University of Alberta

Investigating the Determinants of Health: Three Essays on Assessing and Understanding Population Health

by

©

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ABSTRACT

Health Utilities Index Mark 3 (HUI3) is a multi-attribute and utility-based measure of health-related quality of life (HRQL). HUI3 is widely used in population health surveys and clinical studies in Canada and elsewhere. The general objective of this thesis was to assess the determinants of health of Canadians. The usefulness of HUI3 in population health research was assessed for this purpose. In particular, two specific objectives were to assess the validity of HUI3 and to investigate cross-sectional and longitudinal determinants of health using HUI3. Statistics Canada National Population Health Survey cross-sectional (community and institutional) as well as longitudinal (community) surveys were used as a data source throughout the thesis. The cross-sectional validity of HUI3 was assessed for three chronic conditions common to the middle-age and elderly population: Alzheimer Disease (AD), arthritis (AR), and cataracts (CA). HUI3 was able to describe overall burdens of AD, AR and CA. HUI3 was also able to identify speech and cognition burdens associated with AD, ambulation and pain burdens associated with AR and vision problems associated with CA; all were hypothesized to be important for the specified conditions. The assessment of cross-sectional determinants of health showed important heterogeneity in health determinants between community-dwelling and institutionalized populations. Usual determinants such as advanced age, low education, low financial status and not

being married were unimportant for institutionalized residents, whereas they were important for residents in the community. Health trajectories were estimated using growth-curve models to assess longitudinal determinants of health. Important heterogeneities in life-course trajectories were found across three age groups (age 18-39, 40-64, and 65+). For young and middle-aged (18-64), variations in trajectories were mainly associated with socio-economic factors (i.e. financial status, education, marital status). For seniors (65+), however, unfavourable lifestyle, in particular, physical inactivity was important determinants. Moreover, having more chronic conditions lowered the mean trajectories by similar magnitudes regardless of age. Understanding differential impacts of the determinants of health factors is important in developing effective health policy across populations as well as for various life stages. The program of research showed that HUI3 is a useful tool as a measure of HRQL in population health research.

DEDICATION

I would like to dedicate this thesis to the birthdays of my grandmothers: Kameko for her 102th and Mitsuko for her 92nd. Their wisdom in life always encouraged me to be patient and diligent during the ups and downs in completing my degree. Their values will always be a part of me.

I would also like to dedicate this thesis to my parents, Kouichi and Emiko Asakawa, and all of my relatives who have supported me while I pursued my dreams in Canada. Without their understanding and support, this work would never have been possible.

Also I would like to thank Ken and his family for their kindness that has made me feel Canada is my second home. Their warmth and support helped me overcome many challenging days.

Finally, I would like to dedicate this thesis to my supervisor, Dr. David Feeny. This academic journey would not have started without our little conversation following my final exam in your health-related quality of life class. Your tremendous support expanded my mind to this incredible field of research that I am proud to be a part of.

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Chapter 1: Introduction and background

1-1 Population health approach in Canada

The work by Canadian Institute of Advanced Research [CIAR (currently known as Canadian Institute for Advanced Research, CIFAR)] in the 1980s together with the earlier work by Lalonde[1] contributed importantly to the shift of health policy in Canada, from the focus of medical care to the concept of non-medical determinants of health. These two works helped establish the notion of population health in Canada.[2] In particular, the CIAR population health framework (Appendix A)[3] motivated researchers to expand their perspective beyond health care as a determinant of health.[4] Subsequently, other determinants of health frameworks were developed.[5,6]

There are several common notions of these population health conceptual frameworks. First, health care is no longer a central component as the health determinant. Second, the individual characteristics, social and physical environments, and their complex interactions are considered to be important determinants of health.[7] The focus of health research shifted from narrowly targeted health programs to more integrated approaches by combining micro- and macro-level factors. In addition, dynamic impacts of these factors were also recognized, resulting in the emphasis of longitudinal as well as multilevel data analyses. Accordingly, the population health frameworks initiated various population-level surveys that collect information on health outcomes and medical and non-medical determinants of health variables.[2,8]

The CIAR population health framework did not only impact the research community but also influenced health policy initiatives in Canada. For example, at the Canadian federal level, the Federal, Provincial and Territorial Advisory Committee of Population Health published two comprehensive reports[5,9] to describe the population health approach and major factors in the determinants of health framework. In addition, National Forum on Health was also established in 1994 to disseminate the concepts of the determinants of health and evidence-based health policy.[10]

Federal, Provincial and Territorial Advisory Committee on Population Health defined population health as:

> "... the health of population as measured by health status indicators and as influenced by social, economic and physical environments, personal health practices, individual capacity and coping skills, human biology, early childhood development, and health services ... population health focuses on the interrelated conditions and factors that influence the health of populations over the life course, identifies systematic variations in their patterns of occurrence, and applies the resulting knowledge to develop and implement policies and actions to improve the health and well-being of those populations."[11]

The above definition implies that the term population health does not simply refer to the health status of population but also it initiates at least four general research agendas: (1) measuring health outcomes and instrument validation[11], (2) assessing factors associated with heterogeneities in health outcomes, (3) longitudinal assessment of the determinants of health, and (4) deriving policy implications.[5,11] This thesis attempted to tap into each of these four aspects using Health Utilities Index Mark 3 (HUI3) as a measure of health outcome using nationally representative data for the Canadian population.

1-2 Measuring health status: Health-related quality of life (HRQL)

1-2-1 HRQL measures

Health status is a multi-dimensional concept that represents not only the absence of illness but also physical, mental and social functioning.[12] The process of measuring health status requires the obtaining of subjective information from patients or populations, summarizing the information, and assigning values to health status. Therefore, HRQL is one useful approach for quantifying health status. HRQL is defined as "... the value assigned by individuals, groups or society to duration of life as modified by the impairments, functional status, perceptions, and social opportunities that are influenced by disease, injury, treatment or policy".[13] HRQL is an important concept especially in measuring the health of populations for health policy and resource allocation. Physiological measures are useful in order to provide diagnosis and/or disease management but they may not necessarily reflect ones day-to-day functional status. In addition, HRQL measures are able to capture subtle differences in functional and emotional well-being of individuals, whereas physiological measures may not be sensitive enough to such differences.[14] Moreover, as life expectancy increases in Canada and internationally, more attention has been paid to morbidity (quality of life) in addition to mortality of population.[15] Therefore, measuring HRQL helps to understand better the morbidity and mortality burdens in modern society.

HRQL measures are useful for a variety of purposes. In general, there are three major objectives for measuring HRQL: discrimination (distinguishing the level of morbidity burdens across individuals or groups at a point in time), prediction (e.g. prognosis of morbidity and/or mortality), and evaluation (measuring within-person change in health status over time). In addition, HRQL measures have applications in screening, health status description, policy and resource allocation decisions.[16]

1-2-2 Types of HRQL measures

HRQL measures can be classified as specific or generic, depending on its purpose, target population and attributes (domains) of interests.[13,14,17] Specific measures are often used to measure HRQL when one is interested in measuring HRQL of specific disease, population and/or attributes. Numerous specific measures have been developed to date. Specific measures are generally sensitive to small changes in outcomes. Therefore, they are often useful in clinical trials where the outcomes of interest are narrow (i.e. specific to a certain clinical intervention) and measuring change is important. Generic measures are useful in assessing general health status of general population and/or a group of patients. Because generic measures are intended to be applicable to wider populations, they assess broader aspects of health.

Generic measures are further classified into health profile and preference-based measures. Health profile measures consist of comprehensive lists of domains, dimensions or attributes that attempt to measure all the important aspects of HRQL, for example, from functional and mental health to social interactions and day-to-day activities. Examples of health profile measures are the Sickness Impact

Profile (SIP)[18] and the Medical Outcomes Study 36-item Short-Form Health Survey (SF-36).[19] Health profile measures generate domain-specific scores and some measures also generate overall summary scores.[13] The other category of generic measures, preference-based measures, focuses on the value of health states, preferences over health states. These measures provide overall index scores that range from 0.00 (dead) to 1.00 (perfect health) with negative scores representing health states worse than being dead. Therefore, both morbidity and mortality are incorporated in the overall scores (in contrast, profile measures do not incorporate mortality). Preferences can be obtained directly from general population and patients using various preference elicitation methods [e.g. visual analogue scales (VAS), time trade-off (TTO) and standard gamble (SG)].[20] Alternatively, preferences can be obtained indirectly using multi-attribute classification system and scoring functions. The scoring functions are empirically estimated based on preference scores, usually obtained from a sample of general population using VAS, TTO and/or SG. Examples of indirect systems are Health Utilities Index (HUI) (based on SG)[21], SF-6D (based on SG)[22] , EuroQol-5D (based on TTO)[23] and Quality of Well-being (based on VAS).[24]

1-2-3 Comparisons of alternative HRQL measures

Advantages of generic measures are that scores can be compared among various types of populations and conditions.[13,17] In contrast, comparisons among conditions and populations beyond their targeted subjects are not possible using specific measures. Compared with generic measures, specific measures tend to be more sensitive to small but important difference in HRQL among populations and/or changes in HRQL over time than generic measures. This is because specific measures only include items (questions) that are relevant to particular conditions and/or populations, whereas items included in generic measures are aimed at assessing broader aspects of HRQL.

