BIRTH ORDER AND MORTALITY RISK: ALL-CAUSE AND CAUSE-SPECIFIC TRENDS

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ABSTRACT. This study used 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 accidents, suicides, and events of undetermined intent. The follow-up period is from 1960 to 2007 for all-cause mortality, and from 1968 to 2007 for cause-specific mortality. The analyses are conducted using piece-wise constant survival models, with age as the baseline hazard, and the estimates are adjusted for mother's age at the time of birth, sibship size, 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. This pattern is also consistent for cause-specific mortality risk, but is particularly pronounced for mortality attributable to cancers of the respiratory system. These results 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 in utero conditions on adult outcomes, ranging from health and disease, through to educational attainment and other measures of socioeconomic status. The evidence consistently demonstrates that early-life disadvantage has important, negative, consequences (Gluckman et al., 2008). Birth order can be considered one of these early-life factors, and it has been the subject of a great deal of interest. However, few studies have been able to investigate the relationship between birth order and mortality risk in adulthood (OLeary et al., 1996; Modin, 2002; Smith et al., 2009), and there is little research published addressing birth order and cause-specific mortality risk in adulthood. An exception is a number of studies that have demonstrated a link between birth order and cancer development (Hemminki and Mutanen, 2001; Richiardi et al., 2004; Altieri and Hemminki, 2007; Bevier et al., 2011), though the direction of the relationship varies according to the site of the cancer; for example Bevier et al. (2011) find a positive association between birth order and lung cancer, but a negative association for endometrial 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.

There are several reasons why birth order is likely to be related to mortality risk (Elliott, 1992). To begin with, the pool of parental resources, including both time and material resources, available to each child decreases as the sibship size increases. First and early born children will spend early years having exclusive or close to exclusive attention of parents while later born will have to compete with siblings over resources right after they are born. In addition, younger siblings are likely to be introduced to developmentally inappropriate activities by older siblings (Elliott, 1992) . Finally, a larger sibship increases the likelihood of communicable diseases being introduced into the family, and younger siblings may be more susceptible to these diseases (Elliott, 1992; Holman et al., 2003). Nevertheless, it is a well-documented trend 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 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; Case et al., 2005). A competing explanation is that as older parents typically have accumulated more resources, later born children will on average have parents with more resources. Because of this it is important to take parental age into account when examining birth order.

Using a small (n=1162), and non-representative sample, OLeary et al. (1996) found little relationship between birth order and mortality risk. The only statistically significant result was that women who were neither the oldest nor the youngest in the sibship were significantly more likely to die of other causes, meaning neither cardiovascular disease, nor cancer, relative to the oldest child in the sibship. However, the authors themselves suggest that this result may be an artifact due to the small number dying from other causes in this sample. A study using Swedish data (n=14,192) from the Uppsala Birth Cohort Study Modin (2002) found that birth order was associated with an increased risk of all-cause mortality for both males and females in adulthood (ages 20-54), and for males in middle-to-old-age (ages 55-80), after adjusting for age, mothers age at birth, birth weight, gestational age, diseases of the mother, diseases of the infant, and the mothers social class and marital status at the time of birth. However, no statistically significant patterns were found after adjusting for the socioeconomic status of the ego in adulthood. No adjustment was made for sibship size. Finally, Smith et al. (2009) investigated how a range of early life factors were associated with mortality risk in adulthood using a restricted sample from the Utah Population Database. The impact of birth order on adult mortality risk was not 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 males or females.

At least partly because of less imposing data demands, much more research has been conducted on the relationship between birth order and infant mortality risk. While the picture in developing countries with a high rate of infant mortality is more complicated, trends observed in developed countries, such as Norway, Sweden, and the United States, with a low infant mortality rate point towards a linear relationship between birth order and infant mortality risk (Espehaug et al., 1994; Mathews et al., 2003). Because of data limitations, it has yet to be decisively ascertained as to whether these patterns persist into adulthood, and this

study will be the first to do so. In line with previous research, 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

In this study we use Swedish population register data to investigate the relationship between birth order and mortality risk. We conduct separate analyses for males and females. The individuals under analysis are selected from 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. 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, 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).

