Component of Statistics Canada Catalogue no. 82-003-X
Health Reports

Article

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February, 2009

Statistics Canada Statistique Canada

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Abstract

Background
Taking account of the impacts of institutionalization and death, this study describes the normative trajectories of health-related quality of life (HRQL) in Canada as individuals age from mid - to late life.

Methods
A nationally representative sample of 7,915 community-dwelling adults aged 40 and older in 1994/1995 was studied using 10 years of data from the longitudinal National Population Health Survey. Growth curve models of HRQL over age were fitted to describe the evolution of HRQL. Successive models were tested, first including only those living in a household throughout the entire period, then adding those who moved to an institution, and finally, including those who had died.

Results
HRQL remained generally stable until approximately age 70, when it began to decline. Excluding individuals when they were institutionalized, or ignoring the impact of death resulted in overly optimistic trajectories of HRQL in later years.

Interpretation
These results demonstrate the importance of following individuals into institutions and accounting for death in the production of realistic health estimates in aging populations.

Keywords
aging, health status, health surveys, life expectancy, longevity, longitudinal studies

Authors
Heather M. Orpana (613-951-1650; Heather.Orpana@statcan.gc.ca) and Julie Bernier (613-951-4556; Julie.Bernier@statcan.gc.ca) are with the Health Information and Research Division at Statistics Canada, Ottawa, Ontario, K1A 0T6; Nancy Ross is with McGill University; David Feeny is with Kaiser Permanente Northwest; Bentson McFarland is with the Oregon Health and Science University; and Mark Kaplan is with Portland State University.

In Canada, as in most developed countries, the average age of the population and life expectancies are increasing.[1] The resulting demographic shift toward a population with a larger proportion of older adults has directed attention to understanding how health evolves among adults from mid- to later life. Whether the population is experiencing a compression of morbidity, with ill health being confined to the last few years before death,[2,3] or an expansion of morbidity with the additional years of life lived with disease, disability and loss of quality of life, has implications for society as a whole and for the health care system.[4]

Few studies have employed a growth curve approach to describe health using longitudinal data.[5] However, estimates from longitudinal data of how health changes as people age are likely to differ considerably from those derived from cross-sectional studies.[6] As well, the studies that have employed a growth curve model approach often do not use representative samples, and thus, have limited external validity. An exception is research by Liang et al. who analyzed data for a sample of 2,200 older Japanese adults over 12 years.[7] They observed a slight decline in self-rated health (SRH) from age 60 to 85, after which SRH actually improved. However, this effect may have been due to the deaths of individuals with lower SRH. In another study, McCullogh et al.[8] examined the participants in the Terman Life Cycle Study of Children with High Ability over 59 years. They show a model of SRH decline for both men and women beginning at about age 50 and becoming steeper around age 70, but it is doubtful that these results are generalizable to

entire populations, given that this was a select group who were likely more affluent and, in turn, healthier than most populations.

The purpose of the present study is to describe the pattern of HRQL from mid- to late adulthood in a representative sample of Canadians, while taking into account institutionalization and mortality. The longitudinal National Population Health Survey (NPHS) offers a unique opportunity to study HRQL trajectories in a large sample of the Canadian adult population.[9] Two advantages of the NPHS for this type of analysis are that it follows individuals through the transition from the household to institutions (a common experience among the oldest old),[10] and it provides information about deaths occurring in the sample.

The impacts of institutionalization and mortality on population estimates of health have frequently been overlooked in studies describing normative patterns of health.[11] Indeed, institutionalization is an important consideration when estimating population health, given that in 1992, 24% of the Canadian population aged 80 or older was living in a health care institution.[10] Many longitudinal studies are confined to household samples and thereby exclude the sickest members of society who often live in health care institutions. Such analyses present overly optimistic estimates of the health of the population as it ages. Ignoring the effect of mortality can also result in an overestimate of the health status of the older population, as generally only the healthier individuals survive.[11,12]