Profile measures cover broad aspects of HRQL. However, because of its comprehensiveness, the questionnaire tends to be longer and response burden may be a concern. In addition, because not all profile measures can generate a single overall score and do not incorporate dead, profile measures are not suitable for the use in economic evaluations such as cost-effectiveness and cost-utility analyses.[17] In contrast, preference-based measures generate scores that represent preference weights. These weights, then, can be used to calculate quality-adjusted life years (QALYs) in cost-utility analyses for resource allocation, and to calculate health-adjusted life expectancy (HALE) in population health studies.[21,25,26]

1-2-4 Use of HRQL measures in population health studies

When measuring and comparing HRQL of large population groups, generic and utility-based indirect systems are often useful in population health applications for several reasons. First, population health analyses address the health of large groups within populations with varying co-morbidities and demographic characteristics. In this respect, generic measures are useful in comparing HRQL across populations and patients with varying demographic and clinical characteristics. Second, measuring HRQL for a large numbers of individuals, for example, in the case of population-health surveys, is time consuming. Indirect methods are useful for obtaining comprehensive information on health states in an efficient manner without substantial cognitive burdens for respondents.[25] In contrast, direct elicitation methods such as VAS, TTO and SG are often time-consuming. In particular, the SG elicitation method requires respondents to compare alternative health states involving probabilities. Finally, utility measures can be used in economic evaluations. In this context, the HUI system, a generic and utility-based indirect measure, is one of the measures frequently used in population health studies.[i]

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[i] Although HUI and other indirect utility-based measures are useful in population health research, it is important to note several implications of the underlying assumptions of these measures when applied to assessing population health. First, preferences for indirect HRQL measures are derived from the average of preferences elicited from members of general population. (For example, preference weights for HUI3 were derived using a "person-mean" approach by taking the weighted average of preferences elicited by survey respondents.[27]) As a result, the person-mean approach averages out potential underlying differences in preferences that may be obtained from various demographic and socio-economic groups. Therefore, an implication for the use of indirect measures in population health research is that the derived utility may not represent HRQL burden perceived by specific population groups. Evidence on the generalizability of utility scores suggests that utility measures are generalizable among various population groups as well as internationally.[28] Nonetheless, a further investigation of the generalizability of preferences is warranted. Second, valuation of a health state may depend on the duration of the health state one experiences. Therefore, individuals who experience the same health state may attach different values to the states if the duration of health state differs. For example, in the development of the HUI3 scoring function, preferences of various health states were obtained assuming that each health state lasts for the rest of respondent's lifetime.[27] On the other hand, valuations of health states in the development of EuroQol-5D were based on the

1-2-4-1 Health Utilities Index (HUI)

HUI is a generic, multi-attribute, utility-based HRQL measure capturing functional and emotional health. The HUI system is widely used in population surveys in Canada, in measuring clinical outcomes, and cost-utility analyses[25,29,30]. The HUI system has three versions, Health Utilities Index Mark 1 (HUI1), Mark 2 (HUI2) and Mark 3 (HUI3).[29] The focus of this thesis is on the HUI3 system.

HUI3 consists of a multi-attribute health status classification system and scoring functions (single-attribute and multi-attribute functions). The multi-attribute health status classification system consists of eight attributes: vision, hearing, speech, ambulation, dexterity, emotion, cognition and pain, with 5 or 6 levels in each attribute (Appendix C). HUI3 describes 972,000 unique health states. The single-attribute scoring function generates single-attribute scores that range between 0.00 (most impaired) and 1.00 (no impairment) for each attribute (Appendix D). The multi-attribute scoring function generates overall HUI3 scores that range from -0.36 (most impaired, the all-worst HUI3 health state), 0.00 (being dead) to 1.00 (perfect health) (Appendix E).[27] Therefore, HUI3 has the advantage of incorporating both morbidity and mortality effects into one common scale.[21,31] Because the scoring functions are estimated based on preferences from general populations, the resulting utility scores reflect societal preferences. The HUI3 system has been administered in a number of population-health surveys in Canada and elsewhere.[32]

1-2-5 Validity and instrument validation

To assess the health status of populations with confidence, instrument validation is another important task. Validity answers the question of whether or not the instrument measures what is supposed to measure. An instrument can measure theoretical concept with validity if "... the variation in the attribute causes variation in the measurement outcomes through the response processes that the test elicits".[33] Validity implies a causal relationship between theoretical construct (attributes) and observed scores. Then, our task is to assess if an instrument can properly translates variations in theoretical attributes into variations in measurements, namely instrument

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assumption that each health state lasted for 10 years, followed by death.[23] Such differences in assumptions may have implications to the resulting utility scores.

validation.[33] Instrument validation is conducted by "… testing the hypothesis that the theoretical attribute has a causal effect on test scores".[33] Among several methods of assessing validity, the current thesis assessed the validity of the HUI3 system using a known-group approach (i.e. a regression approach). This was done by testing *a priori* hypothesis about whether or not a group of individuals with conceptually differing (similar) attributes showed differences (similarities) in observed HUI3 scores.[34]

1-3 Assessing heterogeneities in health outcomes: Determinants of health conceptual framework

In assessing heterogeneities in population health outcomes, two conceptual frameworks were used in this thesis: CIAR population health framework by Evans and Stoddart (1990) discussed earlier and a model by Hertzman et al (1994).

There are four unique aspects in the CIAR population health framework (Appendix A). The first characteristic is the distinction between "Disease" and "Health and function", an important distinction to acknowledge the difference between health status perceived by individuals and disease status recognized by health professionals. The distinction is related to the concept of HRQL that emphasized ones perception and subjective judgment about their health status, which is a separate aspect from physical/clinical measures of health. Second, the framework incorporates "Individual response". It indicates that individual response such as biological (e.g. immune system, stress) and behavioural (e.g. lifestyle (smoking, diet and so on)) responses are the reflection of social/physical environment, genetic endowment and health care. An inclusion of these factors provides implications as to why some choose a certain lifestyle and others do not. Third, the model incorporates societal impact of changes in demands on the health care system. Namely, changes in the level of health care utilization affect wealth in a society ("Prosperity"), which influence social and physical environment available to the society. Finally, an incorporation of both the societal and individual-level factors suggests a multilevel nature of the determinants of health.

The determinants health model by Hertzman et al (1994) is a useful tool to operationalize the complex CIAR population health framework for empirical analyses.

The framework is expressed as a cube that consists of three key dimensions: stage of life cycle, subpopulation partitions, and sources of heterogeneity (Appendix B). Stage of life cycle introduces a time component into the conceptual framework; four major stages of life are specified: perinatal (preterm to 1 year), misadventure (1-44 years), chronic disease (45-74 years), and senescence (75+). The second dimension is "subpopulation partitions" that refers to socioeconomic status, ethnicity/migration, geography, gender and special populations (e.g. aboriginal people, certain religious groups).[7] The third dimension, sources of heterogeneity, refers to factors that are observed to operate throughout life-cycle and across subpopulations. Examples are individual life-style, physical environment, social environment and access to health care services.

1-4 Longitudinal determinants of health

The role of time in the determinants of health framework by Hertzman et al (1994) above is an important element that was missing in the original CIAR population health framework. The original CIAR model is defined as a static model without explicit discussion with respect to the temporal relationships among factors.[35] In fact, it is important to consider dynamic relationships between HRQL and its determinants (e.g. lagged effects, heterogeneities in trajectories over time). Hertzman et al (1994) discussed four types of time: elapsed time (e.g. latency, time lag between exposures and health outcomes), biological time (differential impact of exposures on outcomes over the life cycle), cumulative time and historical time (e.g. cohort differences in effects of physical/social environments on health).

Longitudinal effects of various exposures to health outcomes have been assessed extensively in population health with respect to these various aspects of time framework by investigators from a variety of disciplines. For instance, life-course epidemiology hypothesizes that immediate, past and cumulative biological and social factors and exposures through life are all important for the subsequent health in adulthood.[36,37] In the life-course health development (LCHD) framework, it is emphasized that exposures to various risk and protective factors in early stages of the life cycle have life-time, or even inter-generational, effects on health. The LCHD framework acknowledges that factors that impact health trajectories differ across different life stages. It also considers that variations in health trajectories in adulthood are largely due to variations in exposures to macro (e.g. social/physical environments) factors during childhood when health developmental process is sensitive to these factors. Therefore, longitudinal data analyses are an important component in population health research.

