Pathways to Exceptional Longevity: Effects of early-life and intermediate factors on later-life mortality

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Extended Abstract

Background Familial characteristics in early-life are by now established determinants of old-age mortality. The close relationship between the socioeconomic environment in early childhood and health and mortality outcomes in old age has been extensively studied in both epidemiological and demographic fields. Most studies have shown that an adverse environment in childhood leads to levels of morbidity (Blackwell et al., 2001; Hass, 2008; Moody-Ayers et al., 2004) and mortality (Elo and Preston, 1996; Galobardes et al., 2004; Hayward and Gorman, 2004) higher than the average.

The channels through which early life environment is likely to influence mortality in later life are diverse (Hertzman, 1999; Ben-Shlomo and Kuh, 2002). One of the pathways comes from the critical period model which claims that early-life insults during a specific window have irreversible and *direct* effects on mortality later in life (Barker, 1998). For example, exposure to severe infecrions or malnutrition in early childhood was found to be a vector of various diseases later in life, leading to higher mortality, independently of intervening experiences in adulthood (Painter et al., 2005). Some of the strongest evidence for the influence of childhood environmental factors acting directly on later-life mortality comes from studies on the effect of birth weight and seasonality. A person's month of birth can indeed provide a useful proxy measure of seasonal change in the early-life environment at the time of birth as well as for maternal nutritional status during pregnancy and permits to explore relationships between exposures to early-life characteristics and longevity, net of life course factors (Doblhammer, 1999; Gavrilova and Gavrilov, 2010).

Early childhood environment has also been proposed to have *indirect* effects on adult mortality through the lifelong accumulation of detrimental effects (Elo, 2010; Huang and Elo, 2009; Preston et al., 1998). Preston, Hill, and Drevenstedt (1998) argued that conditions in early life might lead to higher mortality in later life not only directly but also indirectly, by having an impact on obtained socioeconomic status. In this line of research, Elo (2010) found that long-term adverse health consequences of

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disadvantaged early life social circumstances could thus be mediated through adult educational attainment and employment opportunities in early adulthood. In this perspective, the life course approach to socioeconomic inequalities in mortality highlights the importance of potential processes through which biologic, social or physical exposures acting at different stages of life can have long-term effects on health in later life and lead to inequalities in longevity.

Research question Despite the ample evidence on the influence of socioeconomic childhood conditions on longevity, less established in the literature is whether this association holds true within long lived families and whether this is a direct effect or an indirect effect. Our paper thus adds to this growing body of literature by investigating the association between childhood family characteristics and mortality after age 40, and through which channels this effect operates. In the first part of this study, we examine whether and how the effect of early-life conditions influence longevity in the general population as well as in families of centenarians. In the second part, we examine whether the association between childhood conditions and old age mortality can be modify by the adjustment for socioeconomic status and marriage in adulthood.

Data and sample Our first sample consists of 806 validated centenarians and 3000 siblings. Centenarians' information was obtained from a list of registered deaths provided by the Institut de la Statistique du Québec, which contains records on centenarians who died between 1985-2005 in the Province. Families were reconstituted by linking these centenarians to their family members through the 1901 and 1911 Canadian censuses, which are available on the Internet through Ancestry and Automated Genealogy. A total of 5,338 siblings of centenarians have been identified. Once the database was completed, we searched for the date of death of each of these individuals through the Quebec Consolidated Deaths Index from the Société de généalogie du Québec. This database allows users to find dates of death and of birth, maiden names, etc. of persons who died in Québec between 1926 and 1996. For deaths occurring beyond 1996, we used a list of registered deaths over 85 years old for the years 1997-2004 provided by l'Institut de la Statistique du Québec. Linkage was made on the basis of information contained in both the censuses and death registers, particularly through the name(s) of the subject, his date and place of birth and the name(s) of his parents. To compare the survival of siblings of centenarians to that of their birth cohort, we used a second sample (control) that consists of a 5% sample of households drawn from the 1901 Canadian Census (Sager and Baskerville, 2007). Then were selected from this random sample, families with at least one child born between 1885 and 1901. Only French Canadian Catholics who went on to live at least to age forty were selected, i.e., 8204 individuals, for whom we found 3784 deaths.