Because of differences in morbidity, institutionalization and mortality between the sexes, this analysis shows separate trajectories for men and women. Although some evidence demonstrates that women live longer than men but have a higher burden of morbidity,[13] sex differences in morbidity among those who remain alive may not be as great as previously suggested. In Canada, women's life expectancy surpasses that of men at birth (reference year 2002) and at age 65 (reference year 2001): 82.1 and 20.5 years for women versus 77.2 and 17 years for men.[14,15] As well, women have higher health-adjusted life expectancy (reference year 2001) at birth and at age 65: 70.8 and 14.4 years for women versus 68.3 and 12.7 years for men. However, at age 65, fewer men (77%) than women (85%) have at least one chronic condition, and women are far more likely to require help with instrumental activities of daily living (29% of women versus 15% of men).[16] From ages 45 to 79, men are more likely than women to live in an institution such as a nursing home; thereafter, women are more likely to be institutionalized.[10]

Methods

Sample and data

This analysis is based on longitudinal data from the first six cycles (1994/1995 through 2004/2005) of the National Population Health Survey (NPHS). The target population of the NPHS Household component includes household residents in the ten Canadian provinces in 1994/1995, excluding persons living on Indian Reserves and Crown Lands, and residents of health institutions, Canadian Forces Bases and some remote areas in Ontario and Quebec.

In 1994/1995, 20,095 households were selected for the NPHS longitudinal panel. Of these, 86% completed the general component of the questionnaire (17,276) and 83.6% of selected respondents provided responses to the in-depth health questionnaire. Response rates in subsequent cycles based on the 17,276 selected respondents were 92.8% in 1996/1997; 88.3% in 1998/1999; 84.9% in 2000/2002; 80.8% in 2002/2003, and 77.6% in 2004/2005. More detailed descriptions of the NPHS design, sample and interview procedures are available elsewhere.[9] Data were collected primarily through computer-assisted personal interviews in 1994/1995 and primarily through computer assisted-telephone interviews thereafter

NPHS respondents were followed up every two years. In the first NPHS cycle, the majority of respondents were interviewed in person; in later cycles, the majority were interviewed by telephone. For this study, 10 years of data were analyzed (1994/1995 through 2004/2005). Attrition due to non-response increased with subsequent cycles, although after 10 years only 17% of respondents aged 40 or older had been lost to follow-up, which is modest compared with attrition in other longitudinal studies of older adults.[17] Because growth curve modelling can be accomplished even with missing data (under certain conditions), the effect of non-response is expected to be minimal in this analysis.[5]

Measures

Health-related quality of life (HRQL) has been defined as "the value assigned to duration of life as modified by the impairments, functional states, perceptions and social opportunities that are influenced by disease, injury, treatment or policy."[18] HRQL was measured by the Health Utilities Index Mark 3 (HUI3). The HUI3 describes health status using eight attributes: vision, hearing, speech, ambulation, dexterity, emotion, cognition, and pain and discomfort.[19] Each attribute has 5 or 6 levels that range from severely impaired (for instance, blind for vision) to no impairment. HUI3 health states are scored using utility functions based on preference scores obtained from a Canadian sample. Thus, each individual has an HUI3 score for each measurement time, which reflects an overall level of HRQL based on the combination of attribute levels they experience.

Overall HUI3 scores can range from -0.36 to 1.00. A score of 1.00 is considered perfect health, while a score of 0 represents the state of being dead, and a score less than 0, a state "worse than dead." Scores less than 0 are possible because certain combinations

of health attributes were considered by the Canadian preference scoring sample to be less preferable than being dead. A score of -0.36 represents the health state comprised of the lowest level of every attribute. For analyses including participants for the first cycle after their death, an HUI3 score of 0 was imputed for that cycle. For example, someone who died in 1997 would have a value of 0 ascribed for the 1998/99 cycle, and be excluded from the analyses thereafter.

Age in years was centered on age 40 (by subtracting 40 from each participant's stated age) to improve the interpretability of estimates. For participants who died, the record for the cycle after their death included an imputed age variable equal to their age at death. Each of these age measures was also squared and cubed in each analysis to allow for the testing of quadratic and cubic effects, because many health states show an increasing rate of decline at older ages, without an initial increase which would be observed in a quadratic model. A cubic model also appeared to be the better fit to plotted raw data.

