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Gender differences in functional limitations among Canadians with arthritis: The role of disease duration and comorbidity

by D. Walter Rasugu Omariba

Abstract

Background
Mechanisms underlying gender disparities in functional limitations among people with arthritis remain unclear. This study examined gender differences in the relationship between disease duration and comorbidity and functional limitations among people with arthritis.

Data and methods
Data were from the arthritis component of the 2009 Survey on Living with Chronic Diseases in Canada. People were considered to have functional limitations if they reported that arthritis limits them "a lot" in activities of daily living. Those with no functional limitations were the reference group. Gender-stratified weighted multivariate binary logistic regression analyses were conducted.

Results
In a fully adjusted multivariate analysis, only among women was time elapsed since the arthritis diagnosis associated with functional limitations. Disabling and life-threatening chronic conditions were associated with functional limitations in both genders. Among men, obesity and low household income were associated with higher odds of functional limitations, while living in British Columbia was associated with decreased odds. For women, smoking, not engaging in physical activity, residing in a non-Atlantic province, and having excess weight increased the odds of functional limitations, while habitual alcohol drinking decreased the odds.

Interpretation
Gender differences in the risks of reporting functional limitations were significant. These differences appear to be driven by duration of having arthritis, and disparities in health behavioural factors, household income and region of residence. The association between chronic conditions and functional limitations was similar for men and women

Keywords
arthritis, activity limitations, functional limitations

Author
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Arthritis is one of the most prevalent chronic illnesses in Canada.[1, 2] It is a major cause of functional limitations, dependency and health care use, and a contributing factor in lower participation in the labour force and in other activities.[3-6] In 2008, an estimated 15% of Canadians aged 12 or older—about 4 million people— reported having been diagnosed with arthritis.[7] The numbers are projected to increase to 20% (6.7 million) for people aged 15 or older by 2031.[8]

The prevalence of arthritis differs markedly by gender[9-11]: in 2008, 19.2% of women versus 12.6% of men had the condition.[8] Moreover, among those with arthritis, women are more likely than men to experience functional limitations.[12-14]

Relatively little research has focused on gender differences in functional limitations among people with arthritis,[3,15-19] especially the potential role of comorbidity, duration of the condition, and behavioural and socio-economic factors. Instead, population studies of its impact generally compare people with and without the condition.[20-23] As well, because it is costly and burdensome to respondents to ask disease-specific questions in general health surveys, previous studies have used data from surveys that included other chronic conditions, and therefore, lack detailed information about arthritis.[3, 12,17,24]

In 2009, Statistics Canada conducted the first cycle of the Survey on Living with Chronic Diseases in Canada (SLCDC) on behalf of the Public Health Agency of Canada. Respondents were people who had reported having a diagnosed chronic condition to the 2008 Canadian Community Health Survey (CCHS). The 2009 SLCDC focused on arthritis and hypertension, and covered issues related to chronic health conditions, including diagnosis, use of health services, medication use, and self-management. The SLCDC will be conducted every two years.

This study used the arthritis component of the 2009 SLCDC to examine gender differences in functional limitations, specifically, the role of disease duration and comorbidity. The study addresses four questions:

1. Are there overall differences in functional limitations between men and women? And are there gender differences in:
   2. the influence of duration of disease on functional limitations?
   3. the effect of chronic comorbidity on functional limitations?
   4. the associations between health-related behaviours, socio-demographic and socio-economic factors and functional limitations?

Methods

Data source

The SLCDC data used in this study were collected in February and March, 2009, as a follow-up to the 2008 CCHS. The SLCDC targeted adults aged 20 or older living in private households in the ten provinces, who had reported to the 2008 CCHS that they had arthritis or hypertension that had been diagnosed by a health professional. The SLCDC excluded residents of the three territories, Indian reserves, Crown lands and institutions, and full-time members of the Canadian Forces.

To produce reliable national estimates, CCHS respondents were stratified by gender and age group (20 to 44, 45 to 64, 65 to 74, and 75 or older). A total of 7,100 individuals who had reported arthritis were selected from 13,459 CCHS respondents, using systematic sampling. To lessen the effect of out-of-scope and non-response—estimated at 10% and 20%, respectively—the sample was inflated by 1.4%. The SLCDC administered separate questionnaires on arthritis and hypertension; to reduce response burden, selected respondents received only one questionnaire. Interviews were conducted using computer-assisted telephone interviewing.

At the time of SLCDC data collection, 17% of the CCHS respondents who had been selected on the basis of having reported arthritis failed to meet all the inclusion criteria. These criteria required that: arthritis had been diagnosed by a health professional; symptoms be present at the time of the SLCDC; and the respondent reside in Canada. Of the 5,820 individuals eligible for inclusion, 4,565 (78.4%) were successfully interviewed and met the study inclusion criteria. Details about the survey have been reported elsewhere.[25] The 2008 CCHS contained background information on the respondents, while the SLCDC provided details about arthritis.

Variables

Outcome variable

The presence of the disease in the selected "arthritis sample" of the SLCDC was verified by re-asking the CCHS question about diagnosis by a health professional, age at diagnosis and at the onset of symptoms, the type of arthritis, and whether their immediate family had a history of arthritis. Functional limitations, hereafter referred to as "limitations," were identified by self-reported activity limitations attributable to arthritis. As an outcome measure, limitations is a composite variable derived from responses to questions about the extent to which, in the past month, arthritis limited routine activities such as bathing or dressing, getting around the house, doing household chores, running errands and shopping and participating in recreational and social activities. Response categories were "a lot," "a little," and "not at all." Respondents who answered "a lot" were considered functionally limited.

Independent variables

The analysis examined the effects of selected factors known to influence health outcomes: disease duration, co-morbid chronic conditions, BMI, smoking, alcohol use, physical activity, socio-demographic characteristics (age, gender, marital status, region of residence), and socio-economic characteristics (household income, education). Disease duration was defined as time elapsed since the arthritis diagnosis. Because of its skewed distribution, disease duration was log-transformed to approximate normality. It was modeled as an interval level measure.

Comorbidity was determined from the questions about chronic conditions. Respondents were instructed that chronic conditions (including arthritis) were conditions that had lasted or were expected to last for at least six months and had been diagnosed by a health professional. Consistent with the literature,[26] chronic conditions were categorized as nondisabling (asthma, high blood pressure, migraine headaches, stomach or intestinal ulcers, urinary incontinence); disabling (back problems excluding arthritis/fibromyalgia, bowel disorders/Crohn's Disease or colitis, chronic bronchitis or emphysema, and Alzheimer's disease or other dementia); and life-threatening (diabetes, heart disease, cancer, and effects of stroke). For each category, a count variable was created indicating the number of co-morbid conditions reported by the respondents.

Smoking status was based on past and current smoking behaviour: never, current, or former smoker. Never smokers were people who reported never having smoked a whole cigarette, and former occasional or daily smokers who had smoked fewer than 100 cigarettes in their life. Current smokers were people who reported smoking at least 100 cigarettes and were currently smoking daily or occasionally. Former smokers were daily or occasional smokers who had smoked at least 100 cigarettes, but had quit.

Based on reported alcohol consumption during the 12 months before the 2008 CCHS, respondents were classified as nondrinkers, habitual drinkers, or occasional drinkers. Nondrinkers were those who reported not drinking in the past year. Habitual drinkers were those who reported consuming alcohol at least once weekly. Occasional drinkers were those who reported consuming alcohol less than once weekly.

Physical activity level was derived from information reported about leisure-time activities in the 12 months before the survey and the energy expenditure (EE) associated with those activities (kilocalories expended per kilogram of

bodyweight per hour of activity). To calculate an average daily EE for an activity, the estimate was divided by 365. Respondents were grouped into three categories based on their average daily EE summed over all activities: active (EE of 3 or more kcal/kg/per day), moderate (EE of 1.5 to 2.9 kcal/kg/per day), and inactive (EE of less than 1.5 kcal/kg/per day).

BMI was calculated from self-reported height and weight (weight in kilograms/height in metres squared). Based on their BMI, respondents were classified as: normal weight (24.9 kg/m^2 or less), overweight (25 to 29.9 kg/m^2), and obese (30 kg/m^2 or more).

Age was grouped into three ranges: 20 to 54, 55 to 74, and 75 or older.

Marital status was categorized as married/common-law, widowed/divorced/separated, and never married.

Because small sample sizes precluded analysis at the provincial level, five geographic regions were defined: Atlantic (Newfoundland and Labrador, Prince Edward Island, Nova Scotia, New Brunswick), Quebec, Ontario, Prairies (Alberta, Manitoba, Saskatchewan), and British Columbia.

Three education categories were created based on the respondent's highest level of attainment: less than secondary school graduation, secondary school graduation or some postsecondary, and postsecondary graduation.

Total household income in 2007, adjusted for household size, was used to identify two income levels. The low-income level was defined as incomes less than $30,000 for households of two, less than $40,000 for households of three or four, and less than $60,000 for households of five or more. The high-income level was defined as incomes above these cut-offs for a given household size. A third category comprised people who did not state their income—about 13% of the sample.

Analytical techniques

With SAS software (version 9.1), univariate analyses were used to estimate the characteristics associated with limitations. Gender differences in the characteristics of people with arthritis were evaluated by t- and X^2 tests as appropriate. The outcome variable has two categories, and therefore, weighted binary logistic regression was used. People without limitations were defined as the reference group. Two gender-stratified models were estimated. The first included duration of arthritis and number of chronic conditions, examined separately, to which the other independent variables were added in the second model. Binary logistic regression was conducted using SAS-callable Sudaan (version 10). All independent variables in this study were tested for multicollinearity, and none violated collinearity assumptions.

Starting with the share weights from the 2008 CCHS, Statistics Canada developed weights for the 2009 SLCDC to reflect whether a respondent received an arthritis or hypertension questionnaire, and to account for sample design, out-of-scope units, and non-respondents including those who did not consent to share and link their survey information. The bootstrap method was used to calculate variance on the estimates.[25]

Results

Characteristics of people with arthritis

A higher percentage of women (63%) than men (37%) reported having been diagnosed with arthritis (Table 1). While about half of men and women with arthritis were in the 55 to 74 age range, a significantly higher percentage of women than men were aged 75 or older (22% versus 16%). Compared with men, women with arthritis were significantly more likely to report having at least one limitation (36% versus 27%). Women with arthritis had it significantly longer than their male counterparts: about 13 years compared with 11 years. As well, the mean number of nondisabling chronic conditions was significantly higher among women than men. No significant differences between men and women emerged for disabling and life-threatening chronic conditions.

What is already known on this subject?

- Arthritis is one of the most prevalent chronic illnesses in Canada and a leading cause of functional limitations.
- Although gender disparities in functional limitations among people with arthritis are well documented, the underlying reasons are less well understood.

What does this study add?

- The data focus exclusively on people with arthritis, and thus allow a more thorough examination of issues related to the disease.
- Obese men and those in low-income households faced higher risks of having functional limitations compared with those of normal weight and those in high-income households.
- Men in British Columbia had lower odds of functional limitations compared with men in the Atlantic region.
- Women who were smokers, did not engage in physical activity, resided in a non-Atlantic province, and had excess weight had higher odds of functional limitations compared with women who did not smoke, engaged in physical activity, lived in the Atlantic region, and had normal weight.

Differences were also evident in the other selected characteristics. For example, a higher percentage of women than men were physically inactive (60% versus 52%). Men (57%) were more likely than women (29%) to consume alcohol regularly. Just over a quarter (27%) of men and women were obese, but men were more likely than women to be overweight (46% versus 35%). Men were more likely than women to

Table 1
Percentage distribution of characteristics of respondents with arthritis, by gender, household population, Canada excluding territories, 2008/2009

Characteristic	Men			Women		
	Sample count	Weighted estimate '000	%	Sample count	Weighted estimate '000	%
Total†	**1,674**	**1,310**	**37.0***	**2,881**	**2,233**	**63.0**
Health and health-related factors						
Limited because of arthritis	485	355	27.1*	948	800	35.8
Years with arthritis (mean number)	11.5	10.7	...	13.8	13.1	...
Chronic conditions (mean number)						
Disabling	0.55	0.59	...	0.67	0.68	...
Nondisabling	0.55	0.70*	...	0.80	0.91	...
Life-threatening	0.35	0.37	...	0.35	0.37	...
Smoking						
Never	282	225	17.2*	1,037	873	39.1
Former	998	769	58.7*	1,332	962	43.1
Current	394	315	24.1*	512	398	17.8
Alcohol use						
Nondrinker	325	221	16.9*	856	744	33.3
Occasional	461	344	26.3*	1,178	844	37.8
Habitual	888	744	56.8*	847	646	28.9
Physical activity						
Active	376	280	21.4	483	382	17.1
Moderate	413	349	26.6	657	502	22.5
Inactive	885	681	52.0*	1,741	1,349	60.4
Body mass index (BMI)						
Normal	522	362	27.7*	1,164	839	37.6
Overweight	719	599	45.7*	955	790	35.4
Obese	433	349	26.6	762	604	27.0
Socio-demographic factors						
Age group						
20 to 54	469	448	34.2	590	618	27.7
55 to 74	850	655	50.0	1,478	1,128	50.5
75 or older	355	207	15.8*	813	487	21.8
Marital status						
Married/Common-law	1,127	1,010	77.1*	1,415	1,386	62.1
Widowed	154	74	5.6*	837	429	19.2
Divorced/Separated	204	114	8.7	421	249	11.1
Never married	189	112	8.6	208	170	7.6
Region						
Atlantic	280	138	10.5	442	218	9.8
British Columbia	183	169	12.9	321	250	11.2
Ontario	631	617	47.1	1,123	1,032	46.2
Prairies	362	200	15.2	593	371	16.6
Quebec	218	185	14.2	402	362	16.2
Socio-economic factors						
Education						
Less than secondary graduation	466	302	23.1	899	593	26.5
Secondary graduation/Some postsecondary	305	226	17.3*	642	582	26.1
Postsecondary graduation	903	781	59.7*	1,340	1,058	47.4
Household income						
Low	454	288	22.0*	1,098	646	28.9
High	1,092	896	68.4*	1,435	1,261	56.5
Missing	128	126	9.6*	348	326	14.6

† percentage of men or women in total arthritis sample
* significantly different from women ($p<0.05$)
... not applicable
Note: The analysis excludes 10 women for whom BMI was not calculated (they were pregnant or did not report their pregnancy status).
Sources: 2008 Canadian Community Health Survey; 2009 Survey of Living with Chronic Diseases in Canada.

be married or living common-law (77% versus 62%) and to have completed postsecondary education (60% versus 47%).

Bivariate analysis: disease duration and comorbidity

The unadjusted results of the binary logistic regression show a strong positive association between duration of arthritis and limitations among men (odds ratio (OR)=1.27) and women (OR=1.30) (Tables 2 and 3; Model 1).

Disabling and life-threatening conditions were also significantly associated with limitations among men and women (Tables 2 and 3; Model 1). However, nondisabling conditions were associated with limitations only among women (Table 3; Model 1). For men, the risk of limitations increased by 91% for each additional disabling chronic condition; for women, the increase was 86%.

Multivariate analysis

In multivariate analyses that accounted for the effects of all selected variables, the association between duration of arthritis and limitations was no longer significant among men, but it remained significant among women (Tables 2 and 3; Model 2). For men, disabling and life-threatening conditions were still associated with limitations, although the odds for disabling chronic conditions were slightly attenuated. For women, disabling and life-threatening conditions remained significant, but nondisabling conditions did not.

Several other factors were associated with limitations. Men who were obese or lived in a low-income household had significantly higher odds of limitations. For men in British Columbia, the odds of limitations were significantly lower, compared with their counterparts in the Atlantic region.

For women with arthritis, smoking, physical inactivity, excess weight, and residing outside the Atlantic region were associated with higher odds of limitations. For example, compared with women of normal weight, overweight

Table 2
Unadjusted and adjusted odds ratios (OR) relating selected characteristics to functional limitations among men aged 20 or older with arthritis, household population, Canada excluding territories, 2008/2009

	Model 1			Model 2		
		95% confidence interval			95% confidence interval	
Characteristic	Unadjusted OR	from	to	Adjusted OR	from	to
Health and health-related factors						
Log years with arthritis	1.27*	1.04	1.56	1.18	0.95	1.46
Chronic conditions						
Disabling‡	1.91*	1.37	2.65	1.80*	1.28	2.52
Nondisabling‡	1.06	0.80	1.40	0.78	0.57	1.08
Life-threatening‡	1.51*	1.10	2.07	1.54*	1.08	2.20
Smoking						
Never†	...	...	...	1.00	...	...
Former	...	...	...	1.33	0.74	2.38
Current	...	...	...	1.28	0.70	2.32
Alcohol use						
Nondrinker†	...	...	...	1.00	...	...
Occasional	...	...	...	0.86	0.46	1.59
Habitual	...	...	...	0.93	0.56	1.55
Physical activity						
Active†	...	...	...	1.00	...	...
Moderate	...	...	...	0.76	0.41	1.41
Inactive	...	...	...	1.57	0.93	2.66
Body mass index (BMI)						
Normal†	...	...	...	1.00	...	...
Overweight	...	...	...	1.21	0.75	1.94
Obese	...	...	...	1.81*	1.06	3.09
Socio-demographic factors						
Age group						
20 to 54†	...	...	...	1.00	...	...
55 to 74	...	...	...	0.88	0.50	1.55
75 or older	...	...	...	0.57	0.30	1.08
Marital status						
Married/Common-law†	...	...	...	1.00	...	...
Widowed	...	...	...	1.24	0.52	2.97
Divorced/Separated	...	...	...	1.07	0.53	2.18
Never married	...	...	...	1.70	0.93	3.09
Region						
Atlantic†	...	...	...	1.00	...	...
British Columbia	...	...	...	0.46*	0.21	1.00
Ontario	...	...	...	0.96	0.55	1.66
Prairies	...	...	...	1.16	0.64	2.09
Quebec	...	...	...	0.95	0.50	1.80
Socio-economic factors						
Education						
Less than secondary graduation	...	...	...	1.07	0.64	1.78
Secondary graduation/Some postsecondary	...	...	...	1.31	0.77	2.25
Postsecondary graduation†	...	...	...	1.00	...	...
Household income						
Low	...	...	...	1.74*	1.03	2.92
Missing	...	...	...	0.87	0.42	1.80
High†	...	...	...	1.00	...	...

† reference category
‡ modelled as continuous variables
* significantly different from reference category (p<0.05)
... not applicable
Note: Because of rounding, odds ratio with 1.00 as upper confidence limit is statistically significant.
Sources: 2008 Canadian Community Health Survey; 2009 Survey of Living with Chronic Diseases in Canada.

and obese women were each 61% more likely to have limitations. Women in British Columbia, Ontario, the Prairies, and Quebec had significantly higher odds of limitations compared with those in the Atlantic region. On the other hand, occasional or regular alcohol consumption was associated with lower odds of limitations.

