The association between height and birth order: evidence from 652 518 Swedish men

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ABSTRACT

Background Birth order is associated with outcomes such as birth weight and adult socioeconomic position (SEP), but little is known about the association with adult height. This potential birth order-height association is important because height predicts health, and because the association may help explain population-level height trends. We studied the birth order-height association and whether it varies by family characteristics or birth cohort.

Methods We used the Swedish Military Conscription Register to analyse adult height among 652 518 men born in 1951–1983 using fixed effects regression models that compare brothers and account for genetic and social factors shared by brothers. We stratified the analysis by family size, parental SEP and birth cohort. We compared models with and without birth weight and birth length controls.

Results Unadjusted analyses showed no differences between the first two birth orders but in the fixed effects regression, birth orders 2, 3 and 4 were associated with 0.4, 0.7 and 0.8 cm (p<0.001 for each) shorter height than birth order 1, respectively. The associations were similar in large and small and high-SEP and low-SEP families, but were attenuated in recent cohorts. Birth cohort characteristics did not explain these associations.

Conclusions Birth order is an important determinant of height. The height difference between birth orders 3 and 1 is larger than the population-level height increase achieved over 10 years. The attenuation of the effect over cohorts may reflect improvements in living standards. Decreases in family size may explain some of the secular-height increases in countries with decreasing fertility.

INTRODUCTION

Adult height is the result of a combination of genetic and environmental factors and an important predictor of adult cognitive ability, health and mortality. The environmental determinants of height include nutrition and early-life disease exposure. Birth order is also potentially important: increasing birth order has been shown to be associated with child outcomes such as decreased cognitive ability and decreased cancer risk, and it is hypothesised that early-life exposure is the mechanism linking birth order to these child outcomes. If childhood disease exposure is the mechanism behind these previously documented associations, and childhood-disease exposure influences adult height, then birth order should be associated also with adult height.

Existing research on the birth order-adult height association is thin and mixed, in particular for developed countries. Moreover, little is known about how family resources or environmental conditions modify the association, or whether the association is driven by prenatal or postnatal exposures.

METHODS

Data Data from the nationwide Swedish Military Service Conscription Register (MSCR) for the years 1969–2004 and male birth cohorts 1951–1984 were analysed. MSCR is described elsewhere; here, we summarise the main characteristics. Until 2007, the conscription examination preceded military service and was mandatory by law for all male Swedish citizens. Only those with a severe handicap or a chronic disease verified by a physician were exempted from conscription examination. The examinations were administered in six centres across Sweden. The majority attended the conscription examination at age 18. MSCR was linked to the Swedish Multi-Generation Register (MGR), the Medical Birth Register (MBR) and the
Swedish Population and Housing Censuses (SPHC) using unique personal identification numbers.

To keep the sample age-homogeneous, conscripts aged less than 17 or more than 20 years were excluded (2% of the conscripts). We also excluded multiple births (1.7%). Our methods are based on comparing brothers from the same families; therefore, individuals who did not have a brother in the data did not contribute to the estimation of the birth order-height association and were excluded. The resulting sample size is 652,518 persons.

Variables
Height (centimetres) was measured in the conscription examination using unified measurement protocols. Conscription age (continuous) and conscription centre were obtained from MSCR. Identifiers for the biological mother, which were used to identify brothers, were obtained from MGR. Birth order (1, 2, ..., 6+), age of the mother at birth (15–19, 20–24, ..., 45–49) and ultimate family size (1, 2, ..., 6+ children) were obtained from MGR. For a subset of the data, those born in 1973–1983, we had information on birth weight and birth length obtained from MBR. We also use information on occupation-based parental socioeconomic position (SEP), which is derived from SPHC and initially classified to a higher-level non-manual, middle-level non-manual or lower-level non-manual farmer, skilled worker, unskilled worker and other. We categorised families with mother or father in the first two categories as high-SEP families (48% of the conscripts) and others as low-SEP families.

