Exploring lifelong pathways to longevity: The role of biodemographic factors, childhood environment and socioeconomic influences in mid-life on later-life mortality

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Abstract

The close relationship between early childhood conditions and health and mortality outcomes in old age has been extensively studied in both the epidemiological and demographic fields. The channels through which early life is hypothesized to influence mortality are diverse and could be direct or indirect via adult characteristics. Despite the ample evidence on the influence of childhood conditions on overall 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. In this paper we investigate the association between biodemographic and socioeconomic factors in early life and mortality after age 40, and through which pathways this effect may operate. 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 mediated by the socioeconomic status in adulthood or by marriage. An event-history database that links individuals to their childhood characteristics gathered from the 1901 and 1911 Canadian census records and to their adult characteristics is used. Non-parametric analyses are performed to estimate the effect of early life and adult variables using the Kaplan-Meier estimator as well as gender-specific proportional hazard models with a Gompertz specification of the risk of mortality. We further suggest the use of structural equation modeling (SEM) to identify direct and indirect effects of early life conditions on later life mortality. Overall, this study will contribute to gain insight into the predictors and pathways associated with longevity in addition to deepen our understanding as to whether mortality determinants among the general population may be different from those among long-lived individuals.

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Extended Abstract

Background

The importance of the familial environment in early life for health and mortality in later life is well recognised. Studies in both the epidemiological and demographic fields have put a particular attention on the socioeconomic environment in early childhood. Most studies have shown that an adverse environment in childhood leads to levels of morbidity and mortality higher than the average(Blackwell et al., 2001; Hass, 2008; Moody-Ayers et al., 2004; Elo and Preston, 1996; Galobardes et al., 2004; Hayward and Gorman, 2004; Bengtsson and Brostrom, 2009; Smith et al., 2009; Mazan and Gagnon, 2007; Gagnon and Bohnert, 2012; van den Berg and Gupta, 2011). In addition to the socioeconomic influence, scholars have argued that elements of the unshared environment such as prenatal conditions, parental characteristics and sibling configuration could all potentially be associated with old-age mortality (Gavrilova and Gavrilov, 2010; Myrskyla and Fenelon, 2012; Modin, 2002; Jarry et al., 2013).

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 infections 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 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. We also investigate whether the association between biodemographic factors and longevity may be moderated or mediated by the socioeconomic context of early life, and vice versa.
In the second part, we examine whether the association between overall childhood conditions and old age mortality can be mediated by the socioeconomic status and marriage in adulthood. In all analyses we question whether men and women follow different pathways to achieve longevity. In other words, are men and women equally sensitive to early life conditions, biodemographic determinants and mid-life circumstances?

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*, the *place of residence* as well as a household variable measuring the health and sanitation. 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 biodemographic variables such as *maternal and paternal ages at childbirth, birth order, birth spacing* and *season of birth.* Additionally, variables measuring the health of the family (*infant mortality rate*) and parental lifespan (*age at death of both parents*) will be considered. 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 mediated by the environment in adulthood, we will run additional 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 (van den Berg and Gupta, 2011). Our adult characteristics come from the marriage certificate and/or the parish registers and the 1921 Canadian census. 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
Marriage Registers	Date of Marriage, Name of spouse, Occupation or spouse's occupation and/or father's occupation, Age gap between spouses