TABLE 1. Study Size

	Males		Females	
Cause-of Death	N	Deaths	N	Deaths
All-cause mortality	917,718	61,148	878,858	36,905
Diseases of the circulatory system	914,166	15,857	873,111	5,492
Neoplasms	914,166	17,188	873,111	19,271
Cancers of the respiratory system	914,166	3,160	873,111	3,273
Accidents, suicides, and events of undetermined intent.	914,166	13,446	873,111	4,575

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

Because the earliest point at which we have data in the mortality register is 1960, we have left censoring in our models. Individuals enter the analysis for all-cause mortality at either age 18, or, for those born in the earliest cohorts, in 1960. The l_{20} for the 1960 cohort was 0.951 for females and 0.935 for males. This means that those born in 1938 enter the analysis at age 22. For the cause-specific analyses, this left censoring is more pronounced. Again, individuals either enter the analysis at age 18, or in 1968. This means that those born in 1938 enter the analysis at age 30. 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 accidents, and suicides for our earliest cohorts. Finally, we right censor for the first out-migration of any

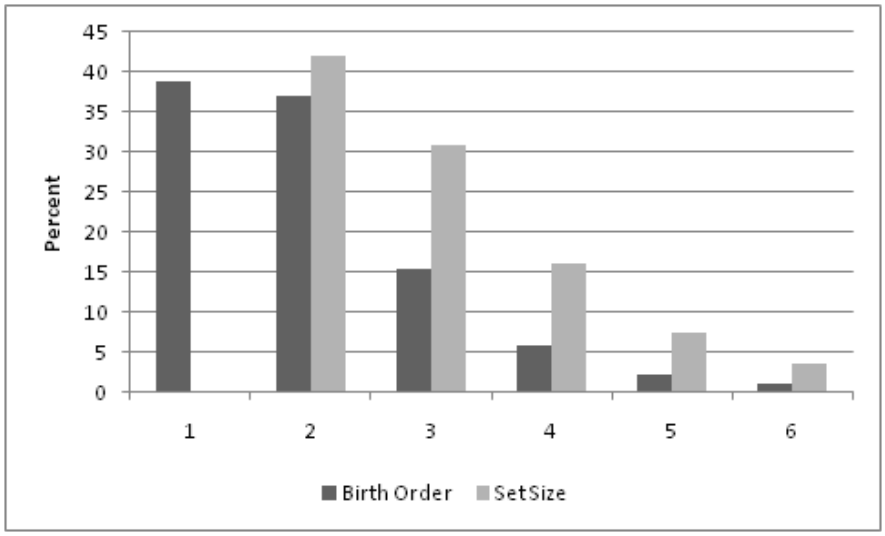

FIGURE 1. Set Order and Set Size Distribution, where Set Size$>$ 1

individual from Sweden. Table 1 shows the study size, and number of deaths, for each of the analyses for males and females.

Our estimates for the relationship between birth order and mortality risk are adjusted for the following variables: age of the ego; the age of the egos mother in the birth year of the ego; cohort-effects; and, the sibling set size of which the ego is a part. Controlling for the overall number of siblings of our ego is critical as number of children of the parents is associated both with socioeconomic status of the parent and child generation. It is also plausible that health outcomes could be related to your overall number of siblings. Here we defined a sibship as a group of siblings with the same mother-father pairing. 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 on longevity (Bengtsson and Broström, 2009; Bengtsson and Mineau, 2009; Gluckman et al., 2008), and also because previous research has indicated that cohort-effects play a more significant role in mortality trends than period-effects (Richards et al., 2006). Furthermore, through changing preferences and the secular trend of increased female labour force participation, cohort effects are also related to family size (Andersson, 1999, 2000), which is obviously related to birth order. For this reason, we include a finely grained birth year variable to fully account for these underlying patterns. 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 obviously do not include only-children in our analysis. The results below show the results from birth order for children born in sibling sets ranging in size from two to six.

METHODS

We use piece-wise constant survival models of the following form to estimate the relationship between birth order and mortality risk:

$$\lambda_i(t \mid x_i) = \lambda_0(t) exp\{x_i'\beta\}$$

The baseline hazard is age. These 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.

RESULTS

The full results for the all-cause mortality analyses for males and females can be seen in table 2. As can be seen in Figure 2, the increasing relative risk of all-cause mortality follows a relatively linear pattern for both males and females. The cause-specific patterns for males and females can be seen in figures 3 and 4.

FIGURE 2. Males and Females: Relative Risk of All-cause Mortality by Birth Order.

For males, the relative risk of mortality observed for mortality attributable to neoplasms, and particularly to cancers of the respiratory system, increases dramatically with rising birth order. The relative risk of mortality attributable to accidents, suicides, and events of undetermined intent increases up to birth order 4, and then levels off, while the pattern for mortality attributable to diseases of the circulatory system is elevated relative to those born first, but

actually falls for birth order six. The cause-specific results for females are similar to the results for males, though the most striking result is again the pattern observed for cancers of the respiratory system.

