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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 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[1] and an important predictor of adult cognitive ability, health and mortality.[2–4] The environmental determinants of height include nutrition and early-life disease exposure.[3 5–11] Birth order is also potentially important: increasing birth order has been shown to be associated with child outcomes such as decreased cognitive ability[12] and decreased cancer risk,[13] and it is hypothesised that early-disease exposure is the mechanism linking birth order to these child outcomes. If childhood disease exposure indeed 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. Research on the association between birth order and birth weight and length documents a positive association,[14–21] suggesting a positive relationship also for adult height. Indeed, an analysis of Germans aged 20–70 found a positive height-birth order association.[22] However, an analysis of the British 1958 birth cohort[23] found no association and a study of British families in the 1930s[24] found an inverse height-birth order association. An analysis of the early growth patterns of 453 Brazilian children found that while first-borns had lower birth weight, at age 4 they were taller than later-borns.[25] Another study on 2249 Brazilian men born in 1982 suggests that this height advantage may persist until early adulthood.[26]

We analysed the association between birth order and height at age 18 among 652 518 Swedish men born in 1951–1983 using fixed effects regression models that compare siblings born to the same mother and remove the confounding influence of all genetic and environmental factors that are shared between brothers. The design does not remove the influence on non-shared factors which may include, for example, maternal age and birth year; therefore, we add additional controls for these factors. We stratified the analysis by family characteristics to study whether family resources modify the association, and by birth cohort to study the influence of environmental conditions. We analysed models with and without controls for birth weight and birth length to study whether the birth order-height association is driven by prenatal or postnatal conditions.

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[27]; 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),[28] the Medical Birth Register (MBR)[29] 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 (eg, 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 V.11.2 (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. Mean family size 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.

Table 1 Descriptive statistics by birth order, Swedish Military Conscription Register

	All birth orders	1	2	3	4	5	6+
Full sample							
Number of persons (total, %)	652518, 100	220563, 33.8	236527, 36.2	122008, 18.7	44142, 6.8	16378, 2.5	12900, 2.0
Height, cm (mean, SD)	179.2, 6.5	179.4, 6.5	179.4, 6.5	179.2, 6.5	178.7, 6.6	178.2, 6.5	177.6, 6.5
Birth year (mean, SD)	1967, 8.8	1965, 8.3	1968, 8.9	1968, 8.8	1966, 8.6	1965, 8.2	1963, 7.8
Maternal age (years (mean, SD))	27.2, 5.4	23.7, 4.0	27.1, 4.4	30.0, 4.6	32.1, 4.7	33.7, 4.7	35.9, 4.6
Conscription age (years (mean, SD))	18.3, 0.4	18.3, 0.5	18.3, 0.4	18.2, 0.4	18.2, 0.4	18.2, 0.4	18.2, 0.5
Number of brothers in the data (mean, SD)	1.3, 0.6	1.2, 0.5	1.2, 0.5	1.4, 0.6	1.6, 0.8	1.8, 0.9	2.0, 1.2
Family size (total number of children (mean, SD))	3.1, 1.3	2.6, 0.9	2.7, 0.9	3.4, 1.0	4.3, 1.2	5.2, 1.5	7.2, 2.2
Family SEP high (a) (%)	47.8	51.9	51.0	45.4	34.6	25.3	16.1
Cohorts for which birth weight and birth length are observed							
Number of persons (total, %)	139963, 100	51153, 36.5	59560, 42.6	21830, 15.6	5250, 3.8	1340, 1.0	830, 0.6
Height (cm (mean, SD))	179.8, 6.5	179.8, 6.5	179.8, 6.5	179.8, 6.5	179.5, 6.7	179.1, 6.6	179.0, 6.6
Birth year (mean, SD)	1978, 2.9	1976, 2.3	1978, 2.7	1979, 2.7	1979, 2.8	1979, 2.8	1978, 2.9
Maternal age (years (mean, SD))	27.0, 4.6	24.5, 3.9	27.4, 4.0	29.8, 4.0	31.7, 4.0	33.3, 4.1	35.4, 4.1
Conscription age (years (mean, SD))	18.2, 0.3	18.2, 0.4	18.2, 0.3	18.2, 0.3	18.2, 0.3	18.2, 0.3	18.2, 0.3
Number of brothers in the data (mean, SD)	1.1, 0.3	1.1, 0.3	1.1, 0.3	1.2, 0.4	1.3, 0.5	1.3, 0.6	1.5, 0.8
Family size (total number of children (mean, SD))	2.8, 1.0	2.5, 0.7	2.6, 0.7	3.3, 0.8	4.1, 1.1	5.0, 1.5	7.4, 2.7
Family SEP high (a) (% (mean, SD))	55.3	56.6	56.4	53.7	46.3	38.6	27.7
Birth weight (g (mean, SD))	3564, 554	3450, 526	3601, 550	3609, 590	3572, 624	3556, 635	3684, 623
Birth length (cm (mean, SD))	50.8, 2.3	50.7, 2.3	50.9, 2.3	50.9, 2.4	50.7, 2.5	50.6, 2.6	51.1, 2.5

