BIRTH ORDER AND MORTALITY: A POPULATION-BASED COHORT STUDY

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IUSSP Conference 2013

Abstract

This study uses Swedish population register data to investigate the relationship between birth order and mortality risk in adulthood for Swedish cohorts born between 1938 and 1960. We investigate both all-cause mortality as well as cause-specific mortality attributable to neoplasms, cancers of the respiratory system, diseases of the circulatory system, and external causes. The follow-up period is from 1960 to 2007 for all-cause mortality, and from 1968 to 2007 for cause-specific mortality. The main analyses are conducted with discrete-time survival analysis using a within-family comparison, with age as the baseline hazard, and the estimates are adjusted for mother's age at the time of birth, and cohort effects. Focusing on sibships ranging in size from two to six, we find that mortality risk in adulthood increases with later birth order. The results show that this pattern is stronger for women than for men. This pattern is consistent for cause-specific mortality risk, but is particularly pronounced for mortality attributable to cancers of the respiratory system, and external causes. Further analyses where we adjust for adult socioeconomic status and adult educational attainment suggest that social pathways play an important role in the relationship between birth order and mortality risk in adulthood.

INTRODUCTION

The relationship between birth order and outcomes in adulthood has been the subject of investigation in demography, sociology, psychology, and economics for many years. The past decade has seen growing attention to the importance of early-life and childhood conditions on adult outcomes, ranging from educational attainment and other measures of socioeconomic status, through to health and disease. The evidence consistently demonstrates that social conditions within the family of origin have important consequences for later health outcomes (Gluckman et al., 2008). Birth order can be considered one of these factors, and it has been the subject of a great deal of interest. However, few studies have investigated the relationship between birth order and mortality risk in adulthood (O'Leary et al., 1996; Modin, 2002; Smith et al., 2009), and there is very little research addressing birth order and cause-specific mortality risk in adulthood. A number of studies have demonstrated a link between birth order and cancer development, though not mortality attributable to cancer (Hemminki and Mutanen, 2001; Richiardi et al., 2004; Altieri and Hemminki, 2007; Amirian et al., 2010; Bevier et al., 2011). The overall pattern is mixed, as the direction of the relationship between birth order and cancer development has been shown to vary according to the site of the cancer. This study is the first to address the relationship between birth order and all-cause mortality risk using a population dataset, and the first to use a sufficiently large database to address cause-specific mortality risk in adulthood. Furthermore, our primary analyses adopt a within-family comparison approach, meaning that we only compare siblings born to the same parents to one another, which has not been used previously to investigate the relationship between birth order and adult mortality. This approach allows us to rule out a wide range of potential confounding factors that may vary considerably between families, such as parental socioeconomic status, as well as other unobserved family-specific characteristics.

The potential mechanisms by which birth order is likely to be related to mortality risk in adulthood are summarized by several independent hypotheses, which are the confluence hypothesis (Zajonc and Markus, 1975; Zajonc, 1976), the resource dilution hypothesis (Blake, 1981), the family dynamics model (Sulloway, 1996; Sulloway and Zweigenhaft, 2010), and the hygiene hypothesis (Strachan, 1989). The former two are hypothesized to have an indirect impact on health, and the latter a direct impact. A further explanation is that younger siblings are introduced to developmentally inappropriate activities at a younger age than they otherwise would have been by older siblings, which may have both direct and indirect influences on adult health (Elliott, 1992; Harakeha et al., 2007). The confluence hypothesis takes account of the fact that children are a part of their own dynamically changing environment, and states that as family size grows with an increasing number of children, the environment becomes steadily less cognitively stimulating (Zajonc, 1976). This less stimulating environment is hypothesized to impact intellectual development (Zajonc, 1976). The resource dilution hypothesis states that the pool of parental resources, which includes material, cognitive, and interpersonal resources (Hertwig et al., 2002), available to each child decreases as the sibship size increases (Blake, 1981). First and early born children will spend early years having the exclusive or close to exclusive attention of parents while later borns are forced to compete with siblings over resources from birth. However, it should be considered that as parents age they typically accumulate resources, meaning that later born children will on average have parents with greater assets. It should be noted that an unequal distribution of resources does not imply parental favouritism; if parents distribute resources equally at any given sibship size, this will lead to a cumulatively unequal distribution amongst siblings over time (Hertwig et al., 2002).

A further extension to the hypothesized relationship between birth order and a range of outcomes comes from Sulloway's family dynamics model (Sulloway, 1996; Sulloway and Zweigenhaft, 2010). This model assumes the fundamental aspects of the resource dilution hypothesis, and extends this to argue that children tend to occupy different niches within the family environment, and that they also attempt to differentiate themselves from one another in order to avoid direct inter-sibling competition. It has been argued that these intrafamily dynamics tend to produce first borns whose values are more closely aligned with those of their parents, and later borns who are more rebellious and more likely to engage in risky activities (Sulloway, 1996; Zweigenhaft and Von Ammon, 2000; Sulloway and Zweigenhaft, 2010). We hypothesize that if there is support for this hypothesis, then mortality attributable to cancers of the respiratory system, and external causes in the form of accidents, suicide, and events of undetermined intent, should be positively associated with birth order. The hygiene hypothesis suggests that a larger sibship increases the likelihood of communicable diseases being introduced into the family, and younger siblings may be more susceptible to these diseases (Strachan, 1989; Holman et al., 2003).

The confluence hypothesis and resource hypothesis have been tested extensively in application to IQ and educational attainment, with mixed results. It has been argued that the results from studies finding a relationship between birth order and intelligence or educational attainment are methodological artifacts (Rodgers, 2001). Termed the admixture hypothesis, this theory states that these results stem from drawing inferences about within-family patterns from between-family data, and that these associations disappear after adjusting for between-family heterogeneity (Rodgers, 2001). The results from studies using within-family data are also mixed (Rodgers et al., 2000; Bjerkedal et al., 2007). Although this dispute remains unresolved, recent research using high quality, population-based, longitudinal Nordic administrative register data suggests that within-family birth order effects do exist (Black et al., 2005; Bjerkedal et al., 2007; Kristensen and Bjerkedal, 2007; Black et al., 2011). These studies indicate that later born children perform worse on measures of both IQ and educational attainment. Given the strong and unambiguous evidence for the relationship between IQ, educational attainment, and socioeconomic status on health outcomes (Mackenbach et al., 1997; Marmot, 2004; Torssander and Erikson, 2010; Lager and Torssander, 2012), we would therefore expect that mortality risk should increase with a higher birth order, and that this should be mediated through social pathways in a way that is at least partially observable by using measures of socioeconomic status and educational attainment. We hypothesize that this pattern should be clearest for cause-specific mortality associated with lifestyle and environmental conditions, such as cancers of the respiratory system, and mortality attributable to external causes. We will be able to test this hypothesis by adjusting for socioeconomic status and educational attainment in adulthood. However, despite this body of research pointing towards later born children having worse outcomes, it is well-documented that later born siblings within a sibship tend to have a greater birth weight than the first born (Magnus et al., 1985), and birth weight has been found to be positively associated with a range of different outcomes, from infant and child health status, through to educational attainment and socioeconomic positioning in adulthood (Boardman et al., 2002; Behrman and Rosenzweig, 2004).

Previous research on the relationship between birth order and mortality risk in adulthood has been mixed, finding that higher birth order children have a greater mortality risk (Modin, 2002), as well as null results (O'Leary et al., 1996; Smith et al., 2009). However, these studies have varied in quality, and in the degree to which they have focused on birth order as a key variable. Using the Utah Population Database, Smith *et al.* (2009) investigated how a range of early life factors were associated with mortality risk in adulthood. The impact of birth order on adult mortality risk was not the main focus of the study. Operationalizing birth order as a binary variable indicating whether the individual was first born or not, this study found no statistically significant associations between birth order and adult mortality risk for either men or women. The study by O'Leary *et al.* (1996) found little relationship between birth order and mortality risk, but used a small (n=1,162), and non-representative sample, with insufficient statistical power to detect any patterns. Finally, a study using Swedish data (n=14,192) from the Uppsala Birth Cohort Study found that birth order was associated with an increased risk of all-cause mortality for both men and women aged 20-54, and for men aged 55-80 (Modin, 2002). No statistically significant patterns were found after adjusting for the socioeconomic status of the ego in adulthood. However, sibship size was not included in the models. Because high birth orders are directly correlated with large family sizes this leaves open the potential for confounding if sibship size is not adjusted for. Furthermore, none of these studies used the within-family comparison approach adopted in this study, leaving open the possibility that spurious associations could be observed even after adjusting for important variables such as sibship size and parental socioeconomic status. Nevertheless, given past research findings on the importance of birth order, we anticipate that all-cause mortality risk will increase with a rising birth order, and we also anticipate that we will observe the same pattern for cause-specific mortality risk.

DATA AND METHODS

Data. In this study we use Swedish population register data to investigate the relationship between birth order and mortality risk. We conduct separate analyses for men and women. The individuals under analysis consist of cohorts born between 1938 and 1960. The year 1938 is practically the earliest point for which we can obtain reliable information on parent-child linkages using the multi-generational Swedish registers. Here we defined a sibship as a group of siblings with the same biological mother-father pairing. We do not restrict the calculation of sibship size or set order to these cohorts, but instead use the full population registers to generate these measures. We link the population register to the Swedish mortality register, which allows for a follow-up from 1960 to 2007 for all-cause mortality, and from 1968 to 2007 for cause-specific mortality. This means that we are able to follow the oldest individuals in our sample until age 69, and the youngest individuals until age 47. Aside from all-cause mortality, we address mortality attributable to the following causes: neoplasms; cancers of the respiratory system; diseases of the circulatory system; and, external causes, which includes accidents, suicides, and events of undetermined intent. These cause-specific outcome variables were coded using the WHO's International Classification of Diseases (ICD), versions 8, 9, and 10, taking into account when the transition between these versions took place in Sweden (Janssen and Kunst, 2004). Because we also study cancers of the respiratory system as a specific outcome, we remove this category of cancers from the larger category of neoplasms for the analyses presented below.