Measures and variables Using a set of family background variables measuring the social level of the family, we first investigate if early-life conditions do have a long-lasting effect on old age mortality. The social origin of the family is measured by the main determinants of housing characteristics found in the 1901 and 1911 censuses, which include the *father's occupation*, the *father's literacy* as well as the *place of residence*. For families residing in rural areas, we also use *homeownership* as a marker of socioeconomic status. In addition we use the *number of acres owned by the household head* as a proxy for socioeconomic standing, presuming that a higher number of acres owned equated with a higher SES (Gagnon and

Bohnert, 2012). The aforementioned shared familial determinants might not be the only ones associated with old age mortality. Other determinants, biological in nature or related to the family structure, could be found to affect exceptional longevity. Consequently, our models will also include *maternal and paternal ages at childbirth, maternal and paternal ages at death, birth order, sibling composition* and *presence in the household of both parents*. Additionally, contextual early-life conditions variables will be considered in the models, particularly the *birth cohort*, the *infant mortality rate* and the *season* or *month of birth*. We will also test for interactions between variables, in particular between maternal age and season of birth as this interaction could be informative as to the biological and environmental context in which the chid is born.

In order to test whether the association between childhood conditions and old age mortality is modified by the adjustment of adult conditions, we will run additionnal models adding various adult variables, such as the *individual's occupation, his/her spouse's occupation* and *rural/urban status*. Furthermore, we will consider in the analysis the *marital status*, the *age at first marriage* and the *age gap between spouses* in order to see if marriage acts as a compensatory device in case of adverse early-life conditions. Our adult characteristics come from the marriage certificate and/or the parish registers. An overview of the data sources used in this study is shown in Table 1.

Table 1: Registers and variables used in this study

Name of Register	Variables
1901 and 1911 Canadian Censuses	Sex, Date of birth, Father's occupation, Father's literacy, Urban/rural residence, Homeownership, Number of acres, Birth order, Season of birth
Birth Certificate	Date of birth, Father's occupation, Birth order, Season of birth
Death Registers	Date of death, Marital status at death, Name of spouse
Marital Registers	Date of Marriage, Name of spouse, Occupation or spouse's occupation and/or father's occupation, Age gap between spouses

Statistical Analysis

Non-parametric analysis was first performed to estimate the effect of each variable included in the models using the Kaplan-Meier estimator. We then carried out gender-specific proportional hazard models with a Gompertz specification of the risk of mortality after age 40, controlling for a number of factors such as the year of birth and family size. The effects of conditions in childhood on later life mortality were analyzed first, then were the effects of both early-life conditions and adult variables on old-age mortality. All models were run for each sex separately in order to evaluate if men and women follow different pathways to reach the oldest age. Because siblings' survival experiences are likely to be clustered, we added a family-specific random effect that represents unobserved influences common to all member of a family and accounts for random unmeasured family-level traits shared by siblings. We modeled the risk of mortality after age 40 in in which our estimated hazard μ_t is

$$\mu(t, z_i, X_{ij}) = z_i, \mu_0(t)e^{\beta X_{ij}} \tag{1}$$

where z_i represents the random variable of the shared frailties, X_{ij} observed explanatory variables and βX_{ij} parameters to be estimated. The frailties, which are assumed to depend on genetic or environmental unobserved characteristics at the family scale, are now assumed to be independent and identically distributed.

Some descriptive results

Data collection and modeling for this paper is still ongoing, however selected preliminary results for a few variables are briefly presented.[1] Figure 1 shows the effect of father's occupation on the age adjusted survival probabilities of men, for both samples, after age 40. It seems that having a father who was a farmer encourages longevity gain in the general population, while in centenarian families, the effect was found to be much smaller. Because it has been argued that genetic and biological influences, rather than social influences, should take on a greater share in affecting mortality as one gets old and because long-lived individuals such as siblings of centenarians may have a stronger genetic basis, we believe that environment in childhood could be less predictive among siblings of centenarians than among siblings from the general population. We plan to investigate this phenomenon more deeply.

Figure 2 illustrates rural-urban status in childhood on the age adjusted survival probabilities of men and women after age 40. The results are quite different across gender. At first glance, place of residence in childhood reveals that men on average enjoy a protective effect of living in a rural setting on their mortality risk after age 40. However, this protective effect seems less evident for women. The stronger protective effect of rural setting experienced by men compared to women could be attributed to a cumulative advantage of men becoming themselves farmers in adulthood. In fact, the literature on the topic usually finds a weaker effect of place of residence in childhood among women because their mortality risk is more likely to be influenced by their place of residence in adulthood.

