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Trajectories of health-related quality of life differ by age among adults: Results from an eight-year longitudinal study

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ABSTRACT

To date, only a few studies have assessed determinants of health trajectories using longitudinal health survey data.

Multilevel models were used to estimate health-related quality of life trajectories and assess factors associated with variations among trajectories, controlling for mortality effects and cohort membership. Four biennial cycles (1996/97–2004/05) of the Canadian National Population Health Survey were used. Information for 13,665 respondents, including those who were subsequently institutionalized and/or died, was used.

A typical life-course trajectory was concave with a slow decline until the age of 60, followed by a more rapid decline. Receiving social assistance, lower education and not being married had significant negative impacts on trajectories for young (age 18–39) and middle-aged (40–64). Chronic conditions and health behaviours such as smoking were important for seniors (65+).

It is important to focus on the most relevant and important determinants of health in each phase of life.

1. Introduction

In a broad determinants of health framework, a number of demographic, socio-economic and behavioural factors interact in a dynamic and complex manner to affect overall health (McDonough et al., 2005). Cross-sectional studies, while useful, are subject to the confounding effect of age-cohort, making it impossible to differentiate effects of aging from cohort differences. Therefore, the analyses of longitudinal data play an important role in disentangling the effects of various factors (Kim and Durden, 2007; McDonough and Berglund, 2003).

To date Canadian longitudinal studies are limited (Shooshtari et al., 2007; Martel et al., 2006; Shields and Martel, 2006; Buckley et al., 2004; Orpana et al., 2009; Kaplan et al., 2008). Most are predictive and examined whether determinants of health factors observed at baseline were associated with changes in health outcomes (Shooshtari et al., 2007; Martel et al., 2006; Shields and Martel, 2006; Buckley et al., 2004). One recent Canadian study (Orpana et al., 2009) used growth models to estimate health trajectories of adults aged 40 and older who were residing in the community at baseline. The study showed that the average trajectory was concave with the decline in health accelerating after the age of 70. However, the study did not assess determinants of the health trajectories. Kaplan et al. (2008) investigated factors associated with being thrivers (maintained exceptional health with no or mild disability), non-thrivers (experienced moderate to severe disability), deceased and institutionalized, using a 10-year longitudinal Canadian population surveys for seniors (aged 65–85 years). The study found that high income, psychosocial factors (low distress, high sense of coherence) and modifiable lifestyle factors (never smoker and moderate alcohol use) were positively associated with the probability of being a thriver. A recently published paper describes trajectories of health-related quality of life (HRQL) in Canada by gender and Body Mass Index but does not comprehensively assess the determinants of health trajectories (Garner et al., 2011).

Several health trajectory studies are available for other countries (McDonough et al., 2005; Herd, 2006; McCullough and Laurenceau, 2004; Sacker et al., 2005; Shaw and Krause, 2002;

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Zaninotto et al., 2009). A recent study by Zaninotto et al. (Zaninotto et al., 2009) estimated health trajectories in UK for those aged 50 and older, finding that education, employment, long-term illness and activity limitations, and psychosocial factors contributed greatly to variations in health trajectories. Moreover, seniors with favourable health determinants (i.e., no physical and psychological illness and high wealth) had better HRQL than middle-aged individuals with unfavourable health determinants.

Previous studies show that estimated trajectories of general health are represented by a downward slope in which the rate of decline in health accelerates with age. Many of the previous studies also found noticeable variations in the trajectories among various determinants of health factors. We used longitudinal data from the Statistics Canada National Population Health Survey (NPHS) to investigate factors associated with variations among HRQL trajectories and whether or not the importance of these factors differ by the phase of life.

2. Method

2.1. Data

Statistics Canada NPHS household longitudinal data was used for the analyses. The target population was community dwellers in the 10 Canadian provinces in Cycle 1 (1994/95). Therefore, the survey excludes those living in Indian reservations, Canadian Forces bases or in long-term care institutions (e.g. nursing home, rehabilitative institutions) at baseline. Information for those who died in the subsequent cycles was retained in the longitudinal panel. For respondents who moved to long-term care institution, the NPHS institutional questionnaire was administered and these responses were also retained in the longitudinal panel (Statistics Canada, 2006a).

We used eight-year follow-up information from Cycles 2 (1996/97) to 6 (2004/05) for adults aged 18 years and older in Cycle 2. Cycle 1 information was not included because of changes in the mode of interview administration (from in-person interviews to telephone interviews). Moreover, a list of physical activities used to derive a physical activity index (one of the explanatory variables in our analyses) was importantly modified between Cycles 1 and 2. Therefore, we used data from Cycles 2 to 6 data to minimize potential impact of systematic differences in data collection and content over time.

Of the initial 17,276 respondents in the initial person-level data, 2752 individuals who were younger than 18 years old in Cycle 2 were excluded, resulting in a sample of 14,524 respondents. Data were then re-arranged as the person-period data contains 87,114 records (=14,524 respondents times six cycles). Records obtained at Cycle 1 and those with missing overall Health Utilities Index Mark 3 (HUI3) scores were further excluded, resulting in 57,239 person-period records. Further, records missing with at least one of the other important variables (4088 records) were excluded. The final sample contains 13,665 respondents with 53,151 records, covering information obtained between Cycles 2 and 6. In the final sample, during the follow-up, 145 individuals were institutionalized but did not die, 1,361 individuals died without being institutionalized, and 191 individuals were institutionalized and subsequently died.

2.2. Variables

The main dependent variable was the HUI3 overall index score. HUI3 is a generic, multi-attribute and utility-based HRQL measure capturing functional and emotional health (Feeny et al., 2002). HUI3 consists of eight attributes (vision, hearing, speech, ambulation, dexterity, emotion, cognition and pain) with five or six levels per attribute, describing up to 972,000 unique health states. Overall HUI3 scores range from 1.00 (perfect health) to −0.36 (“all-worst” HUI3 health state) where 0.00 is defined as the state of being dead. The survey design of NPHS is characterized as an accelerated longitudinal design, which is subject to potential age-cohort effects (Singer and Willett, 2003). To control for cohort effects, cohort dummy variables were included. The follow-up time ($Time_{ti}$) for a person (i) was also included. The choice of independent variables was based on the determinants of health conceptual framework (Evans and Stoddart, 1990). Variables of interest were: chronic conditions, socio-demographic characteristics, and health behavioural factors (alcohol, tobacco, physical activity). To account for death and institutionalization, two additional time-varying dummy variables were included (DEAD and INST). Detailed variable descriptions are found in Appendix A.

In the NPHS longitudinal survey, when an individual was reported to be deceased, his/her response on and the subsequent cycles were coded as missing for all the determinants of health variables. To incorporate potential impact of death on trajectories, information from the decedents up to the first record of death was retained by assigning HUI3 = 0.00. The corresponding values for the independent variables were imputed using a last-observation carried forward (LOCF) method (Orpana et al., 2009).

2.3. Analysis

Two-level linear mixed models (LMM) were estimated by MLWin 2.02 (MLWin, 2005) with a full iterative generalized least squared method. Several important advantages of mixed models over other methods include the ability to incorporate repeated measures (correlated data), unequally spaced measurement occasions, and time-varying predictors (Singer and Willett, 2003; Dubois et al., 2005), all of which are important characteristics of the NPHS longitudinal data. Mixed models are also flexible in handling unbalanced data (data missing for some cycles) provided that data are missing at random (Raudenbush and Bryk, 2002). Model specifications are provided in Appendix B.