Analysis

Three analytical groups were created. To demonstrate the effect of confining the analysis to the healthiest Canadians, only data for individuals living in a household were analyzed in Model 1. To demonstrate the effect of accounting for those who became ill enough to be institutionalized, Model 2 also included residents of institutions. Finally, to show that descriptions of population health are heavily affected by ignoring death as a health state, Model 3 included data not only for all living participants (residents of household and institutions), but also for those who had died—for the first cycle at which death was recorded, their age at death and an HUI3 score of 0 were the data values. Data for decedents in subsequent cycles were not included.

Multilevel growth curve models were estimated to describe the normative trajectory of HRQL in order to answer the question, "How does HRQL change as adults age from mid-life?" A multilevel growth curve model is a hierarchical linear model in which observations over time (level 1) are nested within an individual (level 2). The analysis accounts for the non-independence between observations of the same individual at multiple time points.[5]

A person-period dataset was created, with one record per participant for each cycle at which their HUI3 score was available. A two-level unconditional growth curve model was built in MPLUS[20] predicting HUI3 score from age, age squared and age cubed, and specifying random intercept, slope, and quadratic and cubic terms for each of the three analytical groups. The first level was the within-individual growth model, specified as:

$$HUI_{ij} = \alpha_{0i} + B_{1i}(age_{ij}) + B_{2i}(age^2_{ij}) + B_{3i}(age^3_{ij}) + r_{ij}$$

The second level allows for model parameters to vary between individuals (random effects). It was specified as:

$$\alpha_{0i} = \gamma_{00} + u_{0i}$$
$$B_{1i} = \gamma_{10} + u_{1i}$$
$$B_{2i} = \gamma_{20} + u_{2i}$$
$$B_{3i} = \gamma_{30} + u_{3i}$$

Normalized weights were used to ensure that the sample reflected the Canadian population. Because of the complex sample design of the NPHS, which can result in artificially small variance estimates,[21] a conservative p value of 0.001 was chosen as the threshold for significance to reduce the risk of Type I errors.

Results

The sample of 7,915 community-dwelling adults reflected the Canadian household population aged 40 or older in 1994/1995, and was comprised of 52% men and 48% women. Their mean age was 57 years (range from 40 to 102 in 1994/1995). Most respondents were married or living with a partner. The age and sex distribution by 10-year age group in 1994/1995 can be seen in Table 1. Over the 10 years of the study, 1,562 respondents died. At any cycle, a small number of respondents were institutionalized, ranging from 62 in cycle 2 to 160 in cycle 5.

In 1994/1995, respondents' mean HUI3 score was 0.833, and their modal score was 0.973 (data not shown). The HUI3 score was negatively skewed (skewness = -2.52). As expected, mean HUI3 score decreased with age (Table 1). The intraclass correlation coefficients (ICC), an indicator of the average autocorrelation of the dependent variable across observations, were moderate. The ICC for the HUI3 over time for men living in households was 0.48; for women, 0.52. For those living

Table 1
Characteristics of sample in 1994/1995 and observations over study period, by 10-year age group, population aged 40 or older in 1994/1995, Canada excluding territories

Age group	% female	n in 1994/1995	Observations over study period	Mean HUI3 in 1994/1995
40 to 49	48.5	2,511	7,037	0.88
50 to 59	51.0	1,829	10,903	0.85
60 to 69	53.0	1,655	8,678	0.82
70 to 79	58.6	1,340	7,326	0.77
80 to 89	61.3	518	3,562	0.66
90 or older	61.3	62	562	0.44

Note: N are unweighted; percents and means are weighted estimates.
Source: 1994/1995 to 2004/2005 National Population Health Survey.

Table 2
Parameter estimates for growth curve models of HUI3 over age for men and women aged 40 or older in 1994/1995, Canada excluding territories

	Model 1 (household only)				Model 2 (household and institutions)				Model 3 (household, institutions and deceased)			
	Men		Women		Men		Women		Men		Women	
	Estimate	t-value	Estimate	t-value	Estimate	t-value	Estimate	t-value	Estimate	t-value	Estimate	t-value
Fixed effects												
Intercept	0.918722	119.99	0.911904	88.48	0.926754	115.0	0.917889	80.47	0.926585	106.95	0.921052	95.97
Age	-0.005125	-3.75	-0.009304	-4.69	-0.007832	-5.55	-0.011380	-5.61	-0.008415	-4.91	-0.012727	-6.76
Age squared	0.000279	3.62	0.000502	5.02	0.000483	6.0	0.000664	6.71	0.000548	5.38	0.000768	8.05
Age cubed	-0.000007	-5.96	-0.000010	-6.95	-0.000011	-8.53	-0.000013	-9.35	-0.000015	-8.96	-0.000016	-11.89
Random effects												
Variance intercept	0.010974	5.68	0.017180	8.75	0.017049	3.11	0.032053	3.46	0.007577	3.40	0.015725	7.79
Variance age	0.000028	8.74	0.000022	7.43	0.000052	5.05	0.000058	4.25	0.000054	11.51	0.000034	10.43