Discussion

This study showed clear differences between men and women in the association of disease duration and comorbidity with the risk of having arthritis-related functional limitations. For women, but not men, the number of years with arthritis remained significantly related to the risk of functional limitations, even when behavioural, socio-demographic and socio-economic characteristics were taken into account. Also, the impact of arthritis on limitations manifests as early as the first year of having the disease. Research indicates that arthritis duration is associated with disease severity, joint destruction and functional capacity; without intervention outcomes tend to worsen over time.[27,28]

In the fully adjusted models, disabling and life-threatening chronic conditions were significantly associated with limitations among both men and women, and the strength of association was similar. These results appear to differ from those of other studies on gender differences in the prevalence of chronic conditions and their impacts.[13,15,24,29,30] Those studies showed that women had a higher prevalence of both disabling and nondisabling chronic conditions and were more likely to experience limitations as a result. For example, a prospective study among people with arthritis found that functional decline was more frequent among women than men; these gender differences were largely attributable to comorbid conditions including diabetes, history of stroke, depressive symptoms and cognitive and vision impairment.[13] Murtagh and Hubert found that women were more likely than men to report limitations, largely owing to differences in disability-related health conditions.[24]

Table 3
Unadjusted and adjusted odds ratios (OR) relating selected characteristics to functional limitations among women aged 20 or older with arthritis, household population, Canada excluding territories, 2008/2009

	Model 1			Model 2		
		95% confidence interval			95% confidence interval	
Characteristic	Unadjusted OR	from	to	Adjusted OR	from	to
Health and health-related factors						
Log years with arthritis	1.30*	1.10	1.52	1.27*	1.06	1.52
Chronic conditions						
Disabling‡	1.86*	1.33	2.60	1.63*	1.22	2.19
Nondisabling‡	1.48*	1.20	1.82	1.21	0.99	1.49
Life-threatening‡	1.48*	1.04	2.11	1.34*	1.01	1.76
Smoking						
Never†	...	...	...	1.00	...	...
Former	...	...	...	1.11	0.71	1.74
Current	...	...	...	1.72	1.03	2.88
Alcohol use						
Nondrinker†	...	...	...	1.00	...	...
Occasional	...	...	...	0.67*	0.46	1.00
Habitual	...	...	...	0.43*	0.28	0.66
Physical activity						
Active†	...	...	...	1.00	...	...
Moderate	...	...	...	1.32	0.76	2.30
Inactive	...	...	...	1.78*	1.12	2.82
Body mass index (BMI)						
Normal†	...	...	...	1.00	...	...
Overweight	...	...	...	1.61*	1.03	2.51
Obese	...	...	...	1.61*	1.07	2.42
Socio-demographic factors						
Age group						
20 to 54†	...	...	...	1.00	...	...
55 to 74	...	...	...	0.73	0.49	1.09
75 or older	...	...	...	0.86	0.50	1.47
Marital status						
Married/Common-law†	...	...	...	1.00	...	...
Widowed	...	...	...	1.38	0.91	2.09
Divorced/Separated	...	...	...	0.84	0.53	1.34
Never married	...	...	...	1.09	0.64	1.84
Region						
Atlantic†	...	...	...	1.00	...	...
British Columbia	...	...	...	1.94*	1.13	3.33
Ontario	...	...	...	2.06*	1.30	3.25
Prairies	...	...	...	1.63*	1.03	2.60
Quebec	...	...	...	2.18*	1.28	3.71
Socio-economic factors						
Education						
Less than secondary graduation	...	...	...	0.86	0.59	1.23
Secondary graduation/Some postsecondary	...	...	...	1.53	0.99	2.37
Postsecondary graduation†	...	...	...	1.00	...	...
Household income						
Low	...	...	...	1.08	0.75	1.53
Missing	...	...	...	0.62	0.36	1.06
High†	...	...	...	1.00	...	...

† reference category
‡ modelled as continuous variables
* significantly different from reference category (p<0.05)
... not applicable
Note: Because of rounding, odds ratio with 1.00 as upper confidence limit is statistically significant.
Sources: 2008 Canadian Community Health Survey; 2009 Survey of Living with Chronic Diseases in Canada.

Nonetheless, the findings of this study support research suggesting that people with arthritis require comprehensive disease management that takes account of the added burden of other chronic conditions.[31,32]

Consistent with earlier research,[14,16,17] the influence of the other selected factors on functional limitations also differed by gender. Low household income was significant only for men. Physical inactivity, smoking, regular alcohol consumption, and overweight were significant only for women. Obesity was significant for both sexes. The association with region of residence differed for men and women.

The better health of occasional and habitual drinkers compared with nondrinkers deserves comment. This study assessed only the frequency, not the amount, of alcohol consumed. While consuming large amounts of alcohol has negative health effects,[33,34] moderate consumption is associated with better health outcomes, including an increase in bone density that can delay the onset of physical limitations.[35]

Limitations

This study has several limitations. First, the data are cross-sectional, so causality cannot be inferred. Second, the data are self-reported; no other sources were available for validation. Third, because the SLCDC is a follow-up survey, it is possible that the responses were affected by learning effects and the collection period. Assessing possible response bias is beyond the scope of this study, but it is warranted for follow-up surveys such as the SLCDC.

Fourth, this study examined only one component of arthritis disability—functional *limitations*. Another important component is dependence on others for activities of daily living—functional *dependency*. Limitation and dependency are not mutually exclusive; rather, they are part of a continuum of a person's health. However, SLCDC respondents were not asked if their dependence on others was attributable to arthritis. To provide a more complete picture of the

impact of chronic conditions, future rounds of the SLCDC might explore the potential of including questions about dependency directly attributable to a given condition.

Conclusion

The SLCDC data are well suited for studying quality of life, limitations, and health behaviours and outcomes among people with arthritis. Examining the association between arthritis and activity limitations indicates the types of intervention people with arthritis may need to remain functionally independent. An understanding of the impact of disease duration could help identify the optimal time to introduce interventions that would help to mitigate the effects of the disease. Similarly, insight into the role of comorbidity could inform the design of programs considering the added burden of other chronic conditions. Surveys focusing on specific chronic conditions provide essential details about the impact of those conditions, coping strategies among patients and health care use, all necessary for the formulation of disease-specific interventions. ■

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Official language proficiency and self-reported health among immigrants to Canada

by Edward Ng, Kevin Pottie and Denise Spitzer

Abstract

Background
New immigrants to Canada initially report better health than does the Canadian-born population. With time, this "healthy immigrant effect" appears to diminish. Limited ability to speak English or French has been identified as a possible factor in poor health. This analysis explored the relationship between self-reported official language proficiency and transitions to poor self-reported health.

Data and methods
Statistics Canada's Longitudinal Survey of Immigrants to Canada tracked a sample of the 2001 immigrant cohort for four years (6, 24 and 48 months after arrival). Data from each of the three survey waves were available for 7,716 respondents. Bivariate and multivariate analysis were used to examine associations between official language proficiency and self-reported health, by sex, controlling for selected pre-migration and post-migration factors. The prevalence of poor health among immigrants was compared with rates among the Canadian-born population, based on data from the Canadian Community Health Survey.

Results
Among a representative sample of recent immigrants, the prevalence of poor self-reported health had risen substantially, especially among women, after four years in Canada. Prolonged limited official language proficiency was strongly associated with a transition to poor health among male and female immigrants who had earlier reported good health. Other factors significantly associated with an increase in the prevalence of poor self-reported health differed by sex. Refugee status, self-reported discrimination, and living in Vancouver were significant for men. Age, health care access problems, and limited friendliness of neighbours were significant for women.

Keywords
Health services accessibility, health status, healthy immigrant effect, immigration, longitudinal studies, medical geography

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When immigrants arrive in Canada, they are typically in better health than their Canadian-born counterparts. However, this "healthy immigrant effect" may gradually diminish.[1,2] The transition to poorer health has been found in general self-reported health,[3,4] mental health status,[5-7] the prevalence of chronic diseases,[8-11] and birth and death outcomes.[12-14] A wide variety of pre- and post-immigration demographic, socio-economic and behavioural factors have been proposed as contributors to this health decline,[15-30] among which is the individual's ability to function in the language of the new country.[31]

Based on previous research about immigrant adjustment,[32-36] this study hypothesized that limited official language proficiency may be associated with immigrants' health. Fully 80% of those who came to Canada between 2001 and 2006 were from non-traditional sources—Asia, South America and Africa.[37] Six months after they arrived, a substantial percentage of new immigrants (37%) reported limited official language proficiency.[31] With data from the Longitudinal Survey of Immigrants to Canada, this analysis examines the relationship between self-reported official language proficiency and transitions to poor self-reported health during the first four years in the country.

Methods

Data sources

Statistics Canada's Longitudinal Survey of Immigrants to Canada (LSIC) is a population-based cohort survey. From the approximately 250,000 immigrants who settled in Canada from October 2000 through September 2001, about 21,000 aged 15 or older were selected for the LSIC using a stratified sampling strategy. Around 12,000 of them responded to Wave 1 of the survey six months after their arrival (a response rate of 61%). Wave 2 was conducted about two years after arrival, and Wave 3, four years after arrival. Waves 2 and 3 had

9,322 and 7,716 respondents, yielding longitudinal response rates of 48% and 40%, respectively. This study is based on the 7,716 respondents for whom data from all three waves were available.

The low longitudinal response rates are largely attributable to the 28% of the Wave 1 sample who were untraceable.[38] Among individuals who were traced, response rates were high (around 80%).[39] Model-based techniques were used to correct for biases due to non-response and sample attrition.[40]

One section of the survey was dedicated to health issues, including general health status and health care access and barriers. Other sections collected data that were used as covariates in this analysis: language skills, employment, social participation, housing, social support, friendliness of neighbours, discrimination, and location of residence.

The LSIC was administered in 15 languages—English, French, Chinese (Mandarin, Cantonese), Punjabi, Farsi/Dari (one language), Arabic, Spanish, Russian, Serbo-Croatian, Urdu, Korean, Tamil, Tagalog, and Gujarati; these languages include approximately 93% of immigrants in Canada.

Based on the method employed in an earlier study,[22] data from the 2000/2001, 2002/2003 and 2005 Canadian Community Health Survey (CCHS) were used to provide comparative information for the Canadian-born population. CCHS respondents were selected to correspond to the aging of the LSIC cohort: 15 or older for the first wave of the LSIC in 2001; two years later, 17 or older for the second wave; and four years later, 19 or older for the third wave.

Data analysis

Bivariate statistics were used to profile changes in self-reported health among immigrants 6, 24 and 48 months after they arrived, by selected characteristics. The direct age-standardization method, based on the LSIC population structure, was used to compare prevalence rates of poor health with rates among the Canadian-born population. This standardization adjusts for the relatively young age distribution of recent immigrants.

With logistic regressions, the association between changes in self-reported official language proficiency and a transition to poor self-reported health in Wave 3 among immigrants reporting good health in Waves 1 and 2 was explored, controlling for potentially confounding pre- and post-migration factors. SAS software was used with SAS-callable SUDAAN procedures to incorporate bootstrap weights that account for the survey's complex sampling design. The analysis was conducted separately for men and women.[15,23,24]

Definitions and rationales for inclusion

Self-reported health and language proficiency are the key variables in this analysis. Self-reported health is correlated with morbidity, mortality and the use of health services.[41-44] Respondents were asked to rate their health; their responses were dichotomized as good (excellent, very good, good) and poor (fair or poor).

The LSIC language questions focused on proficiency speaking official languages (English and French). For this analysis, the six possible proficiency categories were dichotomized as good (well, very well, first language) and limited (cannot speak, speak poorly, fairly well).[31,36] Both English and French were used to determine language proficiency in Quebec; English was used to determine proficiency elsewhere.[36]

A variable indicating change in official language proficiency was constructed from Wave 1 and 2 data:

- persistently good if the respondent was proficient in both Waves;
- gaining if the respondent was not proficient in Wave 1, but proficient in Wave 2;
- losing if the respondent was proficient in Wave 1, but not in Wave 2; and
- persistently limited if the respondent was not proficient in either Wave.

The covariates examined in the relationship between official language proficiency and self-reported health were grouped under pre-migration (Wave 1) and post-migration risk factors (Waves 1 to 3).

Pre-migration factors were living standard of the country of origin, immigration class, education at entry, and visible minority status. The Gross Domestic Product (GDP) per capita in the country of origin, adjusted for purchasing power parity[45] to correct for socio-economic differentials that may influence perceptions of health, was used to indicate living standard in the country of origin. Countries were ranked by their GDP level.

Immigration class refers to: refugees (who usually come for humanitarian reasons); family class (who are usually sponsored by Canadian citizens for family reunification); and economic/business class including family members (who usually come to participate in the labour force or to set up a business). Provincial nominees and those who could not be classified (n=43) were excluded.

Visible minority status was determined based on Wave 1 self-reported visible minority status, which includes groups such as Chinese, South Asian, Filipino, Black, etc.

Post-migration factors from Wave 2 that may be involved in the association between language proficiency and health[34] were incorporated in the analysis: economic problems, barriers to health care, and social isolation. Job satisfaction (yes, no, not working) and family income (no income, low or high relative to the median, and missing) were used as a proxy for economic problems. A report of health care access problems (yes, no) was used as a proxy for barriers to health care. Participation in social organizations (yes, no) was used as a proxy for social isolation.

Other post-migration factors drawn from Wave 3 (48 months after arrival) reflect health risk factors related to the needs of new immigrants:

- adequate housing[28]—satisfaction with housing (yes, no) as a proxy;

- social support[18,22,46]—number of people to confide in (none, 1 to 4, 5 or more) as a proxy;
- welcoming communities[29]—friendliness of neighbours (yes, neutral, no) and self-reported discrimination (no, rarely, some/most or all the time) as proxies; and
- importance of place[30]—residing in selected Census Metropolitan Areas (Toronto, Montreal, Vancouver, Edmonton/Calgary) or not.

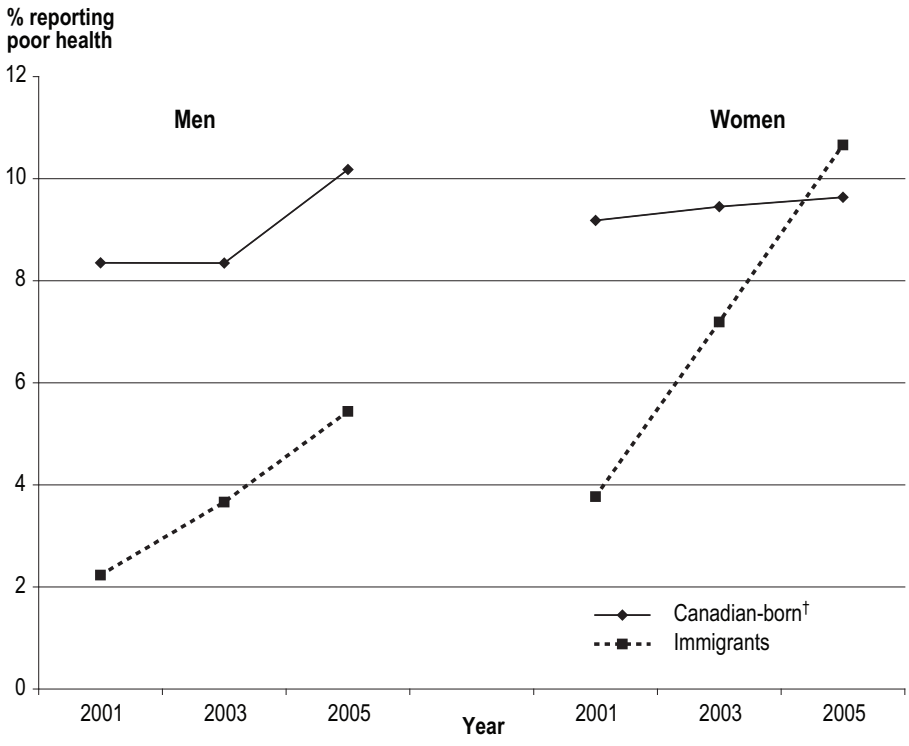
Results

Immigrants to Canada generally arrive in good health. An estimated 2% of men and 4% of women in the 2000/2001 immigrant-landing cohort reported poor health six months after they arrived (Figure 1). The corresponding age-standardized prevalence rates of poor health among the Canadian-born were estimated to be 8% for men and 10% for women. Four years later, an estimated 5% of male and 11% of female members of the immigrant-landing cohort reported poor health, compared with 10% of both sexes in the 2005 Canadian-born population of the same age.

Language proficiency

The self-rated official language (English or French) proficiency of 66% of male and 52% of female immigrants was good six months after they arrived and remained so over the next two years (Table 1). As well, during those two years, the language proficiency of 14% of men and 16% of women improved from limited to good. However, for 15% of men and 27% of women, official language proficiency remained limited, and for 5% of each sex, it declined from good to limited.

Figure 1
Prevalence of poor self-reported health, immigrants aged 15 or older in 2000/2001 and Canadian-born population, by sex, Canada, 2001 to 2005



† age-standardized to Longitudinal Survey of Immigrants to Canada population
Source: Longitudinal Survey of Immigrants to Canada, Waves 1, 2 and 3; 2000/2001, 2002/2003 and 2005 Canadian Community Health Surveys.

Table 1
Percentage distribution of selected characteristics, by sex, immigrants aged 15 or older in 2000/2001, Waves 1 to 3, Longitudinal Survey of Immigrants to Canada, 2001 to 2005

Characteristics	Men	Women
Sample size (number)	**3,761**	**3,872**
Estimated total	**76,623**	**79,027**
Percent (%)	**100**	**100**
Age group (Wave 1)		
15 to 24	11	10
25 to 44	64	67
45 or older	25	23
Language proficiency (Wave 1 to Wave 2)		
Persistently good	66	52
Gaining	14	16
Losing	5	5
Persistently poor	15	27
GDP per capita in country of origin (Wave 1)		
L1 (lowest)	6	6
L2	61	63
L3	19	19
L4 (highest)	13	13
Immigration class (Wave 1)		
Refugee	6	6
Family	21	34
Skilled workers (including business class)	73	60
Visible minority status (Wave 1)		
Yes	79	80
No	21	20
Education at entry (Wave 1)		
Less than secondary graduation	12	16
Secondary graduation	10	14
Some postsecondary	17	22
University graduation	39	33
Master's or more	22	14
Family income (Wave 2)		
No income	16	17
Low income	42	41
High income	39	38
Missing	3	4
Health care access problem (Wave 2)		
No	86	83
Yes	14	17
Job satisfaction (Wave 2)		
Not working	30	52
No	11	7
Yes	59	41
Social participation (Wave 2)		
No	30	26
Yes	70	74
Housing satisfaction (Wave 3)		
No/Don't know/Refused	10	12
Yes	90	88
Social support (Wave 3)		
No	7	6
Some	73	74
Lots	20	20
Friendliness of neighbours (Wave 3)		
No	2	3
Neutral	25	24
Yes	72	73
Perceived discrimination (Wave 3)		
No	69	74
Rarely	11	9
Often/Always	20	17
Residence (Wave 3)		
Toronto	42	43
Vancouver	14	16
Montreal	14	13
Calgary/Edmonton	9	8
Other	21	21

Source: Longitudinal Survey of Immigrants to Canada, Waves 1, 2 and 3.