STATISTICAL METHODS
We use nested linear regression models to study the birth order-height association. Model 1 estimates the non-adjusted birth order-height association. Model 2 is a multivariate model that controls for the observed confounders maternal age, conscription centre and age, birth year, parental SEP and family size, all of which may be associated with height (e.g., birth year because of secular trends in height, and conscription centre because of regional variations in height).

Model 3 is a fixed effects regression model in which an indicator is included for every set of brothers. This model estimates the coefficients from the between-brother variation and removes the confounding influence of all fixed observed and unobserved genetic and social characteristics that are shared by the brothers.30 For example, parental height or SEP to the extent that they do not vary between brothers, are controlled for. Non-shared factors are not controlled for by the fixed effects; these may include maternal age, conscription centre and age and birth year, and we added additional controls for these factors. We estimate model 3 for the full sample and for the subsamples stratified by family size (3 or less vs 4 or more children), parental SEP (high vs low) and birth cohort (1951–1972 vs 1973–1983 cohorts). We used the year 1973 as the cut-off because, for earlier cohorts, birth weight and length are unavailable.

In model 4, we additionally controlled for birth weight and birth length. This model is an important extension because model 3 does not control for intrauterine conditions which may vary systematically between brothers and may be part of the mechanism linking birth order to adult height. If the birth order-height association persists after controlling for birth weight and length, it is possible that the association is driven by postbirth factors rather than intrauterine conditions. Model 4 is estimated for the 1973–1983 birth cohorts because birth characteristics are not available for earlier cohorts.

We tested the sensitivity of our results by adding a control for paternal age, by excluding half-siblings, by including the young (<17 years) and old (20+) conscripts, by estimating the results separately for family sizes 2, 3, 4, 5 and 6+, by estimating a model in which parental SEP is time-varying and by using a random effects versus a fixed effects model.

All models adjust SEs for clustering of the brothers within the mother. All models are estimated using Stata/SE V11.2 (StataCorp, College Station, Texas, USA).

RESULTS
Descriptive analyses
The total sample size was 652,518 (table 1). Owing to the sample selection procedure in which those with no siblings in the data are excluded, the most common birth order was 2 (36%), followed by birth orders 1 (34%) and 3 (19%). Only 11% had a birth order 4 or higher. Average height was 179.2 cm and declined with birth order, being 179.4 cm for birth orders 1 and 2 and 177.6 cm for birth orders 6 and higher.

Average birth year was 1967. Those with a birth order 5 or higher had an average birth year below 1965. Maternal age increased with birth order, being 23.7 for birth order 1 and 35.0 for birth orders 6 and above. Mean age at conscription was 18.3 years, decreasing to 18.2 for birth orders 3 and above. Maternal age was 3.1 children and the mean number of brothers was 1.3; both increased with birth order. Family SEP was high for 48% of the conscripts and declined with birth order.

The sample size for the cohorts 1973–1983 for which birth characteristics are available is 139,963. The descriptive patterns for this subsample correspond to those of the full sample (table 1). Birth weight is lowest for the first-born (3450 g), and highest for birth order 6 or higher (3684 g). Birth length shows a scattered pattern being lowest for birth orders 1, 4 and 5 (50.6–50.7 cm) and highest for birth order 6+ (51.1 cm).

Regression analyses
Table 2 shows the regression results; figure 1 illustrates the key results. The descriptive model 1 showed that the first-born and second-born are equally tall, but for higher birth orders, height decreases: birth orders 3, 4, 5 and 6+ are associated with 0.2, 0.7, 1.1 and 1.8 cm (p<0.001 for each) decreased height.

Model 2 controls for observed confounders. With multivariate controls, all birth orders starting from 2 are associated with decreased height, for example, birth orders 2, 3 and 4 are associated with 0.4, 0.8 and 1.0 cm (p<0.001 for each) decrease. The control variable coefficients are mostly in the expected direction. Birth year, conscription age and parental SEP have positive coefficients, and family size has a negative coefficient. Maternal age is positively associated with height, but this result may be confounded by unobserved maternal characteristics as the association vanishes when such factors are controlled for (model 3).