To test for cohort effects, cohort convergence tests (Miyazaki and Raudenbush, 2000) were conducted for both unconditional and conditional models. These tests were done by comparing a model with and without cohort dummy variables. If cohort effects were significant, cohort dummy variables were included in the final models.

In the preliminary descriptive statistics, the mean HUI3 scores over the five cycles (Cycles 2–6) for young to middle-aged groups (age of 18–64) were fairly stable over time compared with a noticeable concave decline in mean HUI3 scores for the senior group (age 65+: results not shown). Therefore, separate models were estimated for young (baseline age between 18 and 39), middle-age (40–64) and seniors (65+), which was in line with the notion of the difficulty in estimating life-course trajectories (Mirowsky and Kim, 2007).

Normality and homoscedasticity assumptions of errors for conditional models were assessed using model diagnostics (Singer and Willett, 2003). Because the distribution of HUI3 scores is often left skewed, generalized linear mixed models (GLMM) were also estimated by SAS 9.1 GLIMMIX procedure (SAS Institute Inc., 2006). A random variable with a gamma distribution possesses useful distributional characteristics and ranges from zero to positive infinity, which is a mirror image of the distribution of HUI3 in the general population (Eng and Feeny, 2007). Therefore, the dependent variable (overall HUI3 scores) was transformed to disutility (=1 − utility), then a further adjustment was made by adding one to the disutility scores to generate a gamma model (Briggs et al., 2006). The gamma model was estimated using the transformed HUI3 scores as a dependent variable with an identity link function (Barber and Thompson, 2004). Results based on GLMM were compared with those based on LMM.

A series of sensitivity analyses were conducted to assess mortality effects and implication for imputations of independent variables. Excluding decedents (those who died during the follow-up) completely from the analyses could impact the trajectory estimates because it is likely that decedents are systematically different from others. Results presented by Orpana et al. (2009) on trajectories of HRQL underscore the important effects of censoring out those who move from the community to an institution and those who die. If prior health of the decedents was generally good and if many of the decedents had such a pattern (as was the case for many of decedents in samples used in our analyses), then ignoring records of death would inflate trajectories estimated in this study. Because of the absence of a value representing the state of death, previous trajectory studies faced challenges in finding appropriate methods to incorporate the state of death (Herd, 2006). We overcome this issue by assigning the state of being dead as HUI3 = 0.00, as defined in the HUI3 system. To assess mortality selection, unconditional models were re-estimated by excluding records indicating the incidence of death (i.e. DEAD = 1). Plots of unconditional models with and without DEAD = 1 were compared to see if an inclusion of mortality events impacted trajectories. To assess potential impacts of the LOCF imputation on independent variables corresponding HUI3 = 0.00, conditional models were re-estimated by excluding DEAD = 1 and compared any differences in parameter estimates and their significance levels between conditional models with and without DEAD = 1.

For all statistical analyses, normalized sampling weights that represented household population of Canadian provinces at Cycle 1 were used at an individual level. Statistical significance of each parameter was determined based on two-tailed tests; the significance of random effects was based on one-tailed tests (Snijders and Bosker, 1999). A p-value of less than 0.01 was considered as statistically significant (Trottier et al., 2000). We considered differences in mean HUI3 overall scores of 0.03 or greater as definitely important and differences as small as 0.01 may be meaningful (Horsman et al., 2003).

3. Results

Baseline sample characteristics are shown in Table 1. The average age of respondents was 45 years and the average HUI3 score was 0.89. The majority of respondents were white and the sample consisted of slightly more males (51%) than females (49%). Approximately 64% of respondents did not report any of the specified chronic conditions. High proportions of respondents had at least a high school diploma (76%), did not receive social assistance (93%) and were married (64%). Many of the respondents were light to moderate drinkers (76%); current or former smokers (61%) and/or physically inactive (59%). It could be that the effect of income (obtained from the social assistance variable) on health differs between elderly and non-elderly in that the elderly consumes more on the basis of wealth than income. Supplementary information (in Table 1) shows that, the home ownership rates for seniors are as high as (e.g., for age 65–74, 76.3% in 2006) or higher than rates for younger counterparts (e.g., for age 35–54, 72.9% in 2006). Moreover, over the 8 years (1997–2005), the overall proportion of individuals living with low incomes declined. In particular, the proportion of seniors with low incomes declined from 9.1% to 6.1%, below the national average of 10.8% in 2007, while the proportion with low incomes among the younger age groups was higher than the national average.

Table 1
Selected sample characteristics of individuals at baseline.

	Mean	SD
Age	45.0	17.47
HUI3 scores[a]	0.89	0.205

	Category	Frequencies (%)
Race	White	90.3
	Non-white	9.7
Sex	Male	51.1
	Female	48.9
Number of chronic conditions[a]	None	63.9
	One condition	22.1
	Two conditions	8.6
	More than two conditions	5.4
Education[a]	No high school diploma	23.8
	High school diploma	76.2
Social assistance[a]	Receive assistance	6.6
	Did not receive assistance	93.4
Marital status[a]	Not married	36.4
	Married	63.6
Tobacco[a]	Current or former smoker	61.3
	Nonsmoker	38.7
Alcohol[a]	More than moderate drinker	3.4
	Former drinker or abstainer	20.4
	Light to moderate drinker	76.2
Physical activity[a]	Inactive	59.2
	Active	40.8
Low income[b]		
All ages	Year 1997	15.3
	Year 2005	10.8
Age <18 years	Year 1997	17.8
	Year 2005	11.7
Age 18–64	Year 1997	15.5
	Year 2005	11.4
Age 65+ years	Year 1997	9.1
	Year 2005	6.1
Homeownership[c]		
All ages	Year 1996	64.0
	Year 2006	68.9
Age 20–34 years	Year 1996	41.0
	Year 2006	46.0
Age 35–54 years	Year 1996	69.9
	Year 2006	72.9
Age 55–64 years	Year 1996	76.4
	Year 2006	77.9
Age 65–74 years	Year 1996	73.3
	Year 2006	76.3
Age 75+ years	Year 1996	62.3
	Year 2006	68.0

Otherwise indicated, statistics are based on Cycle 2 NPHS (n = 13,665, age 18 years and older; weighted); SD = standard deviation. See Appendix A for definition and derivation of each variable.

[a] Sample size varies due to missing records.

[b] Proportion of persons with low income, based on 1992 Low Income Cut-offs (Source: Statistics Canada, 2007).

[c] Home ownership among household primary maintainers (Hou, 2010).