Table 2
Prevalence of poor self-reported health, by sex and length of time since arrival, immigrants aged 15 or older in 2000/2001, Waves 1 to 3, Longitudinal Survey of Immigrants to Canada, 2001 to 2005

	Men									Women								
	Six months			Two years			Four years			Six months			Two years			Four years		
		95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval	
Characteristics	%	from	to	%	from	to	%	from	to	%	from	to	%	from	to	%	from	to
Total	**2.2**	**1.8**	**2.8**	**3.7**	**3.1**	**4.4**	**5.4**	**4.7**	**6.3**	**3.8**	**3.2**	**4.4**	**7.2**	**6.4**	**8.1**	**10.7**	**9.7**	**11.7**
Age group (Wave 1)																		
15 to 24	2.6[E]	1.4	4.9	3.2[E]	1.8	5.6	3.0[E]	1.8	5.1	2.3[E]	1.2	4.4	3.5[E]	2.0	6.0	2.8[E]	1.7	5.0
25 to 44	1.7[E]	1.2	2.3	2.1	1.6	2.8	4.4	3.6	5.4	2.1	1.6	2.7	5.2	4.4	6.2	8.3	7.2	9.6
45 or older	3.5[E]	2.4	5.1	7.7	6.0	9.9	9.2	7.4	11.3	9.1	7.3	11.4	14.5	12.1	17.1	20.7	18.1	24.0
Language proficiency (Wave 1 to Wave 2)																		
Persistently goodw	1.6[E]	1.1	2.3	2.7	2.1	3.5	4.0	3.3	5.0	1.7[E]	1.1	2.4	4.1	3.2	5.2	6.5	5.4	7.8
Gaining	F	F	F	1.9[E]	1.0	3.5	4.6[E]	3.1	6.5	3.2[E]	2.1	5.0	4.4[E]	2.9	6.5	6.6	4.8	9.1
Losing	F	F	F	F	F	F	6.4[E]	3.4	11.6	F	F	F	7.1[E]	4.1	12.0	9.7[E]	6.0	15.4
Persistently poor	5.4[E]	3.7	7.8	9.2	6.9	12.1	12.4	9.8	15.6	8.4	6.9	10.3	14.9	12.7	17.3	21.2	18.8	23.7
GDP per capita in country of origin (Wave 1)																		
L1 (lowest)	F	F	F	5.1[E]	3.1	8.2	5.6[E]	3.6	8.6	5.5[E]	3.4	8.8	8.5[E]	5.4	13.1	10.2[E]	7.0	14.7
L2	2.6	1.9	3.4	4.1	3.3	5.1	6.0	5.0	7.2	3.8	3.1	4.7	8.6	7.4	9.8	12.7	11.3	14.1
L3	1.7[E]	1.0	3.0	2.5[E]	1.6	4.1	3.8[E]	2.7	5.4	3.6[E]	2.4	5.5	5.4[E]	3.9	7.5	7.1	5.4	9.3
L4 (highest)	F	F	F	2.8[E]	1.6	4.8	5.2[E]	3.4	7.7	3.0[E]	1.8	4.9	2.7[E]	1.6	4.6	6.4[E]	4.5	9.0
Immigration class (Wave 1)																		
Refugee	4.0[E]	2.6	6.2	5.7	4.1	7.9	9.7	7.4	12.8	8.4	6.0	11.5	9.6	7.4	12.3	15.5	12.5	19.2
Family	3.6[E]	2.4	5.4	7.1	5.3	9.4	7.5	5.7	9.8	5.3	4.1	6.8	9.2	7.6	11.0	13.4	11.6	15.5
Skilled workers (including business class)	1.7[E]	1.2	2.4	2.5	1.9	3.3	4.5	3.7	5.4	2.4	1.9	3.2	5.9	4.9	7.0	8.6	7.5	9.9
Visible minority status (Wave 1)																		
Yes	2.2	1.7	2.9	3.8	3.1	4.6	5.7	4.9	6.6	3.8	3.2	4.5	7.7	6.7	8.8	11.7	10.6	13.0
No	2.2[E]	1.4	3.4	3.2[E]	2.2	4.7	4.5[E]	3.2	6.2	3.7[E]	2.5	5.4	5.2	3.8	7.1	6.5	4.9	8.6
Education at entry (Wave 1)																		
Less than secondary graduation	3.4[E]	2.1	5.6	6.2[E]	4.3	8.9	7.1	5.2	9.7	8.8	6.8	11.3	11.5	9.2	14.3	16.0	13.4	19.2
Secondary graduation	3.0[E]	1.7	5.1	4.5[E]	2.7	7.5	7.3[E]	5.0	10.4	2.4[E]	1.4	4.1	8.3	6.2	11.0	14.1	11.2	17.5
Some postsecondary	2.9[E]	1.9	4.6	5.7[E]	4.0	8.1	5.2[E]	3.7	7.5	3.8[E]	2.7	5.4	5.9	4.5	7.9	9.5	7.6	11.8
University graduation	1.8[E]	1.2	2.8	2.4[E]	1.7	3.5	5.4	4.2	6.9	2.4[E]	1.6	3.5	5.1	3.9	6.7	8.6	7.1	10.4
Master's or more	1.4[E]	0.7	2.8	2.6[E]	1.7	3.9	3.9[E]	2.7	5.6	2.5[E]	1.3	4.5	8.0[E]	5.8	11.1	7.7[E]	5.5	10.6
Family income (Wave 2)																		
No income	3.5[E]	2.3	5.4	5.5[E]	3.9	7.8	6.8	5.1	9.1	5.8	4.3	7.8	8.2	6.4	10.6	10.6	8.5	13.3
Low income	2.5[E]	1.8	3.5	3.6	2.7	4.7	6.3	5.1	7.6	4.0	3.1	5.1	8.4	7.0	10.0	12.4	10.7	14.3
High income	1.4[E]	0.9	2.2	2.9	2.1	4.0	3.9	2.9	5.1	2.8[E]	2.0	3.8	5.6	4.4	7.0	8.8	7.3	10.5
Missing	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	11.6[E]	7.0	18.7
Health care access problem (Wave 2)																		
No	2.1	1.7	2.7	3.2	2.6	3.9	5.2	4.4	6.0	3.4	2.8	4.2	5.7	4.9	6.6	9.2	8.2	10.3
Yes	2.9[E]	1.6	5.1	6.6[E]	4.5	9.5	7.2	5.1	10.1	5.4[E]	3.8	7.5	14.5	11.8	17.7	18.1	15.1	21.5
Job satisfaction (Wave 2)																		
Not working	3.7	2.7	5.1	6.5	5.1	8.3	7.5	6.0	9.2	5.5	4.5	6.6	9.5	8.2	10.9	13.0	11.6	14.6
No	F	F	F	4.7[E]	2.8	7.7	7.4[E]	5.1	10.7	F	F	F	8.6[E]	5.6	13.1	13.4[E]	9.4	18.6
Yes	1.6[E]	1.2	2.3	2.0	1.5	2.7	4.0	3.2	5.0	1.9[E]	1.3	2.7	4.1	3.1	5.3	7.2	6.0	8.7
Social participation (Wave 2)																		
No	2.0[E]	1.3	3.2	3.4[E]	2.4	4.9	5.2	3.9	6.9	3.4[E]	2.4	4.9	6.8	5.4	8.7	8.7	7.1	10.7
Yes	2.3	1.8	3.0	3.8	3.1	4.6	5.5	4.7	6.5	3.9	3.2	4.7	7.3	6.4	8.4	11.3	10.2	12.6
Housing satisfaction (Wave 3)																		
No/Don't know/Refused	3.2[E]	1.8	5.6	5.3[E]	3.3	8.5	8.9[E]	6.4	12.3	4.9	3.3	7.3	12.0	9.1	15.8	17.1	13.8	21.0
Yes	2.1	1.7	2.7	3.5	2.9	4.2	5.0	4.3	5.9	3.6	3.0	4.3	6.5	5.7	7.5	9.8	8.8	10.9
Social support (Wave 3)																		
No	F	F	F	4.8[E]	2.6	8.5	9.5[E]	6.3	14.1	5.1[E]	3.1	8.5	8.2[E]	5.5	12.6	16.0	11.7	21.5
Some	2.3	1.8	3.1	3.6	2.9	4.4	5.2	4.4	6.1	3.7	3.1	4.6	7.3	6.3	8.3	10.8	9.7	12.0
Lots	F	F	F	3.6[E]	2.4	5.5	4.9[E]	3.5	6.9	3.4[E]	2.3	5.1	6.7	4.9	9.0	8.6	6.7	11.0
Friendliness of neighbours (Wave 3)																		
No	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	13.4[E]	8.2	21.0
Neutral	2.8[E]	1.8	4.2	4.0[E]	2.8	5.6	7.5	5.9	9.5	4.6	3.4	6.2	10.0	8.1	12.4	13.5	11.2	16.1
Yes	2.0	1.6	2.7	3.4	2.7	4.1	4.7	3.9	5.7	3.5	2.9	4.3	6.3	5.4	7.3	9.6	8.6	10.9
Perceived discrimination (Wave 3)																		
No	2.4	1.9	3.2	3.8	3.1	4.7	4.6	3.8	5.5	4.0	3.3	4.8	6.7	5.8	7.7	10.3	9.2	11.5
Rarely	F	F	F	F	F	F	5.1[E]	3.1	8.2	2.7[E]	1.4	5.0	7.2[E]	4.8	10.8	11.3	8.1	15.4
Often/Always	1.9[E]	1.1	3.4	4.0[E]	2.8	5.8	8.5	6.6	10.9	3.6[E]	2.3	5.5	9.5	7.2	12.4	11.9	9.4	14.9
Residence (Wave 3)																		
Toronto	2.1[E]	1.4	3.1	4.6	3.5	5.9	4.9	3.9	6.2	3.1	2.3	4.2	7.2	5.9	8.7	10.6	9.1	12.4
Vancouver	2.5[E]	1.5	4.2	5.0[E]	3.3	7.4	9.2	6.9	12.2	5.7	4.2	7.6	9.8	7.7	12.4	16.7	14.0	19.8
Montreal	2.6[E]	1.4	4.7	2.7[E]	1.5	4.8	4.4[E]	2.8	6.8	4.7[E]	3.1	7.1	5.9[E]	3.9	8.8	9.2	6.7	12.4
Calgary/Edmonton	F	F	F	2.3[E]	1.3	4.1	5.2	3.4	8.0	3.8[E]	2.2	6.5	7.3[E]	5.0	10.5	8.9	6.4	12.1
Other	2.0[E]	1.2	3.2	2.1[E]	1.4	3.3	4.8[E]	3.5	6.6	3.0[E]	2.1	4.4	6.1	4.6	8.0	7.8	6.1	9.8

[E] use with caution
F too unreliable to be published
Source: Longitudinal Survey of Immigrants to Canada, Waves 1, 2 and 3.

Trends by pre- and post-migration factors

During immigrants' first four years in Canada, the prevalence of poor self-reported health rose among those with persistently limited language proficiency: from 5% to 12% for men, and from 8% to 21% for women. The increase was less among those with persistently good language proficiency: from 2% to 4% among men, and from 2% to 7% among women (Table 2).

Of course, the rising prevalence of poor self-reported health among new immigrants was associated with many factors besides language. The extent of the increase varied by pre- and post-immigration characteristics.

For example, among immigrants aged 45 or older in 2000/2001, the percentage reporting poor health rose over the next four years from 4% to 9% for men, and from 9% to 21% for women. By contrast, among those aged 15 to 24 in 2000/2001, the percentage reporting poor health hovered around 2% or 3% throughout the period.

Over the four years, the prevalence of poor self-reported health among immigrants who reported difficulties accessing health care rose from 5% to 18% for women and from 3% to 7% for men Rates were lower among those who did not report access difficulties, rising from 3% to 9% for women and from 2% to 5% for men.

Several other factors were associated with a high prevalence of poor self-reported health after four years in Canada. By 2005, the prevalence of poor health was at least 10% for men and 15% for women who arrived as refugees or lacked social support. The percentage was also at least 15% for women who had relatively low education; had housing that was not satisfactory; or lived in Vancouver.

Multivariate results

To understand factors related to a health decline the following analysis focuses on the 95% of male and 91% of female immigrants who reported good health in both 2000/2001 and 2003. By 2005, 4% of these men and 7% of these women experienced a health decline, in that they reported their health to be poor.

For both sexes, language proficiency was related to the likelihood of declining health: the age-adjusted odds that immigrants with persistently limited proficiency would report poor health in 2005 were close to three times the odds for immigrants whose language abilities were persistently good (Table 3). However, a number of other pre- and post-migration factors were associated with a health decline. For example, the age-adjusted odds were high for immigrants who were older, who had arrived as refugees, who were not working, who were not satisfied with their housing, and who lived in Vancouver. As well, the factors that were important differed for men and women. Many of these factors were interrelated. To help account for the possibility of confounding, and determine which variables, including language skills, were independently associated with a reported health decline, multivariate analysis was used. All independent variables were tested for multicollinearity and none was found.

When all the selected pre- and post-migration factors were considered simultaneously, relatively few of them remained significantly related to a transition to poor self-reported health. Persistently limited official language proficiency, however, was among them, and it was the only factor that was estimated to be significant for both sexes. Among immigrant men and women with persistently limited proficiency, the odds of a health decline were estimated to be at least double the odds for their counterparts whose language abilities were persistently good. As well, those who gained language skills had estimated odds of a health decline similar to those of immigrants who were persistently proficient.

For men, the other factors that remained significantly associated with a reported health decline were having come to Canada as a refugee, reporting frequent exposure to discrimination, and living in Vancouver. For women, the other significant factors were older age, having health care access problems, and a perception that neighbours' friendliness was limited.

What is already known on this subject?

- In cross-sectional analyses, limited official language proficiency—the inability to speak English or French—has been associated with the reporting of poor health among recent immigrants.

What does this study add?

- This is the first longitudinal Canadian study to examine the role of persistent limited language proficiency on immigrant health.
- For both sexes, persistently limited proficiency in English or French among recent immigrants was strongly associated with an increase in the prevalence of poor self-reported health.
- Those who reported gaining language proficiency had a health outcome similar to those reporting persistently good proficiency.
- Other factors associated with an increase in the prevalence of poor self-reported health differed by sex: refugee status, self-reported discrimination, and living in Vancouver were significant for men; older age, reported health care access problems, and limited friendliness of neighbours were significant for women.

Discussion

Even when pre- and post-immigration risk factors were taken into account, persistently limited official language proficiency remained significantly associated with a reported health decline among both men and

Table 3
Age-adjusted and fully adjusted odds ratios relating selected characteristics to poor self-reported health in Wave 3, by sex, recent immigrants who reported good health in Waves 1 and 2, Canada, Longitudinal Survey of Immigrants to Canada, 2001 to 2005

	Men						Women					
	Age-adjusted odds ratio	95% confidence interval		Fully adjusted odds ratio	95% confidence interval		Age-adjusted odds ratio	95% confidence interval		Fully adjusted odds ratio	95% confidence interval	
Characteristics		from	to		from	to		from	to		from	to
Age (Wave 3)												
15 to 24†	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
25 to 44	1.78*	0.78	4.09	1.54	0.61	3.90	5.60*	2.16	14.53	5.46*	2.01	14.81
45 or older	3.07*	1.34	7.04	2.41	0.97	5.99	13.06*	5.05	33.78	12.09*	4.49	32.55
Language proficiency (Wave 1 to Wave 2)												
Persistently good†	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
Gaining	1.38	0.83	2.3	1.21	0.68	2.17	1.10	0.68	1.76	0.94	0.57	1.55
Losing	1.75	0.67	4.56	1.52	0.56	4.15	1.23	0.55	2.76	1.08	0.48	2.42
Persistently poor	2.82*	1.83	4.34	2.44*	1.46	4.08	2.93*	2.17	3.95	2.02*	1.35	3.02
GDP per capita in country of origin (Wave 1)												
L1 (lowest)	1.28	0.59	2.76	0.64	0.25	1.64	1.65	0.79	3.44	0.99	0.40	2.43
L2	1.17	0.67	2.04	0.91	0.49	1.70	2.10*	1.27	3.48	1.38	0.79	2.41
L3	0.85	0.43	1.67	0.79	0.38	1.62	1.34	0.74	2.43	1.20	0.66	2.19
L4 (highest)†	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
Immigration class (Wave 1)												
Refugee	2.30*	1.42	3.74	2.36*	1.13	4.91	1.96*	1.27	3.03	1.66	0.91	3.02
Family	1.22	0.77	1.93	1.21	0.65	2.24	1.47*	1.09	1.97	1.27	0.87	1.83
Skilled workers (including business class)†	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
Visible minority (Wave 1)												
Yes	1.58	0.93	2.67	1.15	0.60	2.21	2.15*	1.36	3.40	1.40	0.80	2.43
No†	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
Education at entry (Wave 1)												
Less than secondary graduation	1.76	0.85	3.65	1.01	0.40	2.55	2.28*	1.28	4.08	1.18	0.55	2.53
Secondary graduation	1.73	0.86	3.45	1.22	0.51	2.88	2.49*	1.37	4.52	1.76	0.88	3.52
Some postsecondary	1.16	0.58	2.33	0.96	0.45	2.04	1.61	0.92	2.81	1.36	0.74	2.50
University graduation	1.49	0.84	2.65	1.34	0.73	2.45	1.42	0.82	2.43	1.37	0.77	2.43
Master's or more†	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
Family income (Wave 2)												
No income	1.64	0.97	2.78	1.43	0.76	2.69	0.97	0.63	1.49	0.83	0.52	1.33
Low income	1.66*	1.07	2.56	1.29	0.81	2.05	1.29	0.93	1.79	1.07	0.75	1.54
High income†	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
Missing	1.24	0.41	3.72	1.19	0.39	3.65	0.99	0.44	2.24	0.91	0.39	2.12
Health care access problem (Wave 2)												
No†	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
Yes	1.33	0.81	2.19	1.20	0.71	2.02	1.93*	1.38	2.72	2.10*	1.44	3.07
Job satisfaction (Wave 2)												
Not working	1.49*	1.11	2.01	0.91	0.58	1.42	1.49*	1.11	2.01	1.24	0.89	1.72
No	1.54	0.87	2.74	1.36	0.75	2.45	1.54	0.87	2.74	1.24	0.67	2.29
Yes	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
Social participation (Wave 2)												
No	0.94	0.63	1.41	0.88	0.57	1.37	1.40	1.00	1.96	1.16	0.81	1.67
Yes†	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
Housing satisfaction (Wave 3)												
No	1.66*	1.01	2.73	1.26	0.73	2.17	1.64*	1.11	2.42	1.42	0.92	2.18
Yes†	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
Social support (Wave 3)												
No	1.52	0.74	3.12	1.33	0.60	2.95	2.16*	1.14	4.11	1.76	0.90	3.44
Some	1.00	0.62	1.61	1.00	0.60	1.66	1.58*	1.05	2.36	1.50	0.99	2.29
A great deal†	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
Friendliness of neighbours (Wave 3)												
No	1.05	0.19	5.90	1.04	0.18	6.10	1.48	0.71	3.09	1.58	0.73	3.44
Neutral	1.51*	1.01	2.25	1.27	0.84	2.01	1.53*	1.12	2.09	1.43*	1.02	2.00
Yes†	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
Perceived discrimination (Wave 3)												
No†	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
Rarely	1.86*	1.03	3.36	1.86	0.98	3.53	1.42	0.88	2.29	1.43	0.84	2.41
Often/Always	2.61*	1.74	3.90	2.50*	1.60	3.90	1.13	0.78	1.65	1.11	0.73	1.68
Residence (Wave 3)												
Toronto†	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
Vancouver	2.25*	1.35	3.76	1.95*	1.14	3.31	1.50*	1.06	2.13	1.41	0.96	2.07
Montreal	1.31	0.71	2.43	1.52	0.80	2.88	0.90	0.55	1.22	0.94	0.55	1.58
Calgary/Edmonton	1.15	0.59	2.23	1.11	0.54	2.29	0.75	0.46	1.22	0.82	0.48	1.38
Others	1.23	0.74	2.02	1.26	0.72	2.18	0.71	0.48	1.06	0.85	0.56	1.28

† reference category
* significantly different from reference category ($p<0.05$)
... not applicable
Source: Longitudinal Survey of Immigrants to Canada, Waves 1, 2 and 3.

women. This result is consistent with an earlier study based on the LSIC,[22] which found English language proficiency to be important in the maintenance of good health. As well, a study[47] based on the CCHS reported that limited language proficiency in a linguistic minority situation was associated with poorer self-reported health, and that the impact was greater for men, similar to the results shown here.