Note: All reported estimates are significant at the 0.001 level. t-values (estimate/standard error of estimate) are reported instead of standard error to reduce number of digits in table. Age is centered on age 40.
Source: 1994/1995 to 2004/2005 National Population Health Survey.

in households or in institutions, the ICC was 0.47 for men and 0.49 for women. This indicates an important degree of autocorrelation in the data, with about half of the variation in the HUI3 scores over time being within individuals, and half between individuals,[5] thus making a multilevel growth curve model appropriate for these data.

Compared to those with complete data at all six cycles (n=3,375), women for whom data were missing for one to three cycles (n=687) were similar in terms of age in 1994/1995 and baseline HUI3 score. However, women for whom data were missing for four to six cycles (n=300) were four years younger and marginally healthier than women with complete data. Among men with one to three cycles of missing data (n = 650), average age was three years younger than that of those with complete data (n = 2,613); their HUI3 scores were almost identical. For men with four to six cycles of missing data (n=290), average age was almost five years younger than that of those with complete data, and as would be expected for a younger group, their health was marginally better. These relatively small differences between groups lead to the conclusion that missing data likely had little effect on the findings.

Normative growth curve for HRQL

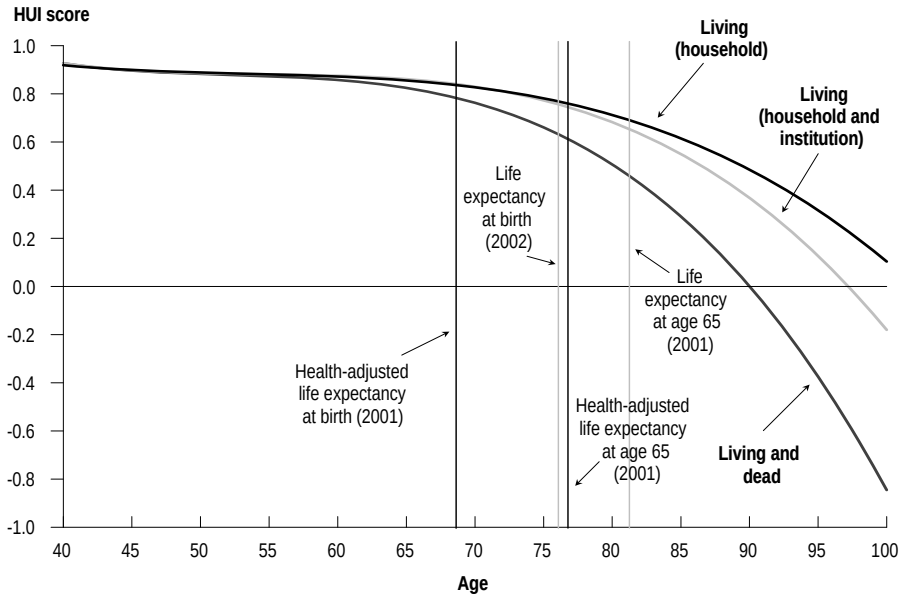
The first growth curve model examined the trajectories of HRQL for men and women separately. The growth curves illustrate the pattern of HRQL of Canadian men and women from age 40 on, given the HRQL observed in the cohort from 1994/1995 to 2004/2005. Model parameters are shown in Table 2, and the modeled normative trajectories are shown in Figure 1 for men, and in Figure 2 for women. For both sexes in all analyses, only the intercept and the linear function of age had significant random effects (that is, significant variation between participants). Thus, only a random intercept and age term were included in the model specification. Because no interindividual predictors were included in the model, these terms are not interpreted further in this paper. The significant variability in these components of the model indicates that future work should examine the determinants of interindividual differences in HUI3 trajectories. In all models, the covariance between the intercept and the linear function of age was non-significant. The fixed effects of age squared and age cubed were significant in all models.