Male birth cohorts 1951–1983.
SEP, socioeconomic position.

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 for the later 1973–1983 cohorts. For example, birth orders 2, 3 and 4 are associated with a 0.4, 0.8 and 1.0 cm shorter stature than birth order 1 among the 1951–1972 birth cohorts. For the 1973–1983 birth cohorts, the corresponding associations are 0.2, 0.4 and 0.5 cm, or approximately 50%, weaker ($p<0.05$ for each comparison). These results suggest that the birth order-height association decreases over birth cohorts.

Model 4 adds controls for birth characteristics to the fixed effects model 3. Birth order continues to be negatively associated with height after controlling for birth weight and length. A comparison of model 4 with model 3, which is estimated for the corresponding subpopulation (1973–1983 cohorts), suggests that birth characteristics do not explain the birth order-height association. For example, for birth orders 2 and 3, the coefficients are −0.25 ($p<0.001$) and −0.38 ($p<0.001$) in model 4, and approximately the same −0.20 ($p<0.01$) and −0.38 ($p<0.01$), for model 3.

Figure 1 illustrates the key results, showing the coefficients for model 3 for the 1951–1972 and 1973–1983 cohorts, as well as for model 4. The figure highlights the robustness of the inverse birth order-height association to birth characteristics and the attenuation of the association across cohorts.

The inverse birth order-height association obtained with model 3 was robust to the sensitivity checks described in the Methods section.

DISCUSSION

We used a large Swedish dataset to analyse the birth order-height association at age 18 for men in the 1951–1983 cohorts. Prior studies have provided mixed evidence 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 height in a study of a 1958 British birth cohort.[34]

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.[35] 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