Model 3 is the fixed effects regression model that controls for familial factors shared by the brothers and for the non-shared factors maternal age, birth year, conscription centre and age. The model estimated for the full sample confirms the inverse birth order-height association. For example, birth orders 2, 3 and 4 are associated with 0.4, 0.7 and 0.8 cm (p<0.001 for each) decreased height.
Model 3 stratified by family size and parental SEP shows that the inverse birth order-height association exists in both small and large families and in high-SEP and low-SEP families. Moreover, the differences in point estimates across these models are small, indicating that the birth order-height association is both qualitatively and quantitatively robust to family resources.

Model 3 stratified by birth cohort showed interesting differences: the birth order effects were particularly large for the 1951–1972 cohorts, but weaker in the 1972–1983 cohorts. Prior work on the birth order-height association,22 24–26 31–33 potentially because of the small sample sizes or lack of control for unobserved parental characteristics. Our results are based on a large population-based dataset, including more than half a million men, and on methods that control for observed and unobserved parental characteristics. The results suggest a strong inverse association between birth order and adult height: compared with the first-born, the second-born and the third-born are approximately 0.4 and 0.7 cm shorter, respectively. We argue that these results represent causal effects because our design removes the confounding influence of all genetic and social factors shared by the brothers, such as parental height, SEP and final family size, and because we were able to further control for several non-shared factors.

The birth order effect is sizeable. Within our study population, average height increased over the 1951–1983 birth cohorts from 178.6 to 180.3 cm, or 0.5 cm/10 birth cohorts. The height difference between birth orders 1 and 3, 0.7 cm, is larger than the 10-year population-level gain. The difference of 0.7 cm is also two times more than the effect of breastfeeding on adult stature.22

The question that emerges from these results is whether decreases in family size and average birth order could explain secular increases in population-level height. Prior work on height trends has mostly focused on improving living standards, which includes nutrition and disease exposure.1 Our results do not challenge these explanations but add a new layer of explanation. The findings suggest that a decrease in average family size from three to two would increase population-level height by 0.2 cm. Thus, a decreasing family size may be an important driver of population-level height particularly in countries experiencing rapid fertility declines. In Sweden, however, the average family size has been remarkably stable.33 In our sample, the fraction of first-born children stayed stable at 41% over the birth cohorts 1951–1983; the increase in the fraction of second-born children was small from 35% to 37%. These changes in the birth order distribution are so small that they cannot explain...
Table 2  Height in centimetres at age18 by birth order