Fig. 1 shows results of unconditional models for the three age groups: young (Fig. 1a), middle-aged (Fig. 1b) and seniors (Fig. 1c). Cohort convergence tests were statistically significant (p < 0.01) (Table 2), therefore, cohort effects were included in all the unconditional models. To help visualize general trends of trajectories over time, overall trajectories were also superimposed in Fig. 1 (Yang, 2007). For young and middle-aged groups, approximately 50% of the variance was attributed to within-individual variations, whereas intra-class correlation coefficient was 0.90 in the model for seniors. Trajectories for the young group were flat with little

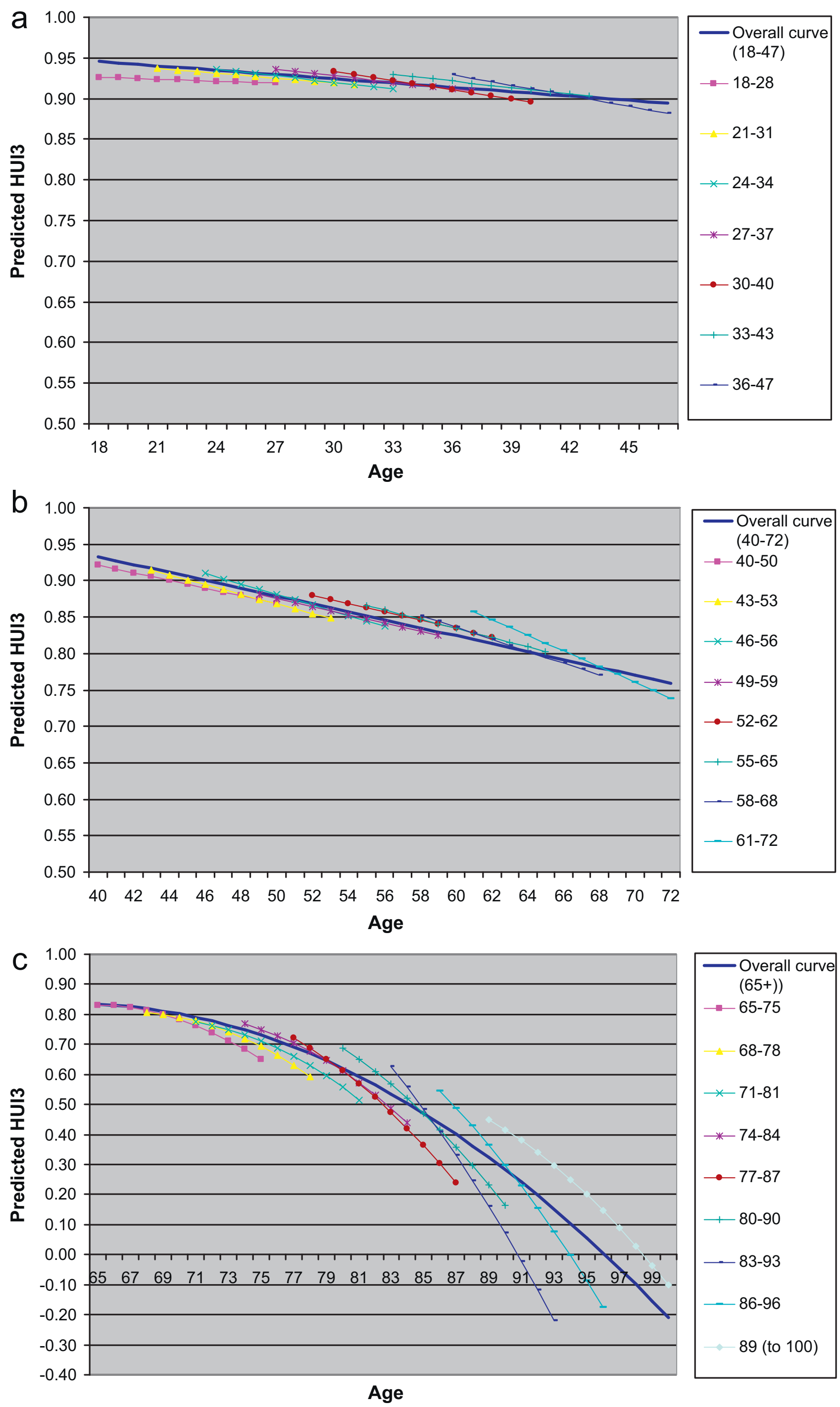

Fig. 1. Unconditional models. (a) Young (age 18–39). (b) Middle-aged (age 40–64). (c) Senior (age 65+).

differences in slopes among cohort trajectories. Trajectories for the middle-age group were also linear, but had steeper decline in trajectories over time compared with those for the youngest group. For the senior group, the trajectories were approximated by curvilinear trends. Another noticeable difference was variations in cohort trajectories; cohort trajectories for first group in seniors (e.g. 65–67 years old) were closer to the overall trajectory. In contrast, large cohort variations as well as large deviations from the overall trajectory were apparent for the oldest age group in seniors (e.g. 83 years and older). Cohort trajectories for young, middle-aged and senior groups significantly deviated ($p < 0.01$) from the overall trajectory for unconditional models.

Table 3 shows results of conditional models. The most parsimonious conditional models are presented for the three age groups after excluding the non-significant variables, one variable at a time. After important demographic and health behavioural factors were controlled, cohort effects were significant only for the middle-aged group and seniors. Therefore, Table 3a does not include cohort effects. Interaction terms between time and covariates were also added to examine if slopes were a function of the independent

Table 2
Test of cohort effects.

Model type[a]	Young (18–39)		Middle-aged (40–64)		Senior (65+)	
	Model with cohort effects	Model without cohort effects	Model with cohort effects	Model without cohort effects	Model with cohort effects	Model without cohort effects
(a) Unconditional models						
Number of parameters	18	6	20	6	23	7
Deviance	−26,212	−26,162	−12,073	−12,022	3818	4046
χ^2, d.f.	50, 12		51, 14		228, 16	
(p-value)	(p < 0.001)		(p < 0.001)		(p < 0.001)	
Conclusion	Significant cohort effect		Significant cohort effect		Significant cohort effect	
(b) Conditional models[b]						
Number of parameters	28	16	30	16	31	15
Deviance	−24,104	−24,081	−19,649	−19,607	−3941	−3894
χ^2, d.f.	24, 12		42, 14		47, 16	
(p-value)	(p = 0.020)		(p < 0.001)		(p < 0.001)	
Conclusion	Non-significant cohort effect		Significant cohort effect		Significant cohort effect	

[a] "Model without cohort effects" refers to overall model that follows the formulation shown in Raudenbush and Bryk (2002).
[b] Conditional models refer to the most parsimonious models. Cohort effect was tested for young group by adding cohort dummy variables in the model shown in (a).

Table 3a
Conditional models: young (18–39).

	b	SE
Fixed effects		
Intercept	0.964*	0.0024
Time	−0.003*	0.0003
DEAD	−0.868*	0.0195
Number of chronic conditions		
1 condition	−0.035*	0.0032
2 conditions	−0.084*	0.0091
>2 conditions	−0.156*	0.0181
No condition (ref)		
Education		
No high school	−0.021*	0.0057
High school (ref)		
Social assistance		
Received	−0.054*	0.0062
Not received (ref)		
Marital status		
Single, divorced, separated or widowed	−0.016*	0.0025
Married, with partner or common-law (ref)		
Tobacco		
Current/former smoker	−0.013*	0.0027
Non-smoker (ref)		
Alcohol		
Abstainer/former drinker	−0.0103*	0.0039
More than moderate drinker	†	
Light/moderate drinker (ref)		
Physical activity		
Physically inactive	−0.015*	0.0018
Physically active (ref)		
Random effects		
Within individuals	0.011*	0.0004
Between individuals		
Variances		
Intercept	0.006*	0.0004
Time	2.E−05*	4.00E−06
Covariances		
Intercept and time	2.E−04*	3.00E−05

Based on 5672 respondents with 22,779 records.
Based on linear mixed model.
Ref: reference group; SE: standard error.
* Significant at 1%.
† Coefficient on more than moderate drinker was excluded because it was not statistically significant. Cohort dummy variables, sex and race variables were not included because they were not statistically significant. INST was not included because there was no incidence of institutionalization for young group among records used in the analyses.

variables. However, none of the interaction terms were statistically significant (results not shown). Therefore, for all models, only the intercepts, not the rate of the change, were functions of the determinants of health variables.