Model	Model 1: descriptive association (no controls)	Model 2: multivariate adjustment	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)							Model 4: fixed effects model with birth weight and length controls
Estimation sample	Full sample: 1951–1983 cohorts	Full sample: 1951–1983 cohorts	Full sample: 1951–1983 cohorts	1951–1983 Cohorts, family size ≤3	1951–1983 Cohorts, family size ≥4	1951–1983 Cohorts, high parental SES	1951–1983 Cohorts, low parental SES	1951–1972 Cohorts	1973–1983 Cohorts	1973–1983 Cohorts
Birth order										
1 (reference)	0	0	0	0	0	0	0	0	0	0
2	0.01	−0.44****	−0.36****	−0.33****	−0.37****	−0.32****	−0.37****	−0.44****	−0.20***	−0.25****
3	−0.18****	−0.78****	−0.66****	−0.61****	−0.71****	−0.61****	−0.65****	−0.79****	−0.38***	−0.38***
4	−0.67****	−1.03****	−0.84****		−0.97****	−0.85****	−0.80****	−1.01****	−0.47*	−0.37*
5	−1.11****	−1.12****	−0.82****		−0.99****	−0.86****	−0.76****	−1.02****	−0.83**	−0.59*
6+	−1.75****	−1.45****	−0.82****		−1.07****	−0.96****	−0.78****	−1.11****	−0.91*	−0.64
Birth year		0.05****	0.13****	0.12****	0.14****	0.11****	0.15****	0.16****	0.11****	0.08****
Conscription age		0.47****	0.50****	0.53****	0.46****	0.52****	0.51****	0.50****	0.51****	0.51****
Maternal age										
15–19		−1.15****	0.01	0.04	0.02	−0.06	0.11	0.02	0.09	0.00
20–24		−0.54****	0.00	0.00	−0.01	−0.02	0.03	0.02	0.03	0.02
25–29 (reference)		0	0	0	0	0	0	0	0	0
30–34		0.37****	0.02	0.02	0.06	0.10	−0.02	−0.01	0.00	0.06
35–39		0.58****	−0.07	−0.06	−0.04	0.08	−0.15	−0.15	0.11	0.26
40–44		0.66****	−0.21	−0.18	−0.17	0.02	−0.34*	−0.33*	0.28	0.63
45–49		0.77***	−0.20	0.23	−0.35	0.48	−0.56	−0.46	0.01	0.69
Family size										
2 (reference)		0								
3		0.02								
4		−0.17***								
5		−0.35****								
6+		−0.39****								
Parental SEP (reference higher-level non-manual)										
Middle-level non-manual		−0.49****								
Lower-level non-manual		−0.85****								
Farmer		−0.61****								
Skilled worker		−1.19****								
Unskilled worker		−1.26****								
Other		−1.50****								
Birth weight										0.09
Birth length										0.67****

Continued

Table 2 Continued

Model	Model 1: descriptive association (no controls)	Model 2: multivariate adjustment	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)							Model 4: fixed effects model with birth weight and length controls
Estimation sample	Full sample: 1951–1983 cohorts	Full sample: 1951–1983 cohorts	Full sample: 1951–1983 cohorts	1951–1983 Cohorts, family size ≤3	1951–1983 Cohorts, family size ≥4	1951–1983 Cohorts, high parental SES	1951–1983 Cohorts, low parental SES	1951–1972 Cohorts	1973–1983 Cohorts	1973–1983 Cohorts
Constant	179.36****	77.38****	−88.35****	−73.21****	−111.17****	−39.51	−117.89****	−144.54****	−43.21	−21.80
Conscription centre controls		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mother fixed effects controls			Yes	Yes	Yes	Yes	Yes	Yes	Yes	YesS
N	652518	652518	652518	479578	172940	311884	340634	457193	195325	138081
Number of families	298053	298053	298053	232854	74146	148015	157035	236950	122642	67147
R^2	0.003	0.024	0.737	0.751	0.731	0.749	0.736	0.768	0.826	0.777
Adjusted R^2	0.003	0.024	0.517	0.516	0.529	0.523	0.510	0.519	0.533	0.565

Swedish Military Conscript 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.