In order to deepen our understanding of the predictors of longevity and to gain insights into the mechanisms that lead to exceptional survival we will undertake, in the next months, additional analyzes taking into account the characteristics in adulthood. Furthermore, our completed models will include all the variables mentioned in the present abstract and all analyzes will be conducted for both samples.

Motivations This article makes three contributions to the literature. The first is to estimate the difference played by early-life and intermediate factors among men and women in a framework that highlights the role played by the familial environment. The second is to unravel whether mortality determinants among the general population may be different from those among long-lived individuals. Finally, the results of this study will mainly shed light on the extent to which the effect of early life conditions on mortality later in life operates directly or indirectly through attained socioeconomic position in adulthood or marital status.

[1] Data collection is soon to be finished for the adult variables of both samples

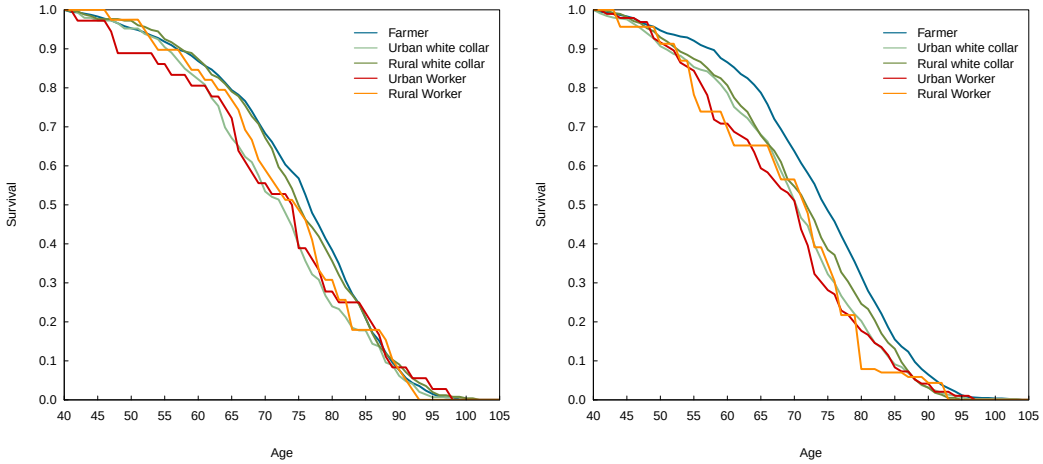

Figure 1: Kaplan-Meier survival curves estimates for forty-year-old and over siblings of centenarians, according to the father's occupation, siblings of centenarians and general population

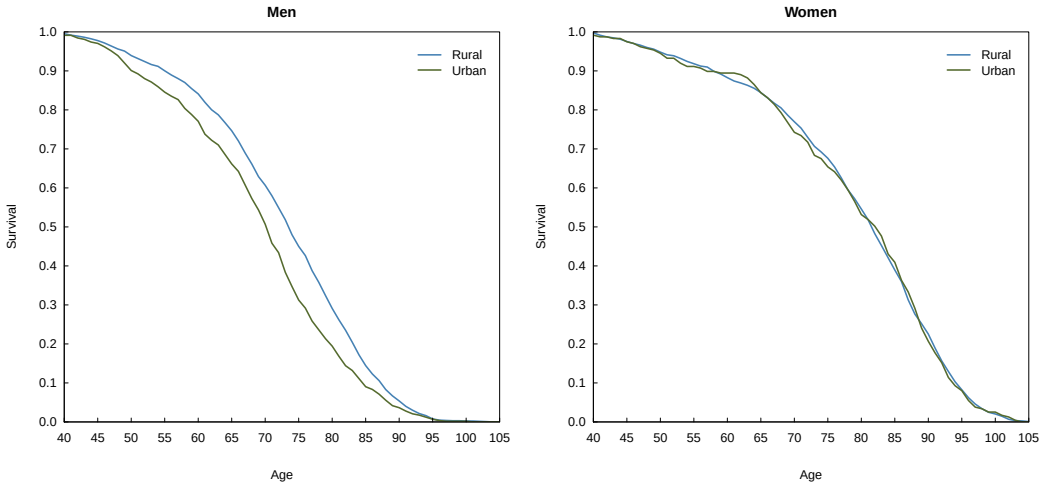

Figure 2: Kaplan-Meier survival curves estimates for forty-year-old and over siblings of centenarians, according to the place of residence in childhood, men and women

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