Statistical Analyses. We conducted both within-family analyses and between-family analyses to estimate the relationship between birth order and mortality risk. The within-family analyses, meaning a within-sibship comparison, used fixed-effect discrete-time survival analysis, in the form of logistic regressions. These are the main results presented in the results section below. The between-family analyses used piece-wise exponential survival models. These results can be seen in the supporting information section of this paper. The baseline hazard is age. The piece-wise exponential survival models have been estimated using cluster-adjusted standard errors to account for any potential intragroup correlation (Primo et al., 2007). The clusters in this study are sibships. The following comments concern the within-family and between-family analyses equally. Because the earliest point at which we have data in the mortality register is 1960, we have left censoring in our models. For the sake of consistency, all individuals enter the analysis for all-cause mortality at age 22, as this is the youngest age at which we have mortality data for for the earliest cohort, born in 1938. The l_{20} for the 1960 cohort was 0.951 for women and 0.935 for men. For the cause-specific analyses, this left censoring is more pronounced. Again, for the sake of consistency, all individuals enter the analysis for cause-specific mortality at age 31, as this is the youngest age at which we have mortality data for for the earliest cohort, born in 1938. While we are unlikely to lose a great deal of information on mortality attributable to diseases of the circulatory system and different cancers, we undoubtedly fail to fully capture all of the deaths attributable to external causes in the form of accidents and suicides. Finally, we right censor for the first out-migration of any individual from Sweden. Table S1 shows the study size, and number of deaths, for men and women. Besides modeling all-cause mortality we also estimate the cause-specific mortality of other causes of death. As we can no longer assume independent right-censoring as our causes of death are dependent upon each other we can no longer estimate the marginal effect (the effect of our covariates on a specific cause of death in the absence of other causes of deaths). We can, however, still examine the extent to which birth order mediates mortality for different causes of death.

Because the within-sibship comparison fixed effect approach requires within-family variation, we are necessarily only able to examine families where at least one of the siblings have died. This means that the frequency of the outcome is very high in the within-family logistic regression models. The procedure by which relative risks and odds ratios are calculated means that when the incidence of an outcome is greater than 10%, as it is in this study, any given odds ratio will be elevated relative to the corresponding relative risk (Sackett et al., 1996; Zhang and Kai, 1998). For example, when the frequency of the outcome is 50%, the odds ratio can be more than 150% higher than the corresponding relative risk (Schmidt and Kohlmann, 2008). Odds ratios are not problematic in and of themselves, but it is important that they are interpreted in terms of a relative increase or decrease in the odds of an outcome, rather than a relative increase or decrease in the probability of an outcome. This means that the size of the estimated coefficients for the within-family discrete-time survival analyses will be larger than those estimated for the between-family piece-wise exponential survival analyses even if the underlying estimated hazard is the same.

Covariates in Survival Analyses. Our estimates for the relationship between birth order and mortality risk are adjusted for a number of different variables, which are theoretically confounders for this relationship. Correlation matrices for these variables can be seen in Table S2. In the within-family analyses, we adjust for the age of the ego's mother in the birth year of the ego, and cohort. Theoretically, all other intrafamily characteristics, including sibship size, geographical location, and parental socioeconomic status, are inherently accounted for by conducting a within-family comparison. In the between-family analyses we adjust for age of the ego's mother in the birth year of the ego, cohort, and the sibling set size of which the ego is a part. Our within-family comparisons allows us to focus exclusively on the importance of birth order for mortality risk, in this case precluding the concerns of the admixture hypothesis, which states that between-family comparisons can lead to the observation of spurious associations due to between-family differences (Rodgers et al., 2000). In the between-family analyses we adjust for sibship size as this is likely to be associated with parental socioeconomic status. Furthermore, the hygiene hypothesis states that health outcomes could be related to the overall number of siblings due to the relationship between family size and potential exposure to different diseases (Strachan, 1989).

We choose to adjust for cohort-effects rather than period-effects for two reasons. The first is the burgeoning evidence about the importance of in utero and early-life conditions, which vary substantially by cohorts over time, on longevity (Bengtsson and Broström, 2009; Bengtsson and Mineau, 2009; Gluckman et al., 2008). Furthermore, previous research has indicated that cohort-effects play a more significant role in mortality trends than period-effects (Richards et al., 2006). In addition, due to changing fertility preferences, cohort-specific fertility patterns are also related to family size (Andersson et al., 2009; Andersson and Kolk, 2011), which is obviously related to birth order. For this reason, we include a variable for birth year to account for these underlying patterns.

We also implicitly adjust for period effects by adjusting for both cohort and age. We adjust for maternal age at birth because evidence suggests that this is an important factor influencing a wide range of adult health outcomes (Myrskylä and Fenelon, 2012). We do not include only-children in our analyses. We also do not include any sibling set that includes multiple births as the meaning of birth order is different in these families. The full results in the supplementary information section of this paper show the association between birth order and mortality for children born in sibling sets ranging in size from two to six, as well as results from sibship size-specific analyses for both the within-family and between-family analyses.

Because previous research has shown that birth order influences education and IQ (Black et al., 2005; Bjerkedal et al., 2007; Kristensen and Bjerkedal, 2007; Black et al., 2011), we also conduct additional analyses to estimate the degree to which the relationship between birth order and mortality risk is mediated by socioeconomic class and educational attainment, measured in adulthood. To do this, we estimated models where we adjust for a common measure of socioeconomic status, the Erikson, Goldthorpe and Portocarero occupational class scheme (EGP) (Erikson and Goldthorpe, 1992), measured between ages 30 and 40 using information on occupation from the Swedish censuses in 1960, 1970, 1980, and 1990. These analyses are limited to individuals aged 41 years or older. The EGP variable used in this study is divided into the following categories: upper service class, including self-employed professionals (EGP=I); lower service class (EGP=II); routine non-manual (EGP=III); self-employed non-professionals, farmers, and fishermen (EGP=IV); skilled and unskilled workers (EGP=VI-VII); and, unknown/other. Again, separate analyses were conducted for men and women. In further models we also adjust for educational attainment using information from the Swedish educational register, which has been updated continuously since 1987, using information on the highest achieved educational level starting from age 51. These analyses also control for socioeconomic status in the form of the EGP class schema.

RESULTS

The main analyses presented in this paper use discrete-time survival analyses in the form of logistic regressions, specifying fixed effects at the sibship level, to perform a within-family comparison, meaning that we only compare siblings born to the same biological mother and father to one another. The results from the within-family analyses for all-cause mortality for men and women can be seen in Figure 1 and Table S3 for men, and Figure 2 and Table S4 for women. These results show that there is a positive and statistically significant relationship between birth order and mortality risk, with the odds of mortality rising steadily with an increasing birth order for both men and women, but that this relationship is considerably stronger for women relative to men. To test the extent to which the relationship between birth order and mortality is mediated by social pathways, additional analyses were conducted where we adjusted for socioeconomic status in adulthood, and both socioeconomic status and educational attainment in adulthood.

The results for all-cause mortality from these additional analyses can be seen in Figure 1 and Table S3 for men, and Figure 2 and Table S4 for women. These additional analyses on men and women aged 41 or older show that the association between birth order and mortality risk was strongly mediated by socioeconomic status. Further analyses of men and women aged 51 or older, also shown in Tables S3 and S4 show that the inclusion of an additional mediating variable for educational attainment in adulthood diminished the assocation of birth with all-cause mortality to a greater extent than the inclusion of the adult socioeconomic status measure for women, but not for men. The results of these within-family analyses, which only compare siblings within the same sibship group to one another, show that the relationship between birth order and mortality risk exists even after accounting for parental socioeconomic status and other unobserved internal family characteristics. Given that these models also adjust for mother's age at the time of birth, as well as birth cohort, it is probable that these results show the causal effect that birth order has on mortality.

The cause-specific patterns for the within-family analyses can be seen in Figure 3 and Table S8 for men, and Figure 4 and Table S8 for women. For men, the odds of mortality attributable to diseases of the circulatory system appear to not vary substantially by birth order, while the odds of mortality attributable to neoplasms, and cancers of the respiratory system are flat until birth orders five and six, at which point they increase substantially. The strongest pattern of association for men is clearly mortality attributable to external causes, which includes accidents, suicides, and events of undetermined intent. The odds of mortality attributable to external causes rises steadily with an increasing birth order. The results for the analyses for women were substantially larger than those observed for men. While the odds of mortality attributable to diseases of the circulatory system were slightly negative for later born siblings, the odds of mortality attributable to neoplasms, cancers of the respiratory system, and external causes increase very substantially with an increasing birth order.

We also conducted further analyses using a between-family comparison approach, using piece-wise exponential survival models. This between-family analysis approach looks at the association between birth order and mortality across all families, rather than conducting a within-family comparison of siblings born to the same mother and father. The all-cause mortality results from these between-family analyses can be seen in Table S5 for men and Table S6 for women, and cause-specific mortality results from the between-family analyses for men and women can be seen in Table S9. Figure S1 shows how the hazard estimates from the between-family piece-wise exponential survival models translate into differences in life expectancy. As can be seen, based upon the between-family analyses, these results predict that second born children have a life expectancy half a year shorter than first borns, third born children a life expectancy a full year shorter than first borns, and sixth born children a life expectancy a year and a half shorter than first borns.

While the analyses presented here pool individuals in sibship sizes ranging from two to six, we also conducted analyses that were sibship size-specific. These results can be seen in Table S7. It should be noted that the overall pattern of increasing mortality risk by birth order is consistent for the sibship size-specific results in both the within-family and between-family analyses. A substantially elevated mortality risk for higher birth orders remains even in families with 2 or 3 children, which are the most common family sizes in Sweden. We also investigated the relationship between birth order and mortality risk for sibship sizes greater than six. The results were consistent with those presented here, with an increasing relative risk of mortality by increasing birth order. However, the patterns observed were more volatile due to the relatively small number of sibships with more than six children.