The number of longitudinal studies of the determinants of health has been increasing in Canada thanks to, in part, an increase in availability of longitudinal population-level health surveys. However, longitudinal evidence is lacking relative to the abundance of results based on cross-sectional studies. Although it is beyond the objectives of this thesis to provide a comprehensive assessment of the longitudinal determinants of health, the determinants of health of health trajectories were investigated in this thesis using data based on the representative Canadian population.

1-5 Summary

For the past few decades, researchers as well as policy makers in Canada have started to emphasize the importance of the population health framework. The population health framework indicates a series of research objectives including measuring health, validating health outcome measures, assessing heterogeneities in health and deriving policy implications. Effective implementation of health policy depends crucially on a proper understanding of tools for assessing health outcomes. In particular, when utilizing limited resources available in society, how patients and members of the general population value the health status produced by health care and health policy will enhance the usefulness of evidence-based decision making and related initiatives. In addition, understanding heterogeneities in health determinants across individuals as well as the longitudinal impacts of these factors on health are equally important for efficient allocation of finite societal resources. The accumulation of evidence with respect to these aspects will contribute to informed health policy decision making; HUI3 can be one useful tool for this purpose.

1-6 Research objectives

The overall objective of this thesis was to assess the determinants of health of Canadians using HUI3 as a measure of HRQL. A key requirement in investigating the determinants of health is a valid measure of HRQL. Therefore, in order to achieve the overall objective, the usefulness of HUI3 in population health research was assessed through two specific objectives: (1) to assess the validity of HUI3 and (2) to investigate the cross-sectional and longitudinal determinants of health of Canadians using HUI3 as the health outcome measure.

1-7 Organization of the thesis

Three papers contributed to the achievement of the above objectives. The first paper (Chapter 2) investigated issues associated with validating HUI3. Chapter 2 assessed the validity of the HUI3 in the context of three major health problems prevalent among the elderly: Alzheimer disease, arthritis and cataracts using nationally representative samples of Canadians aged 40 years and older.[38,39] The remaining two papers are applications of HUI3 to assess heterogeneities in the determinants of health of the Canadian population using cross-sectional (Chapter 3) and longitudinal data (Chapter 4). More specifically, Chapter 3 tested whether the same determinants of health variables explained variations in health for people living in the community and those living in long-term care institutions and sought to identify the factors associated with health in these two populations. Finally, the third paper (Chapter 4) investigated heterogeneities in the determinants of health longitudinally using eight-year follow-up data. The paper estimated HRQL trajectories among the general adult population to assess the association between the individual characteristics and variations among trajectories.

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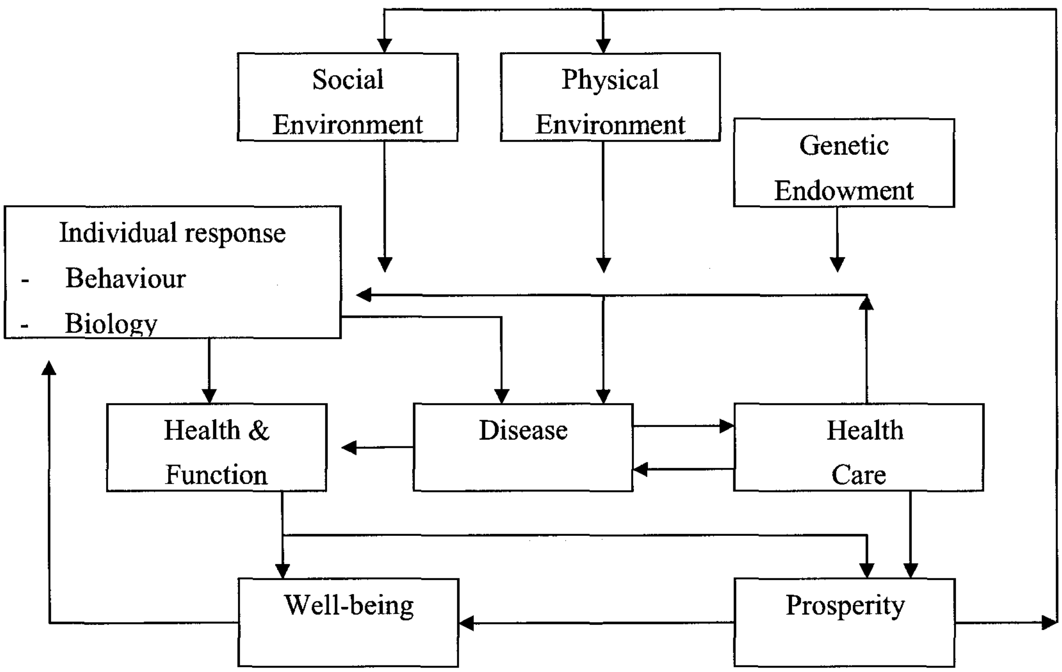
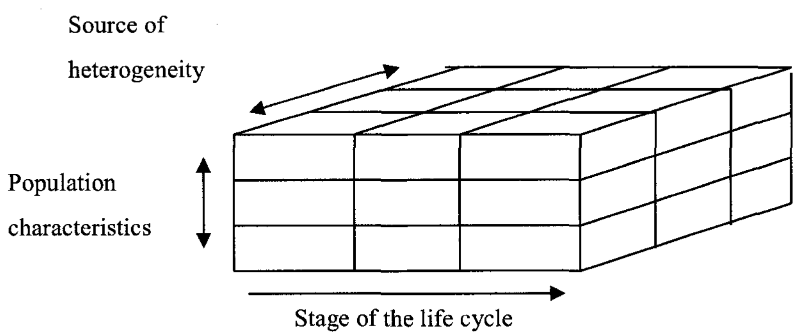
Appendix A CIAR Population Health Framework



Source: Evans and Stoddart (1994)

Appendix B Determinants of health framework



Stage of the life cycle

- Preterm to 1 year (Perinatal)
- 1-44 years (Misadventure)
- 45-74 years (Chronic disease)
- 75+ years (Senescene)

Characteristics

- Socioeconomic status
- Ethnicity/migration
- Geographic
- Male/female
- Special populations (e.g. by religion)

Source of heterogeneity

- Reverse causality
- Differential susceptibility
- Lifestyle (e.g. smoking, diet)
- Physical/social environment
- Access/response to health care services

Source: Hertzman et al (1994)

Appendix C HUI3 multi-attribute health status classification system

Attribute	Level	Level Description
Vision	1	Able to see well enough to read ordinary newsprint and recognize a friend on the other side of the street, without glasses or contact lenses
	2	Able to see well enough to read ordinary newsprint and recognize a friend on the other side of the street, but with glasses
	3	Able to read ordinary newsprint with or without glasses but unable to recognize a friend on the other side of the street, even with glasses
	4	Able to recognize a friend on the other side of the street with or without glasses but unable to read ordinary newsprint even with glasses
	5	Unable to read ordinary newsprint and unable to recognize a friend on the other side of the street, even with glasses
	6	Unable to see at all
Hearing	1	Able to hear what is said in a group conversation with at least three other people, without a hearing aid
	2	Able to hear what is said in a conversation with one other person in a quiet room without a hearing aid, but requires a hearing aid to hear what is said in a group conversation with at least three other people
	3	Able to hear what is said in a conversation with one other person in a quiet room with a hearing aid and able to hear what is said in a group conversation with at least three other people with a hearing aid
	4	Able to hear what is said in a conversation with one other person in a quiet room without a hearing aid, but unable to hear what is said in a group conversation with at least three other people even with a hearing aid
	5	Able to hear what is said in a conversation with one other person in a quiet room with a hearing aid, but unable to hear what is said in a group conversation with at least three other people even with a hearing aid
	6	Unable to hear at all
Speech	1	Able to be understood completely when speaking with strangers or friends
	2	Able to be understood partially when speaking with strangers but able to be understood completely when speaking with people who know the respondent well
	3	Able to be understood partially when speaking with strangers or people who know the respondent well
	4	Unable to be understood when speaking with strangers but able to be understood partially by people who know the respondent well
	5	Unable to be understood when speaking to other people (or unable to speak at all)
Ambulation	1	Able to walk around the neighborhood without difficulty and without walking equipment
	2	Able to walk around the neighborhood with difficulty, but does not require walking equipment or the help of another person
	3	Able to walk around the neighborhood with walking equipment, but without the help of another person
	4	Able to walk only short distances with walking equipment and requires a wheelchair to get around the neighborhood
	5	Unable to walk alone, even with walking equipment; able to walk short distances with the help of another person, and requires a wheelchair to get around the neighborhood
	6	Cannot walk at all

Table continued...