In the young group, all the variables except for sex and race were statistically significant and quantitatively important (Table 3a). The DEAD dummy variable indicated a dominant (−0.87) and statistically significant (p < 0.01) effect. The number of chronic conditions was also significantly associated with median HUI3 after controlling for other factors in the model; compared with a trajectory when one did not have any chronic condition, the average differences for one, two or more than two chronic conditions were −0.04, −0.08 and −0.16, respectively, controlling for other variables. Demographic, socio-economic and health behavioural factors also importantly differentiated the HUI3 level; not having a high school diploma, receiving social assistance, current/former smoker, abstainer/former drinker and physical inactivity were all associated with lower trajectories compared with reference groups.

Results for the middle-aged group (Table 3b) were similar to those for the young group. The coefficient on DEAD of −0.78 indicates that, once an individual dies, his/her trajectory drops, on average, by 0.78. Development of a new chronic condition lowered the trajectory by 0.03, while an additional condition further lowered the curve by 0.05 (=0.08–0.03). Further, when one developed one more chronic condition, the trajectory fell by an additional 0.07 (=0.15–0.08). Consistent with results from the young group, having low education, receiving social assistance, not being married, current smoker, abstainer/former drinker and/or physically inactive all had negative and statistically significant impacts on the HUI3 level. The difference in the HUI3 level when one was in the community and in an institution was not statistically significant.

Results for the senior group (Table 3c) differed from those shown for the young and middle-aged groups. Coefficient on institutionalization (INST) was −0.21 and the coefficient on DEAD was −0.70; both were statistically significant. This indicates that once an individual became institutionalized, their trajectory dropped by 0.21 compared with the trajectory if he/she had remained in the community. Furthermore, if an institutional resident died, then the trajectory dropped further by 0.49 (=0.70–0.21). Having more chronic conditions, being non-white, current/former smoker, abstainer/former drinker and/or physically inactive had negative and statistically significant effects on the trajectories. However, in

Table 3b
Conditional models: middle-aged (40–64).

	b	SE
Fixed effects		
Intercept	0.961*	0.0056
Time	−0.004*	0.0008
Cohort 40–50 (ref)		
Cohort 43–53	−0.007	0.0069
Cohort 46–56	−0.007	0.007
Cohort 49–59	−0.012	0.0077
Cohort 52–62	−0.008	0.0081
Cohort 55–65	−0.012	0.0082
Cohort 58–68	−0.009	0.0085
Cohort 61–72	−0.012	0.0082
Cohort 43–53*time	0.001	0.0012
Cohort 46–56*time	−0.0001	0.0012
Cohort 49–59*time	0.003*	0.0012
Cohort 52–62*time	0.003	0.0013
Cohort 55–65*time	0.004*	0.0015
Cohort 58–68*time	0.003	0.0015
Cohort 61–72*time	0.004*	0.0014
DEAD	−0.781*	0.0109
Number of chronic conditions		
1 condition	−0.033*	0.0028
2 conditions	−0.076*	0.0049
>2 conditions	−0.146*	0.0083
No condition (ref)		
Education		
No high school	−0.019*	0.0049
High school (ref)		
Social assistance		
Received	−0.064*	0.0087
Not received (ref)		
Marital status		
Single, divorced, separated or widowed	−0.028*	0.004
Married, with partner or common-law (ref)		
Tobacco		
Current/former smoker	−0.018*	0.0036
Non-smoker (ref)		
Alcohol		
Abstainer/former drinker	−0.029*	0.0042
More than moderate drinker	†	
Light/moderate drinker (ref)		
Physical activity		
Physically inactive	−0.022*	0.003
Physically active (ref)		
Random effects		
Within individuals	0.015*	0.0004
Between individuals		
Variances		
Intercept	0.010*	0.001
Time	4.E−05*	1.00E−05
Covariances		
Intercept and time	2.E−04*	4.00E−05

Based on 5082 respondents with 20,833 records.
Based on linear mixed model.
Ref: reference group; SE: standard error.
* Significant at 1%.
† Coefficient on more than moderate drinker was excluded because it was not statistically significant. Cohort 40–50: refers to a dummy variable indicating age cohort that the baseline age of the cohort between 40 and 42 years. Similar definition applies for other cohort dummy variables. INST, sex and race variables were not included because they were not statistically significant.

Table 3c
Conditional models: senior (65+).

	b	SE
Fixed effects		
Intercept	0.960*	0.0088
Time	−0.002	0.0012
Cohort 65–75 (ref)		
Cohort 68–78	−0.019	0.01
Cohort 71–81	−0.040*	0.0112
Cohort 74–84	−0.048*	0.0113
Cohort 77–87	−0.084*	0.0127
Cohort 80–90	−0.099*	0.0141
Cohort 83–93	−0.110*	0.0142
Cohort 86–96	−0.156*	0.0197
Cohort 89	−0.162*	0.0192
Cohort 68–78*time	−0.001	0.0019
Cohort 71–81*time	−0.001	0.002
Cohort 74–84*time	−0.002	0.0022
Cohort 77–87*time	−0.004	0.0027
Cohort 80–90*time	−0.010*	0.0031
Cohort 83–93*time	0.003	0.0034
Cohort 86–96*time	0.002	0.0052
Cohort 89*time	0.008	0.0046
INST	−0.211*	0.0767
DEAD	−0.699*	0.0067
Number of chronic conditions		
1 condition	−0.035*	0.0051
2 conditions	−0.073*	0.0063
>2 conditions	−0.140*	0.0075
No condition (ref)		
Race		
Non-white	−0.067*	0.024
White (ref)		
Tobacco		
Current/former smoker	−0.029*	0.0062
Non-smoker (ref)		
Alcohol		
Abstainer/former drinker	−0.034*	0.0057
More than moderate drinker	†	
Light/moderate drinker (ref)		
Physical activity		
Physically inactive	−0.049*	0.0042
Physically active (ref)		
Random effects		
Within individuals	0.028*	0.001
Between individuals		
Variances		
Intercept	0.008*	0.0005
Time	1.00E−05	1.00E−05
Covariances		
Intercept and time	−2.E−04*	4.00E−05

Based on 2911 respondents with 9539 records.
Based on linear mixed model.
Ref: reference group; SE: standard error.
* Significant at 1%.
† Coefficient on more than moderate drinker was excluded because it was not statistically significant. Cohort 65–75: refers to a dummy variable indicating age cohort that the baseline age of the cohort is between 65 and 67 years. Similar definition applies for other cohort dummy variables. Cohort 89 refers to a dummy variable indicating age cohort that the baseline age of the cohort is 89 and older. Sex, education, social assistance and marital status variables were not included because they were not statistically significant.

contrast with results from the younger groups, education, social assistance and marital status were not important factors in differentiating trajectories for seniors.