<table>
<thead>
<tr>
<th>Birth order</th>
<th>Model 1: descriptive association (no controls)</th>
<th>Model 2: multivariate adjustment</th>
<th>Model 3: fixed effects model that includes a control variable for mother and estimates the coefficients from the variation between brothers. This model controls for all observed and unobserved fixed maternal factors (eg, maternal height and socioeconomic status to the extent it does not vary)</th>
<th>Model 4: fixed effects model with birth weight and length controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (reference)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>0.01</td>
<td>-0.44****</td>
<td>-0.26****</td>
<td>-0.32****</td>
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<tr>
<td>3</td>
<td>-0.18****</td>
<td>-0.78****</td>
<td>-0.66****</td>
<td>-0.61****</td>
</tr>
<tr>
<td>4</td>
<td>-0.67****</td>
<td>-1.03****</td>
<td>-0.84****</td>
<td>-0.85****</td>
</tr>
<tr>
<td>5</td>
<td>-1.11****</td>
<td>-1.12****</td>
<td>-0.82****</td>
<td>-0.86****</td>
</tr>
<tr>
<td>6+</td>
<td>-1.75****</td>
<td>-1.45****</td>
<td>-0.82****</td>
<td>-1.07****</td>
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<tr>
<td>Birth year</td>
<td>0.05****</td>
<td>0.13****</td>
<td>0.12****</td>
<td>0.14****</td>
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<td>Conscription</td>
<td>0.47****</td>
<td>0.50****</td>
<td>0.53****</td>
<td>0.46****</td>
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<td>Maternal age</td>
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<tr>
<td>15–19</td>
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<td>20–24</td>
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<td>25–29</td>
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<tr>
<td>Family size</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2 (reference)</td>
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<td></td>
</tr>
<tr>
<td>3</td>
<td>0.17****</td>
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<td></td>
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<tr>
<td>4</td>
<td>-0.17****</td>
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<tr>
<td>5</td>
<td>-0.35****</td>
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<tr>
<td>Parental SEP (reference higher-level non-manual)</td>
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<td>Middle-level non-manual</td>
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<td>Lower-level non-manual</td>
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<tr>
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<td>Birth length</td>
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Continued
<table>
<thead>
<tr>
<th>Model Estimation sample</th>
<th>Model 1: descriptive association (no controls)</th>
<th>Model 2: multivariate adjustment</th>
<th>Model 3: fixed effects model that includes a control variable for mother and estimates the coefficients from the variation between brothers. This model controls for all observed and unobserved fixed maternal factors (e.g., maternal height and socioeconomic status to the extent it does not vary)</th>
<th>Model 4: fixed effects model with birth weight and length controls</th>
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<tr>
<td>Constant</td>
<td>179.36****</td>
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<td>−111.17****</td>
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<td>Conscription centre controls</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Mother fixed effects controls</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>N</td>
<td>652518</td>
<td>652518</td>
<td>479578</td>
<td>457193</td>
</tr>
<tr>
<td>Number of families</td>
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<td>298053</td>
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</tr>
<tr>
<td>R²</td>
<td>0.003</td>
<td>0.024</td>
<td>0.737</td>
<td>0.768</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.003</td>
<td>0.024</td>
<td>0.517</td>
<td>0.533</td>
</tr>
</tbody>
</table>

Swedish Military Conscription Register, 1951–1983 male cohorts.
Model 1: Descriptive association between birth order and height.
Model 2: Add controls for observed parental and other characteristics.
Model 3: Add controls for maternal fixed effects.
Model 4: Add birth weight and birth length controls.
*P<0.10.
**P<0.05.
***P<0.01.
****P<0.001.
SEP, socioeconomic position.
Birth order is associated with birth and adult outcomes such as birth weight, birth length and adult health, but little is known about the association with adult height. The potential birth order-height association is important because height predicts health, and because the association may help explain population-level height trends.

CONCLUSION
Birth order is an important determinant of adult height so that later-born children are shorter. The effect is robust to controls for unobserved confounders that are shared by brothers, and also to observed unshared confounders such as birth year, birth weight, birth length and maternal age. The birth order effect is not modified by family resources but is weaker for later-born than for for earlier-born cohorts. The attenuation of the birth order effect over cohorts may reflect an improvement in living standards, including better nutrition and control of infectious diseases. Size at birth does not explain the effect of birth order on height. Decreases in family size may explain some of the population-level height increases in countries with decreasing fertility; in Sweden, however, family size has been stable and other factors are more likely to explain the height trends.
What this study adds

- We studied how birth order predicts height at age 18 among Swedish men by comparing siblings. Birth order was an important predictor of adult height so that height decreases with birth order. Decreases in the family size and, correspondingly, the average birth order may explain some of the population-level height increases. The birth order effect on height is decreasing over birth cohorts and is not explained by size at birth. The decline of the birth order effect may reflect improvements in living standards.

Contributors
MM designed the study. AJ contributed to the literature review. MM, KS, AJ, PT and FR wrote the paper.

Competing interests
None.

Provenance and peer review
Not commissioned; externally peer reviewed.

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