By contrast, another recent LSIC study[27] that documented a loss in self-reported health among new immigrants did not find a statistical association with language proficiency. However, that analysis used English or French spoken at home as a proxy for language proficiency, whereas the current analysis used the self-reported ability to converse in either official language. Many new immigrants came from countries where English or French may be spoken, but not at home. Consequently, the language spoken at home may not be an ideal proxy.

Language proficiency is part of a constellation of issues that can shape immigrant health. Limited language proficiency could influence health by: 1) impairing access to health services; 2) creating economic difficulties; and 3) reducing social participation.[34] While women frequently cite language limitations as a barrier to health services,[48] in the present analysis, even when language proficiency was taken into account, health care access problems remained associated with a reported health decline. By contrast, the association between employment and a reported health decline disappeard in the multivariate analysis. For women, low social support was associated with poor health in the bivariate analysis, but not when the other variables were considered. And although other research has related poor health to lower levels of social capital,[22] defined in the present study as social participation, was not associated with a transition to poor self-reported health.

Beyond language abilities, immigrant men in Vancouver had relatively higher odds of a health decline, similar to previous LSIC studies.[22,27] Future analyses of LSIC data might consider the population composition of communities in order to understand the contextual effect.

Having arrived as a refugee and perceiving discrimination were both significant risk factors for men. Male refugees often may face a greater loss of social status than do female refugees, which could be associated with their greater health decline.[49,50] As well, links between discrimination and health are well documented.[20,51-53]

Self-reported language proficiency changed over time: improvements and declines were both noted. Declines may have been related to inflated initial reports. They could also result from social alienation, or a change in the reference point from standards of proficiency in the country of origin to those in Canada. For women, care-giving responsibilities could impede participation in language training.[54]

Limitations

The LSIC has several notable limitations. Language proficiency and health status, the two major variables in the analysis, were self-reported; neither was objectively and consistently measured. For language, the results depend not only on immigrants' actual ability to speak, but also on their perception of their ability, which can differ from one individual to another and change over time. As well, the survey did not collect data about health behaviours (for example, smoking, physical activity) that might have influenced changes in self-reported health. Finally, although sample weights were used to adjust for attrition, the longitudinal response rates were relatively low.

Conclusion

Persistently limited language proficiency was found to be associated with a decline in self-reported health among male and female immigrants during their first four years in Canada. Those who gained language proficiency were found to have a health outcome similar to those with persistently good language proficiency. This suggests that the benefits of acquiring official language skills may not only be social and economic, but may also be associated with the maintenance of health. ■

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The healthy immigrant effect and mortality rates

by Edward Ng

Abstract
According to the 2006 Census, almost 20% of the Canadian population were foreign-born, a percentage that is projected to reach at least 25% by 2031. Studies based on age-standardized mortality rates (ASMR) have found a healthy immigrant effect, with lower overall rates among immigrants. A duration effect has also been observed—immigrants' mortality advantage lessened as their time in Canada increased. ASMRs based on the 1991 to 2001 census mortality follow-up study indicate a healthy immigrant effect and a duration effect at the national level for all-cause mortality for both sexes. However, at the national level, the mortality rate among women from the United States and from Sub-Saharan Africa was similar to that of Canadian-born women. For the three largest Census Metropolitan Areas (Toronto, Montreal and Vancouver), a healthy immigrant effect was not observed among women or among most men from the United States or Sub-Saharan Africa.

Keywords
Age-standardized mortality rate, death rate, longitudinal, record linkage

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In 2006, immigrants made up one-fifth (19.8%) of Canada's population, a percentage that is expected to reach at least 25% by 2031.[1] The health and the health services needs of this large and growing share of the population are not necessarily the same as those of people born in Canada.[2,3] Research has repeatedly found a "healthy immigrant effect"—immigrants' health is generally better than that of the Canadian-born, although it tends to decline as their years in Canada increase.[4-14] However, the relationship between immigration and health is complex, especially because the origins of immigrants to Canada are increasingly diverse. Since the 1960s, the major source countries have shifted from European to non-European nations. Consequently, it is important to analyze the healthy immigrant effect by birthplace and period of immigration.

The present analysis used the 1991 to 2001 Canadian census mortality follow-up study to explore associations between mortality and birthplace and period of immigration (see *The data*). The objectives were to determine:

1. if immigrants have better health, as measured by age-standardized mortality rates (ASMRs) than does the Canadian-born population (overall healthy immigrant effect);
2. if immigrants' initial health advantage lessens over time (duration effect); and
3. if the results hold for immigrant subgroups, by birthplace and by selected country at the national level and for the three largest Census Metropolitan Areas (CMAs)—Toronto, Montreal and Vancouver (where possible).

The adult immigrant population

The total 1991 to 2001 Canadian census mortality follow-up cohort numbered 2.7 million individuals who were aged 25 or older in 1991; 552,300, or 20% of them, were immigrants. Close to 50% of these immigrants were born in Western Europe (comprising North, South and West Europe), followed by Eastern Europe (13%), the Caribbean/ Central and South America (8%), and East Asia (8%). The majority (56%) were established immigrants who arrived in Canada before 1971; 23% arrived between 1971 and 1981; and 21% were more recent immigrants who arrived in the 1981-to-1991 period. Immigrants from Europe and the United States were more likely to be "established," while those from Asia and Africa were more likely to be "recent." For example, 80%

The data

The 1991 to 2001 Canadian census mortality follow-up study is a probabilistically linked cohort consisting of a 15% sample (n = 2,735,152) of the non-institutionalized population aged 25 or older, all of whom were enumerated via the 1991 census long-form questionnaire. This cohort was tracked for mortality from June 4, 1991 through December 31, 2001. Because names were not captured on the census database, but were needed to link to the mortality data, creation of the cohort required two probabilistic linkages. First, eligible census respondents were linked to a nominal list (name) file (abstracted from 1990 and 1991 tax-filer data and then encrypted) using common variables such as date of birth and postal code; 80% of eligible respondents were successfully matched. Then, the census plus encrypted names were matched to the Canadian Mortality Database. Based on 1991 deaths, which could be identified independently in the Canadian Mortality Database and/or the name file, ascertainment of deaths in the cohort followed for mortality was estimated to be 97% overall. Specifically, more than 260,000 deaths over the 10.6-year follow-up period were linked to the cohort.[15]

The 1991 Census defined immigrants as people who were, or who had been, landed immigrants in Canada. A landed immigrant is not a Canadian citizen by birth, but has been granted the right to live in Canada permanently. In this study, the Canadian-born population (non-immigrants) is the reference group. The analysis excluded refugee claimants and non-permanent residents (on employment or student authorizations).

To examine the duration aspect of the healthy immigrant effect, immigrants were classified by period of immigration and by place of birth. The period-of-immigration categories were: before 1970 (established), 1970 through 1980 (medium-term), and 1981 through June 1991 (recent). The world regions of birth were defined as: United States, Caribbean/Central and South America, Western Europe, Eastern Europe, Sub-Saharan Africa, North Africa/Middle East/ West Asia, South Asia, South East Asia, East Asia, and Oceania. These are non-standard 1991 Census classifications of place of birth, established in order to achieve a balance between creating homogeneous categories for epidemiological research and having a manageable number of groups. For example, for conciseness, South, Central, West and East Africa were combined, whereas North Africa, the Middle East and West Asia were grouped because the people in these regions share cultural and epidemiological characteristics. South Asia, South East Asia and East Asia were categorized separately according to the 1991 Census definition, except that Singapore, which is part of South East Asia in the census definition, was included in East Asia. For Europe, the standard 1991 Census groupings of West, South and North Europe were combined with the Scandinavian countries as Western Europe, except that Albania and Yugoslavia, which are part of South Europe in the census definition, were included with Eastern Europe. South and Central America (including Mexico) and the Caribbean were combined. The United States of America was singled out as a place of birth instead of being part of North America. Greenland and St. Pierre and Miquelon, the other two components of North America, were included with Oceania. However, Oceania was dropped from the analyses by world region of birth because of the small sample size (n=4,600).

Immigrants from three countries—China (including Hong Kong), India and the United Kingdom—were selected for more in-depth analysis. Because the baseline data were obtained in 1991, before the influx of immigrants from the People's Republic of China, those in the sample who were born there most likely lived in Hong Kong before coming to Canada. For this analysis, the People's Republic of China and Hong Kong were grouped as China.

This study also examines mortality in three Census Metropolitan Areas (CMA): Toronto, Montreal and Vancouver.

Age- and sex-specific mortality rates by 5-year age group (at baseline) were used to derive age-standardized mortality rates (ASMRs), with the population structure of the census mortality follow-up cohort as the standard. ASMRs were calculated at the national level by sex for:

1) total population
2) Canadian-born population (reference)
3) total immigrant population and by period of immigration.
4) immigrant population by world region of birth and then by period of immigration.
5) immigrant population for China, India and the United Kingdom.

These calculations were repeated for the three CMAs, except for period of immigration, which was not possible because of small sample sizes. Rate ratios were calculated to determine if the ASMRs for various immigrant subgroups were significantly different from those for the Canadian-born population, and therefore, indicated a healthy immigrant effect. The duration effect was determined based on whether immigrants' health advantage lessened, as reflected in rising ASMRs with increased years in Canada as indicated by period of immigration.

The coefficient of variation was used to ensure that the ASMR estimates could be released; estimates with a coefficient of variation larger than 33.3% were suppressed.

This study has several limitations. First, even with such a large database, sample size becomes a problem with finer geographic breakdowns. A second possible limitation is differential attrition in the census mortality follow-up database. If immigrants are more likely than the Canadian-born to leave the country, a healthy immigrant effect might partly be explained by this differential loss to follow-up. However, while the possibility of immigrants moving out of the country exists, this is most common among younger people. Mortality rates at younger ages tend to be low, so such attrition should not have a noticeable impact on the results. Third, the analysis is limited by the lack of information about risk factors, such as physical activity, body mass index, smoking, nutrition and alcohol consumption.

Finally, immigration category (economic, family or refugee) may be an important determinant of post-immigration health outcomes; however, such data are not available in the 1991 to 2001 census mortality follow-up study.

of immigrants from Western Europe arrived before 1971, whereas the figure for immigrants from South Asia was 8%.

In this study, close to one in five immigrant adults (19%) was aged 65 or older, compared with 15% of Canadian-born adults. The higher percentage of seniors among immigrants reflected the higher percentage who had been born in Europe and the United States and is indicative of the diverse waves of immigration and settlement patterns that have occurred in Canada. For instance, 36% of immigrants in the study from Eastern Europe were seniors, compared with 5% of those from Sub-Saharan Africa and Western Asia.

More than half (54%) of immigrant adults lived in Toronto, Montreal or Vancouver. The percentage varied from 28% of those from the United States to 73% of those from the Caribbean/Central and South America. By comparison, 25% of Canadian-born adults lived in these three cities.

Healthy immigrant effect: Lower mortality rates

For Canada's adult population overall, the age-standardized mortality rates (ASMRs) per 100,000 person-years at risk were 1,230 for men and 703 for women. Immigrants had significantly lower ASMRs than did Canadian-born adults: 1,006 versus 1,305 for men, and 610 versus 731 for women (Table 1).

However, as immigrants' time in Canada lengthened, their ASMRs tended to rise. It is hypothesized that this upward trend in ASMRs reflects a loss of immigrants' health advantage over time. The AMSRs among men were 720, 913 and 1,054 for recent, medium-term and established immigrants, respectively. Among immigrant women, the corresponding rates were 491, 546 and 637. Nonetheless, these rates remained significantly lower than those of the Canadian-born population.

Birthplace matters

ASMRs varied widely depending on where immigrants had been born (Table 1). Among men, ASMRs ranged from 668 (South Asia) to 1,112 (United States); among women, the range was from 439 (Southeast Asia) to 699 (United States). Despite these wide variations, the ASMRs of immigrants were generally lower than those of Canadian-born adults. The only exceptions were women from the United States and from Sub-Saharan Africa whose ASMRs were similar to that of Canadian-born women.

Table 1
Age-standardized mortality rates,† by sex, birthplace and period of immigration, non-institutional cohort members aged 25 or older at baseline, Canada, 1991 to 2001

	Men	Women
Total	**1,230**	**703**
Canadian-born	**1,305**	**731**
Immigrants (total)	**1,006***	**610***
Before 1971	1,054*	637*
1971 to 1980	913*	546*
1981 to 1991	720*	491*
United States	**1,112***	**699**
Before 1971	1,104*	729
1971 to 1980	1,110*	636*
1981 to 1991	953*	739
Caribbean/Central and South America	**825‡***	**487‡***
Before 1971	893*	552*
1971 to 1980	817*	475*
1981 to 1991	750*	409*
Western Europe	**1,055‡***	**642‡***
Before 1971	1,070*	649*
1971 to 1980	1,056*	587*
1981 to 1991	898*	573*
Eastern Europe	**1,048‡***	**605‡***
Before 1971	1,062*	609*
1971 to 1980	954*	573*
1981 to 1991	862*	533*
Sub-Saharan Africa	**903***	**640**
Before 1971	825*	677
1971 to 1980	990*	636
1981 to 1991	992	600
North Africa/Middle East/ West Asia	**813‡***	**512***
Before 1971	937*	538*
1971 to 1980	825*	579*
1981 to 1991	556*	395*
South Asia	**668‡***	**550***
Before 1971	861*	579*
1971 to 1980	703*	603
1981 to 1991	509*	517*
South East Asia	**669***	**439‡***
Before 1971	606*	530*
1971 to 1980	792*	432*
1981 to 1991	627*	419*
East Asia	**794‡***	**470‡***
Before 1971	952*	501*
1971 to 1980	819*	486*
1981 to 1991	636*	402*

† per 100,000 person-years at risk
‡ support for duration effect
* significantly different from Canadian-born population
Note: Reference population (person-years at risk) for age standardization was taken from age distribution of entire cohort (5 -year age groups).
Source: 1991 to 2001 Canadian census mortality follow-up study.

The study results indicate that ASMRs for immigrants from most regions of the world increased with time in Canada (duration effect):

- among both sexes – from the Caribbean/Central and South America; Western Europe; Eastern Europe; East Asia.
- among men only – North Africa/ Middle East/West Asia; South Asia.
- among women only – South East Asia.

However, the rise in ASMRs with duration of residence in Canada did not occur in all cases. For example, men who came to Canada from Sub-Saharan Africa before 1971 had a lower ASMR (825) than did those who arrived in the 1981-to-1991 period (992).

Toronto, Montreal and Vancouver

ASMRs in Toronto, Montreal and Vancouver also support the healthy immigrant effect For instance, the ASMR for immigrant men in Toronto was 974, significantly below the 1,280 for Canadian-born men in that CMA; the corresponding figures for women were 589 and 775 (Table 2).

ASMRs at the CMA level are heavily influenced by immigrants' birthplace and period of immigration. At least 40% of the immigrants in each of Toronto, Montreal and Vancouver came from Western Europe and had been in Canada for more than ten years. As a result, while ASMRs were lower compared with the Candian-born, overall ASMRs were closer to the levels for Western European immigrants who made up a larger percentage of the population in the study, compared with immigrants from

Table 2
Age-standardized mortality rates,† by sex and birthplace, non-institutional cohort members aged 25 or older at baseline, Toronto, Montreal, Vancouver, 1991 to 2001

	Men	Women
Canadian-born		
Toronto	1,280	775
Montreal	1,393	680
Vancouver	1,233	731
Immigrants (total)		
Toronto	974*	589*
Montreal	929*	463*
Vancouver	982*	613*
United States		
Toronto	1,129	671
Montreal	1,262	617
Vancouver	1,109	719
Caribbean/Central and South America		
Toronto	869*	546*
Montreal	842*	386*
Vancouver	611*	396*
Western Europe		
Toronto	1,062*	633*
Montreal	958*	476*
Vancouver	1,080*	676*
Eastern Europe		
Toronto	1,014*	587*
Montreal	934*	458*
Vancouver	1,016*	629*
Sub-Saharan Africa		
Toronto	881*	674
Montreal	F	F
Vancouver	1,135	810
North Africa/Middle East/ West Asia		
Toronto	698*	586*
Montreal	872*	447*
Vancouver	364*	F
South Asia		
Toronto	784*	626
Montreal	422*	455
Vancouver	752*	523*
South East Asia		
Toronto	593*	432*
Montreal	765*	475*
Vancouver	701*	470*
East Asia		
Toronto	775*	459*
Montreal	756*	363*
Vancouver	829*	499*

† per 100,000 person-years at risk
* significantly different from Canadian-born population
F too unreliable to be published
Note: Reference population (person-years at risk) for age standardization was taken from age distribution of entire cohort (5 -year age groups).
Source: 1991 to 2001 Canadian census mortality follow-up study.