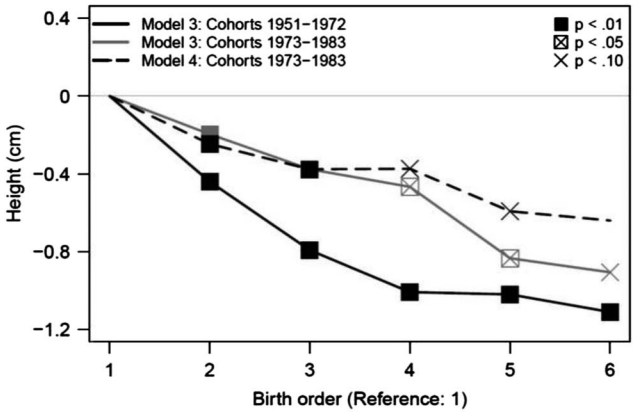

Figure 1 Height at age 18 by birth order (N=652 518), Swedish men born in 1951–1983. Data: Swedish Multi-Generation Register and Military Conscript Register. Height is measured in centimetres at conscription. The coefficients represent the difference with respect to the reference birth order 1. Model 3 is a fixed effects regression model that estimates the coefficients from the variation between brothers born to the same mother. Thus, the model controls for all social and genetic characteristics that are shared between brothers by including fixed effects (indicators) for the biological mother. The model also controls for non-shared factors through additional controls for maternal age, birth year, conscription age and conscription centre. Model 4 adds as additional controls birth weight and birth length. Comparison of model 3 results for the 1951–1972 and 1973–1983 birth cohorts illustrates the attenuation of the birth order effect over cohorts; comparison of models 3 and 4 for the cohorts 1973–1983 illustrates the robustness of the birth order effect net of birth weight and length.

the secular increase in height in Sweden, and other factors, possibly relating to living standards, must explain the recent trends in Sweden.

A decrease in height by birth order may reflect dilution of parental resources, increased postnatal exposure to infectious diseases or differentials in prenatal environment and growth. We found that the birth order-height association is similar in large and small families, as well as in high-SEP and low-SEP families. This suggests that family resources have limited potential in modifying the birth order-height association, and do not support the resource dilution mechanism as it appears unlikely that, in high-SEP Swedish families in the latter half of the 20th century, parental resources would be constrained enough to limit the children's growth. Controlling for birth weight and length did not influence the birth order-adult height association, suggesting that the postnatal environment is responsible for the association. It is, however, not known whether the ultimate height advantage of the first-borns represents a growth-suppression of the later-born or a particularly rapid catch-up growth of the earlier born.[25 26]

The birth order effect is markedly weaker for the 1973–1983 than for the 1951–1972 cohorts. Over these cohorts, the living standards and health improved rapidly in Sweden. For example, between 1951 and 1973, infant mortality decreased from 21.3 to 9.8/1000 live-births[36] and per capita gross domestic product at constant prices doubled.[37] The attenuation of the association may reflect improvements in the postnatal environment, including better nutrition and a decrease in exposure to infectious diseases.

It remains unclear what in the postnatal environment links birth order to adult height. Future studies should focus on unravelling the mechanism. Our findings on the inverse relationship between birth order and height closely resemble the inverse birth order-IQ association.[12] Furthermore, the attenuation of the birth order effect on height mirrors the attenuation of the IQ difference between twins and singletons over birth cohorts.[38] Joint analyses of physical characteristics such as height and IQ might shed further light on the mechanism through which birth order influences child outcomes.

Our unadjusted results suggested no difference in height between the first two birth orders. The reason why the unadjusted results between birth orders 1 and 2 were flat is likely to be due to confounding by birth year, as our additional analyses (available upon request) showed that the inverse association between these birth orders emerges already after the birth year was controlled for.

Our study has several distinct strengths compared with earlier research on height and birth order. First, the dataset is very large, allowing us to focus on the magnitude of the associations rather than on the statistical significance. Second, military conscription was mandatory, so the data are not prone to self-selection. Third, we used a statistical design which removes the confounding influences of genetic and social characteristics shared by brothers, such as parental height, parental SEP or ultimate family size. Fourth, our analysis is the first to study whether the birth order-height association varies by family characteristics, is influenced by time trends, or is explained by birth size.

This study has limitations. First, the sample included only men who had at least one brother; the associations may be different for women or for men who do not have brothers. Second, although we controlled for factors shared by the brothers and for several non-shared factors such as birth weight, birth length, parental age, birth year and conscription age, yet other non-shared factors such as non-shared genetic factors or parental health could influence our results. Further studies should consider the importance of these factors. Third, individuals with severe chronic diseases were exempt from conscription; our results apply to those who did not have such conditions.

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 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 is already known on this subject

- 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.

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.

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