates to childhood IQ [29, 30].

A major study limitation is the narrow age range of the cohort. Although this is a strength of the study design in controlling for confounding secular changes in height and intelligence, it limits the generalisability of the results: other cohorts may have different socio-environmental exposures. Similarly, the cohort is geographically restricted. Finally, survival to 87 years is uncommon; attrition from mortality and serious morbidity is high at this age. Against this, participants able to attend at age 87 were, ipso facto, in fairly good health, so relationships between height and intelligence are less likely to be confounded by significant disease.

Height and intelligence are recognised as important developmental biomarkers. In this study, we observe that they may also be important biomarkers of the degenerative stages of the human life course.

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**Key points**

- Height and intelligence continue to positively correlate with each other in old age.
- Relative cognitive decline before 79 years predicts height loss after 79 years.
- In terms of a ‘common cause’ model of ageing, changes in cognitive function precede changes in height.

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**Conflicts of interest**

None of the authors have any conflicts of interest.

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**References**


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