We also conducted robustness checks where we compared the analyses that control for adult characteristics and restrict the data by starting from older ages to analyses that do not control for adult characteristics and start from the same older age. These analyses use the within-family comparison approach, and the results can be seen in Table S10. As can be seen, the models where we look at the relationship between birth order and mortality without adjusting for adult socioeconomic status and education starting at age 51 are fully consistent with those presented for the full range of cohorts. Finally, we also conducted robustness checks to verify that the main results presented above were not skewed by the differences in the follow-up time for different cohorts. For these analyses we used piece-wise exponential models, meaning a between-family comparison, and restricted the follow-up period to age 65. The reason for using the between-family comparison approach was that because the within-family approach requires that at least two children be alive in each sibship group, and since they must have an opportunity to live to the age of 65, this requires that we focus only upon cohorts born from 1938 to 1942. This means that larger sibship groups are particularly unusual, as they require that multiple siblings are born within a limited time period, which introduces endogeneity problems. The results of these robustness checks can be seen in Table S11. As can be seen, the results are still fully consistent with the main results. We also conducted analyses where we restricted the follow-up period to age 60, and age 55, with the analyses conducted on the 1938-1947 and 1938-1952 cohorts respectively. These results are also shown in Table S11. As can be seen, these results are also fully consistent with the results presented throughout this study.

Discussion

The results presented above demonstrate that birth order matters for mortality risk in adulthood, for both men and women, and the results from the within-family comparison give strong ground for believing that this relationship is causal. This is true for all-cause mortality risk, as well as several cause-specific patterns, and is particularly pronounced for mortality attributable to external causes for men, and for mortality attributable to neoplasms, cancers of the respiratory system, and external causes for women. The within-family comparison results show that the relationship between birth order and adult mortality is substantially larger for women than for men. While the reason for this is not clear, previous research has shown that women are much more closely involved in kin work, such as maintaining kinship ties (Young and Willmott, 1957; Hagestad, 1986; di Leonardo, 1987; Rossi and Rossi, 1990). It may be that these closer ties to kin mean that women are more affected by internal family dynamics than are men. The overall pattern of these all-cause mortality results are consistent with those reported by Modin (2002). A larger volume of research has shown that sibship size is consistently related to mortality risk both in childhood as well as adulthood, but few studies have had a sufficiently large database to investigate the impact of birth order itself on mortality risk, and particularly not to conduct a within-family analysis. Previous research in epidemiology has identified the relationship between birth order and the development of tumours at various sites (Hemminki and Mutanen, 2001; Richiardi et al., 2004), including lung cancer (Bevier et al., 2011), but this is the first time that this has been demonstrated for mortality risk. A consequence of the increasing relative risk of mortality by rising birth order is that the calendar death dates of siblings will be more densely concentrated than they would be in the absence of this relationship.

By using a within-family comparison approach, only comparing siblings born to the same biological mother-father pairing, and adjusting for all known confounders, it is probable that the results presented in this study reflect the causal effect of birth order on adult mortality (Pearl, 2009). This applies to both the all-cause and cause-specific mortality results. However, while the results from the within-family analyses presented support the conclusion that the relationship between birth order and mortality is causal, these results do not allow us to distinguish between the different hypotheses by which it has been proposed that this relationship operates. These include the confluence hypothesis (Zajonc, 1976), the resource dilution hypothesis (Blake, 1981), the hygiene hypothesis (Strachan, 1989), as well as the family dynamics model (Sulloway, 1996). Each of these hypotheses predicts that later born siblings have poorer outcomes for IQ and educational attainment, meaning that the observed association between birth order and mortality in adulthood is predicted to be transmitted through social pathways such as adult socioeconomic status. Additional models where we adjust for socioeconomic status and educational attainment show that the association between birth order and mortality risk is substantially attenuated by adjusting for these mediating factors. These results suggests that the chain of social risk by which birth order is related to mortality in adulthood flows to a strong extent through adult socioeconomic positioning, which is consistent with both the literature linking birth order to IQ and educational attainment, as well as the literature demonstrating the relationship between socioeconomic status, education, and health.

Although this study has primarily focused upon the social pathways by which birth order is linked to outcomes in adulthood, it is possible that there are also biological pathways, explained by prenatal or gestational factors (Gualtieri and Hicks, 1985). However, the evidence for biological pathways predicting a negative relationship between birth order and health is sparse. One example of research that strongly supports the hypothesis that it is the social conditions within a family that link birth order to observed differences in IQ and educational attainment has shown that the IQ of second borns in families where the first child died in infancy, and the IQ of third borns where the first two children died in infancy, is equal to that of first borns in families where no infant mortality has occurred (Kristensen and Bjerkedal, 2007). The attenuated association between birth order and mortality observed in this study after adjusting for adult socioeconomic status and educational attainment supports that conclusion, but does not enable us to discriminate between the different hypotheses in terms of their explanatory power. However, the results from the cause-specific mortality analyses, where mortality attributable to external causes rises sharply by birth order for men and women, and mortality attributable to cancers of respiratory system rises sharply by birth order for women, suggests that there may be support for the family dynamics model. This model argues that children tend to occupy different niches within the family environment, and that these intrafamily dynamics tend to produce first borns whose values are more closely aligned with those of their parents, and later borns who are more rebellious and more likely to engage in risky activities (Sulloway, 1996; Zweigenhaft and Von Ammon, 2000; Sulloway and Zweigenhaft, 2010). These predictions would be consistent with the patterns observed for mortality attributable to cancers of the respiratory system, and external causes.

A potential alternative explanation for the pattern observed for mortality attributable to cancers of the respiratory system is sibling influence. Research in the fields of social psychology and social networks has consistently and convincingly demonstrated the importance of alters, including parents and siblings, for shaping health behaviours (Christakis and Fowler, 2008; Rosenquist et al., 2010; Leonardi-Bee et al., 2011). Studies more particularly focused on sibling influence show that younger siblings - those with a higher birth order - are more likely to begin smoking if an older sibling already smokes, but this relationship is not reversed (Harakeha et al., 2007). There are also indications that because of this pattern of smoking uptake by younger siblings, they are likely to begin smoking at younger ages (Bard and Rodgers, 2003). Smoking initiation at younger ages is associated with a greater daily cigarette consumption, and a stronger tendency towards smoking continuation, particularly when smoking initiation begins before the age of 16 (Chen and Millar, 1998; Khuder et al., 1999). This would suggest that individuals with a higher birth order should be more likely to smoke in the long term, with obvious implications for the future health conditions of that individual's respiratory system, regardless of the socioeconomic trajectory that that individual follows over the life course. While smoking behaviour would also impact the health of the circulatory system, previous research indicates that younger siblings demonstrate both a higher rate of alcoholism, and a greater proclivity to initiate developmentally inappropriate activities at younger ages (Blane and Barry, 1973; Rodgers and Rowe, 1988). Another partial alternative explanation for increasing mortality risk by birth order is elevated mortality risk after the death of a sibling (Rostila et al., 2012).

While this study has many strengths, there are certain factors that are difficult to account for when using register data. In study we have looked at birth order within sibships, where a sibship is defined as a group of children born from the same biological mother-father pairing. Our research excludes half-brothers or half-sisters who may, practically speaking, be part of a sibship. This can be seen as both an advantage and a disadvantage. Indeed, a general shortcoming is that we are not able to observe which children are in the household, which is an important factor when considering the potential importance of a shared pool of resources and how this might be related to later health outcomes. A further factor that we do not adjust our models for is the potential role of the time interval between the births of siblings. However, birth intervals are strongly endogenous, and will be strongly related to the socioeconomic status of the parents, meaning that the extent to which the results would further clarify the underlying processes would necessarily be limited. Furthermore, it is not possible to overcome this endogeneity by using a within-family comparison, because the values for the interaction between birth order and birth intervals are constant within a sibship group. Overall the results of this study demonstrate how social conditions within the family of origin can influence long-term health outcomes in a substantial manner.

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FIGURES

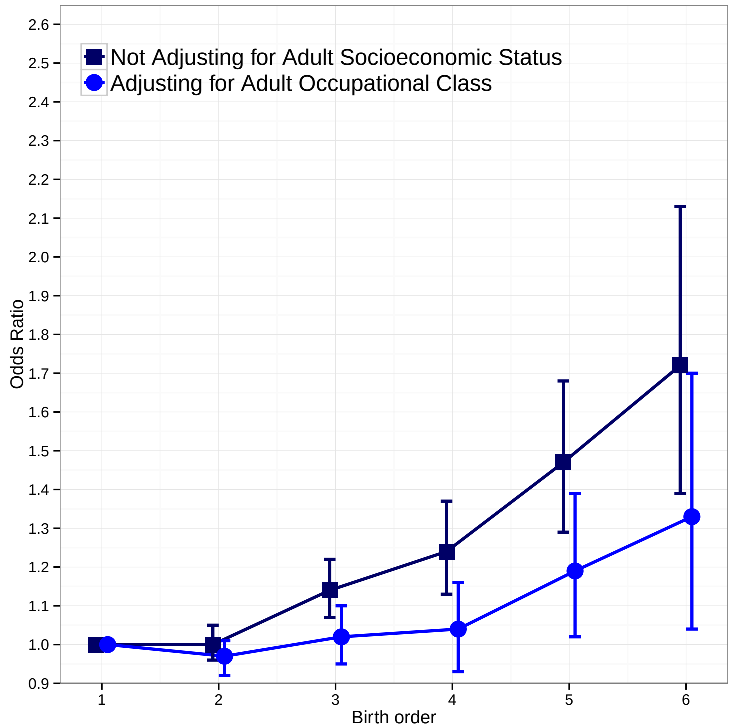

FIGURE 1. Within-family discrete-time survival analyses: All-cause mortality by birth order, Swedish men born 1938-1960. Error bars are 95% confidence intervals.