Dexterity	1	Full use of two hands and ten fingers
	2	Limitations in the use of hands or fingers, but does not require special tools or help of another person
	3	Limitations in the use of hands or fingers, is independent with use of special tools (does not require the help of another person)
	4	Limitations in the use of hands or fingers, requires the help of another person for some tasks (not independent even with the use of special tools)
	5	Limitations in the use of hands or fingers, requires the help of another person for most tasks (not independent even with the use of special tools)
	6	Limitations in the use of hands or fingers, requires the help of another person for all tasks (not independent even with the use of special tools)
Emotion	1	Happy and interested in life
	2	Somewhat happy
	3	Somewhat unhappy
	4	Very unhappy
	5	So unhappy that life is not worthwhile
Cognition	1	Able to remember most things, think clearly and solve day to day problems
	2	Able to remember most things, but have a little difficulty when trying to think and solve day to day problems
	3	Somewhat forgetful, but able to think clearly and solve day to day problems
	4	Somewhat forgetful, and have a little difficulty when trying to think or solve day to day problems
	5	Very forgetful, and have great difficulty when trying to think and or solve day to day problems
	6	Unable to remember anything at all, and unable to think or solve day to day problems
Pain	1	Free of pain and discomfort
	2	Mild to moderate pain that prevents no activities
	3	Moderate pain that prevents a few activities
	4	Moderate to severe pain that prevents some activities
	5	Severe pain that prevents most activities

Source: http://www.fcs.mcmaster.ca/hug/index.htm

Appendix D HUI3 Single-attribute utility functions

Vision		Hearing		Speech		Ambulation		Dexterity		Emotion		Cognition		Pain	
x1	y1	x2	y2	x3	y3	x4	y4	x5	y5	x6	y6	x7	y7	x8	y8
1	1.00	1	1.00	1	1.00	1	1.00	1	1.00	1	1.00	1	1.00	1	1.00
2	0.95	2	0.86	2	0.82	2	0.83	2	0.88	2	0.91	2	0.86	2	0.92
3	0.73	3	0.71	3	0.67	3	0.67	3	0.73	3	0.73	3	0.92	3	0.77
4	0.59	4	0.48	4	0.41	4	0.36	4	0.45	4	0.33	4	0.70	4	0.48
5	0.38	5	0.32	5	0.00	5	0.16	5	0.20	5	0.00	5	0.32	5	0.00
6	0.00	6	0.00	6	n/a	6	0.00	6	0.00	6	n/a	6	0.00	6	n/a

Notes: x_i refers to the attribute (1 through 8) and y_i refers to the single-attribute scores for the levels for that attribute. The scale for each single-attribute utility function varies from 0.00 for the lowest level (most impaired or disabled) for that attribute to 1.00 for level 1 (normal, not impaired) for that attribute. The single-attribute utility score for Level 3 Cognition is greater than the single-attribute utility score for Level 2 Cognition.

Source: Feeny et al (2002): Table 4

Appendix E HUI3 Multi-attribute Utility Functions: Simplified Format on Dead-Prefect Health Scale

Vision		Hearing		Speech		Ambulation		Dexterity		Emotion		Cognition		Pain	
x1	b1	x2	b2	x3	b3	x4	b4	x5	b5	x6	b6	x7	b7	x8	b8
1	1.00	1	1.00	1	1.00	1	1.00	1	1.00	1	1.00	1	1.00	1	1.00
2	0.98	2	0.95	2	0.94	2	0.93	2	0.95	2	0.95	2	0.92	2	0.96
3	0.89	3	0.89	3	0.89	3	0.86	3	0.88	3	0.85	3	0.95	3	0.90
4	0.84	4	0.80	4	0.81	4	0.73	4	0.76	4	0.64	4	0.83	4	0.77
5	0.75	5	0.74	5	0.68	5	0.65	5	0.65	5	0.46	5	0.60	5	0.55
6	0.61	6	0.61	6	n/a	6	0.58	6	0.56	6	n/a	6	0.42	6	n/a

Formula (Dead-Perfect Health Scale)

$$u^* = 1.371(b1*b2*b3*b4*b5*b6*b7*b8) - 0.371$$

Notes: Where u^* is the utility of a chronic health state[ii] on the utility scale where dead[iii] has a utility of 0.00, and healthy (perfect health) has a utility of 1.00. The single-attribute utility score for Level 3 Cognition is greater than the single-attribute utility score for Level 2 Cognition.

Source: Feeny et al (2002): Table 3

[ii] Chronic states, and the perfect health state, are here defined as lasting for a lifetime.

[iii] Dead is defined as immediate.

Chapter 2: The validity of the Health Utilities Index Mark 3 (HUI3) in the National Population Health Survey: Alzheimer Disease, arthritis, and cataracts[iv]

2-1 Abstract

The objective of this study was to assess the cross-sectional validity of the Health Utilities Index Mark 3 (HUI3) in Alzheimer disease (AD), arthritis (AR), and cataracts (CA). The 1996/97 Canadian National Population Health Survey for community and institution-dwelling respondents aged 40 years and above was used in the study. Adjusted means for overall and single-attribute HUI3 scores of five subgroups were compared: (1) AD only, (2) AR only, (3) CA only, (4) at least two of the three conditions, and (5) none of the three (reference group). Regression analyses were conducted for community and institutional data to obtain adjusted mean utility scores. Of the 76 *a priori* hypotheses, 55 were confirmed. HUI3 was able to describe overall burdens of AD, AR, and CA as well as vision problems associated with CA, speech and cognition problems associated with AD, and ambulation and pain problems associated with AR. Adjusted mean differences in overall HUI3 scores between AD, AR, or CA only groups and reference group ranged from -0.04 to -0.42 ($p < 0.05$); all differences were quantitatively important. HUI3 is useful in assessing the health-related quality of life of AD, AR, and CA of those living in the community and institutions.

[iv] A version of this chapter has been published. Asakawa *et al.* 2008. *Journal of Clinical Epidemiology* Vol.61, No.7: 733-739.

2-2 Introduction

In an aging society, an understanding of the physical and psychological burdens associated with aging is crucial for the efficient delivery of health and social services, particularly for those who are at risk for burdens prevalent among the elderly. Assessing the health-related quality of life (HRQL) in the population with age-related health conditions enables decision-makers to recognize the true physical and psychological burdens this population faces. Therefore, it is important that the validity of outcome measures be evaluated in target chronic conditions before they are used in clinical, population health, and economic decision-making processes.

Health Utilities Index Mark 3 (HUI3) is a generic, multi-attribute, utility-based measure that assesses health status and HRQL. The HUI3 consists of a multi-attribute health status classification system and utility-based scoring functions. The multi-attribute health status classification system consists of eight attributes: vision, hearing, speech, ambulation, dexterity, emotion, cognition and pain, with five or six levels in each attribute. Single-attribute scoring function generates scores that range between 0.00 (most impaired) and 1.00 (no impairment) for each attribute. The multi-attribute scoring function generates overall HUI3 scores ranging from -0.36 (most impaired, the all-worst HUI3 health state), to 0.00 (being dead) to 1.00 (perfect health)[1]. HUI3 has been used in population health surveys to assess health status and HRQL for a number of chronic conditions.[2-5] However, some of previous studies are based on samples, which may not be representative of the entire population. HRQL for patients/people with cataracts (CA) has been assessed previously[4-6], although the validity of HUI3 in people with CA has not been established.

The paper assessed the cross-sectional validity of the HUI3 system by testing hypotheses about the ability of HUI3 to capture the burdens associated with disparate, but important conditions in older adults: Alzheimer Disease (AD), arthritis (AR), and CA. We explored two research questions: (1) are overall HUI3 utility scores of individuals with AD and/or CA and/or AR lower than scores for those without any of the three conditions, and (2) are HUI3 single-attribute utility scores able to detect burdens specific to different chronic conditions? We hypothesized that AD generates burdens mainly in speech, ambulation, dexterity and cognition; AR mainly affects ambulation, dexterity, emotion and pain; and CA mainly affect vision and emotion.

2-3 Methods

2-3-1 Data

Cycle Two (1996/97) of the National Population Health Survey (NPHS) cross-sectional data of community (household, n=81,804) and health institutional (n=2,118) surveys from Statistics Canada was used for our analyses.[7,8] Cycle Two NPHS was preferred to other cycles of NPHS because the combined sample size was the largest among the available cycles of NPHS. The NPHS household survey targets household residents in all provinces excluding those in Indian Reserves, Canadian Forces Bases and some remote areas in Quebec and Ontario. The household survey consisted of two components: General and Health. The Health component, which included in-depth questions about the health status of individuals, including HUI3 questions, was administered to one person randomly chosen from the household. The Health component file was the primary data used. Socio-demographic characteristics, income and general health status information for corresponding respondents was obtained from the General component file.

The health institution survey targeted residents in health-related institutions (e.g. institutions for the elderly, institutions for the cognitively disabled, and other rehabilitative institutions). Residents in long-term care institutions in all provinces (excluding territories, Indian Reserves and Canadian Forces Bases) were included in the survey. Information such as health status, socio-demographic characteristics, healthcare utilization and medication use was collected in the survey.[7]

The target population for our study is those aged 40 years and older who were living in the community or in institutions. AD, AR and CA were chosen as target chronic conditions as all three conditions are prevalent among the elderly, but having AD, AR or CA is expected to affect different attributes within the HUI3 classification system. The middle-aged to elderly population (age 40+) was selected because these three conditions are increasingly prevalent with age, and the accuracy of responses of the existence of AD by younger age groups may be problematic.