Differences in the size of coefficients across the three age groups (Tables 3a–3c) are also of interest. Although the magnitude of the coefficients on DEAD was large for all groups, the young group had a much larger coefficient (|0.87|, an absolute value of 0.87) than for the older two groups (|0.78| for the middle-aged group and |0.70| the senior group). Impact of low education on trajectories was comparable for young (|0.02|) and middle-aged (|0.02|) groups. Coefficients on socio-economic factors such as social assistance and marital status were greater for the middle-aged group (|0.06| and |0.03|, respectively) compared with those for the young group (|0.05| and |0.02|, respectively). For seniors, however, these factors are less important. Health behavioural factors such as use of tobacco or alcohol and physical activity showed greater impacts on trajectories for seniors than for younger groups. In particular, the average decrement in trajectories when one became inactive was |0.05| for seniors, which was more than twice as large as the decrements estimated for young (|0.02|) and middle-aged (|0.02|) groups. The magnitude of coefficients on the number of chronic conditions was comparable across the three age groups.

Based on normality plots, level-1 and level-2 residuals showed evidence of non-normal distributions, especially a highly left skewed residuals at level 2 (results not shown). Therefore, results from LMM were compared with those from GLMM. For unconditional models, comparisons of estimated trajectories between LMM and GLMM models showed little difference in the shape of trajectories and cohort variations. Comparisons of conditional models found negligible differences in parameter estimates and their significance level (results not shown). Therefore, the impact of the violation of the normality assumption for study results was negligible. Scatter plots of unstandarized residuals against each level of the independent variables showed little evidence of heteroscedasticity (results not shown).

When HUI = 0.00 scores for the dead were included in the model, the HRQL trajectory was much steeper, implying that, on average, those who had a negative change (i.e., change from positive HUI3 scores before death) had greater impact on slope of the trajectory than those who had a positive change [i.e., negative HUI3 scores (worse than being dead) before death] (Fig. 1a–c versus Fig. 2a–c). This suggests the importance of including a value for dead, rather than simply excluding these cases, in estimating lifetime trajectories in the middle-aged and senior groups, with the greatest impact for seniors.

To assess potential implications of imputing systematically missing values for independent variables, conditional models shown in Tables 3a–3c were re-estimated by excluding records that refer to the incidence of death (i.e. DEAD = 1, a total of approximately 1550 records). These results are shown in Tables 4a–4c. In general, little difference was found; comparisons of the size and significance of estimated coefficients for the determinants of health variables showed negligible differences. Therefore, study results were consistent.

A potential concern was the appropriateness of imputing missing records for the corresponding independent variables. However, sensitivity analyses showed little difference in estimated coefficients between conditional models with and without records of DEAD = 1 (Tables 3a–3c versus Tables 4a–4c). This may be because the proportion of records indicating the incidence of death consisted of less than 5% of the total number of records. Despite these results, one may still argue that it is not fundamentally appropriate to impute any determinants of health factors once an individual has died. However, sensitivity analyses showed that an exclusion of the incidence of death importantly affected the estimated trajectories but the impact of the LOCF imputation on study implication was negligible. Therefore, the importance of including the incidence of death surpassed the potential concerns associated with the feasibility of imputing values for the corresponding independent variables.

4. Discussion

Understanding the process of aging on health and HRQL trajectories is a complex matter because of the number of determinants of health that affect health dynamically. Our analyses revealed important heterogeneity in the determinants and their impacts on HRQL trajectories.

First, unfavourable socio-economic factors such as receiving social assistance or not being married had the greatest impact for the middle-aged (age 40–64), implying that these determinants are less important both at earlier and later stages of adult life. The absence of a relationship between income (or wealth) and health among the elderly Canadian was also seen in several other studies that found that household income was not associated with the self-reported prevalence of hypertension (Kaplan et al., 2010) and HRQL (Huguet et al., 2008). In contrast, income and health gradients were found among the elderly in the United States. The absence of the income–health relationship among seniors could be a reflection of consistently low levels of poverty among Canadian seniors (less than 10%, Table 1). Alternatively, differences in societal determinants of health, such as the universal health care system itself may ameliorate the impact of income on HRQL in old age. Further, the material standard of living of the elderly reflects both wealth and current household income whereas household income is relatively more important for non-elderly adults. In fact, homeownership rates in the later stage of the lifecycle are fairly stable (Table 1). When the imputed contribution of housing services from homeownership (i.e., implicit returns from homeownership such as shelter that would have required an expenditure on rent) was added to the traditional income estimates, it was also reported that the income of those aged 60–69 years would have been 10–13% higher and that the income of those aged 70 and older would have been 12–15% higher (Brown et al., 2010).

Second, the impact of unfavourable health behaviours increased with age. In particular, the negative impact of physical inactivity was noticeably greater for the senior group, results that were similar to those found in other Canadian studies (Martel et al., 2006; Shields and Martel, 2006). It is notable that the effects of the number of chronic conditions on trajectories were similar for young, middle-aged and seniors. Therefore, contrary to findings for other variables, negative impacts of having additional chronic conditions persisted regardless of the life stage. Finally, as would be expected, death was far more devastating event for the young than for older groups.

Third, physical inactivity is certainly common in old age. Compared to younger adults, older adults may also be more vulnerable to the negative impact of similar levels of inactivity, resulting in a greater impact on HRQL. This would be supported by our finding that the impact of chronic conditions on HRQL trajectories was similar across all age groups, while physical inactivity had a greater impact in the elderly. The frailty model may assist in conceptualizing this finding. Frailty increases with age and, like HRQL, is a multidimensional construct going beyond the number of chronic conditions. As has been demonstrated elsewhere, frailty can be graded and typically depends on the accumulation of a large number of deficits. Recently, in one longitudinal cohort, it was demonstrated that exercise attenuated the impact of age on mortality across all grades of frailty, with its greatest benefits on those who were the most frail at baseline (Hubbard et al., 2009).

Our study provides unique empirical and methodological contributions to existing Canadian longitudinal studies. To our knowledge, this is the first study to estimate HRQL trajectories for the general adult Canadian population. Our study compared the potential differences in impacts of determinants of health factors on trajectories in various stages of life. With the use of five waves of longitudinal national population survey, results are generalizable to the adult population, including those living in long-term care institutions and we were also able to assess potential non-linear trajectories. The study also explicitly tested and controlled for cohort effects. Finally, we incorporated an approach to retaining decedents in the longitudinal panel, by assigning the HUI3 utility score of 0.00 for the state of being dead.