Table 3
Age-standardized mortality rates,† for immigrants from China, India or United Kingdom, by sex, non-institutional cohort members aged 25 or older at baseline, Toronto, Montreal, Vancouver, 1991 to 2001

	Men	Women
Canadian-born		
Toronto	1,280	775
Montreal	1,393	680
Vancouver	1,233	731
Immigrants (total)		
Toronto	974*	589*
Montreal	929*	463*
Vancouver	982*	613*
China		
Toronto	790*	460*
Montreal	765*	373*
Vancouver	854*	502*
India		
Toronto	796*	634
Montreal	437*	503
Vancouver	779*	515*
United Kingdom		
Toronto	1,146*	700*
Montreal	1,019*	580*
Vancouver	1,083*	700

† per 100,000 person-years at risk
* significantly different from Canadian-born population
Note: Reference population (person-years at risk) for age standardization was taken from age distribution of entire cohort (5 -year age groups).
Source: 1991 to 2001 Canadian census mortality follow-up study.

Asia, whose ASMRs tended to be lower, but who made up a smaller percentage of the overall CMA immigrant population at that time.

For women in the three CMAs who had been born in the United States or in Sub-Saharan African countries, ASMRs were closer to those of Canadian-born women living in these locations. As well, the healthy immigrant effect was less evident among men from the United States living in these three CMAs—their ASMRs more closely resembled those of the Canadian-born than those of other immigrant groups. By contrast, for the Sub-Saharan African group, in Toronto, where close to half of them lived, ASMRs of male immigrants compared favourably with those of other immigrant groups.

China, India and the United Kingdom

In the 1991-to-2001 census mortality follow-up study, China (including Hong Kong) and India were leading source countries of recent immigrants to Canada, whereas the United Kingdom had been a major source in the past.

Overall, a healthy immigrant effect was apparent among immigrants from each of these countries. The ASMRs among men were 690 for those from India, 810 for those from China, and 1,105 for those from the United Kingdom; this compared with 1,305 for Canadian-born men (data not shown). Among women, the ASMRs were 537 (India), 471 (China), 695 (United Kingdom) and 731 (Canadian-born).

At the CMA level, ASMRs for immigrants from these three countries were generally lower than those for the Canadian-born population (Table 3). The exceptions were women from India living in Toronto (634) and in Montreal (503) and women from the United Kingdom residing in Vancouver (700), whose ASMRs did not differ significantly from those of Canadian-born women in these CMAs.

When cause of death is examined, the elevated ASMR among women from India at the CMA level reflects higher circulatory disease ASMRs (data not shown).[16] Similarly, in Vancouver, the higher ASMR among women from the United Kingdom was partially due to circulatory disease and cancer.[16] Immigrants from China typically had low ASMRs, but in Montreal, the cancer ASMR among women from China was comparable to that of Canadian-born women.[16]

Conclusion

The results of this study indicate an overall healthy immigrant effect that diminishes with years since immigration to Canada. Moreover, even after 20 or more years in the country, immigrants' ASMRs were generally lower than those of the Canadian-born population.

However, the analysis of ASMRs by birthplace, period of immigration

and area of residence in Canada reveals the heterogeneity between and within immigrant subgroups and highlights the importance of country-specific research at the CMA level.

As the percentage of the population made up of immigrants continues to grow, interest in their health status will increase. As a result, the need for in-depth analysis based on surveys with larger samples of immigrants and on linked data such as the Canadian census mortality follow-up study will also increase. ■

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Remaining life expectancy at age 25 and probability of survival to age 75, by socio-economic status and Aboriginal ancestry

by Michael Tjepkema and Russell Wilkins

Abstract
Previously, little information has been available about life expectancy and the probability of survival by socio-economic status or for Aboriginal groups. However, data from the 1991 to 2001 Canadian census mortality follow-up study made it possible to construct life tables for the non-institutional population aged 25 or older by a range of census variables. Those life tables have now been updated to include deaths through to the end of 2006. This report summarizes the updated findings. Life expectancy at age 25 and the probability of survival to age 75 tended to be low for people with low income and education, for residents of shelters, rooming houses and hotels, and for Registered Indians, non-Status Indians and Métis. In general, socio-economic disparities in mortality were greater for men than for women.

Keywords
cohort studies, education, homeless persons, housing, income, life tables, North American Indians

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Although life expectancy in Canada is among the longest in the world,[1] it differs across population groups.[2-6] Until recently, estimates by socio-economic indicators and for Aboriginal peoples have generally not been available, because information about these characteristics is not recorded on death registrations. With data from the 1991 to 2001 census mortality follow-up study, which tracked mortality in a 15% sample of the population, it became possible to construct life tables for such groups. These life tables have been updated to include deaths through to the end of 2006 (see *The data*). This report summarizes the updated findings. The objectives are to calculate remaining life expectancy at age 25 and the probability of survival to age 75 during the 1991-to-2006 period by income adequacy, education and residence in shelters, rooming houses and hotels, and for Registered Indians, non-Status Indians and Métis.

Life expectancy at age 25

At age 25, remaining life expectancy for members of the 1991 to 2006 Canadian census mortality follow-up cohort overall was 52.6 years among men and 57.9 years among women (Table 1). However, estimates of life expectancy varied with income, education, housing, and Aboriginal ancestry.

Life expectancy was shorter for people in lower income adequacy quintiles. For men, remaining life expectancy at age 25 was 55.3 years among those in the highest income quintile, but 48.2 years among those in the lowest, a difference

Table 1
Remaining life expectancy at age 25, by sex, income adequacy quintile, education, housing and Aboriginal ancestry, non-institutional cohort members aged 25 or older, Canada, 1991 to 2006

	Men			Women		
		95% confidence interval			95% confidence interval	
	Years remaining	from	to	Years remaining	from	to
Total cohort	**52.6**	**52.5**	**52.6**	**57.9**	**57.9**	**57.9**
Income adequacy quintile						
1 (lowest)	48.2	48.1	48.3	55.0	54.9	55.1
2	51.4	51.3	51.5	57.4	57.3	57.5
3	52.9	52.8	53.0	58.5	58.4	58.6
4	53.9	53.8	54.0	59.2	59.1	59.4
5 (highest)	55.3	55.2	55.4	59.9	59.8	60.0
Education						
Less than secondary graduation	50.5	50.4	50.6	56.4	56.3	56.5
Secondary graduation	53.0	53.0	53.1	58.5	58.5	58.6
Postsecondary diploma	55.0	54.8	55.1	59.7	59.6	59.8
University degree	56.5	56.3	56.6	60.6	60.4	60.8
Resident of shelter/rooming house/hotel	41.8	41.2	42.4	49.7	48.7	50.7
Aboriginal ancestry						
Registered Indian	46.9	46.5	47.3	51.1	50.7	51.5
Non-Status Indian	48.1	46.8	49.3	53.3	51.9	54.8
Métis	48.5	47.7	49.4	52.5	51.6	53.4

Source: 1991 to 2006 Canadian census mortality and cancer follow-up study. CANSIM Table 109-5401.

Table 2
Probability of survival to age 75, by sex, income adequacy quintile, education, housing and Aboriginal ancestry, non-institutional cohort members aged 25 or older, Canada, 1991 to 2006

	Men			Women		
		95% confidence interval			95% confidence interval	
	%	from	to	%	from	to
Total cohort	**64.6**	**64.5**	**64.8**	**78.1**	**78.0**	**78.3**
Income adequacy quintile						
1 (lowest)	50.1	49.7	50.5	69.5	69.1	69.9
2	60.1	59.8	60.5	76.3	75.9	76.6
3	65.3	64.9	65.7	79.4	79.1	79.8
4	68.7	68.4	69.1	81.4	81.1	81.7
5 (highest)	72.8	72.4	73.1	83.4	83.1	83.8
Education						
Less than secondary graduation	58.6	58.4	58.9	74.2	73.9	74.4
Secondary graduation	66.3	66.0	66.6	79.8	79.5	80.1
Postsecondary diploma	71.4	70.9	72.0	82.6	82.2	83.0
University degree	77.0	76.5	77.4	85.1	84.6	85.6
Resident of shelter/rooming house/hotel	30.7	29.2	32.2	56.2	53.2	59.2
Aboriginal ancestry						
Registered Indian	48.0	46.5	49.5	58.8	57.4	60.2
Non-Status Indian	49.9	45.0	54.7	61.3	56.1	66.6
Métis	54.2	51.1	57.2	60.6	57.3	63.9

Source: 1991 to 2006 Canadian census mortality and cancer follow-up study. CANSIM Table 109-5402.

of 7.1 years. Among women, the corresponding estimates were 59.9 years versus 55.0 years, a difference of 4.9 years.

As well, lower levels of education were associated with shorter life expectancy. For example, remaining life expectancy at age 25 was 56.5 years for men with a university degree, but 50.5 years for those with less than secondary graduation, a difference of 6.0 years. The figures for women were 60.6 and 56.4 years, a difference of 4.2 years.

Residents of shelters, rooming houses and hotels at time of the 1991 Census had a considerably shorter life expectancy than did other Canadians. For men in such accommodations, remaining life expectancy at age 25 was 41.8 years, or 10.8 years less than for the entire male cohort. For their female counterparts, remaining life expectancy at age 25 was 49.7 years, or about 8.2 years less than for the entire female cohort.

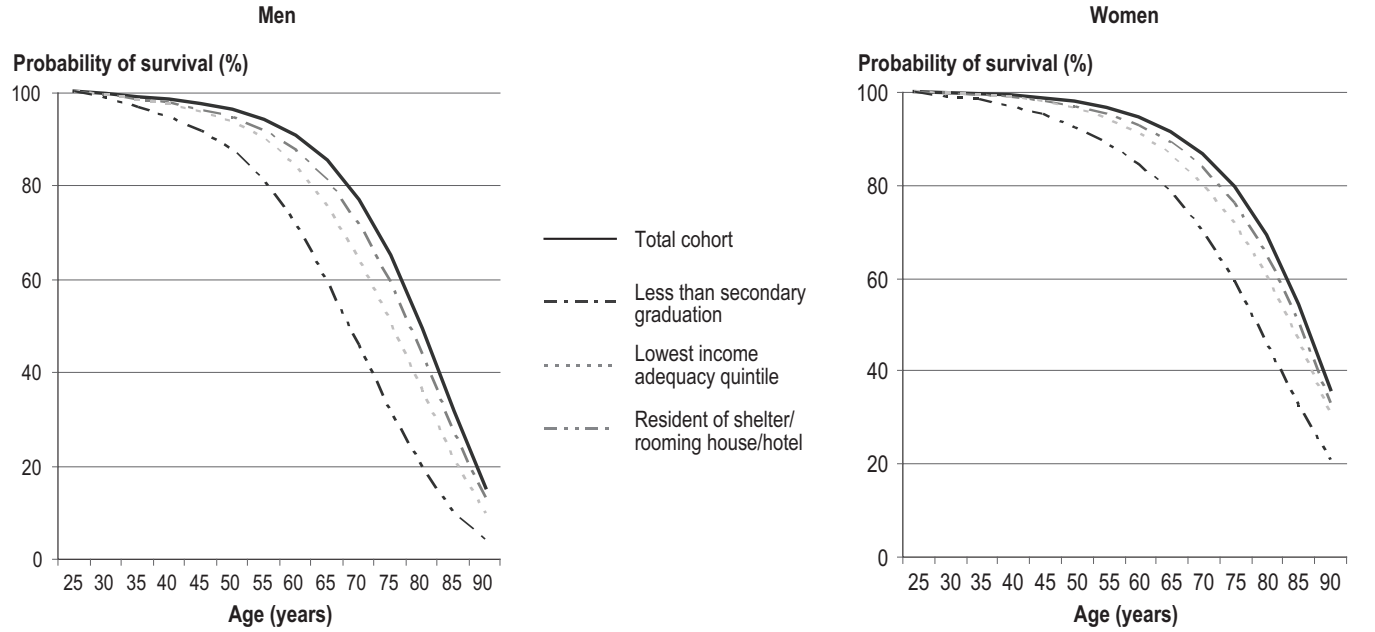
Life expectancy at age 25 was also shorter for cohort members reporting Aboriginal ancestry. Among men, remaining life expectancy at age 25 was 46.9 years for Registered Indians, 48.1 years for non-Status Indians, and 48.5 years for Métis—4.1 to 5.7 years less than for all men in the cohort. Among women, remaining life expectancy at age 25 was 51.1 years for Registered Indians, 53.3 years for non-Status Indians, and 52.5 years for Métis—4.6 to 6.8 years less than for all women in the cohort.

Probability of survival to age 75

In previous studies, death before age 75 has been considered premature.[7,8] Overall, 65% of male and 78% of female cohort members were expected to live to at least age 75 (Table 2).

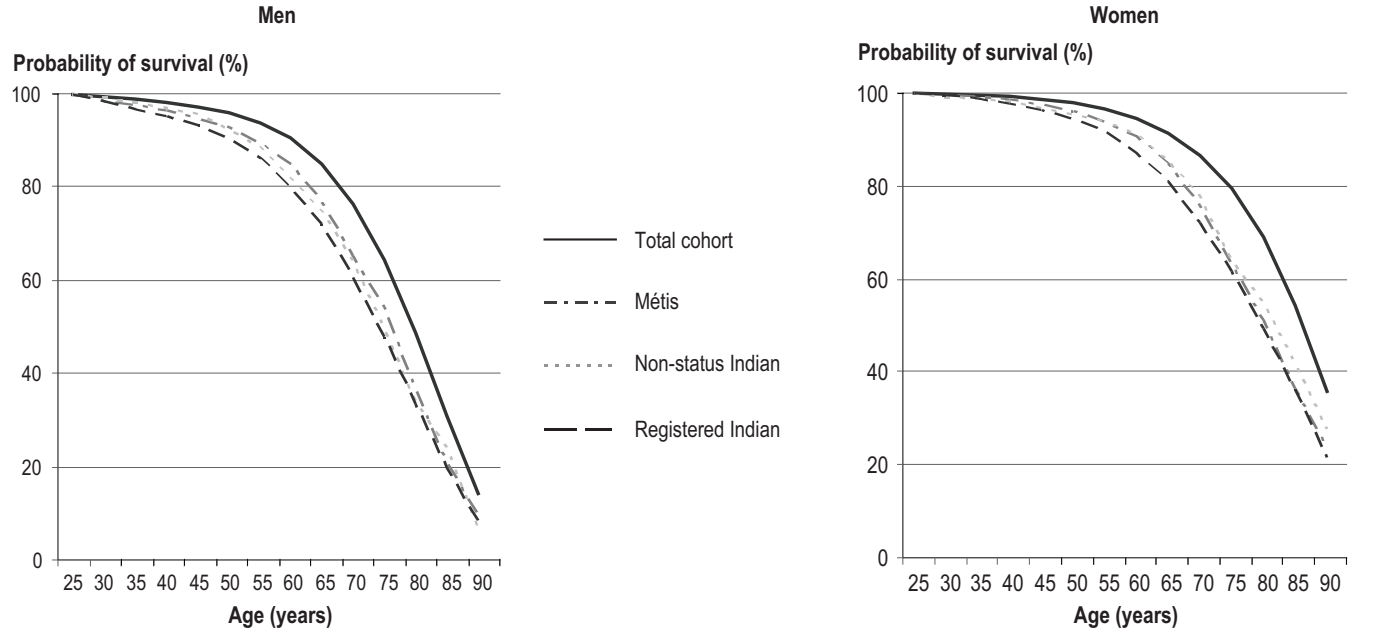
The probability of survival to age 75 varied by income adequacy quintile. Among men, the probability was 73% for those in the highest quintile and 50% for those in the lowest. The pattern was similar for women, although the gradient was not as steep: their probability of living to age 75 was 83% for those in the highest quintile, and 70% for those in the lowest.

Figure 1
Probability of survival for residents of shelters/rooming houses/hotels, people in lowest income adequacy quintile and people with less than secondary graduation, non-institutional cohort members aged 25 or older, Canada, 1991 to 2006



Note: The groups are not mutually exclusive; it is possible for the same individual to be a member of all groups.
Source: 1991 to 2006 Canadian census mortality and cancer follow-up study. CANSIM Table 109-5402.

Figure 2
Probability of survival, by sex and Aboriginal ancestry, non-institutional cohort members aged 25 or older, Canada, 1991 to 2006



Source: 1991 to 2006 Canadian census mortality and cancer follow-up study. CANSIM Table 109-5402.

The data

The 1991 to 2006 Canadian census mortality and cancer follow-up study tracked mortality in a 15% sample of the non-institutional adult population. People were eligible to be included in the study cohort if they were aged 25 or older and a usual resident of Canada on Census Day in 1991; were not a long-term resident of an institution; and were enumerated on the long-form questionnaire (Appendix table A).

Deaths of cohort members were determined by linking census records to the Canadian Mortality Database (4 June 1991 to 31 December 2006). Details about the construction and contents of the linked file have been reported elsewhere.[9,10]

Age was transformed from age at baseline to age at the beginning of each year of follow-up. Deaths and person-years at risk were calculated separately for each year (or partial year) of follow-up and then pooled by age at the beginning of each follow-up year. Abridged period life tables (based on 5-year age groups) for men and women, standard errors, and 95% confidence intervals were calculated according to the method of Chiang.[11] Remaining life expectancy is the average number of years a person at a given age would be expected to live if the mortality rates observed for a specific period persisted into the future.[12] Additional results for each population subgroup are available in CANSIM Tables 109-5401 and 109-5402.

Income adequacy quintiles were calculated by summing total pre-tax, post-transfer income from all sources for all family members, and then taking the ratio of total income to the Statistics Canada low-income cut-off for the applicable family size and community size group.[13] Quintiles were derived based on this ratio.[9]

Highest level of education was grouped into four categories: less than secondary graduation, secondary graduation or trades certificate, postsecondary certificate or diploma, and university degree or equivalent.

The category "shelters, rooming houses and hotels" comprises people whose usual residence at the time of census enumeration was one of the following types of non-institutional collective dwellings: shelters and hostels for the homeless, missions, YMCA/YWCA facilities, rooming and lodging houses, hotels, motels, and tourist homes.[14]

Registered Indian status was determined by a direct question: "Is this person a Registered Indian as defined by the Indian Act of Canada?" (yes, no). Non-Status Indians were defined as respondents who indicated a single ancestry of North American Indian, but were not a Registered Indian. Métis were defined as respondents who indicated a single ancestry of Métis, or who indicated two or more Aboriginal ancestries, one of which was Métis.