NPHS respondents were asked if they have "… 'long-term conditions' that have lasted or are expected to last 6 months or more and that have been diagnosed by a health professional".[8] The list includes "arthritis or rheumatism", "Alzheimer's disease or any other dementia," and "cataracts".[7,8] To formulate comparisons for tests of validity, five mutually exclusive groups were identified: (1) has AD, no AR, no CA (AD only), (2) has AR, no AD, no CA (AR only), (3) has CA, no AD, no AR (CA only), (4) has at least two of the three conditions (Combined), and (5) has none of the three conditions (reference).

2-3-2 Statistical analyses

A regression approach was used to assess the validity of HUI3.[2] A number of linear regression models were fitted to compare adjusted (predicted) mean overall and single-attribute utility scores across the five subgroups. The dependent variables were the overall or single-attribute HUI3 scores, each as a continuous variable. Independent variables consisted of four dichotomous variables indicating subgroups (AD only, AR only, CA only and Combined) and control variables representing determinants of health factors (described below).

Validity tests were performed in two steps. First, using regression results, adjusted mean HUI3 scores for each subgroup were obtained by holding various determinants of health factors fixed at their overall means. Second, adjusted mean differences and their standard errors were calculated for each paired comparison. We formulated 38 *a priori* hypotheses for data from each survey (household and institutions) as tests of validity (Table 2-1). In all cases, we considered meaningful differences to be those that were statistically significant, using directional (i.e. one-sided) tests and a 5% level of significance, as well as quantitatively important. For HUI3, it is suggested that differences of 0.03 (0.05) or greater in mean HUI3 overall (single-attribute) scores are definitely important[3], and differences in mean overall scores as little as 0.01 may be meaningful and important in some contexts.[9]

We included age, gender, education, race, area of residency (rural/urban), income (received social assistance or not, and received food assistance or not), marital status, and tobacco and alcohol consumptions as control variables (Table 2-2).[10] A dichotomous variable was defined to indicate whether the questionnaire was completed by the participant or proxy. The number of chronic conditions other than AD, AR, and CA were included to control for the existence of multiple chronic conditions. Based on previous evidence and theoretical interests, six interaction terms were also included in each model: disease group and age, disease groups and gender, disease groups and education, disease groups and marital status, disease groups and information source, and age and marital status.[2,11-19] A stratified analysis was conducted for models with significant interaction term(s) with respect to subgroup variables.

To take account for a multi-stage complex survey design of NPHS, normalized sampling weights were used. Standard errors of estimates were obtained using a bootstrap method for the household data and a Taylor linearization method for the institutional data.[20,21] SAS 9.1[22] and SUDAAN 9.0.1[23] were used for the statistical analyses.

2-4 Results

2-4-1 Descriptive statistics

After excluding subjects under 40 years old and/or with missing data for important variables, sample sizes for overall HUI3 models were 34,935 for the household data and 1,259 for the institutional data. Sample sizes for each single-attribute models were similar, although exact sample size cannot be reported due to confidentiality concerns. The majority of individuals living in the community (73.3%) were in the reference group, whereas only 29.5% of individuals living in institutions were in the reference group (Table 2-2). Mean age for the household (institutional) data was 56.4 (80.4) years. Individuals in the community tended to have fewer co-morbidities, be more educated, and be married. Although only 2.6% of information was collected from proxy respondents in the household data, approximately 55% of responses were by proxy for the institutional data.

2-4-2 Validity tests

Of the 76 *a priori* hypotheses, 55 (27 for the household survey and 28 for the institutional survey) were consistent with *a priori* hypotheses (Table 2-3). Only selected results are presented and discussed here (full results are available from the authors). Generally, consistent results were mainly found for overall scores and the vision, hearing, speech, cognition and pain attributes.

As expected, adjusted mean differences for overall HUI3 scores between disease and reference groups were negative, quantitatively important (difference $\geq |0.01|$) and statistically significant at 5%. Consistent with our hypothesis that those with CA would report more vision problems, adjusted mean differences in single-attribute vision utility scores for CA only-reference were negative, quantitatively important (difference ≥ |0.05|), and statistically significant (-0.05 for the household data, -0.15 [female and proxy] and -0.28 [male and proxy] for the institutional data) (Table 2-4).

We expected that speech and cognition scores would be importantly lower for AD only. Our *a priori* hypothesis was supported for proxy (female) stratum for the household (institutional) data for speech scores; adjusted mean differences for AD only-reference was negative, greater than |0.10|, and statistically significant. For cognition, the *a priori* hypothesis was also supported for the same comparisons for all strata. It was hypothesized that subjects with AR would suffer more from pain. Results were consisted with expectation. For both household and institutional samples, adjusted mean differences in pain scores for AR only-reference were negative, greater than |0.10| and statistically significant.

No differences in adjusted means were expected for hearing scores across all disease groups. All the comparisons in hearing scores were consistent with our expectations except for one comparison (AR only-reference for proxy in the institutional data). Although we expected that AD and AR would affect ambulation and dexterity, little difference in these scores were found between AD only or AR only and reference group for most comparisons. Although emotional problems were expected to be evident for those with AR and CA, no important deficit was shown for AR only and CA only compared with reference for the household data. For the institutional data, adjusted mean emotion score was significantly and importantly lower for the CA only compared to reference (-0.07).

2-5 Discussion

Comparisons of adjusted means showed the ability of the HUI3 system to discriminate various aspects of the burdens associated with these three chronic conditions for those living in the community and those living in the long-term care institutions. Overall HUI3 scores were able to describe the detrimental impacts of having AD, AR and/or CA on HRQL, after controlling for various determinants of health.

More stringent validity tests were performed by comparing single-attribute scores across disease groups. For both household and institutional data, single-attribute HUI3 scores were able to differentiate various aspects of functional capacity that were expected to differ: speech and cognition problems associated with AD, ambulation and pain problems associated with AR, and vision problem associated with CA. In addition, consistent with our predictions, HUI3 scores for hearing were similar across groups.

However, HUI3 did not capture ambulation and dexterity problems expected to be present with AD and, similarly, dexterity problems with AR; nor did the HUI3 consistently capture emotional problems we hypothesized would be associated with AR and CA. Lack of information regarding the severity of each chronic condition in the NPHS data may be one reason for these findings. As a result, calculated adjusted means did not take account of the distribution of individuals with varying levels of disease severity within each group, leading to adjusted mean scores that were indistinguishable across the groups. The merger of any two combinations of conditions as one of the comparison groups (Combined) may be an additional source of ambiguity; the existence of a potentially very heterogeneous group (i.e. Combined) may make the comparisons in scores among the remaining groups misleading.

Another unexpected finding was that emotion scores for AD only were lower than for AR or CA in the household data. The finding contradicts the usual clinical observation that those with AD generally retain their pre-morbidity self-report of quality of life whereas those with AR or CA tend to express discouragement because of their difficulties in performing day-to-day activities. In exceptional cases, individuals with early AD may express depressive symptoms. Therefore, potential emotional problems with these subjects may have affected our results, suggesting the possibility of specifying different hypotheses for different stages of AD. However, because the NPHS lacks information with respect to disease stage, we were only able to test *a priori* hypotheses about the average characteristics of AD. Alternatively, noting the large proportion of proxy respondents for those with AD, the emotional status of the proxy respondents may influence their judgment about the emotional status of AD subjects and may account for the results observed.[24]

We recognize four additional potential limitations. First, because the NPHS relies on self or proxy reports, the accuracy of subjective responses may be of concern. For example, those with early stages of dementia may choose not to report (or may not realize) the existence of the condition. Moreover, with self-report, problems with cognition as well as functional impairment may be under-reported because of loss of insight.[25,26] Under-reporting of AD cases may bias validity tests toward null hypotheses (i.e. no difference), if a large number of undetected AD cases were assigned to other comparison groups (AR only, CA only or reference). Nonetheless, HUI3 was able to describe overall, speech, and cognitive burdens for AD only group.

Second, data for a substantial proportion of subjects were obtained from proxy respondents, especially in the institutional survey (55%). Systematic disagreement in the level of the HRQL burden between proxy and self-reports has been reported in previous studies.[18,27] Therefore, the observed level of burden may be subject to the reporting bias.

Third, the study utilized Cycle Two (1996/97) NPHS data, which was collected more than a decade ago. Cycle Two NPHS was chosen because the sample size was the largest among the available NPHS cycles at the time of the analyses. Therefore, it may be useful to compare the results using data from Cycle 2 to results using data based on recent population health surveys to assess whether or not the results are robust.