It is important to consider the policy implications of the results. An implication is that a public policies designed to increase educational attainment and reduce poverty rates among non-senior populations may pay dividends in more favourable trajectories of HRQL. As noted above the lack of a link between health and the

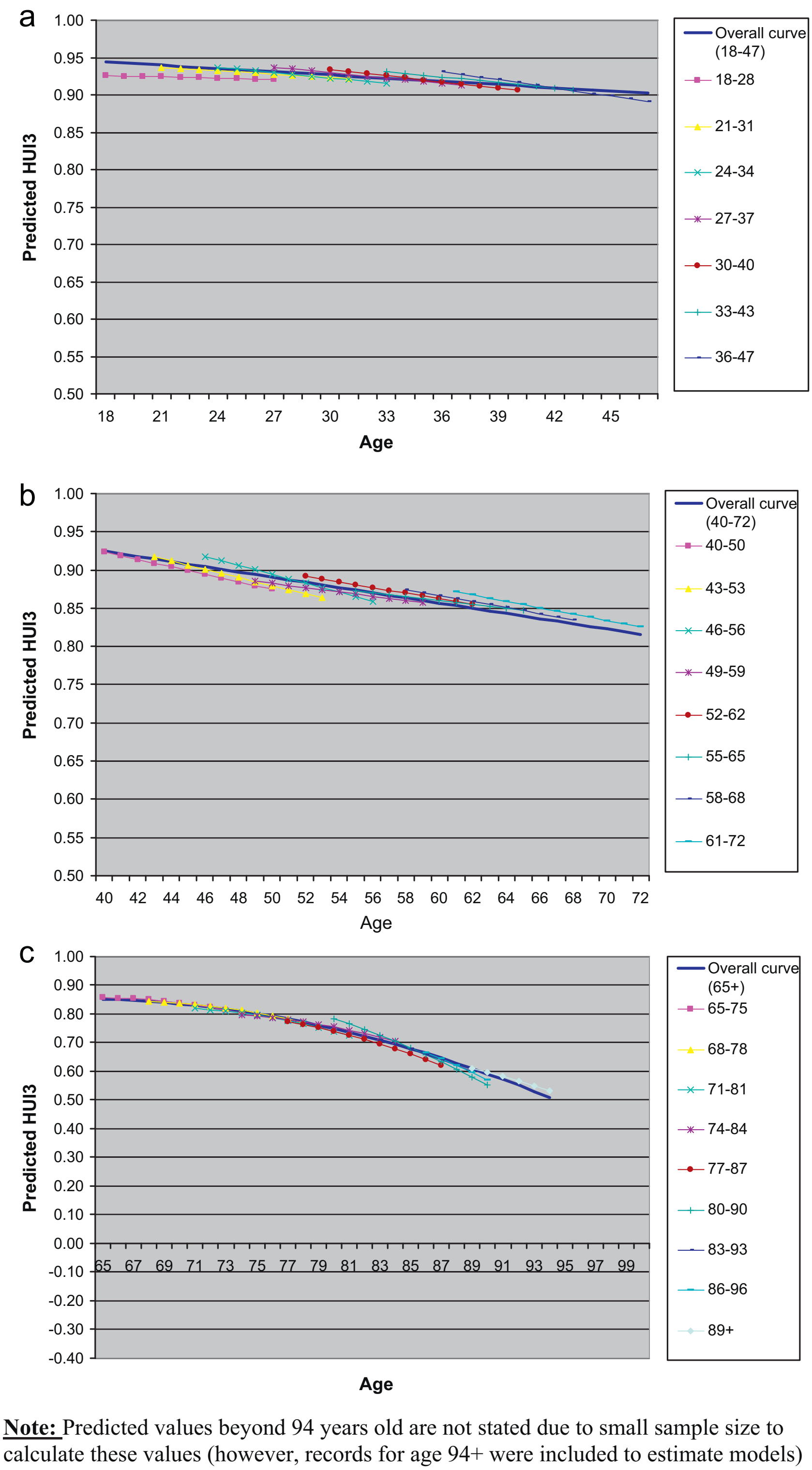

Fig. 2. Sensitivity analyses (unconditional models excluding records indicating the incidence of death (DEAD = 1)). (a) Young (age 18–39). (b) Middle-aged (age 40–64). (c) Senior (age 65+).

standard of living of the elderly reflects in part recent reductions in Canada in poverty among the elderly. That unfavourable health behaviours and additional chronic conditions are important for all three age groups underscores the implications of life course epidemiology models (Kuh et al., 2003). In the life course model current health status reflects the accumulation of the effects of previous exposures and experiences. Public health and healthcare interventions to improve health behaviours and delay the onset of chronic conditions have the potential to have far reaching dynamic effects on HRQL trajectories. That the impact of unfavourable health

Table 4a
Sensitivity analyses (conditional models excluding records indicating the incidence of death (DEAD = 1)): young (18–39).

	b	SE
Fixed effects		
Intercept	0.964*	0.0024
Time	−0.003*	0.0003
Number of chronic conditions		
1 condition	−0.035*	0.0032
2 conditions	0.084*	0.0091
>2 conditions	−0.157*	0.0182
No condition (ref)		
Education		
No high school	−0.021*	0.0057
High school (ref)		
Social assistance		
Received	0.054*	0.0062
Not received (ref)		
Marital status		
Single, divorced, separated or widowed	−0.016*	0.0025
Married, with partner or common-law (ref)		
Tobacco		
Current/former smoker	−0.013*	0.0027
Non-smoker (ref)		
Alcohol		
Abstainer/former drinker	−0.011*	0.0039
More than moderate drinker		
Light/moderate drinker (ref)		
Physical activity		
Physically inactive	−0.015*	0.0019
Physically active (ref)		
Random effects		
Within individuals	0.011*	0.0004
Between individuals		
Variances		
Intercept	0.006*	0.0005
Time	0.00002*	0.000004
Covariances		
Intercept and time	0.0002*	0.00003

Based on linear mixed model.
Ref: reference group; SE: standard error.
* Significant at 1%.

Table 4b
Sensitivity analyses (conditional models excluding records indicating the incidence of death (DEAD = 1)): middle-aged (40–64).

	b	SE
Fixed effects		
Intercept	0.961*	0.0057
Time	−0.004*	0.0008
Cohort 40–50 (ref)		
Cohort 43–53	−0.007	0.0071
Cohort 46–56	−0.006	0.0071
Cohort 49–59	−0.011	0.0079
Cohort 52–62	−0.008	0.0083
Cohort 55–65	−0.012	0.0085
Cohort 58–68	−0.007	0.0087
Cohort 61–72	−0.011	0.0086
Cohort 43–53*time	0.0004	0.0012
Cohort 46–56*time	0.00004	0.0012
Cohort 49–59*time	0.003*	0.0012
Cohort 52–62*time	0.003	0.0013
Cohort 55–65*time	0.004*	0.0015
Cohort 58–68*time	0.003	0.0015
Cohort 61–72*time	0.003	0.0014
Number of chronic conditions		
1 condition	−0.032*	0.0029
2 conditions	−0.077*	0.0049
>2 conditions	−0.147*	0.0084
No condition (ref)		
Education		
No high school	−0.020*	0.0051
High school (ref)		
Social assistance		
Received	−0.063*	0.0087
Not received (ref)		
Marital status		
Single, divorced, separated or widowed	−0.028*	0.0041
Married, with partner or common-law (ref)		
Tobacco		
Current/former smoker	−0.017*	0.0036
Non-smoker (ref)		
Alcohol		
Abstainer/former drinker	−0.029*	0.0043
More than moderate drinker		
Light/moderate drinker (ref)		
Physical activity		
Physically inactive	−0.021*	0.0023
Physically active (ref)		
Random effects		
Within individuals	0.015*	0.0004
Between individuals		
Variances		
Intercept	0.011*	0.0006
Time	0.00004*	0.00001
Covariances		
Intercept and time	0.0003*	0.00004

Based on linear mixed model.
Ref: reference group; SE: standard error.
* Significant at 1%.

behaviours increases with age is also consistent with the life course perspective.