Undercoverage of the 1991 Census was estimated at 3.4%. These missed individuals were more likely to be young, mobile, low income, of Aboriginal ancestry,[15] or homeless. A total of 78 Indian reserves (about 38,000 people) were either not enumerated or incompletely enumerated and so were excluded from the census database and could not be part of the follow-up cohort.[16] People in long-term care facilities, seniors' residences or prisons, and non-tax-filers in the 1990 and 1991 tax years (data needed for linkage) were excluded from the cohort. As a result of these exclusions, at age 25 male cohort members had 4 months more of remaining life expectancy, and females cohort members had 6 months more, compared with the total population.[17,18]

Information about income, education, place of residence, and type of housing was collected only at baseline (1991 Census); these characteristics could have changed during the follow-up period.

The concept of ethnic or cultural ancestry (used to categorize persons as Métis or non-Status Indians) is fluid. It reflects individuals' understanding and views about their origins, awareness of their family background, and the social climate at the time of the census, all of which can influence the reporting of ethnic origin or ancestry, and all of which are subject to change. Thus, the results of this analysis may be affected by conditions that prevailed when the 1991 Census was conducted, and that may differ from more recent censuses.[19]

By level of education, degree-holders had the highest probability of living to age 75 (77% for men, 85% for women), whereas the lowest probability was for people who had not graduated from secondary school (59% for men, 74% for women). Differences were greater for men (18.4 percentage points) than for women (10.9 percentage points). The largest gap was between those who had and had not graduated from secondary school.

About a third (31%) of men residing in shelters, rooming houses and hotels at the time of the 1991 Census were expected to live to age 75—34 percentage points below the figure for all men in the cohort. Among women, 56% of those in shelters, rooming houses and hotels could expect to live to age 75—22 percentage points below the figure for all women in the cohort.

The probability of living to age 75 was also relatively low for Registered Indians, non-Status Indians and Métis. Among men, the probability was 48% for Registered Indians, 50% for non-Status Indians and 54% for Métis—10 to 17 percentage points lower than for the entire male cohort (Table 2). Among women, the probability of survival to age 75 was 59% for Registered Indians, and 61% for non-Status Indians and for Métis—17 to 19 percentage points lower than for the entire female cohort.

Survival curves for cohort members in the lowest income adequacy quintile were below the curves for people with less than secondary graduation (Figure 1). However, the survival curves for residents of shelters, rooming houses and hotels were far lower.

Among men, survival curves for Registered Indians, non-Status Indians and Métis were broadly similar, although each was below the curve for the entire male cohort (Figure 2). Among women, differences between the survival curves of the three Aboriginal groups were even smaller than for men, but the difference from the entire female cohort was larger.

Conclusion

Life tables for the 1991-to-2006 period, calculated by various indicators of socio-economic status and for Aboriginal groups, reveal considerable ranges in remaining life expectancy at age 25 and in the probability of survival to age 75. ■

Acknowledgements

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Appendix

Table A
Cohort members, person-years at risk, and deaths in follow-up period, by sex, income adequacy quintile, education, housing and Aboriginal ancestry, non-institutional population in Canada at baseline, 1991 to 2006

	Men			Women		
	Cohort members	Person-years at risk	Deaths	Cohort members	Person-years at risk	Deaths
Total cohort	**1,358,200**	**18,968,550**	**240,987**	**1,376,600**	**19,773,520**	**185,992**
Income adequacy quintile						
1 (lowest)	197,300	2,555,390	52,828	273,000	3,681,630	65,032
2	260,800	3,499,990	62,137	270,300	3,826,020	43,996
3	287,700	4,077,240	45,962	277,600	4,056,340	29,015
4	302,600	4,359,170	40,279	278,200	4,105,320	24,411
5 (highest)	309,900	4,476,770	39,781	277,500	4,104,200	23,538
Education						
Less than secondary graduation	474,900	6,249,140	138,071	478,500	6,563,790	110,472
Secondary graduation	510,400	7,318,980	69,084	484,000	7,096,100	47,128
Postsecondary diploma	168,300	2,457,660	15,493	253,000	3,734,390	19,960
University degree	204,600	2,942,760	18,339	161,100	2,379,250	8,432
Resident of shelter/rooming house/hotel	10,500	128,850	3,483	4,600	58,340	1,463
Aboriginal ancestry						
Registered Indian	24,900	347,730	4,037	32,400	468,990	3,832
Non-Status Indian	2,500	34,980	365	2,600	38,380	258
Métis	5,700	81,360	864	6,100	89,260	671

Source: 1991 to 2006 Canadian census mortality and cancer follow-up study.

The impact of considering birthplace in analyses of immigrant health

by Michelle Rotermann

Abstract

Background
Despite the heterogeneity of Canada's immigrant population, small sample sizes often prevent health researchers from studying specific subgroups. This report demonstrates how combining cycles of the Canadian Community Health Survey (CCHS) makes it possible to move beyond the Canadian-born/immigrant dichotomy to more refined analyses of immigrant health.

Data and methods
Based on combined data from the 2003, 2005, and 2007/2008 CCHS, this analysis compares the age-standardized prevalence of fair/poor self-perceived health, diabetes and arthritis among immigrants and the Canadian-born population at three progressively more precise breakdowns of immigrants by birthplace.

Results
Overall, immigrants were more likely than the Canadian-born to report poor health and diabetes, but less likely to report arthritis. This association changed when the immigrant group was disaggregated. This report demonstrates the importance of analyzing immigrants' health outcomes by birthplace and duration of residence in Canada.

Interpretation
Studies based on the immigrant/non-immigrant dichotomy combine immigrants with different risk factors, settlement experiences and health behaviours, and can yield findings that appear contradictory. Analysis of more specific immigrant subgroups improves understanding of immigrants' health relative to that of the Canadian-born population.

Keywords
Arthritis, diabetes, birthplace, health surveys, immigration, self-perceived health, time since immigration

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According to the 2006 Census, nearly 20% of Canada's population were foreign-born.[1] Moreover, in the last 35 years, the predominant source countries of immigrants to Canada have shifted from Europe to Asia, the Middle East and Africa.[1] Because of immigrants' increasingly diverse origins, it is important to study them as a non-homogenous group. A challenge facing health researchers is that small sample surveys can limit the analysis of immigrant subpopulations.[2,3]

The objective of this article is to illustrate how combining data from several cycles of the Canadian Community Health Survey (CCHS) increases analytical power and yields a clearer picture of immigrant health by identifying more precise subgroups. Examples are presented to demonstrate how indicators of health status vary by birthplace and period of immigration.

Data and methods

The data are from Statistics Canada's 2003, 2005, and 2007/2008 Canadian Community Health Survey (CCHS). The CCHS collects information about health determinants, socio-demographic characteristics and disease status. The survey targets people aged 12 or older who live in private dwellings in the provinces and territories. Residents of Indian reserves, Crown lands, institutions and certain remote areas, and full-time members of the Canadian Armed Forces are excluded. The survey covers approximately 98% of the population aged 12 or older in the provinces; 90% in the Yukon; 97% in the Northwest Territories; and 71% in Nunavut.[4,5]

Data were collected by computer-assisted telephone and in-person interviews; 30% to 40% of the interviews were conducted in person. Each Statistics Canada Regional Office recruited interviewers with a wide range of language skills so that when necessary, interviews were conducted in the language of the respondents.[5]

In all of the CCHS cycles, respondents were asked where they were born. Those who reported a country other

than Canada were asked if they had been born Canadian citizens. For this article, respondents who indicated that they had not been born Canadian citizens and who provided their country of birth were initially grouped into two broad categories: European and non-European immigrants. The European category includes the United States of America and Oceania/other. Next, respondents were assigned to one of six regions of birth: 1) United States of America/Oceania/other, 2) Caribbean/Central and South America, 3) Europe, 4) Sub-Saharan Africa, 5) Asia, and 6) North Africa/Middle East (including Kazakhstan, Kyrgyzstan, Uzbekistan) (Appendix Table A). Immigrants were also classified by period of immigration: "recent" (arrived in the ten years before their CCHS interview) and "long-term" (had been in Canada eleven or more years).

Three measures of health—self-perceived health, arthritis and diabetes—were used to demonstrate how the immigrant group definition can influence results. Self-perceived health is a reliable and valid summary measure of health[6] and is strongly predictive of future morbidity and mortality, regardless of race or ethnicity.[6,7] Arthritis and diabetes are associated with decreased quality of life, considerable medical expense, and reduced life expectancy.[8-10] Research suggests that the prevalence of these conditions varies by country of birth.[8-10] and duration of residence in Canada.[11,12] Respondents were asked if a health professional had diagnosed them as having conditions that had lasted, or were expected to last, at least six months. Respondents were then read a list of conditions that included arthritis and diabetes.

The overall response rates to the 2003, 2005 and 2007/2008 CCHS were 81%, 79% and 76%, respectively.[5] Data from these three cycles were combined to attain sample sizes large enough to yield releasable estimates. The combined sample of respondents aged 18 or older who provided enough information to determine their immigration status and place of birth numbered 350,927. Each cycle contributed approximately one-third of the study participants (Appendix Table B). The unweighted pooled survey sample comprised 48,229 immigrants (29,175 European and 19,054 non-European) and 302,698 Canadian-born respondents. The original sampling weights were adjusted by a factor of three (because three cycles were combined) to represent the Canadian household population. The rescaled weighted samples represented 5.1 million immigrants and 18.6 million non-immigrants. The combined estimates do not represent the population of any particular year; rather, they reflect the average Canadian household population across the 2003-to-2007/2008 period. More information about combining CCHS cycles is available elsewhere.[13]

Age is a major determinant of health.[14] The age distributions of Canadian- and foreign-born populations differ substantially. Rates were age-adjusted to eliminate the effects that result from differences in the age distributions of the various populations (Appendix Table C).[15] Age adjustments were done using the direct method; all rates were age-standardized to the 2006 Canadian Census of Population.[16]

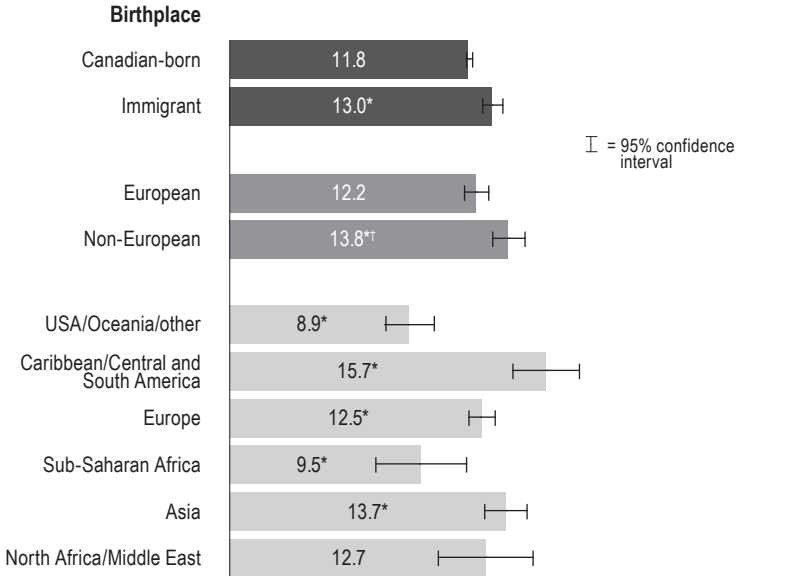
Cross-tabulations were used to compare bivariate rates on the three measures of health—self-perceived health, diabetes and arthritis—for the Canadian-born and immigrant populations. All differences were tested to ensure statistical significance at the α=0.05 level. To account for survey design effects, standard errors and coefficients of variation were estimated with the bootstrap technique.[17,18]

Results

Self-perceived health

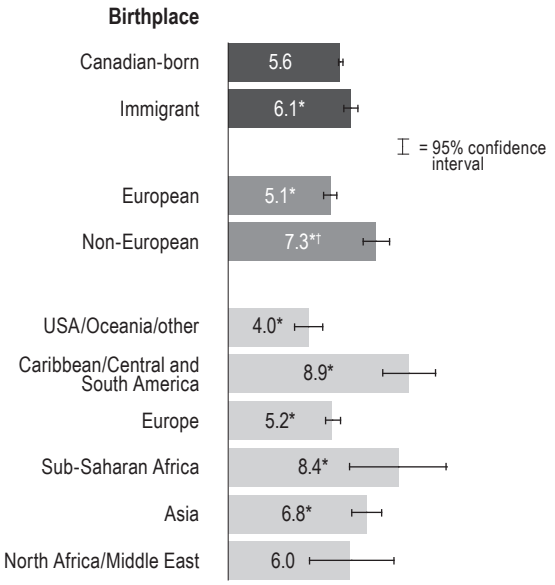
Overall, immigrants were more likely than the Canadian-born to report poor health, but this association depended on immigrants' origins (Figure 1). For example, rates of fair/poor health among

Figure 1
Age-standardized prevalence of fair/poor self-perceived health, by immigrant status and birthplace, household population aged 18 or older, Canada, 2003, 2005 and 2007/2008 combined



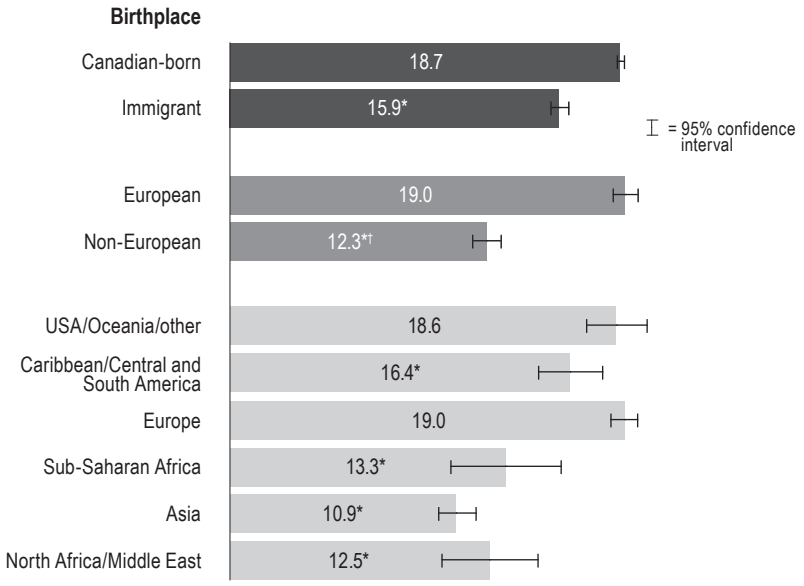
* significantly different from estimate for reference category (p<0.05)
† significantly different from estimate for European (p<0.05)
Note: Unless otherwise stated, reference category is Canadian-born.
Sources: 2003, 2005 and 2007/2008 Canadian Community Health Survey.

Figure 2
Age-standardized prevalence of diabetes, by immigrant status and birthplace, household population aged 18 or older, Canada, 2003, 2005 and 2007/2008 combined



* significantly different from estimate for reference category (p<0.05)
† significantly different from estimate for European (p<0.05)
Note: Unless otherwise stated, reference category is Canadian-born.
Sources: 2003, 2005 and 2007/2008 Canadian Community Health Survey.

Figure 3
Age-standardized prevalence of arthritis, by immigrant status and birthplace, household population aged 18 or older, Canada, 2003, 2005 and 2007/2008 combined



* significantly different from estimate for reference category (p<0.05)
† significantly different from estimate for European (p<0.05)
Note: Unless otherwise stated, reference category is Canadian-born.
Sources: 2003, 2005 and 2007/2008 Canadian Community Health Survey.

European immigrants were similar to those of the Canadian-born, but non-European immigrants were more likely to report fair/poor health.

When immigrants were further disaggregated by world region of birth, those from the Caribbean/Central and South America, Asia and Europe were significantly more likely than the Canadian-born to report fair/poor health, while those from Sub-Saharan Africa and the United States/Oceania/other were less likely to do so. And when duration of residence in Canada was also considered, the higher rates of fair/poor self-perceived health of immigrants from the Caribbean/Central and South America, Asia and Europe were largely attributable to long-term immigrants (Table 1). Recent immigrants from the Caribbean/Central and South America and Europe were less likely than the Canadian-born to report fair/poor health; recent immigrants from Asia had rates comparable to those of the Canadian-born.

Diabetes

A higher percentage of immigrants than the Canadian-born reported diabetes (Figure 2). However, the prevalence was generally higher among immigrants from non-European countries and among those who had lived in Canada for at least ten years (Table 1). Immigrants born in the Caribbean/Central and South America, Sub-Saharan Africa and Asia, especially long-term immigrants, were more likely than the Canadian-born to report diabetes; rates among North African/Middle Eastern immigrants were similar to those of people born in Canada.

Arthritis

The patterns differed for arthritis, which was less common among immigrants overall than among the Canadian-born (Figure 3). However, it was reported by roughly equal percentages of European immigrants and the Canadian-born. When duration of residence was considered, a nearly twofold difference in arthritis prevalence emerged between long-term and recent European

Table 1
Prevalence of fair/poor self-perceived health, diabetes and arthritis by immigrant status, birthplace and duration of residence, household population aged 18 or older, Canada 2003, 2005 and 2007/2008 combined

World region of birth/ Duration of residence	Fair/Poor self-perceived health			Diabetes			Arthritis		
		95% confidence interval			95% confidence interval			95% confidence interval	
	%	from	to	%	from	to	%	from	to
Canadian-born	**11.8**	**11.7**	**12.0**	**5.6**	**5.4**	**5.7**	**18.7**	**18.5**	**18.9**
Immigrant									
Recent	11.4†	10.0	13.0	5.3	4.3	6.5	9.0*†	7.8	10.4
Long-term	13.7*	13.1	14.2	6.4*	6.0	6.8	17.2*	16.7	17.8
European									
Recent	8.2*†	6.2	10.9	F	...	...	10.5†*	8.4	13.1
Long-term	12.8*	12.1	13.5	5.3	4.9	5.6	20.0*	19.3	20.7
Non-European									
Recent	12.3	10.6	14.2	6.1	4.8	7.6	8.6†	7.2	10.2
Long-term	14.7*	13.8	15.7	7.9*	7.2	8.8	13.6	12.7	14.4
USA/Oceania/other									
Recent	5.8E*	3.2	10.2	2.9E*	1.5	5.5	10.7E*†	7.5	15.1
Long-term	9.4*	8.0	11.1	4.0*	3.3	4.9	19.7	17.9	21.6
Caribbean/Central and South America									
Recent	9.5E*†	6.3	14.3	8.1E	4.6	13.6	6.3E*†	3.8	10.2
Long-term	16.9*	15.1	19.0	9.4*	8.0	11.0	17.7	16.0	19.5
Europe									
Recent	8.7*†	6.4	11.7	2.2E*†	1.2	4.0	10.5*†	8.1	13.4
Long-term	13.1*	12.3	13.9	5.4	5.0	5.8	20.0*	19.2	20.7
Sub-Saharan Africa									
Recent	7.9E	4.2	14.5	F	...	...	14.2E	8.8	22.1
Long-term	9.5	7.3	12.3	9.4*	6.8	12.9	13.6*	10.9	16.9
Asia									
Recent	12.9	10.9	15.1	6.3	4.9	8.2	8.8*†	7.1	10.7
Long-term	14.6*	13.4	15.9	7.1*	6.3	8.0	11.7*	10.7	12.9
North Africa/Middle East									
Recent	14.5E	8.3	23.9	F	...	...	13.3E	7.3	23.1
Long-term	13.4	10.8	16.6	7.7E	5.3	11.2	14.0*	11.4	17.2

* significantly different from estimate for Canadian-born (p<0.05)
† significiantly different from estimate for recent immigrants (p<0.05)
E interpret with caution
F too unreliable to be published
... not applicable
Sources: 2003, 2005 and 2007/2008 Canadian Community Health Survey.