Finally, HUI3 utility scores range from 0 (dead) (or lower [worse than dead]) to 1 (perfect health) for overall scores and from 0 (the lowest capacity) to 1 (full capacity) for single-attribute utility scores. Regression estimates may be biased and inconsistent if one ignores censoring of the outcome variable, and incorporating estimation techniques such as Tobit method may be of interest.[28] However, among our predicted utility scores (based on a model without taking account of censoring), the only adjusted mean score that exceeded one was that for pain for AD only in the household data (1.03, data not shown). Therefore, the models used in the current analyses are considered to be generally reasonable.

2-6 Conclusion

Our results indicate that the HUI3 system is useful in describing the overall HRQL burdens as well as vision problem associated with CA, speech/cognition problems associated with AD, and ambulation/pain problems associated with AR. One of the primary contributions of this study was to provide additional evidence of validity of HUI3 in AD and AR based on data representative of the entire population, and to provide evidence for the first time that HUI3 is valid in measuring HRQL associated with CA. In addition, a key feature of this study was the use of both community and institutional data from the NPHS, one of the largest population health surveys currently available in Canada, making the results and implications generalizable to both community-dwelling and institutionalized populations.

Disclaimer

The research and analysis reported in this paper are based on data from Statistics Canada and the opinions expressed do not represent the views of Statistics Canada.

Table 2-1 ***A priori* hypotheses**

Comparisons (Adjusted mean differences)	Overall	Vision	Hearing	Speech	Ambulation	Dexterity	Emotion	Cognition	Pain
AD only-AR only			ND	-			+	-	+
AD only-CA only		+	ND	-	-	-	+	-	
AD only-combined			ND						
AD only-reference	-		ND	-	-	-		-	
AR only-CA only		+	ND		-	-			-
AR only-combined			ND						
AR only-reference	-		ND		-	-	-		-
CA only-combined			ND						
CA only-reference	-	-	ND				-		
combined-reference	-		ND						

Abbreviations: ND, adjusted mean differences are not quantitatively important (for overall HUI3 scores, an adjusted mean difference < 0.01; for single-attribute HUI3 scores, an adjusted mean difference < 0.05).

Notes: Cells in blank indicate that there is no *a priori* hypothesis.

"+" indicates that adjusted mean differences are positive and quantitatively important.

"-" indicates that adjusted mean differences are negative and quantitatively important.

Table 2-2 Demographic Characteristics of community and institution samples

Control variables	Community (n=34,935) [a] (%)	Institution (n=1,259) (%)
Disease groups [b]		
AD only	0.2	14.4
AR only	21.4	18.4
CA only	2.3	8.8
Combined	2.8	28.9
Reference (Ref)	73.3	29.5
Age [c]		
AGE1	10.5 *(age ≥ 75)*	43.8 *(age ≥ 85)* [d]
AGE2	16.7 *(65 ≤ age < 75)*	31.4 *(75 ≤ age < 85)*
AGE3 (Ref)	72.8 *(age < 65)*	24.8 *(age < 75)*
Other chronic conditions		
Has one other condition	29.5	17.4
Has two other conditions	17.2	19.1
Has more than two other conditions	16.2	53.7
Has no other condition (Ref)	37.1	9.8
Gender		
Female	51.9	69.4
Male (Ref)	48.1	30.6
Education		
Less than high school education	31.2	71.1
At least high school education (Ref)	68.8	28.9
Race		
Nonwhite	7.7	2.7
White (Ref)	92.3	97.3
Place of residency		
Urban resident	81.1	Not applicable
Rural resident (Ref)	18.9	Not applicable
Social assistance		
Yes	4.9	8.1
No (Ref)	95.1	91.9
Food assistance		
Yes	4.0	Not applicable
No (Ref)	96.0	Not applicable
Marital status		
Single, divorced, widowed or separated	27.4	84.4
Married, common-law or with partner (Ref)	72.6	15.6
Smoking		
Current or former smoker	61.0	48.9
Never smoked (Ref)	39.0	51.1
Alcohol		
Current drinker	73.0	27.3
Former drinker or abstainer (Ref)	27.0	72.7
Information source [e]		
Proxy	2.6	54.6
Self-report (Ref)	97.4	45.4

Table continued ...

Notes: Differences in proportions of disease groups, other chronic conditions, gender, education, race, social assistance, marital status, smoking, alcohol and information source between the household and institutional data were statistically significant ($p<0.01$).

Ref indicates the reference group in the regression analysis.

Abbreviations: AD, Alzheimer Disease; AR, arthritis; CA, cataracts.

[a] Data are based on n = 34,935 for household and n = 1,259 for institutions; proportions are based on normalized weights.

[b] Disease groups: AD only (has AD, no AR, no CA), AR only (has AR, no AD, no CA), CA only (has CA, no AD, no AR), Combined (has at least two of the three conditions), reference (has none of the three conditions).

[c] Mean age (standard deviation) = 56.4 years (12.55) for household, = 80.4 years (12.32) for institutions; mean difference in age between the two groups was significant ($p < 0.01$).

[d] The definition of age group differs from the household data because a much higher proportion of the residents of institutions was 75 years of age and older (approximately 75%).

[e] Information source: for household data, proxy = proxy for health component questionnaire; for institutional data, proxy = staff or family proxy.

Table 2-3 Results of validity tests – summary

Household (Community) data

Comparisons (Adjusted mean differences)	Overall	Vision	Hearing	Speech	Ambulation	Dexterity	Emotion	Cognition	Pain
AD only-AR only			ND	-			+	-	+
AD only-CA only		+	ND	-	-	-	+	-	
AD only-combined			ND						
AD only-reference	-		ND	-	-	-		-	
AR only-CA only		+	ND		-	-			-
AR only-combined			ND						
AR only-reference	-		ND		-	-	-		-
CA only-combined			ND						
CA only-reference	- *	-	ND				-		
combined-reference	-		ND						

Notes: Cells in blank indicate that there is no *a priori* hypothesis; Shaded cells indicate comparisons that were consistent with *a priori* hypotheses.

Abbreviations: ND, adjusted mean differences are not quantitatively important (for overall HUI3 scores, an adjusted mean difference < 0.01; for single-attribute HUI3 scores, an adjusted mean difference < 0.05).

"+" indicates adjusted mean differences are positive and quantitatively important; "-" indicates that adjusted mean differences are negative and quantitatively important; * p = 0.051.

Table continued...

Institutional data

Comparisons (Adjusted mean differences)	Overall	Vision	Hearing	Speech	Ambulation	Dexterity	Emotion	Cognition	Pain
AD only-AR only			ND	-			+	-	+
AD only-CA only		+	ND	-	-	-	+	-	
AD only-combined			ND						
AD only-reference	-		ND	-	-	-		-	
AR only-CA only		+	ND		-	-			-
AR only-combined			ND						
AR only-reference	-		ND		-	-	-		-
CA only-combined			ND						
CA only-reference	-*	-	ND				-		
combined-reference	-		ND						

Notes: Cells in blank indicate that there is no *a priori* hypothesis; Shaded cells indicate comparisons that were consistent with *a priori* hypotheses.

Abbreviations: ND, adjusted mean differences are not quantitatively important (for overall HUI3 scores, an adjusted mean difference < 0.01; for single-attribute HUI3 scores, an adjusted mean difference < 0.05).

"+" indicates that adjusted mean differences are positive and quantitatively important; "-" indicates that adjusted mean differences are negative and quantitatively important; * $p = 0.051$.

Table 2-4 Adjusted mean differences between disease and reference groups from multiple regression analysis for overall and single-attribute HUI3 scores [a]

Attributes	Strata [b]	AD only-reference [c]	AR only-reference	CA only-reference
Household				
Overall	Proxy	−0.42*	−0.17*	−0.21*
	Self-report	−0.19*	−0.08*	−0.04*
Vision		— [d]	—	−0.05*
Hearing		0.02	−0.01*	−0.01
Speech	Proxy	−0.13*	—	—
	Self-report	−0.03	—	—
Ambulation	Age ≥ 75	0.00	−0.09*	—
	Age 65-74	0.00	−0.01*	—
	Age < 65	0.01	−0.01*	—
Dexterity		−0.02	−0.01*	—
Emotion		—	0.00	0.01*
Cognition	Proxy	−0.54*	—	—
	Self-report	−0.24*	—	—
Pain		—	−0.11*	—
Institutions				
Overall		−0.08*	−0.09*	−0.10*
Vision	Female and Proxy	—	—	−0.15*
	Female and Self-report	—	—	−0.04
	Male and Proxy	—	—	−0.28*
	Male and Self-report	—	—	−0.03
Hearing	Proxy	−0.03	−0.14*	−0.08
	Self-report	0.01	0.02	−0.02
Speech	Female	−0.18*	—	—
	Male	0.02	—	—
Ambulation		0.08*	−0.08*	—
Dexterity		0.02	−0.02	—
Emotion		—	−0.03*	−0.07*
Cognition	Proxy	−0.31*	—	—
	Self-report	−0.30*	—	—
Pain		—	−0.11*	—

[a] Adjusted mean differences were derived from a regression model controlling for age, the number of other chronic conditions, gender, education, race, place of residency (rural/urban, for household data only), social assistance, food assistance (for the household data only), marital status, smoking, alcohol, and proxy status; standard errors were based on bootstrap (Taylor linearization) method for the household (institutional) data.