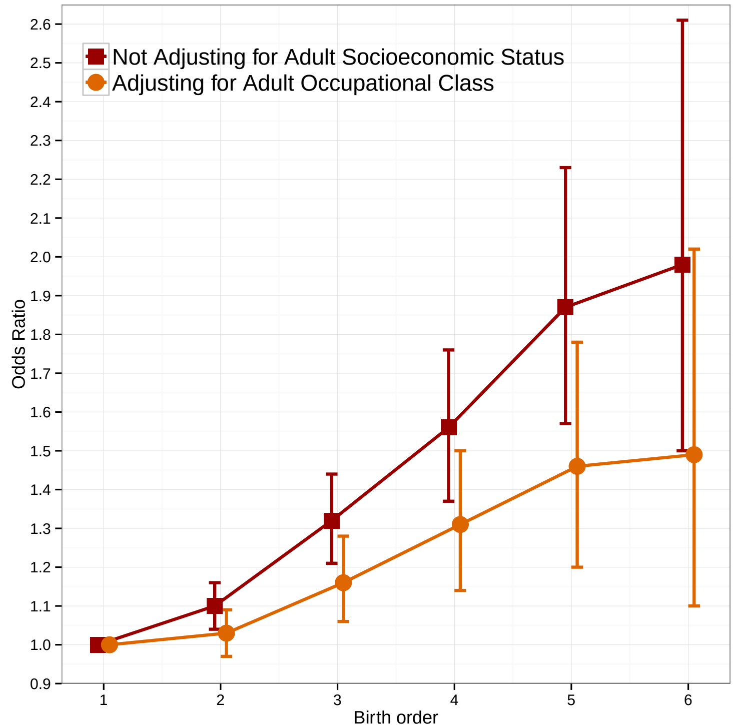

FIGURE 2. Within-family discrete-time survival analyses: All-cause mortality by birth order, Swedish women born 1938-1960. Error bars are 95% confidence intervals.

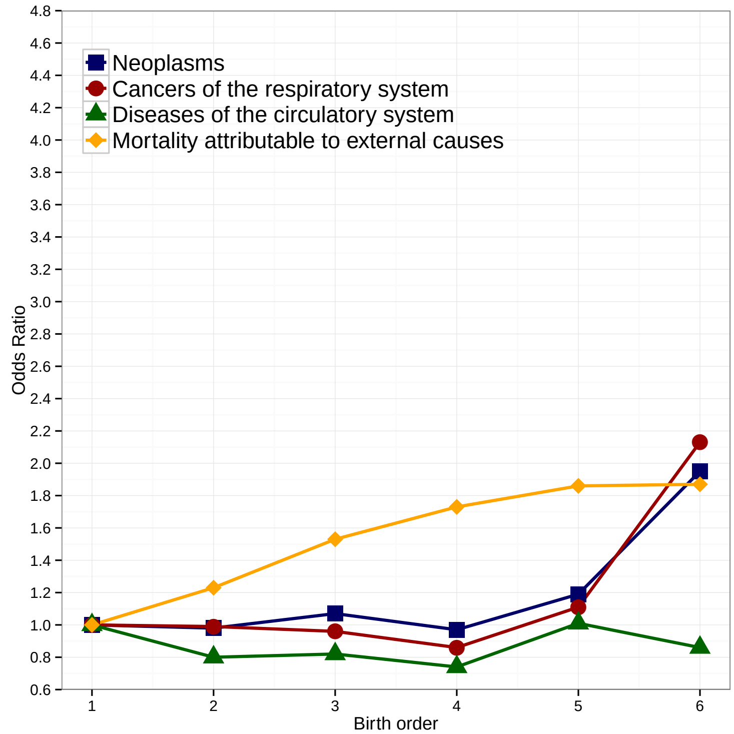

FIGURE 3. Within-family discrete-time survival analyses: cause-specific mortality by birth order, Swedish men born 1938-1960

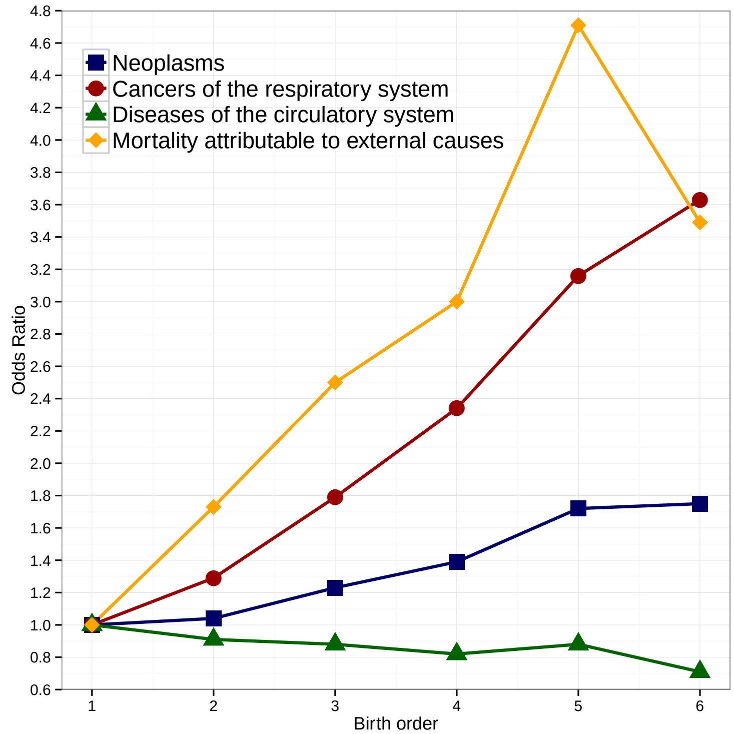

FIGURE 4. Within-family discrete-time survival analyses: cause-specific mortality by birth order, Swedish women born 1938-1960

Supporting Information

TABLE S1. Description of study population by set order, set size, birth year, study size, and causes of death.

Set Order by Birth Year

Set Order	Birth Year 1938-1945	1946-1950	1951-1955	1956-1960	Total
1	233,142	155,409	147,420	155,517	691,488
2	189,285	163,070	150,689	155,368	658,412
3	63,766	66,370	64,579	65,579	260,294
4	18,676	24,083	23,618	24,494	90,871
5	4,474	8,282	8,408	8,355	29,519
6	641	2,214	2,484	2,465	7,804
Total	509,984	419,428	397,198	411,778	1,738,388

Set Size by Birth Year

Set Size	Birth Year 1938-1945	1946-1950	1951-1955	1956-1960	Total
2	218,224	181,607	169,982	180,049	749,862
3	150,876	126,946	123,730	134,127	535,679
4	80,870	65,219	62,104	62,060	270,253
5	40,028	30,600	28,101	24,668	123,397
6	19,986	15,056	13,281	10,874	59,197
Total	509,984	419,428	397,198	411,778	1,738,388

Set Order by Set Size

Set Order	Set Size 2	3	4	5	6	Total
1	391,014	195,385	71,711	24,305	9,073	691,488
2	358,848	188,444	74,409	26,512	10,199	658,412
3		151,850	69,593	27,661	11,190	260,294
4			54,540	25,227	11,104	90,871
5				19,692	9,827	29,519
6					7,804	7,804
Total	749,862	535,679	270,253	123,397	59,197	1,738,388

Study Size

Cause of Death	Men N	Men Deaths	Women N	Women Deaths
All-cause mortality	870,510	56,282	830,952	34,348
Diseases of the circulatory system		14,947		5,129
Neoplasms		16,006		18,060
Cancers of the respiratory system		2,977		3,145
External causes		10,285		3,602

Source: Swedish administrative register data, compiled by the authors.

TABLE S2. Descriptive Statistics: Correlation Matrices

Cohorts 1938-1947

Men		Dead at Sixty	Set Order	Set Size	Mother's Age	Birth Year
	Dead at Sixty	1.0000				
	Set Order	0.0017	1.0000			
	Set Size	0.0091	0.4709	1.0000		
	Mother's Age	-0.0216	0.4601	-0.0519	1.0000	
	Birth Year	0.0133	0.1280	-0.0306	0.0255	1.0000
Women		**Dead at Sixty**	**Set Order**	**Set Size**	**Mother's Age**	**Birth Year**
	Dead at Sixty	1.0000				
	Set Order	0.0010	1.0000			
	Set Size	0.0009	0.4739	1.0000		
	Mother's Age	-0.0117	0.4626	-0.0451	1.0000	
	Birth Year	0.0144	0.1306	-0.0292	0.0306	1.0000

Cohorts 1938-1960

Men		Set Order	Set Size	Mother's Age	Birth Year
	Set Order	1.0000			
	Set Size	0.5232	1.0000		
	Mother's Age	0.5002	0.0180	1.0000	
	Birth Year	0.0919	-0.0328	-0.0559	1.0000
Women		**Set Order**	**Set Size**	**Mother's Age**	**Birth Year**
	Set Order	1.0000			
	Set Size	0.5235	1.0000		
	Mother's Age	0.5012	0.0210	1.0000	
	Birth Year	0.0910	-0.0334	-0.0548	1.0000

Source: Swedish administrative register data, compiled by the authors.