What is already known on this subject?

- Differences in immigrants' health and health care use can exist by world region of birth and duration of residence in Canada, but sample sizes from most surveys do not permit such breakdowns.

What does this study add?

- This study demonstrates the analytical advantage of combining cycles of the Canadian Community Health Survey (CCHS) to examine immigrant health.
- When three cycles of CCHS data are combined, differences emerge in the prevalence of self-reported fair/poor health, arthritis and diabetes by immigrants' birthplace and duration of residence in Canada.
- The combined data demonstrate how moving beyond the Canadian-born/immigrant dichotomy can improve understanding of the health of Canada's immigrant population.

immigrants (Table 1). And based on the world-region-of-birth breakdown and duration of residence, the prevalence of arthritis was similar among people born in Canada and long-term immigrants from the United States/Oceania/other and the Caribbean/Central and South America. The prevalence of arthritis among immigrants exceeded that among the Canadian-born only for long-term European immigrants. Conversely, long-term immigrants from North Africa/Middle East, Sub-Saharan Africa and Asia were less likely than the Canadian-born to report arthritis.

Discussion

Given the growth and diversity of immigrant populations in Canada, a more accurate understanding of their health is important. However, when immigrant groups with different risk factors, settlement experiences and health behaviours are examined as a whole, findings can be contradictory. For example, according to some studies based on the immigrant/non-immigrant dichotomy, immigrants tend to report poorer health.[3] Other studies find that immigrants have a health advantage with respect to chronic diseases.[19-21] And still other studies reveal no difference in self-perceived health between the Canadian- and foreign-born.[2] While variations in methodology, data sources and indicators contribute to this inconsistency, so, too, does use of the broad immigrant/non-immigrant categorization.

This study demonstrates the analytical advantage of combining cycles of the CCHS. It also shows how sensitive estimates of the health status of immigrant

subpopulations are to categorizations by birthplace and time in Canada.

The data from the three CCHS cycles are consistent with the "healthy immigrant effect,"[22,23] in that they suggest that the health of immigrants who have been in Canada for a decade or more tends to be worse than that of more recent immigrants. Nevertheless, this should be interpreted cautiously, because cross-sectional data cannot be used to determine if the health of immigrants actually deteriorated with longer residence in Canada. It might simply be a cohort effect, whereby the majority of long-term immigrants may have immigrated in worse health than those who arrived more recently. It may also be that immigrants' perception of their health changes over time; that is, declines in reported health may reflect changes in perception rather than actual health status.[20] Another possibility is that with time in Canada, immigrants' use of health services increases, so the higher prevalence of chronic conditions could reflect a greater likelihood of a pre-existing condition being diagnosed.[22,24] Nonetheless, without longitudinal data to track the health status of individuals over time, it is not possible to determine if health changes are taking place.

To fill this data gap and to address other information needs, Statistics Canada is creating longitudinal databases. Specifically, the Longitudinal Health and Administrative Data Initiative (LHAD) links Statistics Canada data, such as the Census, to administrative health records of participating provinces. This makes it possible to study the health of populations, such as immigrants, who otherwise cannot be identified in administrative data. The linked data also permit analyses of subgroups that generally could not be carried out using survey data. The first LHAD linkages for Ontario and Manitoba were completed in 2011.[25]

Limitations

Although combining CCHS cycles can reduce the problem of small sample sizes, it is not completely eliminated, especially for less populous immigrant groups such as those from Sub-Saharan Africa. Also, analyses using the world-region-of-birth breakdowns could be problematic for many provinces because of the uneven geographical distribution of immigrants. And for some research questions, the six-world-region/duration-of-residence breakdown may still group individuals with different risk factors. This is especially true for geographically and ethnically diverse regions like "Asia," which includes China, India, Japan and the Philippines.[26-29] Furthermore, some immigrants lived in countries other than their country of birth before they came to Canada, thereby potentially reducing the importance of birthplace as a determinant of health.

The CCHS data are self-reported, and so may be subject to reporting error. In particular, respondents from different cultures may not interpret survey questions in the same way as people who are Canadian-born.[30] The survey instrument was tested only for the general Canadian Anglophone and Francophone populations.[30] To the extent that cultural or other differences exist in the way that some immigrant subpopulations answer questions about health indicators, the measurement of these indicators may be biased.[30] It was also not possible to examine health differences in the immigrant population by landing status—for example, those who arrived as refugees compared with those who came as family class or as economic class immigrants—because the CCHS does not collect this information.

Respondents were asked if chronic conditions had been diagnosed by a health care professional, but no independent source was available to confirm diagnoses. As well, immigrants may encounter cultural, linguistic, or other barriers that deter them from consulting health care professionals, which could lead to under-diagnosis of chronic conditions.[31]

Finally, the cross-sectional nature of the data does not allow for causal inferences.

Conclusion

A more accurate picture of how immigrants' health compares with that of the Canadian-born is important to ensure that the supply and type of health care services is appropriate. As this analysis demonstrates, general patterns in immigrant health, based on several indicators, do not apply when the immigrant population is examined by birthplace and by duration of residence in Canada. The Canadian Community Health Survey is a rich source of information about health determinants, socio-demographic characteristics and disease status not typically available elsewhere. By combining cycles of that survey, the problem of small sample sizes, which often affects studies of immigrants, can be reduced. This allows a more detailed analysis across subpopulations, which, in turn, improves understanding of immigrant health. ■

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Appendix

Table A
Countries by world region

World region	Countries
United States/Oceania/other	Australia, Fiji, Nauru, New Zealand, Papua New Guinea, St. Pierre and Miquelon, Western Samoa,United States of America
Caribbean/Central and South America	Anguilla, Antigua, Argentina, Aruba, Bahamas, Barbados, Belize, Bermuda, Bolivia, Brazil, Central America, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, French Guyana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Mexico, Montserrat, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, South America , St. Christopher and Nevis, St. Lucia, St. Vincent and the Grenadines, Surinam, Trinidad and Tobago, Uruguay, Venezuela, Virgin Islands (USA), West Indies
Europe	Albania, Andorra, Armenia, Austria, Azerbaijan, Belarus, Belgium, Bosnia-Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Czechoslovakia, Eastern Europe, Estonia, Europe, Finland, France, Georgia, Germany, Gibraltar, Greece, Hungary, Iceland, Ireland, Ireland (Republic of), Italy, Latvia, Lithuania, Luxembourg, Macedonia, Malta, Moldova, Montenegro, Netherlands, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom, USSR, Yugoslavia
Sub-Saharan Africa	Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Comoros, Democratic Republic of Congo, Djibouti, Eastern Africa, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Ivory Coast, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Reunion, Rwanda, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, St. Helena and Ascension, Swaziland, Swaziland, Tanzania, Togo, Uganda, West Africa, Zambia, Zimbabwe
Asia	Bangladesh, Bhutan, Brunei, China, Hong Kong, Indian, Indonesia, Japan, Kampuchea, Korea, Laos, Macao, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, Philippines, Singapore, South Asia, South Korea, Sri Lanka, Taiwan, Thailand, Vietnam
North Africa/Middle East	Afghanistan, Algeria, Angola, Bahrain, Egypt, Iran, Iraq, Israel, Jordan, Kazakhstan, Kuwait, Kyrgyzstan, Lebanon, Libya, Middle East, Morocco, Northern Africa, Oman, Palestine, Qatar, Saudi Arabia, Sudan, Syria, Tunisia, Turkey, Turkmenistan, United Arab Emirates, Uzbekistan, Yemen

Table B
Sample size, estimated number and percentage distribution of study sample, by birthplace and Canadian Community Health Survey (CCHS) cycle, household population aged 18 or older, Canada

	Total			2003 CCHS			2005 CCHS			2007/2008 CCHS		
Birthplace	Sample	Estimated number ('000)	%	Sample	Estimated number ('000)	%	Sample	Estimated number ('000)	%	Sample	Estimated number ('000)	%
Total	**350,927**	**23,649.6**	**100.0**	**117,917**	**7,739.1**	**32.7**	**114,666**	**7,625.8**	**32.2**	**118,344**	**8,284.7**	**35.0**
Canadian-born	302,698	18,575.5	78.5	101,413	6,060.7	78.3	100,886	6,200.9	81.3	100,399	6,313.9	76.2
USA/Oceania/other	3,926	269,2	1.1	1,382	95.5	1.2	1,217	83.2	1.1	1,327	90.5	1.1
Caribbean/Central and South America	4,259	602.0	2.6	1,408	200.9	2.6	1,032	137.8	1.8	1,819	263.4	3.2
Europe	25,249	2,027.3	8.6	8,980	711.7	9.2	7,466	609.8	8.0	8,803	705.8	8.5
Sub-Saharan Africa	1,477	179.4	0.8	482	58.6	0.8	302	37.2	0.5	693	83.6	1.0
Asia	11,057	1,649.7	7.0	3,474	501.7	6.5	3,259	487.4	6.4	4,324	660.6	8.0
North Africa/Middle East	2,261	346.5	1.5	778	110.0	1.4	504	69.5	0.9	979	166.9	2.0

Source: 2003, 2005 and 2007/2008 Canadian Community Health Survey.

Table C
Age distribution and age-adjustment weights

Age group	Population ('000)	Adjustment weight
18 or older	25,579.6	1
18 to 39	9,797.5	0.383021
40 to 64	11,457.3	0.447906
65 or older	4,324.8	0.169073


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Strategies for handling normality assumptions in multi-level modeling: A case study estimating trajectories of Health Utilities Index Mark 3 scores

by Julie Bernier, Yan Feng and Keiko Asakawa

Abstract

Background
With longitudinal data, lifetime health status dynamics can be estimated by modeling trajectories. Health status trajectories measured by the Health Utilities Index Mark 3 (HUI3) modeled as a function of age alone and also of age and socio-economic covariates revealed non-normal residuals and variance estimation problems. The possibility of transforming the HUI3 distribution to obtain residuals that approximate a normal distribution was investigated.

Data and methods
The analysis is based on longitudinal data from the first six cycles of the National Population Health Survey (NPHS). The data pertain to 7,784 individuals, who, in 1994/1995, were aged 40 to 99, were living in private households, and had complete information on HUI3. A multi-level growth model was used to examine the hierarchical structure of NPHS data (repeated measurements nesting within respondents). The transformation of arcsine [2 × (HUI + 0.36) / (1 + 0.36) – 1] was used to improve the distribution of the residuals at both levels and limit the conditional mean to the -0.36 to 1.00 interval. A model was estimated using socio-economic determinants. Analyses were performed with SAS and MLwiN.

Results
After the transformation of HUI3, the model was satisfactory and allowed for inclusion of new socio-demographic and health variables in order to estimate their impact on the health-related quality of life of aging populations. Because of the complex transformation of the arcsine model, the regression coefficients were not interpreted. Instead, the estimation results were summarized graphically.

Keywords
Health status indicators, health surveys, health transition, logistic models, longitudinal studies, multilevel growth model

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Longitudinal data from Statistics Canada's National Population Health Survey (NPHS) can be used to assess health status dynamics. For more than a decade, the NPHS collected repeated samples every two years. Estimations of repeated measures data are facilitated by using a growth-curve (multi-level) model approach,[1] which allows the estimation of within-individual (level-1) and between-individual (level-2) variations in outcomes. With a growth-curve model, the dynamics can be presented by a trajectory, and associations between socio-economic and health determinants and trajectories of health-related quality of life (HRQL) can be examined.

As with any regression method, the utility of the estimation results depends on the degree to which model assumptions are met. In single-level models, assumptions about model (for example, linearity, omitted variables, interactions) and stochastic specifications (for example, heteroskedasticity, normality of errors) should be assessed carefully.[2,3] This article focuses on the normality of error assumption in a growth-curve model setting. In such a model, where respondents are considered as the level-2 unit and occasions (time) within each respondent are considered as the level-1 unit, the normality of error assumption indicates univariate normality of residuals at level-1 and univariate or multivariate normality (if more than one parameter was considered as random) of random components at level-2. Failure of the normality assumption at level-1 will not bias estimation of the fixed effects, but it will introduce bias into standard errors at both levels, thereby affecting the validity of confidence intervals and hypothesis tests. Estimation of the level-2 fixed effects will not be biased by non-normality of the errors at level-2.

However, the presence of skewness will affect inferences at level-2.[2]

In analyses of longitudinal data from surveys such as the NPHS, the normality of error assumption must be considered because population health outcomes such as HRQL are often skewed. A measure of HRQL collected in the NPHS is the Health Utilities Index Mark 3 (HUI3). This is a generic, multi-attribute, continuous preference-based indicator that describes health status with a single summary measure ranging from -0.36 to 1.00 (1.00 = perfect health; 0.00 = dead; -0.36 = a state worse than dead).[4] However, because of the highly skewed distribution of HUI3,[5,6] the normality of error assumption may be violated when it is used in estimating growth curve models. When determinants of health variables are introduced into the model, standard errors of the parameters cannot be estimated properly.

One method of dealing with violation of the normality assumption is to transform the outcome variable to improve the error distribution. (The transformation is intended to yield unskewed residuals, not unskewed dependent variables.) This study assesses the utility of *arcsine* transformation, which stabilizes the variance and improves the symmetry of the residuals.[7] An earlier study showed that when an untransformed HUI3 was used as the outcome variable, the predicted HUI3 scores fell below the theoretical lower bound of -0.36.[1]

A preliminary investigation of the arcsine transformation of a particular form (arcsine[2 × (HUI3 + 0.36) / (1 + 0.36) -1]) resulted in predicted back-transformed HUI3 scores that were above the theoretical lower bound of -0.36. While the arcsine transformation has been used,[8] to our knowledge it has not been applied to analyses of longitudinal population health data. Thus, how this transformation handles the normality of error assumption in a growth-curve model setting is not known.

The primary objective of this study was to evaluate the feasibility of using the arcsine transformation from the family of trigonometric functions to estimate growth-curve models with non-normally distributed residuals. It was assessed for a simple socio-economic model that included marital status, education and household income. Two other transformations were also considered: one from a log family (natural logarithmic transformation) and another from an exponent family (square-root transformation). The performance of these three transformations was compared.

An additional challenge of the model transformation is interpretation of estimation results. Because back-transformation of estimated coefficients is difficult, if not impossible, the secondary objective was to present a graphical approach to interpreting estimation results, based on a model with a transformed dependent variable.

A case study focusing on the performance of growth-curve models using various types of transformations of HUI3 as an outcome variable was conducted. The aim was to provide a pragmatic approach to handling the normality of error assumption, not to find the best-fitting model among possible types of functional forms, estimation techniques, or model specifications. This study demonstrates the potential of the arcsine transformation in a growth-curve model setting by comparing its performance with those of other commonly used transformation methods.

Methods

Data source

The data are from the household component of the 1994/1995 to 2006/2007 National Population Health Survey (NPHS), which collected longitudinal information about Canadians' health and socio-demographic characteristics. The target population was household residents in the ten provinces in 1994/1995, excluding residents of Indian Reserves and Crown Lands, health institutions and some remote areas in Ontario and Quebec; full-time members of the Canadian Forces; and all residents (military and civilian) of Canadian Forces bases.

To study HUI3 trajectories, data from the NPHS longitudinal square file were used. The square file includes all 17,276 respondents to cycle 1 (1994/1995), regardless of their response pattern in the next six cycles. The longitudinal sample size remained the same for all cycles.[9,10]

For this study, respondents aged 40 to 99 in 1994/1995 who had complete HUI3 information were selected. Exclusion of the small number of people aged 100 or older did not affect the estimates of parameters in the regression model. The target population included the 252 respondents who were institutionalized at some point during the six follow-up cycles. The 1,295 respondents who died during follow-up were also included, but only for the cycle in which their death was reported; information for subsequent cycles was left as missing. The final sample consisted of 7,784 respondents.

Outcome variable

The outcome variable was HUI3, a continuous variable that ranges from -0.36 to 1.00 (1.00 = perfect health; 0.00 = dead; -0.36 = a state worse than dead). To compare models with various transformations, the HUI3 scores were transformed as described below.

Independent variables

Linear and non-linear forms of a variable indicating the age of respondents were included in the model to represent time in the analyses. The age variable was centered at 57, the mean age at baseline. Gender, marital status, education and household income were added as independent variables. Gender (female as reference group) was included as a time-invariant variable. Marital status, education and household income were included as time-varying covariates. Marital status was categorized as married/common-law/living with partner (reference group) or single/separated/divorced/widowed. Education was categorized as less than secondary graduation or at least secondary

graduation (reference group). Household income was categorized as low (less than $15,000), middle ($15,000 to $29,999), or high ($30,000 or more; reference group).

Two sets of time-varying dummy variables were created as control variables: place of residence (1 if institutionalized, 0 otherwise) and the state of being dead (1 if dead, 0 otherwise). To account for mortality effects in the analyses,[1] the record of the first report of death was retained in the analyses by assigning a value of HUI3 = 0.00 to the dependent variable. For the independent variables, the last observed value for each was assigned to the first record of death; subsequent records were left as missing.

Modelling

The NPHS data consist of repeated measurements of respondents over six cycles of data collection. The hierarchical structure of the data—repeated measurements nesting within respondents—can be modeled using a two-level growth model. A multi-level growth model simultaneously incorporates within-person and between-person change. The within-subject model (level-1) was specified as a function of a set of growth parameters and individual time-varying characteristics over time with measurement error. The growth parameters and time-invariant individual characteristics, which are a source of heterogeneity, were specified in the between-subject model (level-2) to capture the variation of growth across the population.