According to Model 1 (Table 2), at age 40, men's average HUI3 score was 0.92. With a one-year increase in age, this value declined by the sum of a decrease of 0.005*(age – 40), an increase of $0.0003*(age - 40)^2$, and a decrease of $0.000007*(age - 40)^3$. Although the coefficients in the equation predicting HUI3 from age, age squared and age cubed appear small, at increasing ages their effects are quite large, as a decrease in an overall HUI3 score of 0.03 or more is considered to be clinically important.[22,23]

The growth curves for men and women living in a household (Model 1) were relatively similar, with men having better HRQL than women before age 74, and the trend reversing after age 74 (Table 2, Figures 1 and 2). An important difference between the sexes was the decrease in HUI3 among the youngest women in the cohort. From age 40 to age 50, women's average HUI3 fell by 0.06, twice the threshold considered clinically important. After this initial downturn, the HRQL of female household residents remained relatively stable until about age 70, and then declined to approximately 0.70 at age 80.

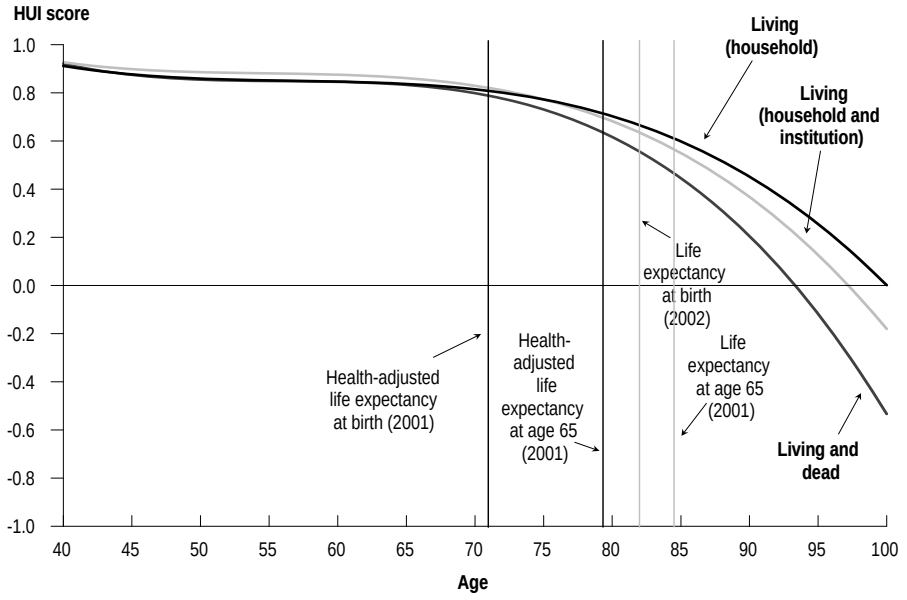
The results of Model 2, which included respondents in both households and institutions, were less optimistic than those of Model 1. After age 75

Figure 1
HUI 3 trajectories, by age, men aged 40 or older in 1994/1995, Canada excluding territories



Source: 1994/1995 to 2004/2005 National Population Health Survey.

Figure 2
HUI 3 trajectories, by age, women aged 40 or older in 1994/1995, Canada excluding territories



Source: 1994/1995 to 2004/2005 National Population Health Survey.

for men and after age 80 for women, HRQL declined more sharply in Model 2 than Model 1. This is not surprising, because the mean HUI3 score among the non-institutionalized sample was 0.83, while the mean HUI3 score among the institutionalized sample was 0.14, and institutionalization rates increase with age.

As well as residents of households and institutions, Model 3 included respondents who had died for the first cycle after their death, with a value of 0 for their HRQL at their age of death. This model showed a slow decline from scores close to 1 to around 0.8 for men and women until about age 70, after which HRQL declined more rapidly for men than for women. This reflects the effect of men's higher mortality at older ages. Taking death into account had a large effect on the growth curves: for men, HRQL was lower after age 60 when accounting for death compared with only institutionalization; for women, this discrepancy emerged around age 70.