TABLE S3. Within-family discrete-time survival analyses: all-cause mortality results by birth order, Swedish men

		No Adult SES Controls			Adult EGP			Adult EGP & Education		
Covariates		OR	S.E.	95% CI	OR	S.E.	95% CI	OR	S.E.	95% CI
Set Order	1	1.00 (ref)			1.00 (ref)			1.00 (ref)		
	2	1.00	0.02	0.96 - 1.05	0.97	0.02	0.92 - 1.01	0.97	0.03	0.91 - 1.04
	3	1.14	0.04	1.07 - 1.22	1.02	0.04	0.95 - 1.10	1.00	0.06	0.89 - 1.11
	4	1.24	0.06	1.13 - 1.37	1.04	0.06	0.93 - 1.16	1.04	0.09	0.88 - 1.22
	5	1.47	0.10	1.29 - 1.68	1.19	0.09	1.02 - 1.39	1.21	0.15	0.94 - 1.54
	6	1.72	0.19	1.39 - 2.13	1.33	0.17	1.04 - 1.70	1.48	0.33	0.96 - 2.28
Mother's Age	<20	1.00	0.06	0.88 - 1.13	0.93	0.07	0.81 - 1.08	1.30	0.16	1.03 - 1.64
	20-25	0.96	0.03	0.90 - 1.02	0.91	0.03	0.85 - 0.98	0.96	0.05	0.87 - 1.07
	26-30	1.00 (ref)			1.00 (ref)			1.00 (ref)		
	31-35	0.99	0.03	0.94 - 1.05	1.08	0.04	1.01 - 1.15	0.97	0.05	0.87 - 1.07
	36-40	1.04	0.05	0.94 - 1.15	1.16	0.07	1.04 - 1.30	0.89	0.08	0.74 - 1.06
	>40	1.07	0.09	0.91 - 1.26	1.31	0.12	1.10 - 1.57	0.97	0.14	0.72 - 1.30
Birth Year	1938-1945	1.00 (ref)			1.00 (ref)			1.00 (ref)		
	1946-1950	0.95	0.03	0.90 - 1.01	1.09	0.04	1.02 - 1.17	0.89	0.04	0.81 - 0.97
	1951-1955	1.04	0.05	0.94 - 1.14	1.07	0.06	0.96 - 1.19			
	1956-1960	1.03	0.07	0.90 - 1.18	0.86	0.07	0.74 - 1.01			
Age	22-25	0.01	0.00	0.01 - 0.01						
	26-30	0.01	0.00	0.01 - 0.01						
	31-35	0.02	0.00	0.01 - 0.02						
	36-40	0.03	0.00	0.03 - 0.03						
	41-45	0.07	0.00	0.07 - 0.07	0.04	0.00	0.04 - 0.04			
	46-50	0.16	0.00	0.16 - 0.17	0.13	0.00	0.12 - 0.13			
	51-55	0.43	0.01	0.41 - 0.44	0.39	0.01	0.38 - 0.40	0.28	0.01	0.27 - 0.29
	56-60	1.00 (ref)			1.00 (ref)			1.00 (ref)		
	61-65	2.61	0.04	2.53 - 2.70	2.82	0.05	2.73 - 2.92	3.10	0.06	2.99 - 3.21
	>65	6.85	0.21	6.45 - 7.27	7.69	0.24	7.24 - 8.18	8.86	0.29	8.31 - 9.44
Occupational Class	Upper service class				0.47	0.02	0.43 - 0.51	0.68	0.05	0.59 - 0.78
	Lower service class				0.60	0.02	0.57 - 0.64	0.71	0.03	0.64 - 0.78
	Routine non-manual				0.73	0.03	0.68 - 0.78	0.78	0.04	0.69 - 0.87
	Self-employed, farmers				0.87	0.03	0.80 - 0.94	0.83	0.05	0.73 - 0.93
	Skilled/unskilled workers				1.00 (ref)			1.00 (ref)		
	Other/unknown				3.09	0.10	2.90 - 3.29	2.71	0.14	2.45 - 3.01
Education	Missing							1.61	0.21	1.25 - 2.08
	Primary							1.00 (ref)		
	Secondary							0.80	0.03	0.75 - 0.86
	Tertiary							0.51	0.03	0.45 - 0.57
N			97,647			82,030			43,588	
Deaths			56,606			47,703			29,059	

Source: Swedish administrative register data, compiled by the authors. Robustness checks show that the pattern of increasing mortality risk by birth year observed in the models is reversed without the inclusion of the maternal age covariate.

TABLE S4. Within-family discrete-time survival analyses: all-cause mortality results by birth order, Swedish women

		No Adult SES Controls			Adult EGP			Adult EGP & Education		
Covariates		OR	S.E.	95% CI	OR	S.E.	95% CI	OR	S.E.	95% CI
Set Order	1	1.00 (ref)			1.00 (ref)			1.00 (ref)		
	2	1.10	0.03	1.04 - 1.16	1.03	0.03	0.97 - 1.09	1.01	0.04	0.92 - 1.10
	3	1.32	0.06	1.21 - 1.44	1.16	0.06	1.06 - 1.28	1.15	0.08	1.00 - 1.32
	4	1.56	0.10	1.37 - 1.76	1.31	0.09	1.14 - 1.50	1.24	0.13	1.00 - 1.53
	5	1.87	0.17	1.57 - 2.23	1.46	0.15	1.20 - 1.78	1.30	0.21	0.94 - 1.78
	6	1.98	0.28	1.50 - 2.61	1.49	0.23	1.10 - 2.02	1.48	0.38	0.89 - 2.45
Mother's Age	<20	1.08	0.09	0.91 - 1.27	1.06	0.10	0.89 - 1.28	0.89	0.13	0.66 - 1.19
	20-25	1.05	0.04	0.97 - 1.14	1.08	0.05	0.99 - 1.18	1.10	0.07	0.96 - 1.25
	26-30	1.00 (ref)			1.00 (ref)			1.00 (ref)		
	31-35	1.00	0.04	0.92 - 1.08	0.97	0.04	0.89 - 1.05	0.92	0.06	0.81 - 1.04
	36-40	0.97	0.06	0.85 - 1.10	0.93	0.07	0.81 - 1.07	0.88	0.10	0.70 - 1.10
	>40	1.05	0.11	0.85 - 1.30	1.08	0.13	0.86 - 1.36	0.77	0.15	0.53 - 1.12
Birth Year	1938-1945	1.00 (ref)			1.00 (ref)			1.00 (ref)		
	1946-1950	1.01	0.04	0.94 - 1.09	1.21	0.05	1.12 - 1.31	0.99	0.06	0.88 - 1.10
	1951-1955	1.02	0.06	0.90 - 1.15	1.31	0.09	1.14 - 1.50			
	1956-1960	1.05	0.09	0.88 - 1.25	1.20	0.12	0.99 - 1.47			
Age	22-25	0.00	0.00	0.00 - 0.00						
	26-30	0.01	0.00	0.01 - 0.01						
	31-35	0.01	0.00	0.01 - 0.01						
	36-40	0.02	0.00	0.02 - 0.02						
	41-45	0.06	0.00	0.05 - 0.06	0.04	0.00	0.03 - 0.04			
	46-50	0.15	0.00	0.14 - 0.16	0.13	0.00	0.12 - 0.13			
	51-55	0.39	0.01	0.38 - 0.41	0.37	0.01	0.36 - 0.38	0.26	0.01	0.25 - 0.27
	56-60	1.00 (ref)			1.00 (ref)			1.00 (ref)		
	61-65	2.48	0.05	2.38 - 2.58	2.60	0.06	2.49 - 2.71	2.87	0.06	2.75 - 3.00
	>65	6.26	0.24	5.80 - 6.75	6.80	0.27	6.30 - 7.35	8.00	0.33	7.38 - 8.68
Occupational Class	Upper service class				0.56	0.04	0.49 - 0.65	0.97	0.11	0.78 - 1.22
	Lower service class				0.66	0.03	0.61 - 0.72	0.90	0.06	0.79 - 1.02
	Routine non-manual				0.96	0.04	0.89 - 1.04	0.90	0.05	0.80 - 1.01
	Self-employed, farmers				0.83	0.06	0.73 - 0.95	0.79	0.08	0.65 - 0.96
	Skilled/unskilled workers				1.00 (ref)			1.00 (ref)		
	Other/unknown				1.40	0.05	1.32 - 1.50	1.15	0.06	1.04 - 1.27
Education	Missing							3.34	0.73	2.18 - 5.14
	Primary							1.00 (ref)		
	Secondary							0.74	0.03	0.68 - 0.81
	Tertiary							0.47	0.03	0.41 - 0.54
N			59,579			51,872			27,769	
Deaths			34,458			30,223			18,457	

Source: Swedish administrative register data, compiled by the authors. Robustness checks show that the pattern of increasing mortality risk by birth year observed in the models is reversed without the inclusion of the maternal age covariate.

TABLE S5. Between-family piece wise exponential survival analyses: all-cause mortality results by birth order, Swedish men