Statistical Analysis

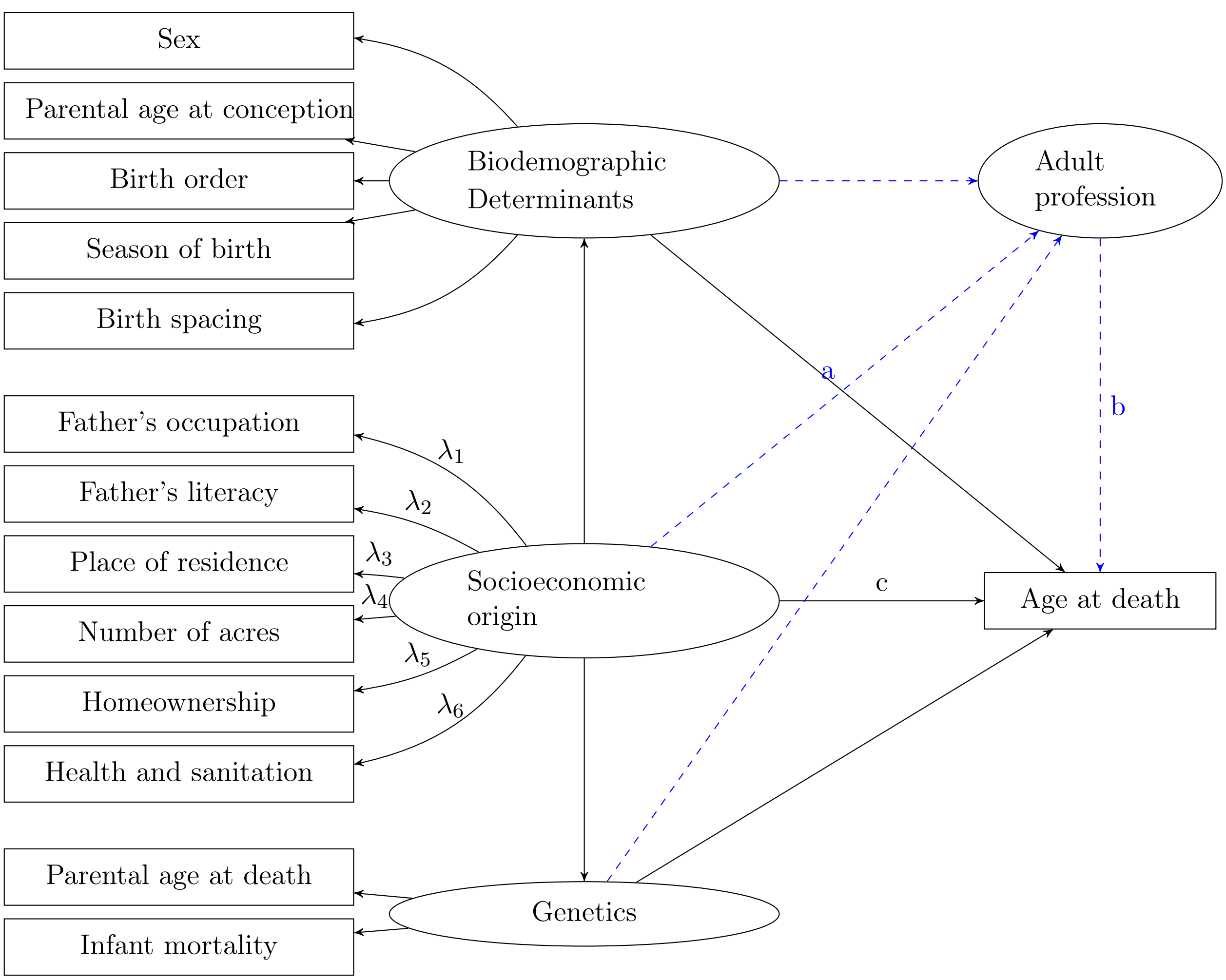
Non-parametric analysis was first performed to estimate the effect of each variable included in the models using the Kaplan-Meier estimator. We then carried out gender-specific proportional hazard models with a Gompertz specification of the risk of mortality after age 40, controlling for a number of 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. Because selection into the study population may affect the true relationship between early life and adult conditions and longevity, we use a two-stage Heckman sample selection procedure to correct for the possibility that individuals for which we find a date of death differ from others.

Furthermore, because early life conditions can influence mortality in later life both directly and indirectly through their influence on subsequent life course trajectories, we propose the use of structural equation modeling (SEM) to identify direct and indirect effects of early life conditions on later life mortality. The direct pathway suggests that early life SES or other biodemographic measures can affect mortality directly, and this effect is not mediated by characteristics in adulthood. According to the indirect pathway, on the other hand, the effect of early life SES is transmitted via the adult socioeconomic status. A conceptual model illustrating the two pathways is presented in Figure 1.

Figure 1: Conceptual structural equation model of childhood conditions, biodemographic factors, adulthood socioeconomic status and longevity



- - - Indirect effect: Cumulative disadvantage hypothesis
— Direct effect: The latent model (or critical period)

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 2 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 3 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. Estimates of the gender-specific proportional hazard models shown in Table 2 illustrate similar findings.

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 analyses taking into account the biodemogarphic variables as well as characteristics in adulthood. Furthermore, our completed models will include all the variables mentioned in the present abstract and all analyses 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.

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

Figure 2: Kaplan-Meier survival curves estimates after the age of 40, according to the father's occupation. Siblings of centenarians and general population.