Discussion

On average, HRQL remains relatively high from mid- to later life, suggesting that the older population is well and enjoying high quality of life in the years leading up to normal Canadian life expectancy. This is consistent with findings from international comparisons, which indicate that Canada ranks high on measures of life expectancy and disability-adjusted life years.[24,25]

Perhaps most important, this study demonstrates that excluding data for institutionalized individuals presents a biased view of the aging process, as does the failure to take mortality into account when describing the health of the population.[12] Inclusion of the institutionalized elderly results in less optimistic, but more accurate, estimates of population health. The effect of death on men's HRQL is greater than that on women's until quite late in life, reflecting men's earlier average mortality and women's additional years of life

What is already known on this subject?

- By global standards, the Canadian population is generally healthy, with long life expectancies for both men and women.
- Cross-sectional studies indicate that health and health-related quality of life tend to decline with age.

What does this study add?

- Canadians enjoy high health-related quality of life from mid-life into advanced ages.
- Men and women have similar trajectories of health-related quality of life with the exception of a notable decline among women in their 40s.
- Excluding data for institutionalized individuals and decedents presents an unduly optimistic view of the aging process.

lived in disability.[15,16] Either postponing mortality or reducing health problems should result in curves that maintain a higher level of HRQL longer through the lifespan. Future research can compare curves of successive cohorts to identify whether, when accounting for institutionalization and death, the health of the population is, indeed, improving.

The findings of the present analysis are consistent with some studies of self-rated health (SRH) trajectories, where SRH has been found to decline with advancing age,[8] but contrast with results from a study that showed an increase in SRH at older ages.[7] The results of the latter likely reflect a "survivor effect," whereby individuals with the worst SRH evaluations die and are thus removed from the analysis. Although we did not observe an increase in scores in older people, the difference between models 1 and 3 shows a "survivor effect."

The differences between the findings of the present study and those of others may reflect differences between HRQL as measured by the HUI3 and the use of SRH as the outcome measure. The HUI3 (in self-reports of health states) and SRH both contain a component of subjectivity, however at different levels. The results of this study highlight the importance of avoiding selection bias by following subjects into health care institutions and by including in the analyses those who die during the follow-up period.

Limitations

This study is based on self-reported health states that were transformed into a health utility score determined from societal preferences for different health states. Health states may not be accurately reported, and societal preferences for different health states may change over a long period, such as the 10 years covered in this study. Furthermore, the sample suffered attrition over time—in the last cycle analyzed, almost one in five respondents was lost to follow-up (and had not died or entered an institution). If the health status of the group lost to follow-up differed systematically from that of respondents who remained in the study, this could introduce bias into the results. However, respondents who dropped out were relatively similar to those who remained, and were younger. Because of the large number of younger participants in this study, the effect of attrition is likely to be diluted.

The results presented here are descriptive. The growth curve models employed are useful for describing patterns over time, but may not be appropriate for analyses aimed at explaining those patterns. Because age was centred on 40, the intercept is interpreted as the value of HUI for a 40-year-old. For explanatory models, other methods of centering age may be more appropriate and improve interpretability. Even so, analyses centering age on its mean value (57) did not differ substantially from the models presented here.

Conclusion

In summary, Canadians are, on average, quite healthy as they age from mid- to later life. While patterns of HRQL are similar for men and women, these deviate when institutionalization and death are considered. Furthermore, ignoring institutionalization and death portrays a healthier population than is actually the case, at least at advanced ages.

This research highlights the importance of moving beyond cross-sectional and household surveys in the study of successful aging. It also illustrates the need for data or surveys that include residents of institutions.

Future research should examine inter-individual variation in healthy aging, and focus on the predictors of successful aging as defined by HRQL. Such research will allow us to better understand aging in terms of health, broadly defined, and to identify ways in which policy and programs can promote healthy aging. ■

Funding and conflict of interest

The study was supported by grant AG027129 from the National Institute on Aging, National Institutes of Health. David Feeny has a proprietary interest in Health Utilities Incorporated (HUInc.), Dundas, Ontario, Canada. HUInc. distributes copyrighted Health Utilities Index (HUI) materials and provides methodological advice on the use of HUI. HUInc. received no payment for the use of HUI in the survey from which the data reported in this paper were obtained.

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