		No Adult SES Controls			Adult EGP			Adult EGP & Education		
Covariates		RR	S.E.	95% CI	RR	S.E.	95% CI	RR	S.E.	95% CI
Set Order	1	1.00 (ref)			1.00 (ref)			1.00 (ref)		
	2	1.06	0.01	1.04 - 1.08	1.04	0.01	1.02 - 1.06	1.00	0.01	0.97 - 1.03
	3	1.10	0.02	1.07 - 1.14	1.08	0.02	1.04 - 1.11	0.98	0.02	0.94 - 1.03
	4	1.11	0.03	1.06 - 1.17	1.09	0.03	1.03 - 1.15	1.02	0.04	0.95 - 1.09
	5	1.17	0.05	1.09 - 1.27	1.18	0.05	1.08 - 1.28	1.07	0.07	0.95 - 1.20
	6	1.16	0.09	1.00 - 1.35	1.17	0.10	0.99 - 1.38	1.08	0.15	0.82 - 1.41
Set Size	2	1.00 (ref)			1.00 (ref)			1.00 (ref)		
	3	0.98	0.01	0.96 - 1.00	0.95	0.01	0.93 - 0.97	0.96	0.01	0.94 - 0.99
	4	1.02	0.01	0.99 - 1.05	0.97	0.01	0.94 - 1.00	0.97	0.02	0.94 - 1.01
	5	1.07	0.02	1.03 - 1.11	0.98	0.02	0.94 - 1.02	0.99	0.02	0.94 - 1.04
	6	1.03	0.03	0.98 - 1.09	0.92	0.03	0.87 - 0.97	0.94	0.03	0.88 - 1.00
Mother's Age	<20	1.38	0.03	1.32 - 1.44	1.21	0.03	1.15 - 1.26	1.12	0.04	1.05 - 1.19
	20-25	1.14	0.01	1.11 - 1.16	1.07	0.01	1.04 - 1.09	1.02	0.02	0.99 - 1.05
	26-30	1.00 (ref)			1.00 (ref)			1.00 (ref)		
	31-35	0.94	0.01	0.91 - 0.96	0.97	0.01	0.94 - 1.00	0.98	0.02	0.95 - 1.02
	36-40	0.93	0.01	0.90 - 0.95	0.98	0.02	0.94 - 1.01	0.98	0.02	0.94 - 1.02
	>40	0.93	0.03	0.88 - 0.98	0.98	0.03	0.93 - 1.04	1.01	0.04	0.94 - 1.09
Birth Year	1938-1945	1.00 (ref)			1.00 (ref)			1.00 (ref)		
	1946-1950	0.94	0.01	0.92 - 0.97	0.91	0.01	0.89 - 0.93	0.78	0.01	0.76 - 0.81
	1951-1955	1.04	0.01	1.01 - 1.07	0.86	0.01	0.83 - 0.89			
	1956-1960	1.14	0.02	1.11 - 1.18	0.76	0.02	0.73 - 0.79			
Age	22-25	0.03	0.00	0.03 - 0.03						
	26-30	0.10	0.00	0.10 - 0.11						
	31-35	0.12	0.00	0.12 - 0.13						
	36-40	0.19	0.00	0.18 - 0.20						
	41-45	0.32	0.01	0.31 - 0.33	0.07	0.00	0.07 - 0.07			
	46-50	0.55	0.01	0.54 - 0.57	0.58	0.01	0.57 - 0.60			
	51-55	1.00 (ref)			1.00 (ref)			1.00 (ref)		
	56-60	1.47	0.02	1.44 - 1.51	1.44	0.02	1.40 - 1.47	9.56	0.14	9.29 - 9.84
	61-65	2.09	0.03	2.03 - 2.16	2.03	0.03	1.97 - 2.10	12.04	0.19	11.68 - 12.43
	>65	2.26	0.06	2.15 - 2.38	2.15	0.06	2.05 - 2.26	12.46	0.32	11.85 - 13.12
Occupational Class	Upper service class				0.53	0.01	0.51 - 0.55	0.73	0.02	0.69 - 0.77
	Lower service class				0.64	0.01	0.62 - 0.66	0.75	0.01	0.73 - 0.78
	Routine non-manual				0.80	0.01	0.78 - 0.83	0.88	0.02	0.84 - 0.92
	Self-employed, farmers				0.81	0.02	0.78 - 0.84	0.80	0.02	0.76 - 0.84
	Skilled/unskilled workers				1.00 (ref)			1.00 (ref)		
	Other/unknown				2.02	0.03	1.97 - 2.07	1.92	0.04	1.85 - 1.99
Education	Missing							1.42	0.06	1.30 - 1.55
	Primary							1.00 (ref)		
	Secondary							0.84	0.01	0.82 - 0.87
	Tertiary							0.63	0.01	0.60 - 0.65
N			870,510			837,990			365,756	
Deaths			56,282			47,231			28,544	

Source: Swedish administrative register data, compiled by the authors. Robustness checks show that the pattern of increasing mortality risk by birth year observed in the models is reversed without the inclusion of the maternal age covariate.

TABLE S6. Between-family piece wise exponential survival analyses: all-cause mortality results by birth order, Swedish women

		No Adult SES Controls			Adult EGP			Adult EGP & Education		
Covariates		RR	S.E.	95% CI	RR	S.E.	95% CI	RR	S.E.	95% CI
Set Order	1	1.00 (ref)			1.00 (ref)			1.00 (ref)		
	2	1.07	0.01	1.04 - 1.10	1.05	0.01	1.02 - 1.08	1.03	0.02	1.00 - 1.07
	3	1.13	0.02	1.08 - 1.17	1.11	0.02	1.07 - 1.16	1.05	0.03	0.99 - 1.11
	4	1.11	0.04	1.04 - 1.18	1.09	0.04	1.02 - 1.16	1.02	0.05	0.93 - 1.11
	5	1.14	0.06	1.03 - 1.26	1.10	0.06	0.98 - 1.23	0.92	0.08	0.78 - 1.08
	6	1.17	0.11	0.97 - 1.42	1.19	0.12	0.97 - 1.45	1.10	0.18	0.80 - 1.52
Set Size	2	1.00 (ref)			1.00 (ref)			1.00 (ref)		
	3	0.96	0.01	0.94 - 0.99	0.95	0.01	0.92 - 0.98	0.95	0.02	0.92 - 0.99
	4	0.95	0.02	0.92 - 0.99	0.93	0.02	0.89 - 0.96	0.93	0.02	0.89 - 0.97
	5	0.98	0.02	0.93 - 1.03	0.95	0.02	0.90 - 1.00	0.94	0.03	0.89 - 1.01
	6	1.03	0.03	0.97 - 1.10	0.98	0.03	0.92 - 1.05	1.03	0.04	0.95 - 1.12
Mother's Age	<20	1.30	0.04	1.23 - 1.37	1.20	0.04	1.13 - 1.28	1.10	0.05	1.02 - 1.20
	20-25	1.12	0.02	1.09 - 1.15	1.07	0.02	1.04 - 1.10	1.03	0.02	0.99 - 1.07
	26-30	1.00 (ref)			1.00 (ref)			1.00 (ref)		
	31-35	0.97	0.02	0.94 - 1.00	1.00	0.02	0.97 - 1.03	1.01	0.02	0.97 - 1.05
	36-40	0.92	0.02	0.88 - 0.96	0.95	0.02	0.91 - 0.99	0.98	0.03	0.93 - 1.03
	>40	0.93	0.03	0.86 - 0.99	0.95	0.03	0.89 - 1.03	0.93	0.04	0.84 - 1.02
Birth Year	1938-1945	1.00 (ref)			1.00 (ref)			1.00 (ref)		
	1946-1950	0.95	0.01	0.92 - 0.97	0.91	0.01	0.88 - 0.94	0.81	0.02	0.78 - 0.84
	1951-1955	1.00	0.02	0.97 - 1.04	0.94	0.02	0.91 - 0.98			
	1956-1960	1.08	0.02	1.03 - 1.12	0.85	0.02	0.81 - 0.89			
Age	22-25	0.02	0.00	0.02 - 0.02						
	26-30	0.08	0.00	0.07 - 0.08						
	31-35	0.10	0.00	0.09 - 0.10						
	36-40	0.17	0.00	0.16 - 0.18						
	41-45	0.32	0.01	0.31 - 0.34	0.07	0.00	0.07 - 0.07			
	46-50	0.58	0.01	0.56 - 0.60	0.61	0.01	0.59 - 0.63			
	51-55	1.00 (ref)			1.00 (ref)			1.00 (ref)		
	56-60	1.54	0.03	1.49 - 1.59	1.50	0.03	1.46 - 1.56	10.07	0.18	9.71 - 10.43
	61-65	2.00	0.04	1.92 - 2.08	1.95	0.04	1.88 - 2.03	11.58	0.23	11.13 - 12.04
	>65	2.06	0.07	1.93 - 2.20	2.10	0.07	1.97 - 2.24	11.68	0.39	10.94 - 12.47
Occupational Class	Upper service class				0.67	0.02	0.64 - 0.71	0.91	0.04	0.83 - 0.99
	Lower service class				0.70	0.01	0.67 - 0.72	0.87	0.02	0.83 - 0.92
	Routine non-manual				0.88	0.02	0.85 - 0.91	0.90	0.02	0.86 - 0.94
	Self-employed, farmers				0.82	0.03	0.77 - 0.87	0.82	0.03	0.76 - 0.88
	Skilled/unskilled workers				1.00 (ref)			1.00 (ref)		
	Other/unknown				1.20	0.02	1.16 - 1.23	1.11	0.02	1.07 - 1.16
Education	Missing							2.23	0.15	1.96 - 2.54
	Primary							1.00 (ref)		
	Secondary							0.80	0.01	0.78 - 0.83
	Tertiary							0.60	0.01	0.58 - 0.63
N			830,952			797,989			350,812	
Deaths			34,348			29,992			18,147	

Source: Swedish administrative register data, compiled by the authors. Robustness checks show that the pattern of increasing mortality risk by birth year observed in the models is reversed without the inclusion of the maternal age covariate.

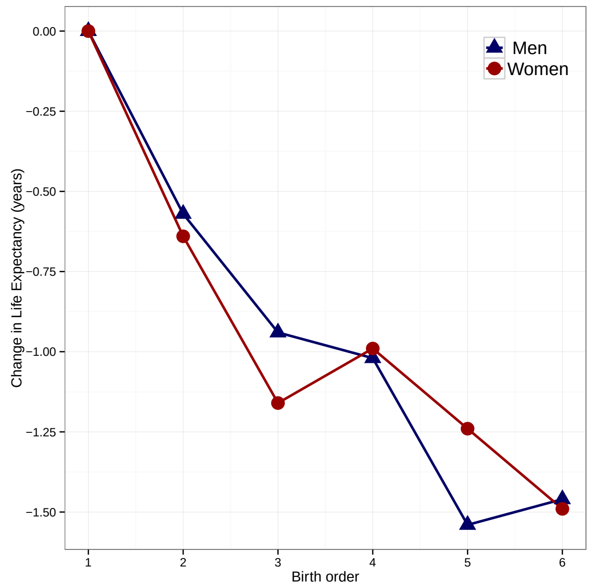

FIGURE S1. Differences in life expectancy based upon the between-family piecewise exponential all-cause mortality survival analyses, Swedish men and women born 1938-1960. Assuming that a change in hazard from the survival models is translated into an increase in age-specific mortality q_x for ages 20 to 69, we use standard life tables obtained from the Human Mortality Database (Database, 2012) to calculate the implications of birth order for life expectancy. These estimates are likely to be conservative as it is highly plausible that the observed hazard estimates will persist at ages greater than 69 and therefore translate into higher differences by birth order on life expectancy. We use 2007 Swedish life tables by sex and use the results from the all-cause mortality between-family comparison models to calculate how life expectancy differs by birth order.

TABLE S7. Within-family discrete-time survival analyses and between-family piece-wise exponential survival analyses: set-specific all-cause mortality results by birth order, Swedish men and women born 1938-1960.