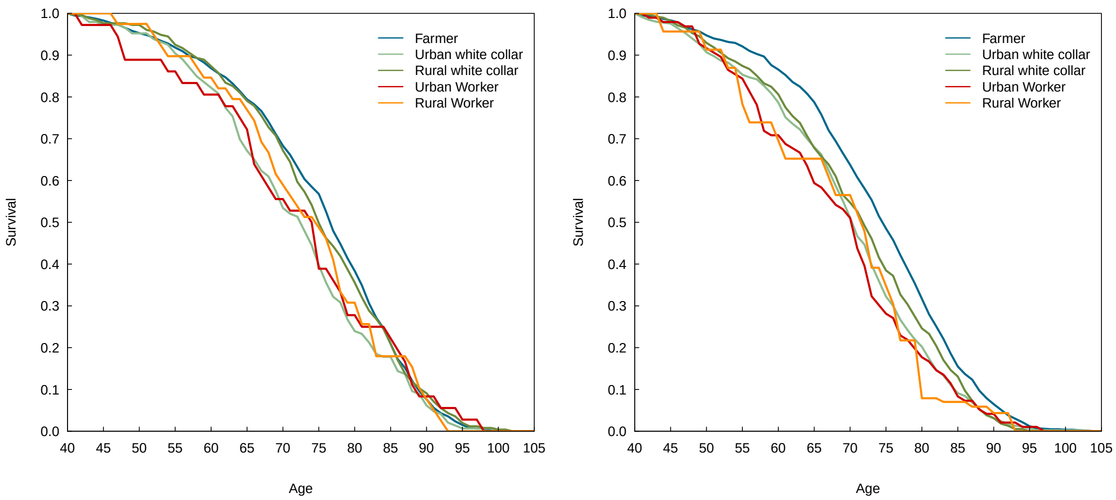

Figure 3: Kaplan-Meier survival curves estimates after the age of 40 for the general population according to the place of residence in childhood. Men and women.

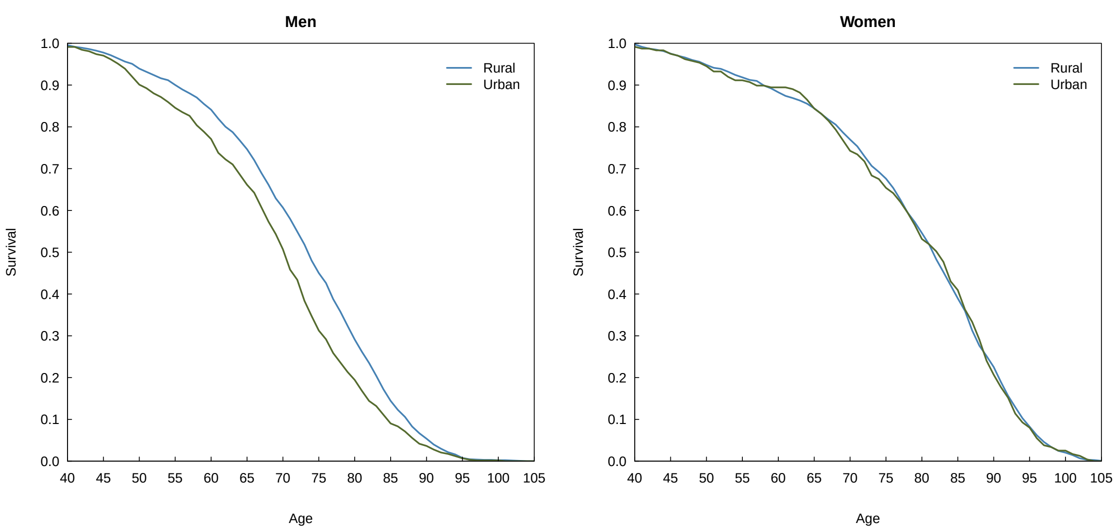

Table 2: Measuring the childhood family environment:
Gompertz proportionnal hazard models of mortality risks after age 40 accounting for unobserved heterogeneity

	Centenarian family		**General Population**	
	Hazard ratio		**Hazard ratio**	
	Female	Male	Female	Female
Year of birth	0.996	1.005	0.985*	1.003
Family size	0.994	0.991	0.991	0.993
Father's literacy				
Literate	1.055	1.068	1.144&	0.925
Unknown	1.000	1.000	1.451&	0.953
Illiterate	réf.	réf.	réf.	réf.
Father's profession				
Urban worker	1.029	1.422***	1.180**	1.398***
Rural worker	0.969	1.081	0.991	1.037***
Urban white collar	0.951	1.215	1.097	1.529***
Rural white collar	1.156	1.284	1.117	1.381
Unknwon	1.207&	0.926	0.180	1.203
Farmer	réf.	réf.	réf.	réf.
Gamma	0.088***	0.094***	0.079***	0.093***
Theta	5.91e-08	0.056	2.89e-07	0.128

*** Estimate statistically significant on a 0.5% level.
** Estimate statistically significant on a 1% level.
* Estimate statistically significant on a 5% level.

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