Some study considerations are that, first, NPHS is based on self (or proxy) report, therefore, inconsistency in reporting over time may arise. Second, the multilevel model approach incorporates respondents with at least one data point, provided that data is missing at random (MAR) (Singer and Willett, 2003). The violation of this assumption is unlikely in our analyses because past health states are likely to be related to current (but unobserved) health states (Dubois et al., 2005). Although it may be argued that this assumption may not hold for decedents because their health could have been very poor had we have observed it (Lynch, 2003), we considered this assumption to be reasonable because the HUI3 score of 0.00 was used for the dependent variable for the decedents, where missing records for decedents after the first are related to the past observed values (i.e. HUI3 = 0.00). Nonetheless, assessment of attrition bias may be warranted to examine bias arising from systematic differences between those who remained and those who dropped out from the surveys (other than due to death) (Vandecasteele and Debels, 2007). Third, any non-random selection of respondents to be excluded from the analyses leads to a potential generalizability issue. We found that a significant association between the number of unfavourable factors (e.g., low HUI3 scores, low education, receiving social assistance, institutionalization) and exclusion, implying the potential underestimation of effects of these factors on trajectories. However, impacts should be minimal because these variables already had significant effects on trajectories and less than 5% of respondents were completely excluded from our analyses. Fourth, we did not address potential two-way causality between health behavioural factors and health (e.g., physical inactivity can be both a cause of subsequent declines in health status and an effect of the previous declines in health). Given that information on the severity of chronic conditions is not available in the NPHS data set, unfavourable health behaviours may also be a marker for the severity of various chronic conditions. Finally, NPHS longitudinal sampling weights represent sample characteristics at Cycle 1 without adjustment for the subsequent cycles (Shields and Martel, 2006). Therefore, data used in the current analyses may not fully represent the Canadian population at Cycle 1 due to sample attrition in the subsequent cycles.

Table 4c
Sensitivity analyses (conditional models excluding records indicating the incidence of death (DEAD = 1)): senior (65+).

	Model 3	
	b	SE
Fixed effects		
Intercept	0.962*	0.0098
Time	−0.001*	0.0012
Cohort 65–75 (ref)		
Cohort 68–78	−0.015	0.0110
Cohort 71–81	−0.039*	0.0128
Cohort 74–84	−0.051*	0.0133
Cohort 77–87	−0.081*	0.0156
Cohort 80–90	−0.096*	0.0183
Cohort 83–93	−0.136*	0.0229
Cohort 86–96	−0.196*	0.0303
Cohort 89	−0.261*	0.0467
Cohort 68–78*time	−0.001	0.0020
Cohort 71–81*time	−0.003	0.0021
Cohort 74–84*time	−0.003	0.0023
Cohort 77–87*time	−0.009*	0.0032
Cohort 80–90*time	−0.018*	0.0038
Cohort 83–93*time	−0.011	0.0056
Cohort 86–96*time	−0.022*	0.0065
Cohort 89*time	−0.013	0.0090
INST	−0.194*	0.0696
Number of chronic conditions		
1 condition	−0.035*	0.0054
2 conditions	−0.078*	0.0068
>2 conditions	−0.151*	0.0085
No condition (ref)		
Race		
Non-white	−0.070*	0.0263
White (ref)		
Tobacco		
Current/former smoker	−0.023*	0.0071
Non-smoker (ref)		
Alcohol		
Abstainer/former drinker	−0.037*	0.0063
More than moderate drinker		
Light/moderate drinker (ref)		
Physical activity		
Physically inactive	−0.045*	0.0044
Physically active (ref)		
Random effects		
Within individuals	0.026*	0.0008
Between individuals		
Variances		
Intercept	0.014*	0.0007
Time	0.00001	0.00001
Covariances		
Intercept and time	0.0004*	0.00004

Based on linear mixed model.
Ref: reference group; SE: standard error.
* Significant at 1%.

5. Conclusion

The key conclusions are that the socio-economic factors such as financial status, education and marital status were important factors that differentiate among HRQL trajectories for the young and middle-aged population. However, in the later life, lifestyle factors such as physical activity became more important. The magnitude of the impacts of chronic conditions was important and similar throughout the life cycle. An implication of the study results is that it is important to recognize such heterogeneity in trajectories and therefore to focus on appropriate aspects of the determinants of health in various phases of life.

Competing interests

It should be noted that Dr. David Feeny has a proprietary interest in Health Utilities Incorporated, Dundas, Ontario, Canada. HUInc. Distributes copyrighted Health Utilities Index (HUI) materials and provides methodological advice on the use of HUI. It should also be noted that HUInc. received no payment from Statistics Canada for the use of the Health Utilities Index Mark 3 in the National Population Health Survey, the data source for the research reported in this paper. None of the other authors declared a conflict of interest.

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Disclaimer

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Appendix A. Variable descriptions

Age [time-varying]: Age of respondents i at each cycle t was calculated by subtracting their reported birth dates from their interview dates at each cycle. For example, if the birth date of a hypothetical respondent was June 1, 1980 and the interview date was April 1, 2004 for Cycle 6, then the age of the respondent in Cycle 6 was 23 years old. Similar calculations were conducted for all respondents included in our analyses for each cycle.

Cohort dummy variables ($Cohort_i$) [time-invariant]: To estimate finer trajectories without sacrificing sample size for each cohort, cohort groups based on three-year bands for age were defined at baseline and 24 dummy variables ($Cohort_i$) were defined to indicate the age cohorts (18–21, 22–25,. . .,89+) to which a person i belongs. For young group, three-year age bands at baseline (Cycle 2) are defined as those with the age at baseline of the following seven groups: 18–20, 21–23, 24–26, 27–29, 30–32, 33–35, and 36–39. The corresponding seven age cohorts during the eight-year study period were defined as: Cohort $18–28_i$, Cohort $21–31_i$, Cohort $24–34_i$, Cohort $27–37_i$, Cohort $30–40_i$, Cohort $33–43_i$, Cohort $36–47_i$, respectively. For example, a respondent whose age was between 18 and 21 at Cycle 2 was indicated as Cohort $21–31_i = 1$.

For middle-age group, age bands at baseline are defined as those with the age at baseline of the following eight groups: 40–42, 43–45, 46–48, 49–51, 52–54, 55–57, 58–60 and 61–64. The corresponding eight cohort dummy variables were specified: Cohort $40–50_i$, Cohort $43–53_i$, Cohort $46–56_i$, Cohort $49–59_i$, Cohort $52–62_i$, Cohort $55–65_i$, Cohort $58–68_i$, and Cohort $61–72_i$, respectively.

For senior group, age bands at baseline are defined as those with the age at baseline of the following nine groups: 65–67, 68–70, 71–73, 74–76, 77–79, 80–82, 83–85, 86–88 and 89+. The corresponding nine cohort dummy variables were specified: Cohort 65–75$_i$, Cohort 68–78$_i$, Cohort 71–81$_i$, Cohort 74–84$_i$, Cohort 77–87$_i$, Cohort 80–90$_i$, Cohort 83–93$_i$, and Cohort 86–96$_i$, and Cohort 89$_i$, respectively.

The follow-up time ($Time_{ti}$) for a person i in a cohort was determined by subtracting the weighted (by survey weights) median age of the particular cohort to which each person belongs from the age of the person at the follow-up in Cycle t (t = 2, 3,. . .,6).