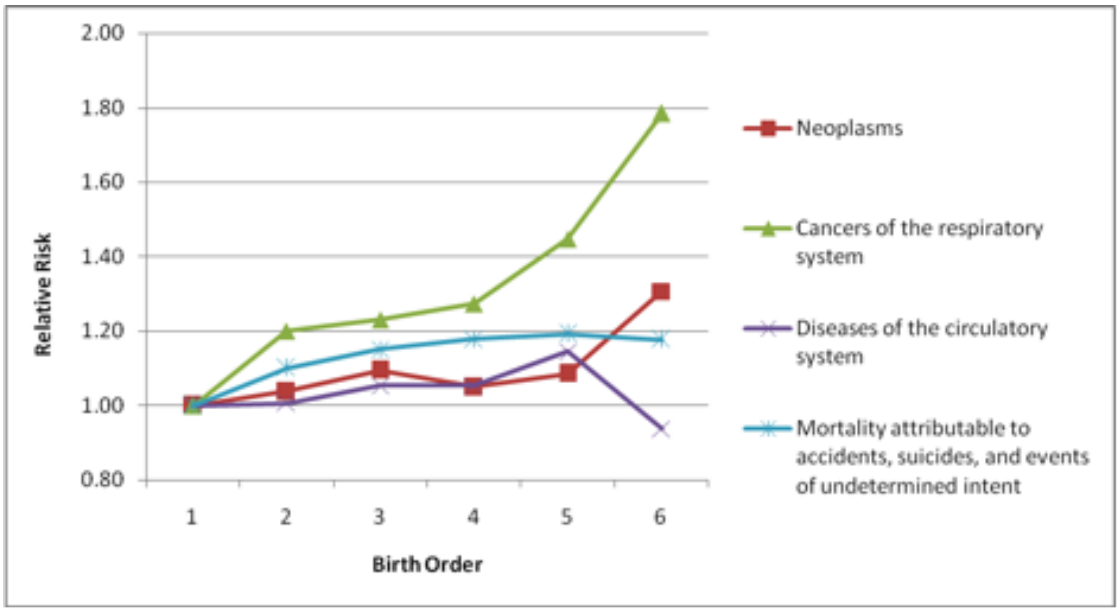

FIGURE 3. Males: Relative Risk of Mortality by Cause of Death and Birth Order.

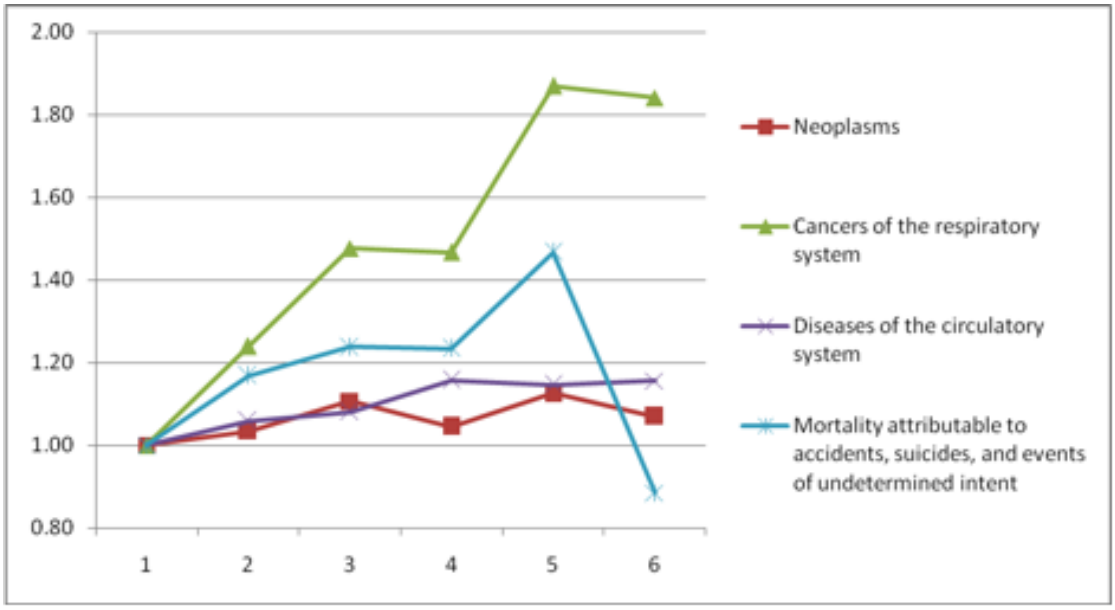

FIGURE 4. Females: Relative Risk of Mortality by Cause of Death and Birth Order.