[b] A stratified analysis was conducted if a final regression equation contains interaction terms associated with disease groups; crude analyses were conducted for models without stratification.

[c] See *Method* section for definition of subgroups.

[d] No *a priori* hypothesis was defined for these comparisons.

* Statistically significant at 5% using one-sided tests.

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Chapter 3: Determinants of health of people living in the community and in institutions[v]

3-1 Abstract

Determinants of health studies have mainly dealt with samples of community-dwelling subjects. We utilized the 1996/97 Canadian National Population Health Survey community and institutional surveys to test whether the same determinants of health variables explain variations in health in both groups. The secondary objectives were to identify factors associated with health in these two populations and to investigate factors associated with the selection to institutions. A multiple linear regression model (dependent variable: Health Utilities Index Mark 3 (HUI3) score) with individual characteristics, socio-economic status, health risk factors, and a dummy variable indicating community or institution was estimated. A partial F-test was conducted to test the equality of the regression coefficients for the two groups. Stratified analyses were done to identify factors associated with the health in the two groups. A logistic regression model was used to investigate factors associated with selection to institutions. The partial F-test was significant ($p < 0.001$), indicating that the determinants of health differ between the two groups. Stratified analyses showed that advanced age, higher number of chronic conditions, lower education and financial status, not being married, smoking and non-drinker were negatively and significantly associated with HUI3 scores for the community sample. Except for chronic conditions and alcohol, none of these factors appeared to be important for the institutional sample. The logistic regression showed that lower HUI3 scores as well as determinants of health factors were associated with the probability of being in an institution. This study formally tests for differences in the determinants of health factors between those living in the community and in institutions using a representative sample of the Canadian population. Implications are that, for those who were institutionalized, the usual determinants of health factors are less important. In

[v] A version of this chapter has been submitted for publication. Asakawa *et al. Social Science and Medicine.*

conclusion, there appears to be important heterogeneity in determinants of health in the two populations.

3-2 Background and objectives

The identification of non-medical factors that explain the heterogeneity in population health is an important topic in health policy in Canada and elsewhere (Lalonde (1974), Hancock (1986), Hertzman (1990), Frank (1995), National Forum on Health (1996), Feinstein (1993), Chenier (2002)). In particular, in an aging society, as the number of individuals in long-term care institutions increases, the effective management of the health-related quality of life (HRQL) of residents in institutions is one important policy objective. For example, in Canada, approximately 173,000 individuals aged 65 years and older were estimated to be in long-term care institutions in 1981[1]; the number increased to approximately 263,000 by 2001.[1] By 2013, the number of institutionalized elderly Canadians (65+) is projected to be between 550,000 and 750,000.[2] The projected increase in the number of institutionalized elderly in Canada is indeed substantial. Similar trends are being observed in other developed countries.[3,4]

Although a number of studies have been conducted to identify factors associated with the health of people living in the community[5,6], the determinants of health of people living in institutions are under-investigated. Many existing studies focus only on the determinants of the place of residence, community or institutions, rather than the determinants of health of those who are already living in institutions.[2,7-11] Using data from the 1996/97 National Population Health Survey community and institutional samples, Ramage-Morin[1] used self-perceived health status as the measure of health. However, empirical analyses were conducted only for the institutional sample. To date, little is known about whether or not the determinants of health factors differ between those living in the community and those living in long-term care institutions. Therefore, our primary objective was to test whether or not the same determinants of health variables explain variations in the health of people living in the community and in institutions. If the determinants differ importantly, then our secondary objective was to identify which factors appeared to be important for the community and for institutional samples. More specifically, we investigated two additional questions: (1) for those who are in an institution, what are the important determinants of health and do those factors differ from the important determinants of health for people living in the community, and (2) what are important factors associated with the probability of being in an institution?

3-3 Methods

3-3-1 Data

Data from cycle 2 (1996/97) Canadian National Population Health Survey (NPHS) community (household) and institutional cross-sectional data were used[12,13]. Cycle 2 of the NPHS was chosen for our analyses of community and institutional samples because the combined sample size of this survey was the largest among the cycles of the NPHS (community (n = 81,804) and institutions (n = 2,118)). Given that the majority of residents in long-term care institutions are middle-aged or older, the target population for our study was those aged 40 years or older.

NPHS community survey targets household residents in all the 10 provinces excluding those in Indian Reserves, Canadian Forces Bases and some remote areas in Quebec and Ontario. The community survey consists of two components: General and Health. The General component consists of information on socio-demographic characteristics, income, and health status information from all the household members. The Health component contained in-depth questions about the health status of individuals. The Health component was administered to one person randomly chosen from the households.[13] Information from both general and health components were used for the analyses.

NPHS health institution survey targets Canadian residents in health-related institutions such as those for the elderly and cognitively disabled and other rehabilitation institutions. Residents in long-term care institutions in all the 10 provinces except those in territories, Indian Reserves and Canadian Forces Bases were included in the survey. In the NPHS, information on health status, socio-economic and socio-demographic characteristics, healthcare utilization and medication use was collected.

3-3-2 Data analysis

A linear regression model was estimated to assess whether or not the determinants of health model differed between those living in the community and those living in institutions. A partial F-test, also referred to as the Chow test[14], was conducted by estimating the following model:

$$Y_i = \alpha_0 + \sum_{m=1}^{M} \beta_m X_{im} + \gamma D_{INS} + \sum_{m=1}^{M} \delta_m (X_{im} * D_{INS}) + e_i \qquad (i = 1, \ldots, N) \qquad \text{(eq.1)}$$

Where Y_i is a continuous dependent variable that measures health outcomes, X_{im} is a set of m determinants of health factors, and D_{INS} refers to a dummy variable indicating place of residence ($D_{INS} = 1$ if one resides in a long-term care institution; $D_{INS} = 0$ if one resides in the community). $X_{im} * D_{INS}$ denotes interaction terms between a dummy variable and each of the determinants of health factor. A partial F-test was conducted by testing the parameter restriction, H_0: $\gamma = \delta_1 = \delta_2 = \ldots = \delta_M = 0$ (against H_1: *At least one of the parameters in H_0 is not equal to zero*) in eq.1. Rejection of H_0 would indicate that determinants of health are different between the two groups and would suggest the need for a stratified analysis. Failing to reject H_0 implies equality in the determinants of health parameters for the two groups. If H_0 were rejected, then we conducted a stratified analysis of the above determinants of health using the model described in equation 1 (without the resident indicator variable), one each for those living in the community and those living in institutions. We also estimated a logistic regression to investigate further factors associated with the selection to institutions.

3-3-3 Variables

The dependent variable for the linear regression model described in equation 1 was the overall Health Utilities Index Mark 3 (HUI3) utility score, a continuous variable. For the logistic regression model, the dependent variables was a dichotomous variable indicating the place of residence (= 1 for institutional residents, = 0 for community residents).

HUI3 is a generic, multi-attribute, utility-based measure that assesses health status and HRQL. The HUI system is widely used in population health surveys, clinical studies and cost-utility analyses. HUI3 consists of two components: a multiattribute health status classification system and utility-based scoring functions. The multi-attribute health status classification system consists of eight attributes (dimensions) of health status: vision, hearing, speech, ambulation, dexterity, emotion, cognition and pain, with five or six levels in each attribute. The multiplicative multi-attribute utility function for HUI3 is based on preferences obtained from a random sample of the Canadian population. The scoring function generates overall HUI3 scores that range from -0.36 (most impaired, the all-worst HUI3 health state) to 1.00 (perfect health); the score for dead is 0.00.[15] Negative utility scores imply health states considered to be worse than dead. We chose overall HUI3 scores as a dependent variable because, with its broad range of scores, including negative utility scores, HUI3 was considered to be suitable for assessing the health status of both community and institutional populations, and capable of capturing severe health problems, in particular, in those living in long-term care institutions.