Time variable (*Time$_{ti}$*) *[Time-varying]*: Defined as person-median centered age (Raudenbush and Bryk, 2002). The variable was obtained by subtracting the weighted median age of the particular cohort that person i belongs to from the age of the individual i at cycle t. Therefore, $\text{Time}_{ti} = (\text{Age}_{ti} - \text{MAge}_k)$, where "MAge$_k$" refers to weighted median age for Cohort k.

For example, if respondent i's baseline age at Cycle 2 was 20 years old, then the respondent belongs to "Cohort 18–28" group defined above. In addition, if the age of the respondent in Cycles 3–6 were 22, 24, 26 and 28, respectively, and the weighted median age for respondents belonging to Cohort 18–28 group was 22 years, then Time$_{ti}$ for respondent i were coded as −2, 0, 2, 4, 6 for Cycles 2–6, respectively.

Quadratic and cubic variations of *Time* were also considered for each model.

Death [Time-varying]: Defined as a dummy variable, DEAD = 1 for records indicating death, =0 otherwise.

Institutionalization [Time-varying]: Defined as a dummy variable, INST = 1 for records indicating institutionalization, =0 otherwise.

Determinants of health variables

Race [Time-invariant]: Race was defined as a dummy variable, =1 if non-white, =0 if white (reference).

Sex [Time-invariant]: Sex was defined as a dummy variable, =1 if female, =0 if male (reference).

Number of chronic conditions [Time-varying]: Three dummy variables were included in the model to indicate the number of chronic conditions: no chronic condition (reference group), has one condition, has two conditions, has more than two conditions.

The variable in the number of chronic conditions was calculated by summing the number of long-term chronic conditions that an individual had or were expected to last for 6 months or more and had been diagnosed by health care professionals (Statistics Canada, 2006b). Because the list of chronic conditions differed throughout the cycles as well as between the household and institutional questionnaires, the following 13 conditions common across all of the questionnaires were selected: asthma, arthritis or rheumatism, high blood pressure, chronic bronchitis or emphysema, diabetes, epilepsy, heart disease, stomach or intestinal ulcers, effects of stroke, urinary incontinence, Alzheimer disease or other dementia, cataracts and glaucoma.

Education [Time-varying]: The level of educational attainment was defined as a dummy variable, =1 if no high school diploma, =0 has more than high school diploma (reference).

Social assistance [Time-varying]: To assess impacts of financial capacity on health trajectories, we included a dummy variable indicating whether or not one received social assistance, namely, =1 if on receives social assistance, =0 otherwise (reference).

We did not use total household income as an independent variable to capture standard of living. This was because information on a household income was frequently missing. In addition, income may not reflect the standard living accurately for some groups such as the seniors for whom wealth is also important.

Marital status [Time-varying]: A dummy variable indicating marital status was created: =1 if single, divorced, widowed or separated, =0 if married, common-law or with partner (reference).

Tobacco [Time-varying]: A dummy variable was created: =1 if current or former smoker, =0 if never smoker (reference).

Alcohol [Time-varying]: A finer categorization of the level of alcohol consumption was created to differentiate light to moderate drinkers from more frequent drinkers, as growing evidence shows beneficial effects of moderate alcohol consumption on various health outcomes (Martel et al., 2006; Iestra et al., 2005).

Two dummy variables were created: "More than moderate drinker" (=1 if one drank in the past 12 months and more than three drinks per day on average, =0 otherwise); and "Former drinker or abstainer" (=1 if one did not drink the last month or never drank, =0 otherwise). Light to moderate drinker (i.e., those who drank in the past 12 months and zero to two drinks per day on average, or daily/occasional drinker for those living in an institution) was considered as the reference category.

Physical activity [Time-varying]: Based on the total daily energy expenditure during the leisure time activities based on the frequency, duration and intensity of each activity. A dummy variable was created: =1 if physically inactive, =0 if physically active (active or moderately active; reference) (Statistics Canada, 2006c).

Low income: Proportion of individuals in low income (based on 1992 Low Income Cut-offs) after tax. This statistics was presented for descriptive comparisons only. It was not used in statistical analyses.

Homeownership: Proportion of homeownership among household primary maintainers, aged 20 and over in Censuses 1996 and 2006. This statistics was presented for descriptive comparisons only. It was not used in statistical analyses.

Appendix B. Model specification (Singer and Willett, 2003)

General specification of unconditional model

$$HUI_{ti} = \pi_{0i} + \pi_{1i}(TIME_{ti}) + \pi_{2i}(TIME_{ti})^2 + \varepsilon_{ti}$$

$$\pi_{0i} = \gamma_{00} + \zeta_{0i}$$

$$\pi_{1i} = \gamma_{10} + \zeta_{1i}$$

$$\pi_{2i} = \gamma_{20} + \zeta_{2i}$$

where HUI_{ti} is HUI3 scores for a respondent i at time (cycle) t, $TIME_{ti}$ is person-median centered age defined in Appendix A. The first equation above represents a within-individual level regression model, which is specified as a quadratic function of Time. A cubic specification was also considered for each age group. However, none of the cubic terms were statistically significant or a model reached a boundary constraint with the inclusion of a cubic term (Singer and Willett, 2003). The remaining three equations specify between-individual level models. π_{0i} refers to the intercept of the model representing mean HUI3 score for respondents with age at sample medians over time. The parameters π_{1i} and π_{2i} refer to the rate of change and the rate of acceleration of HUI3 scores, respectively. Within-individual residuals were denoted by ε_{ti}, which were assumed to be normally distributed and with constant variance. ζ_{0i}, ζ_{1i} and ζ_{2i} are between-individual intercept, slope and curvature residuals, respectively which are assumed to be multivariate normal and constant variance. The above model was estimated for young, middle-aged and senior groups, separately.

General specification of the conditional model

$$HUI_{ti} = \pi'_{0i} + \pi'_{1i}(TIME_{ti}) + \pi'_{2i}(TIME_{ti})^2 + \varepsilon'_{ti}$$

$$\pi'_{0i} = \gamma'_{00} + \sum_{j=1}^{J} \gamma'_{0j} Cohort_{ji} + \sum_{m=1}^{M} \delta'_{0m} X_{mi} + \zeta'_{0i}$$

$$\pi'_{1i} = \gamma'_{10} + \sum_{j=1}^{J} \gamma'_{1j} Cohort_{ji} + \sum_{m=1}^{M} \delta'_{1m} X_{mi} + \zeta'_{1i}$$

$$\pi'_{2i} = \gamma'_{20} + \sum_{j=1}^{J} \gamma'_{2j} Cohort_{ji} + \sum_{m=1}^{M} \delta'_{2m} X_{mi} + \zeta'_{2i}$$

where HUI_{ti} and $TIME_{ti}$ are defined above. $Cohort_{ji}, j = 1,\ldots,J$ denotes the cohorts, where $J = 6$ for young, =7 for middle-aged and =8 for senior groups (see Appendix A). X_{mi} ($m = 1,\ldots,M$) denotes the determinants of health and control variables. $Time_{ti}$ is a cohort-median centered age defined earlier. Parameters γ'_{0j} and δ'_{0m} differentiate levels of trajectories whereas γ'_{1j}, γ'_{2j}, δ'_{1m} and δ'_{2m}, differentiate rate of change in trajectories. Within- and between-individual residual residuals are defined in the same way as in unconditional model. The above model was estimated for young, middle-aged and senior groups, separately.

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