TABLE 2. Results: Males & Females

		Males				Females			
Covariates		RR	S.E.	P-value	95% CI	RR	S.E.	P-value	95% CI
Age	18-25	1.39	0.04	0.00	1.31 - 1.46	1.14	0.05	0.00	1.05 - 1.24
	26-30	1.00				1.00			
	31-35	1.22	0.04	0.00	1.15 - 1.30	1.24	0.06	0.00	1.14 - 1.36
	36-40	1.89	0.05	0.00	1.78 - 2.00	2.16	0.09	0.00	2.00 - 2.34
	41-45	3.22	0.09	0.00	3.06 - 3.39	4.22	0.16	0.00	3.92 - 4.54
	46-50	5.88	0.15	0.00	5.60 - 6.18	8.07	0.29	0.00	7.52 - 8.66
	51-55	11.29	0.28	0.00	10.75 - 11.85	14.71	0.53	0.00	13.72 - 15.78
	56-60	17.84	0.45	0.00	16.97 - 18.75	24.23	0.87	0.00	22.58 - 26.00
	61-65	28.82	0.77	0.00	27.36 - 30.36	36.49	1.37	0.00	33.90 - 39.28
	Over 66	44.61	1.54	0.00	41.69 - 47.73	55.57	2.61	0.00	50.67 - 60.94
Mother Age	Under 20	1.38	0.03	0.00	1.32 - 1.43	1.28	0.04	0.00	1.22 - 1.35
	20-25	1.14	0.01	0.00	1.11 - 1.16	1.11	0.02	0.00	1.08 - 1.14
	26-30	1.00				1.00			
	31-35	0.93	0.01	0.00	0.91 - 0.96	0.97	0.01	0.04	0.94 - 1.00
	36-40	0.92	0.01	0.00	0.90 - 0.95	0.92	0.02	0.00	0.89 - 0.96
	Over 40	0.92	0.02	0.00	0.87 - 0.97	0.92	0.03	0.02	0.86 - 0.99
Birth Year	1938	1.00				1.00			
	1939	1.01	0.02	0.56	0.97 - 1.06	1.09	0.03	0.01	1.03 - 1.15
	1940	1.00	0.02	0.95	0.96 - 1.05	1.10	0.03	0.00	1.04 - 1.17
	1941	1.05	0.03	0.04	1.00 - 1.10	1.14	0.04	0.00	1.08 - 1.22
	1942	1.04	0.02	0.14	0.99 - 1.08	1.12	0.03	0.00	1.05 - 1.19
	1943	1.06	0.02	0.01	1.01 - 1.11	1.19	0.04	0.00	1.12 - 1.26
	1944	1.05	0.02	0.04	1.00 - 1.10	1.16	0.04	0.00	1.09 - 1.23
	1945	1.03	0.02	0.20	0.98 - 1.08	1.17	0.04	0.00	1.10 - 1.25
	1946	1.09	0.03	0.00	1.04 - 1.14	1.21	0.04	0.00	1.13 - 1.29
	1947	1.08	0.03	0.00	1.02 - 1.13	1.14	0.04	0.00	1.07 - 1.22
	1948	1.05	0.03	0.06	1.00 - 1.10	1.20	0.04	0.00	1.13 - 1.28
	1949	1.05	0.03	0.09	0.99 - 1.10	1.21	0.04	0.00	1.13 - 1.30
	1950	1.15	0.03	0.00	1.09 - 1.22	1.25	0.04	0.00	1.17 - 1.34
	1951	1.22	0.03	0.00	1.15 - 1.29	1.32	0.05	0.00	1.23 - 1.42
	1952	1.23	0.04	0.00	1.16 - 1.30	1.31	0.05	0.00	1.22 - 1.41
	1953	1.25	0.04	0.00	1.18 - 1.32	1.36	0.05	0.00	1.26 - 1.46
	1954	1.27	0.04	0.00	1.20 - 1.35	1.38	0.05	0.00	1.28 - 1.49
	1955	1.40	0.04	0.00	1.32 - 1.49	1.42	0.06	0.00	1.31 - 1.54
	1956	1.48	0.05	0.00	1.40 - 1.58	1.55	0.06	0.00	1.43 - 1.68
	1957	1.42	0.05	0.00	1.33 - 1.51	1.60	0.07	0.00	1.47 - 1.74
	1958	1.44	0.05	0.00	1.35 - 1.54	1.43	0.07	0.00	1.30 - 1.56
	1959	1.40	0.05	0.00	1.31 - 1.50	1.52	0.07	0.00	1.39 - 1.67
	1960	1.59	0.06	0.00	1.49 - 1.71	1.59	0.08	0.00	1.45 - 1.75
Set Order	1	1.00				1.00			
	2	1.06	0.01	0.00	1.04 - 1.08	1.07	0.01	0.00	1.04 - 1.10
	3	1.12	0.02	0.00	1.09 - 1.15	1.12	0.02	0.00	1.08 - 1.17
	4	1.14	0.03	0.00	1.09 - 1.19	1.12	0.03	0.00	1.05 - 1.19
	5	1.19	0.04	0.00	1.10 - 1.28	1.17	0.06	0.00	1.06 - 1.29
	6	1.19	0.08	0.01	1.04 - 1.37	1.15	0.10	0.13	0.96 - 1.37
Set Size	2	1.00				1.00			
	3	0.98	0.01	0.04	0.96 - 1.00	0.97	0.01	0.02	0.94 - 1.00
	4	1.01	0.01	0.36	0.99 - 1.04	0.95	0.02	0.01	0.92 - 0.99
	5	1.05	0.02	0.00	1.02 - 1.09	0.98	0.02	0.51	0.94 - 1.03
	6	1.02	0.02	0.34	0.98 - 1.07	1.02	0.03	0.52	0.96 - 1.08
	Constant	0.00	0.00	0.00	0.00 - 0.00	0.00	0.00	0.00	0.00 - 0.00
N				917,718				878,858	
Deaths				61,148				36,905	