		Set Size									
		2		3		4		5		6	
	Set Order	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Within-Family											
Men	1	1.00 (ref)		1.00		1.00		1.00		1.00	
	2	1.10	1.00 - 1.20	1.02	0.95 - 1.09	1.02	0.93 - 1.11	0.93	0.81 - 1.05	1.02	0.84 - 1.24
	3			1.10	0.98 - 1.24	1.01	0.90 - 1.15	1.04	0.89 - 1.21	1.18	0.94 - 1.48
	4					0.96	0.81 - 1.16	1.01	0.82 - 1.23	1.23	0.93 - 1.63
	5							1.03	0.78 - 1.36	1.42	1.01 - 2.01
	6									1.37	0.88 - 2.11
Women	1	1.00 (ref)		1.00		1.00		1.00		1.00	
	2	1.13	1.00 - 1.26	1.14	1.04 - 1.25	1.09	0.97 - 1.23	1.08	0.91 - 1.28	1.11	0.87 - 1.41
	3			1.48	1.26 - 1.73	1.23	1.04 - 1.46	1.13	0.92 - 1.40	1.18	0.89 - 1.58
	4					1.32	1.04 - 1.68	1.16	0.88 - 1.53	1.20	0.84 - 1.71
	5							1.34	0.93 - 1.94	1.25	0.80 - 1.97
	6									1.34	0.76 - 2.37
	Set Order	RR	95% CI	RR	95% CI	RR	95% CI	RR	95% CI	RR	95% CI
Between-Family											
Men	1	1.00 (ref)		1.00		1.00		1.00		1.00	
	2	1.08	1.05 - 1.11	1.03	0.99 - 1.06	1.08	1.02 - 1.14	0.95	0.87 - 1.04	1.08	0.93 - 1.24
	3			1.07	1.02 - 1.13	1.12	1.05 - 1.19	1.07	0.97 - 1.18	1.13	0.97 - 1.31
	4					1.20	1.10 - 1.30	1.07	0.96 - 1.20	1.09	0.92 - 1.29
	5							1.11	0.96 - 1.28	1.25	1.03 - 1.52
	6									1.12	0.88 - 1.42
Women	1	1.00 (ref)		1.00		1.00		1.00		1.00	
	2	1.08	1.04 - 1.12	1.06	1.01 - 1.11	1.09	1.01 - 1.18	1.04	0.93 - 1.17	1.04	0.88 - 1.23
	3			1.14	1.07 - 1.22	1.15	1.06 - 1.26	1.08	0.95 - 1.22	0.97	0.80 - 1.17
	4					1.24	1.11 - 1.38	1.02	0.87 - 1.18	1.03	0.83 - 1.27
	5							1.14	0.94 - 1.37	1.02	0.79 - 1.32
	6									1.11	0.82 - 1.51

Source: Swedish administrative register data, compiled by the authors. The within-family analyses also include covariates for age, mother's age, and birth year, and the between-family analyses also include covariates for age, mother's age, birth year, and set size.

TABLE S8. Within-family discrete-time survival analyses: cause-specific mortality results by birth order, Swedish men and women born 1938-1960.

			No Adult SES Controls			Adult EGP			Adult EGP & Education		
	Cause-of Death	Set Order	OR	S.E.	95% CI	OR	S.E.	95% CI	OR	S.E.	95% CI
Men	Neoplasms	1	1.00			1.00			1.00		
		2	0.98	0.04	0.90 - 1.06	0.96	0.04	0.89 - 1.05	0.96	0.06	0.86 - 1.08
		3	1.07	0.07	0.94 - 1.21	1.03	0.07	0.90 - 1.17	0.92	0.09	0.76 - 1.11
		4	0.97	0.09	0.80 - 1.18	0.93	0.09	0.76 - 1.13	0.78	0.11	0.59 - 1.04
		5	1.19	0.17	0.90 - 1.57	1.25	0.18	0.94 - 1.66	0.71	0.16	0.46 - 1.11
		6	1.95	0.43	1.27 - 3.00	1.92	0.44	1.23 - 2.99	1.99	0.72	0.98 - 4.05
	Cancers of the	1	1.00			1.00			1.00		
	respiratory system	2	0.99	0.10	0.82 - 1.20	1.01	0.10	0.83 - 1.23	1.16	0.16	0.89 - 1.51
		3	0.96	0.15	0.71 - 1.31	0.96	0.15	0.70 - 1.32	1.06	0.23	0.69 - 1.63
		4	0.86	0.19	0.56 - 1.34	0.87	0.20	0.55 - 1.36	1.04	0.33	0.55 - 1.94
		5	1.11	0.37	0.58 - 2.12	1.15	0.39	0.59 - 2.22	0.77	0.39	0.29 - 2.07
		6	2.13	1.10	0.77 - 5.89	2.23	1.19	0.78 - 6.35	0.89	1.03	0.09 - 8.61
	Diseases of the	1	1.00			1.00			1.00		
	circulatory system	2	0.80	0.03	0.74 - 0.87	0.79	0.03	0.72 - 0.86	0.80	0.05	0.71 - 0.90
		3	0.82	0.06	0.72 - 0.94	0.79	0.06	0.69 - 0.91	0.75	0.08	0.61 - 0.91
		4	0.74	0.07	0.61 - 0.89	0.71	0.07	0.58 - 0.87	0.66	0.10	0.49 - 0.88
		5	1.01	0.14	0.78 - 1.32	0.95	0.13	0.72 - 1.25	1.02	0.22	0.67 - 1.56
		6	0.86	0.20	0.55 - 1.35	0.81	0.19	0.50 - 1.29	0.57	0.24	0.25 - 1.30
	Mortality attributable	1	1.00			1.00			1.00		
	to external causes	2	1.23	0.06	1.12 - 1.36	1.12	0.06	1.00 - 1.25	1.34	0.14	1.10 - 1.64
		3	1.53	0.12	1.31 - 1.79	1.25	0.11	1.04 - 1.49	1.62	0.27	1.17 - 2.23
		4	1.73	0.19	1.38 - 2.15	1.30	0.17	1.01 - 1.68	2.13	0.52	1.32 - 3.42
		5	1.86	0.29	1.37 - 2.52	1.16	0.21	0.81 - 1.66	3.66	1.32	1.80 - 7.44
		6	1.87	0.45	1.17 - 2.98	1.00	0.29	0.57 - 1.75	3.71	2.11	1.22 - 11.32
Women	Neoplasms	1	1.00			1.00			1.00		
		2	1.04	0.04	0.96 - 1.12	1.02	0.04	0.94 - 1.11	1.06	0.06	0.94 - 1.19
		3	1.23	0.08	1.09 - 1.39	1.19	0.08	1.05 - 1.35	1.18	0.11	0.98 - 1.42
		4	1.39	0.12	1.16 - 1.65	1.29	0.12	1.08 - 1.55	1.14	0.16	0.86 - 1.50
		5	1.72	0.22	1.33 - 2.21	1.56	0.21	1.20 - 2.03	1.26	0.27	0.83 - 1.92
		6	1.75	0.36	1.17 - 2.62	1.58	0.34	1.04 - 2.40	1.47	0.50	0.75 - 2.86
	Cancers of the	1	1.00			1.00			1.00		
	respiratory system	2	1.29	0.12	1.08 - 1.54	1.32	0.12	1.09 - 1.58	1.19	0.15	0.93 - 1.53
		3	1.79	0.26	1.34 - 2.38	1.77	0.26	1.32 - 2.37	1.58	0.32	1.06 - 2.35
		4	2.34	0.49	1.56 - 3.51	2.39	0.51	1.58 - 3.62	1.99	0.58	1.12 - 3.54
		5	3.16	0.91	1.80 - 5.55	3.24	0.96	1.82 - 5.78	1.96	0.85	0.84 - 4.58
		6	3.63	1.54	1.57 - 8.35	3.95	1.70	1.70 - 9.19	4.05	2.39	1.27 - 12.88
	Diseases of the	1	1.00			1.00			1.00		
	circulatory system	2	0.91	0.07	0.78 - 1.05	0.92	0.07	0.79 - 1.07	0.83	0.09	0.67 - 1.03
		3	0.88	0.10	0.69 - 1.11	0.87	0.11	0.68 - 1.11	0.88	0.16	0.62 - 1.26
		4	0.82	0.14	0.59 - 1.13	0.79	0.14	0.56 - 1.11	0.79	0.21	0.47 - 1.33
		5	0.88	0.21	0.55 - 1.39	0.82	0.20	0.51 - 1.32	0.60	0.24	0.28 - 1.32
		6	0.71	0.27	0.33 - 1.50	0.51	0.22	0.22 - 1.20	0.49	0.36	0.12 - 2.05
	Mortality attributable	1	1.00			1.00			1.00		
	to external causes	2	1.73	0.15	1.46 - 2.05	1.50	0.14	1.24 - 1.81	1.31	0.23	0.93 - 1.85
		3	2.50	0.34	1.91 - 3.28	2.29	0.35	1.69 - 3.09	1.63	0.48	0.91 - 2.91
		4	3.00	0.59	2.03 - 4.42	2.58	0.57	1.67 - 3.99	5.58	2.37	2.42 - 12.82
		5	4.71	1.24	2.81 - 7.91	3.18	0.97	1.75 - 5.79	3.94	2.56	1.11 - 14.06
		6	3.49	1.43	1.57 - 7.78	1.61	0.80	0.61 - 4.25	2.39	2.30	0.36 - 15.84

Source: Swedish administrative register data, compiled by the authors. These models also include covariates for age, mother's age, and birth year.

TABLE S9. Between-family piece wise exponential survival analyses: cause-specific mortality results by birth order, Swedish men and women born 1938-1960.