As in an earlier study,[1] age was expressed in a cubic form: a linear growth rate (Age), a quadratic growth rate (Age^2), and a cubic growth rate (Age^3). Only the intercept was considered as varying randomly across individuals, which is a simpler form than that presented in the previous study.[1]

The growth model including household income, education, marital status, death and institutionalization at level-1, and gender at level-2, is:

Level-1:

$$Y_{ij} = \beta'_{0j} + \beta'_{1j} Age_{ij} + \beta'_{2j} Age_{ij}^2 + \beta'_{3j} Age_{ij}^3 + \sum_{n=4}^{N} \beta'_{nj} X_{nj} + \varepsilon'_{ij}$$

$$\varepsilon'_{ij} \sim N(0, \sigma'^2_{\varepsilon})$$

Level-2:

$$\beta'_{0j} = \beta'_{00} + \beta'_{10} \text{Gender}_j + \zeta'_{0j}$$

$$\zeta'_{0j} \sim N(0, \sigma'^2_0)$$

where Y_{ij} is the HUI3 scores for individual j at cycle i. The level-1 4 β's are the true growth parameters varying across individuals. σ^2_{ε} describes within-individual random deviation of HUI3 scores from his/her own trajectory. β_{00} represents the population mean HUI3 score at age 57, and σ^2_0 represents the between-individual random deviation in mean HUI3 scores (at age 57).[3]

A person-period dataset was created for the analysis of multi-level growth models. The date of birth and the date of the interview recorded in the NPHS microdata made it possible to use the time-unstructured characteristic of the NPHS data (the actual ages of respondents may not necessarily change by a two-year increment between assessment periods) by calculating respondents' actual age.[3] Therefore, the model was fit using the actual numeric values of AGE (the difference between the interview date and the self-reported date of birth) as a temporal variable, rendering the person-period data time-unstructured. As in most longitudinal studies, the data were unbalanced because of attrition. Growth curve models allow the estimation using the time-unstructured and unbalanced data. Of the 7,784 individuals in the sample, 2,989 (38.4%) had six records; 1,546 (19.9%) had five records; 1,141 (14.7%) had four records; 928 (11.9%) had three records; 748 (9.6%) had two records; and 432 (5.6%) had one record.

Transformation

Arcsine transformation was used to transform the dependent variable (HUI3) to improve the normality of residuals. The arcsine transformation is usually applied to a variable with a [-1, 1] range. If a variable X ranges from -1 to 1, arcsine(X) will range from negative infinity to positive infinity. However, HUI3 is bounded by -0.36 and 1.00. Therefore, the arcsine transformation may not be implemented effectively to modify the HUI3 distribution because of the theoretical lower bound of -0.36. To facilitate an arcsine transformation, HUI3 was first linearly transformed so that the transformed HUI3 scores were bounded by -1 and +1 using the following equation:

$$2 \times \frac{HUI3 + 0.36}{1 + 0.36} - 1$$

The arcsine transformation was implemented using the transformed HUI3 scores (arcsine [2 × (HUI3 + 0.36) / (1 + 0.36) − 1]). This improved the prediction of the trajectory for an aging population by allowing the predicted back-transformed HUI3 scores to lie within the theoretical lower bound of -0.36. By contrast, in the earlier study, the predicted HUI3 scores fell beyond -0.36 when an untransformed HUI3 was used as the outcome variable.[1]

Assessment of normality assumption

The normality of error assumption was assessed by comparing skewness statistics among alternative models. Higher-level statistics like kurtosis were not estimated. In these analyses, errors were considered close to normally distributed if the skewness statistic was zero.[11] An improvement in the normality of error assumption is considered to have occurred if the skewness statistics of level-1 and level-2 errors for one model are closer to zero than those of another model. Normal probability plots were also used to assess the distribution of residuals at both levels. Straight-line plots of theoretically generated normal scores against standardized residuals indicate normally distributed residuals.[12]

The appropriateness of the arcsine transformation was assessed by comparing distributions of residuals of the model with those of the untransformed model and two alternative

models, each based on a different form of transformation of the dependent variables: natural logarithm[13] and square-root.[7] The normality of error assumption was assessed by comparing skewness statistics and normal probability plots across the four models.

Interpretation of models

Based on results of the arcsine-transformed model, a graph representing estimated trajectories was constructed by setting values of explanatory variables at different levels. Specifically, trajectories of back-transformed HUI3 scores were plotted by gender, marital status, education, household income, and place of residence (community or institution).

All analyses were performed with SAS and MLwiN. Models were weighted using the sampling weights to account for the unequal selection probabilities of the NPHS, and the weights were applied to the second level of the model. Variance estimates were not adjusted for the complex sampling design of the survey.

Results

Preliminary descriptive investigation of health trajectories

To identify a suitable functional form for the level-1 sub-model and to summarize how health status changes over time, empirical growth plots for HUI3 with smooth nonparametric trajectories were examined by age group. The trajectory of mean HUI3 by age suggested that the level-1 sub-model was nonlinear.[1] The trajectory of HUI3 displays a quadratic and a cubic trajectory (plots not shown). Instead of selecting a unique polynomial form for each person, the highest order polynomial was selected to summarize individual change for any person. Therefore, linear, quadratic and cubic terms of Age were included in all models.

Regression results

Because of the complexity of back-transforming estimated coefficients in the arcsine HUI3 model to the original scale, the estimated parameters are not interpreted separately. Moreover, when a transformation is applied to the outcome variable, the estimated parameters of the transformed model have the least squares properties with respect to the transformed observations only, not with respect to the original observations.[14] Therefore, only parameters of the transformed models are presented in this study.

Comparison of proposed models

Comparisons among models showed that the model with arcsine transformation (Model 3) had the skewness of level-1 residuals as -0.74, which was the closest to zero among the models (Table 1). In particular, the skewness statistics of level-1 residuals in log (Model 1) and square-root models (Model 2) were as large as -1.77 and -1.88, respectively. Comparisons of normal probability plots for untransformed HUI3 (Figure 1a) with arcsine transformation showed that the residual plots for the arcsine model (Model 3, Figure 1b) appeared to be the closest to linearity among the four models (figures for Models 1 and 2 not shown).

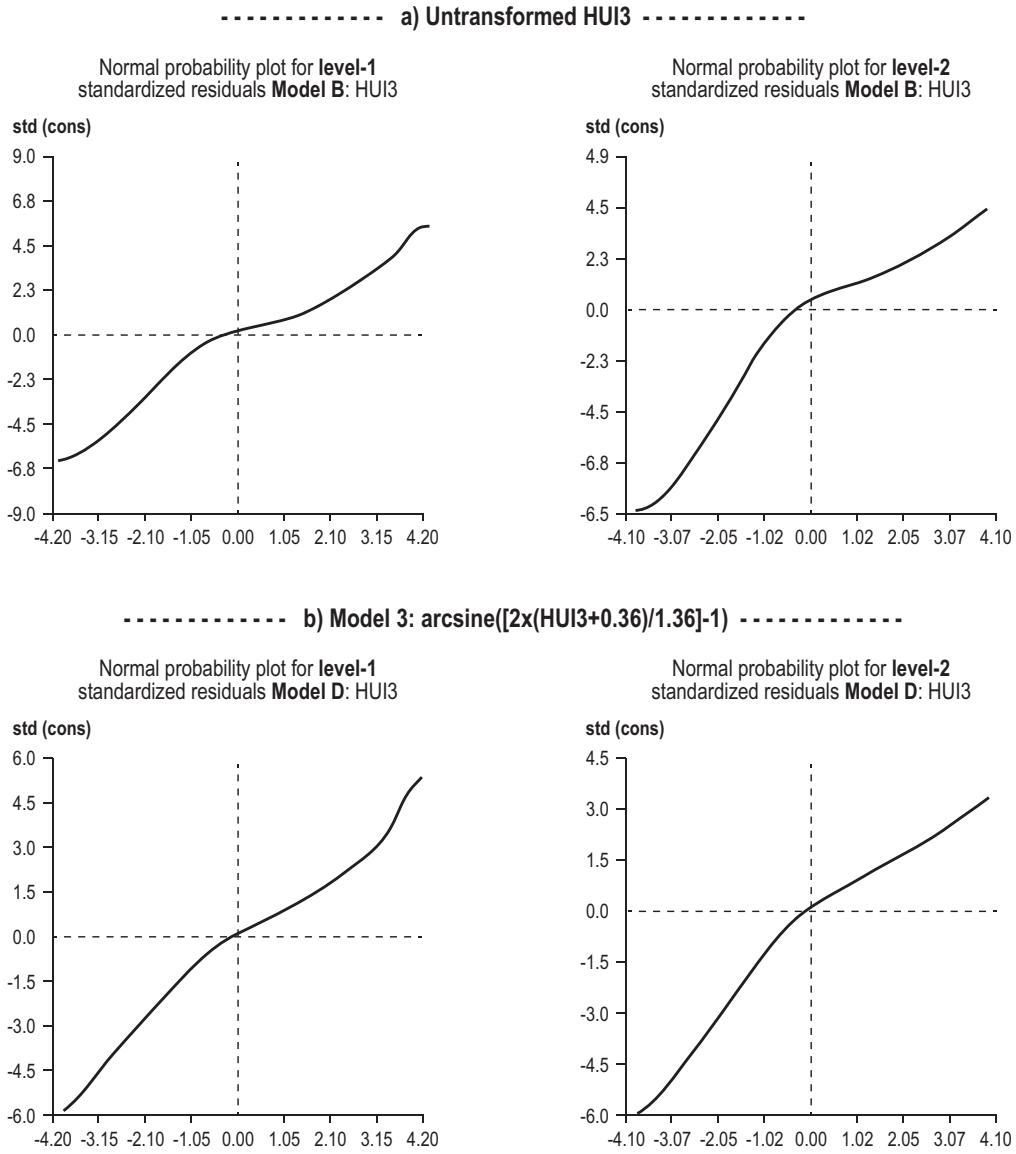
The skewness statistics of level-2 residuals in both Model 1 and Model 2 were approximately -1.90, further from zero compared with level-1. The skewness statistic for the arcsine transformation (Model 3) was -1.06, which was closest to zero among the models. The normal probability plots for standardized residuals at level-2 showed that the plots for Model 3 were the closest to linearity among the four models, although the tails still deviated from normality at the upper end of the distribution (Figure 1b).

Table 1
Comparison of fitting alternative polynomial change trajectories

	Untransformed HUI3	Model 1	Model 2	Model 3
Fixed effects				
Intercept	0.882576**	0.627531**	0.952846**	1.076387**
Mean age	-0.001724**	-0.000962**	-0.000682**	-0.005272**
Mean age squared	-0.000050**	-0.000033**	-0.000023**	-0.000018**
Mean age cubed	-0.000004**	-0.000003**	-0.000002**	-0.000008**
Deceased	-0.668605**	-0.489359**	-0.340475**	-1.134217**
Institutionalized	-0.459094**	-0.352409**	-0.253395**	-0.810786**
Female†	...	...	...	...
Male	0.0006329	0.003433	0.002511	0.023969*
Secondary graduation or more	...	...	...	...
Less than secondary graduation†	-0.037715**	-0.023636**	-0.016734**	-0.082577**
Married/Common-law/Living with partner†	...	...	...	...
Single	-0.01384	-0.007427	-0.005187	-0.03341
Divorced/Separated/Widowed	-0.014254**	-0.00808**	-0.005672**	-0.030819**
High income	...	...	...	...
Middle income	-0.020276**	-0.013019**	-0.009237**	-0.042748**
Low income	-0.045075**	-0.029279**	-0.020741**	-0.091397**
Random effects				
Level-1 (σ_ε^2 (within-person))	0.024419**	0.010790**	0.00542**	0.106314**
Level-2 ($\sigma_{\zeta 0}^2$ (intercept))	0.016104**	0.006713**	0.003357**	0.069918**
Skewness				
Level-1	-1.35	-1.77	-1.88	-0.74
Level-2	-1.59	-1.91	-1.93	-1.06

* significantly different from estimate for reference group (p<0.0005)
** significantly different from estimate for reference group (p<0.0001)
† reference category
... not applicable
Notes: Untransformed: HUI3 as a dependent variable
Model 1: ln (HUI3+1) as a dependent variable
Model 2: Square-root of [(HUI3+0.36)/1.36] as a dependent variable
Model 3: Arcsine of [2 × (HUI3 + 0.36) / (1 + 0.36) – 1] as a dependent variable
Source: 1994/1995 to 2006/2007 National Population Health Survey, longitudinal square file.

Figure 1
Comparison of normal probability plots of residuals

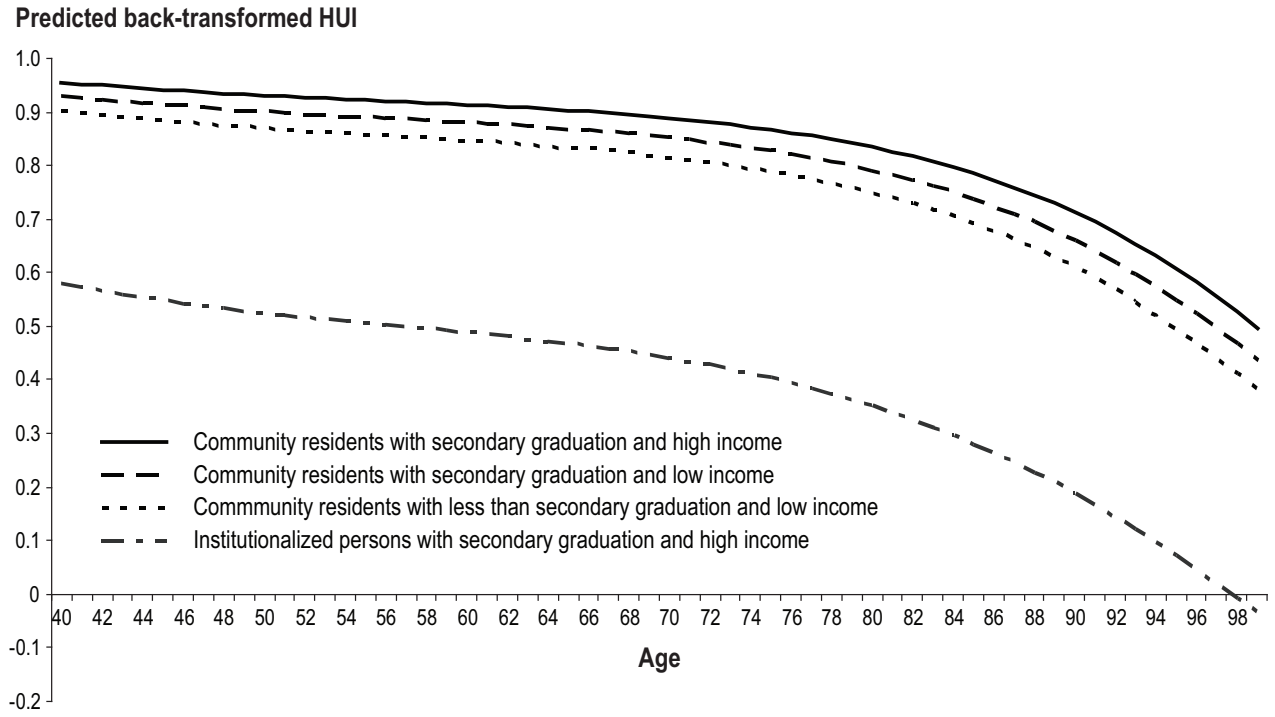


Source: 1994/1995 to 2006/2007 National Population Health Survey, longitudinal square file.

Model interpretation: A graphical approach

As an illustration, the health trajectories for women with selected socio-demographic profiles based on the model with arcsine transformation (Model 3) are presented (Figure 2). When all other socio-demographic characteristics were held constant, women living in the community had substantially different health trajectories than did women in institutions. Women in the community were, on average, much healthier, a difference that became more pronounced with advancing age. Education was also associated with health trajectories. Among women living in the community in a low-income household, those with less than secondary graduation had a lower HUI3 trajectory than did those who were at least secondary graduates. Household income was also related to the variation in health trajectories.

Figure 2
Predicted HUI3 trajectories for four groups of married women aged 40 or older, by single-year-of-age, education and household income, Canada excluding territories, 1994/1995 to 2006/2007



Source: 1994/1995 to 2006/2007 National Population Health Survey, longitudinal square file.

Discussion

In assessing the health status of a population, it is not uncommon for continuous measures of HRQL to be non-normally distributed, leading to the violation of normality assumptions in regression analyses. The issue affects the estimation of growth curve models, in that failure of the normality assumption will bias standard errors, thereby affecting the validity of confidence intervals and hypothesis tests. This analysis presents a case study to determine if transformation of the outcome variable as *arcsine* [2 × (HUI3 + 0.36) / (1 + 0.36) – 1] has the potential to address this problem. Results showed that the arcsine-transformed model reduced the skewness of the residual distribution. The symmetry of the residual distribution was noticeably improved, compared with the untransformed models and models with natural logarithm and square-root transformations. A graphical approach is also presented by plotting predicted back-transformed HUI3 trajectories, although the complexity of interpreting estimation results based on a model with a non-linearly transformed dependent variable is recognized.

The case study is unique in that, to our knowledge, arcsine transformation has not been applied to a growth-curve model in the analysis of population health surveys, and the performance of the transformation was superior to untransformed or natural logarithmic and square-root transformations. The graphical approach is a straightforward way of interpreting results from the arcsine model without the complexity of exploring the back-transformation of the set of estimated coefficients.

Several considerations should be noted. First, the record of death of a respondent was assigned the last observed values for the explanatory variables. This simple approach may not be optimal, as other methods are available.[15] Nonetheless, fewer than 1% of all the records used in the analyses that corresponded to the first record of death were imputed; values for the subsequent cycles were left as missing, so any bias resulting from this approach is likely to be minimal. Second, the three models that were tested are not an exhaustive representation of potential transformations. Third, some measures of HRQL, including HUI3, are subject to a ceiling effect. However, the ceiling effect is unlikely to be an issue in this study because only 10% of all records for respondents aged 40 or older (fewer than 1% of those for respondents aged 65 or older) had a HUI3 score of 1.00 (perfect health). Fourth, the explanatory variables in the models were chosen only to illustrate the usefulness of transforming HUI3. Before choosing a definitive model, more attention must be paid to selecting covariates and examining a possible random slope effect. Fifth, in theory, numeric utilities such as HUI3 are unique

up to positive linear transformation,[16] but the arcsine transformation is non-linear. Nonetheless, the proposed method is pragmatic and useful, with the back-transformed HUI3 trajectories helping to visualize important heterogeneities in health trajectories.

The case study showed the arcsine transformation to be a statistically appropriate way of handling the normality of error assumption in multi-level modeling. It is also useful in estimating the impact of various determinants of health on health trajectories. The method is accessible through most statistical packages and can describe variations in health trajectories among socio-economic groups. The approach can also be used to assess other determinants of health. This case study is an initial attempt to introduce this transformation in a multi-level model setting. Further investigation is warranted to examine the potential of the arcsine transformation for other types of transformations, estimation methods and populations. ■

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