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

While the analyses presented here pool individuals in sibship sizes ranging from two to six, we also conducted analyses that were sibship size-specific. The results for these later analyses, holding sibship size constant, were wholly consistent with the results presented below. 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 slightly more volatile due to the relatively small number of sibships with more than six children. We have also conducted analyses to examine whether there is an interaction between birth order and the gender composition of siblings. However, a detailed analysis of the gender composition of siblings in sibship sizes two and three suggested that this factor no impact on mortality risk for the focal individual. We also estimated the models specifying shared frailty amongst siblings, according to a gamma distribution. The results were almost identical to those reported here.

DISCUSSION AND CONCLUSION

The results presented above demonstrate that birth order matters for mortality risk in adulthood, for both males and females. This is true for all-cause mortality risk, and well as several cause-specific trends, but is particularly pronounced for mortality attributable to cancers of the respiratory system. A larger volume of research has shown that sibship size is consistently related to mortality risk both in childhood as well as adulthood, but fewer studies have had a sufficiently large database to investigate the impact of birth order itself on mortality risk (Hart and Davey-Smith, 2003; Altieri and Hemminki, 2007). 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. This latter trend in particular suggests that social pathways play an important role in mediating the relationship between birth order and mortality risk in adulthood.

Several explanations have been put forward regarding why birth order should affect mortality risk in adulthood, and these include diminishing resources, an increased likelihood of younger siblings being introduced to developmentally inappropriate activities by older siblings (Elliott, 1992), and 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 (Elliott, 1992; Holman et al., 2003). Given the patterns observed here, it seem likely that the second of these three propositions has the greatest explanatory power. Research in social psychology and using social network data 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).

Furthermore, there are indications that because of this pattern of smoking uptake by younger siblings, they are also 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. It should be added that while the most dramatic pattern observed in this study was for cancers of the respiratory system, a greater relative risk of mortality was also observed for mortality attributable to neoplasms generally, diseases of the circulatory system, and accidents, suicides, and events of undetermined intent.

While smoking behaviour also would impact the health of the circulatory system, previous research indicates that younger siblings also demonstrate a higher rate of alcoholism, and are more likely to initiate sexual activity at a younger age (Blane and Barry, 1973; Rodgers and Rowe, 1988). Research on birth order outside of the realm of health outcomes, notably the work of Sulloway (1996), has suggested that this factor plays an important role in shaping the social pathways that an individual follows. In particular, Sulloway (1996) suggests that first born children are more likely to identify with authority figures and support the status quo, whereas later born children are far more likely to rebel against it.

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 mother-father pairing. This means that we are forced to draw several assumptions that we cannot readily test. The first of these is that we do not account for half-brothers or half-sisters who may, practically speaking, be part of a sibship. 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 is that we do not adjust our models for the potential role of the time interval between siblings. This may be an important factor. For example, a third or fourth order child may be disadvantaged relative to the older siblings is born soon after them, but if there is a greater gap, parental resources may have increased substantially, and more time and attention may be available to be devoted to the younger child. This could include attention from older siblings, who may adopt a caretaker role. However, including this nuance in the analytical models would plausibly involve very complicated interactions that would need to factor in the time interval between both earlier and later born siblings, as well as birth order, and potentially also the gender composition of the siblings. Our objective was to look at the relationship between birth order and mortality risk using a more straight forward approach.

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