			No Adult SES Controls			Adult EGP			Adult EGP & Education		
	Cause-of Death	Set Order	RR	S.E.	95% CI	RR	S.E.	95% CI	RR	S.E.	95% CI
Men	Neoplasms	1	1.00			1.00			1.00		
		2	1.04	0.02	1.01 - 1.08	1.03	0.02	0.99 - 1.07	1.02	0.02	0.97 - 1.07
		3	1.10	0.03	1.04 - 1.17	1.08	0.03	1.02 - 1.15	1.04	0.04	0.97 - 1.12
		4	1.07	0.05	0.98 - 1.17	1.06	0.05	0.96 - 1.16	1.04	0.06	0.92 - 1.18
		5	1.10	0.09	0.94 - 1.28	1.13	0.09	0.96 - 1.32	0.94	0.11	0.74 - 1.18
		6	1.26	0.19	0.93 - 1.70	1.32	0.21	0.97 - 1.81	1.41	0.33	0.90 - 2.23
	Cancers of the	1	1.00			1.00			1.00		
	respiratory system	2	1.22	0.05	1.12 - 1.33	1.18	0.05	1.08 - 1.29	1.15	0.06	1.04 - 1.27
		3	1.24	0.09	1.08 - 1.42	1.16	0.08	1.01 - 1.33	1.03	0.09	0.87 - 1.22
		4	1.35	0.15	1.09 - 1.67	1.27	0.14	1.02 - 1.57	1.33	0.17	1.03 - 1.71
		5	1.48	0.27	1.04 - 2.11	1.41	0.26	0.99 - 2.02	1.15	0.29	0.70 - 1.89
		6	1.75	0.62	0.88 - 3.52	1.74	0.62	0.87 - 3.48	0.77	0.56	0.19 - 3.17
	Diseases of the	1	1.00			1.00			1.00		
	circulatory system	2	1.01	0.02	0.97 - 1.05	0.98	0.02	0.94 - 1.02	0.95	0.02	0.91 - 1.00
		3	1.04	0.03	0.98 - 1.10	1.00	0.03	0.94 - 1.07	0.90	0.04	0.83 - 0.97
		4	1.03	0.05	0.94 - 1.14	0.98	0.05	0.89 - 1.09	0.90	0.06	0.79 - 1.02
		5	1.18	0.09	1.02 - 1.37	1.11	0.09	0.95 - 1.30	1.04	0.11	0.85 - 1.29
		6	0.93	0.15	0.67 - 1.28	0.90	0.15	0.64 - 1.26	0.69	0.20	0.39 - 1.23
	Mortality attributable	1	1.00			1.00			1.00		
	to external causes	2	1.15	0.03	1.10 - 1.21	1.12	0.03	1.06 - 1.19	1.11	0.05	1.01 - 1.21
		3	1.23	0.05	1.14 - 1.32	1.21	0.05	1.11 - 1.32	1.16	0.08	1.01 - 1.34
		4	1.27	0.07	1.14 - 1.41	1.28	0.08	1.13 - 1.46	1.28	0.14	1.04 - 1.59
		5	1.33	0.11	1.13 - 1.58	1.34	0.14	1.10 - 1.64	1.75	0.30	1.25 - 2.45
		6	1.38	0.21	1.03 - 1.87	1.43	0.26	1.00 - 2.04	2.01	0.68	1.04 - 3.88
Women	Neoplasms	1	1.00			1.00			1.00		
		2	1.05	0.02	1.01 - 1.09	1.04	0.02	1.00 - 1.08	1.04	0.02	0.99 - 1.09
		3	1.13	0.03	1.07 - 1.19	1.12	0.03	1.06 - 1.19	1.08	0.04	1.01 - 1.17
		4	1.09	0.05	1.00 - 1.19	1.07	0.05	0.98 - 1.17	1.02	0.06	0.90 - 1.15
		5	1.17	0.08	1.01 - 1.34	1.13	0.09	0.97 - 1.31	1.00	0.11	0.80 - 1.24
		6	1.17	0.16	0.89 - 1.53	1.22	0.17	0.92 - 1.61	1.19	0.27	0.76 - 1.86
	Cancers of the	1	1.00			1.00			1.00		
	respiratory system	2	1.27	0.06	1.16 - 1.38	1.22	0.06	1.12 - 1.33	1.21	0.07	1.08 - 1.35
		3	1.51	0.10	1.33 - 1.72	1.43	0.10	1.26 - 1.64	1.34	0.11	1.14 - 1.58
		4	1.57	0.16	1.28 - 1.92	1.48	0.15	1.20 - 1.81	1.39	0.18	1.07 - 1.79
		5	2.03	0.32	1.49 - 2.78	1.82	0.30	1.33 - 2.51	1.59	0.35	1.04 - 2.45
		6	1.99	0.60	1.10 - 3.60	1.91	0.58	1.06 - 3.47	1.89	0.82	0.81 - 4.43
	Diseases of the	1	1.00			1.00			1.00		
	circulatory system	2	1.07	0.04	1.00 - 1.14	1.02	0.04	0.95 - 1.09	0.94	0.04	0.86 - 1.03
		3	1.10	0.06	0.99 - 1.22	1.03	0.06	0.93 - 1.15	0.95	0.06	0.83 - 1.08
		4	1.16	0.09	0.99 - 1.36	1.08	0.09	0.92 - 1.28	0.94	0.10	0.76 - 1.16
		5	1.08	0.15	0.83 - 1.41	1.00	0.14	0.76 - 1.31	0.69	0.15	0.46 - 1.05
		6	1.01	0.25	0.62 - 1.66	0.77	0.22	0.43 - 1.36	0.76	0.32	0.33 - 1.75
	Mortality attributable	1	1.00			1.00			1.00		
	to external causes	2	1.20	0.05	1.11 - 1.31	1.18	0.06	1.07 - 1.30	1.18	0.09	1.02 - 1.36
		3	1.29	0.08	1.14 - 1.46	1.34	0.10	1.16 - 1.54	1.15	0.14	0.91 - 1.45
		4	1.24	0.12	1.02 - 1.51	1.33	0.15	1.06 - 1.66	1.51	0.27	1.06 - 2.15
		5	1.46	0.22	1.09 - 1.96	1.43	0.26	1.00 - 2.03	1.23	0.42	0.63 - 2.41
		6	1.22	0.35	0.70 - 2.13	1.26	0.44	0.64 - 2.49	1.20	0.89	0.28 - 5.10

Source: Swedish administrative register data, compiled by the authors. These models also include covariates for age, set size, mother's age, and birth year.

TABLE S10. Within-family analyses: Results with and without the inclusion of control variables for adult socioeconomic status for Swedish men and women aged 51 and over.

		No Adult SES Controls			Adult EGP			Adult EGP & Education		
	Set Order	OR	S.E.	95% CI	OR	S.E.	95% CI	OR	S.E.	95% CI
Men	1	1.00			1.00			1.00		
	2	0.97	0.03	0.91 - 1.02	0.94	0.03	0.89 - 0.99	0.97	0.03	0.91 - 1.04
	3	1.01	0.05	0.92 - 1.10	0.96	0.05	0.87 - 1.05	1.00	0.06	0.89 - 1.11
	4	1.08	0.08	0.94 - 1.24	1.01	0.07	0.88 - 1.16	1.04	0.09	0.88 - 1.22
	5	1.26	0.13	1.04 - 1.54	1.14	0.12	0.93 - 1.39	1.21	0.15	0.94 - 1.54
	6	1.66	0.28	1.19 - 2.30	1.53	0.26	1.10 - 2.12	1.48	0.33	0.96 - 2.28
Women	1				1.00			1.00		
	2	1.03	0.04	0.96 - 1.10	1.00	0.04	0.93 - 1.08	1.01	0.04	0.92 - 1.10
	3	1.16	0.07	1.03 - 1.30	1.11	0.07	0.98 - 1.25	1.15	0.08	1.00 - 1.32
	4	1.32	0.12	1.11 - 1.57	1.24	0.11	1.04 - 1.47	1.24	0.13	1.00 - 1.53
	5	1.42	0.18	1.10 - 1.83	1.31	0.17	1.02 - 1.70	1.30	0.21	0.94 - 1.78
	6	1.72	0.35	1.15 - 2.58	1.58	0.33	1.06 - 2.37	1.48	0.38	0.89 - 2.45

Source: Swedish administrative register data, compiled by the authors. These models also include covariates for age, mother's age, and birth year.

TABLE S11. Between-family analyses: Restricted follow-up period to ages 65, 60, and 55 for Swedish men and women.

		Cohorts 1938-1942			Cohorts 1938-1947			Cohorts 1938-1952		
	Set Order	RR	S.E.	95% CI	RR	S.E.	95% CI	RR	S.E.	95% CI
Men	1	1.00			1.00			1.00		
	2	1.03	0.02	0.99 - 1.07	1.05	0.02	1.02 - 1.09	1.07	0.02	1.03 - 1.10
	3	1.05	0.03	0.99 - 1.12	1.09	0.03	1.03 - 1.14	1.15	0.03	1.10 - 1.21
	4	1.10	0.06	0.99 - 1.23	1.15	0.05	1.07 - 1.25	1.15	0.05	1.07 - 1.25
	5	1.23	0.14	0.98 - 1.55	1.20	0.08	1.05 - 1.37	1.22	0.08	1.08 - 1.38
	6	1.70	0.70	0.76 - 3.80	1.22	0.19	0.91 - 1.64	1.25	0.15	0.99 - 1.58
Women	1	1.00			1.00			1.00		
	2	1.04	0.03	0.99 - 1.09	1.07	0.02	1.02 - 1.11	1.07	0.02	1.03 - 1.12
	3	1.06	0.04	0.98 - 1.15	1.12	0.04	1.05 - 1.19	1.16	0.04	1.08 - 1.23
	4	1.11	0.08	0.96 - 1.28	1.13	0.06	1.02 - 1.25	1.19	0.06	1.08 - 1.32
	5	1.04	0.17	0.75 - 1.42	1.21	0.11	1.02 - 1.43	1.29	0.10	1.10 - 1.51
	6	1.19	0.69	0.38 - 3.73	1.38	0.24	0.98 - 1.94	1.21	0.18	0.90 - 1.63

Source: Swedish administrative register data, compiled by the authors. These models also include covariates for age, set size, mother's age, and birth year.