Independent variables consisted of a various determinants of health factors and a dummy variable indicating place of residence (community or institutions). Variables included were informed by previous epidemiological studies and the determinants of health conceptual framework.[16,17] Identification of independent variables in our study was based on three conceptual categories: stage of life cycle (i.e., age, the number of chronic conditions), personal characteristics (i.e., gender, education, race, financial status and marital status), and sources of heterogeneity (i.e., tobacco and alcohol consumptions).[17] Preliminary investigation of the distribution of age and the number of chronic conditions variables showed large variation between those living in the community and those living in institutions (results not shown). Therefore, we used categorical variables to take account of these variations as well as possible non-linear associations between these variables and the health outcome. We used four age groups: 40-65, 65-74, 75-84, and $\geq$ 85. The number of chronic conditions was classified into six categories (Table 3-1). Because the chronic conditions assessed in the community and institutional questionnaires differed, the number of chronic conditions was based on the following conditions common to both surveys: asthma, arthritis, high blood pressure, chronic bronchitis, diabetes, epilepsy, heart disease, ulcers, stroke, urinary incontinence, Crohn's disease, Alzheimer disease, cataracts, glaucoma, and thyroid conditions. A high proportion of the target population in this study (especially those 65 years or older) was expected to be retired and to rely on their assets and/or other financial support. Therefore, financial status was measured by whether or not they reported receiving social assistance. Education, race groups, marital status, tobacco and alcohol variables are defined in Table 3-1. Given the potential for systematic differences in responses between proxy and self report[18-23], a dichotomous variable indicating information source (proxy or self report) was also included. Finally, to conduct a partial F-test, a dichotomous variable indicating place of residence (community or institutions) was included. For the logistic regression model, overall HUI3 score was included as an additional independent variable.

3-3-4 Model diagnostics and variance estimation

Impacts of influential observations, outliers, and collinearity were examined using statistics such as Cook's distance, leverage and variance inflation factors for linear regressions.[24] Directions of effects of independent variables such as income and marital status on health outcomes (overall HUI3) could run both ways. As a strategy to assess the potential endogeneity of these variables, sensitivity analyses were conducted for linear regression models to examine the impacts of including or excluding these variables on the resulting parameter estimates and hence their inferences.[25] For the logistic regression, differences in observed and predicted probabilities were calculated to assess the model fit. In addition, changes in Pearson chi-square, deviance and estimated regression coefficients with deletion of the observation were plotted against predicated probabilities as model diagnostics.[26,27] In the logit analyses, a preliminary assessment of the assumption of linear effects of HUI3 (independent variable) on the dependent variable (logit of the probability of being in an institution) showed potential nonlinearity. Therefore, the HUI3 scores were trichotomized following pre-defined levels of severity: (none/mild (HUI3 $\geq$ 0.89), moderate (HUI3 0.70-0.88) and severe (HUI3 $<$ 0.70).[28]

The NPHS used a multi-stage sampling design with unequal selection probabilities. To account for the complex survey design, sampling weights were used to obtain unbiased estimates of regression coefficients. Normalized sampling weights were used to obtain descriptive statistics and model diagnostics. In addition, Taylor linearization was used for variance estimation of regression coefficients and hypothesis tests.[29]

We considered a significance level of less than 5% as statistically significant. For HUI3, it is suggested that differences of 0.03 or greater in mean HUI3 overall scores are definitely important, and differences as little as 0.01 may be meaningful and important in some contexts.[30-33]

Data preparation, descriptive statistics and model diagnostics were conducted using SAS 9.0.[34] Estimations of regression models were conducted using SUDAAN 9.0.1.[35]

3-3-5 Hypotheses

Expected signs of coefficients were informed by evidence from clinical, epidemiological and population-health studies. In linear regression models, we expected that both advanced age and having a higher number of chronic conditions would be negatively associated with HRQL. Higher educational attainment was expected be associated with higher HRQL.[36,37] Given that we defined the reference groups for financial and marital status to be those who did not receive social assistance and those who were married, we expected the coefficients on receiving social assistance and being single, divorced, widowed or separated to be negative. We did not consider *a priori* hypothesis for gender and race variables. Lifestyle factors such as drinking and smoking behaviour were also included and it was hypothesized that they would be negatively associated with HRQL. Finally, although systematic differences in responses between proxy and self reports are often observed, the direction of the effects of proxy responses on HRQL cannot be examined in the current analyses due to the absence of paired data for proxy- and self-report respondents. Therefore, no *a priori* hypothesis was specified for effects of information source. In logistic regression models, we hypothesized that lower HUI3 scores, advanced age, a higher number of chronic conditions, lower education, receiving social assistance and not being married would all be associated with increased odds of being in an institution. For parameters with *a priori* hypotheses, hypothesis tests were based on one-sided tests. Two-sided tests were considered for other parameters.

3-4 Results

3-4-1 Sample selection and comparison

Of the original sample of 83,922 observations (n = 81,804 for the community sample and n= 2,118 for the institutional sample), those who did not have survey design information and/or those under 40 years old (n=43,026) were eliminated, leaving 40,896 observations. Of the targeted sample of 40,896, due to missing values for at least one of the variables used in our analyses, an additional 4,784 observations were eliminated. Therefore, the final sample size was 36,112 (34,763 for the community sample and 1,349 for the institutional sample). Comparisons of included (n=36,112) and excluded (n=4,784) samples showed that the excluded sample was older (mean (SD) ages were 56.7 (13.07) and 60.7 (11.97) years old for the included and excluded samples, respectively) and had lower overall HUI3 scores (mean (SD) overall HUI3 scores were 0.86 (0.229) and 0.81 (0.266), respectively). The excluded group had higher proportions of individuals who did not complete high school (36.5% for the excluded group and 31.7% for the included group), were not married (33.0 % and 28.1%, respectively) and were former drinker/abstainer (41.6% and 27.1%, respectively). In addition, a higher proportion of responses were based on proxy reports in the excluded group (10.8%) compared with the included sample (3.2%).

3-4-2 Descriptive statistics

The mean overall HUI3 score for the community sample was importantly higher than that for the institutional sample (Table 3-1). The average age for the community sample was lower than that for the institutional sample. In fact, close to one half of individuals (44.8%) living in the institutions were over 85 years old, whereas more than 70% of those living in the community were under 65 years old. In addition, on average, those in institutions had more chronic conditions than those living in the community. Fifty percent of the community sample did not have any of the specified conditions; the proportion was only 9.2% in the institutional sample.

Noticeable differences in socio-economic characteristics were found for the education, marital status, alcohol and tobacco variables. Individuals in institutions tended to be less educated, not married, non-current drinker and/or non-smoker. Finally, the proportion of proxy responses was higher for the institutional sample with 55.5% of responses from proxy reports. In contrast for the community sample, 97.4% of responses were based on self-report.

3-4-3 Comparison of determinants between community and institutional samples

3-4-3-1 Partial F-test

We conducted a partial F-test for the equality of the determinants of health parameters using a combined sample of the community and institutional samples (n =

36,112). The adjusted Wald F-statistic for the partial F-test was statistically significant ($p < 0.001$), leading us to reject the null hypothesis of the equality in parameters (Table 3-2). Therefore, we conclude that the determinants of health model significantly differed between the two populations. Coefficients for the interaction terms indicated that the determinants of health factors differed between the two groups with respect to age, the number of chronic conditions, financial status (receiving social assistance), marital status and report by a proxy respondent. Coefficients of the interaction terms for gender and alcohol with the resident indicator variable were not statistically significant ($p = 0.09$ and $p = 0.08$, respectively).

3-4-3-2 Stratified analyses

With a rejection of the partial F-test, we conducted the independent multiple regression analysis of HUI3 score for residents from community and institution. Results are shown in Table 3-3.

Community sample

Except for gender and race, all other variables in the stratified model for the community sample were statistically significant at 5% level (Table 3-3). Compared with those aged between 40 to 65 years old, those between 75 and 84 had significantly lower (by 0.046) mean overall HUI3 score. Similarly, on average, those in the oldest age group (≥ 85) had a lower mean (by 0.194) overall HUI3 score compared with the youngest (40-65) age group (mean overall HUI3 score for the youngest age group was 0.90). However, no statistically significant difference was found in overall HUI3 scores between those in the age group 40-64 and those in the age group 65-74. We also found that the average HUI3 scores were lower for those with a greater number of chronic conditions. Compared with the reference group (has none of the chronic conditions), the overall HUI3 score for those with one chronic condition was, on average, 0.047 lower. The difference in mean HUI3 scores was as great as 0.382 for the comparison between those with no chronic conditions and those with four or more conditions. Furthermore, lower educational attainment, receiving social assistance, being single, widowed, separated or divorced, and being a current/former smoker were all associated with lower mean overall HUI3 scores. The mean overall HUI3 score was 0.038 higher for current drinkers than for former drinkers/abstainers. The mean overall HUI3 score was significantly and importantly lower (-0.204) for proxy report than for self-report.

Institutional Sample

Results from institutional sample differed from the community sample with respect to age, education, financial status, marital status and smoking (Table 3-3). Mean overall HUI3 scores for the older age groups were significantly higher for those living in the institutions. More specifically, contrary to findings from the community sample, coefficients on ages 65-74 and 75-84 groups were positive (0.095 and 0.081, respectively) ($p < 0.10$), indicating that mean overall HUI3 scores were importantly higher for these two age groups than for those in the youngest age group. For the institutional sample, none of the estimated coefficients for education, financial status, and smoking were statistically significant. We also found that the mean overall HUI3 score for single, divorced, separated or widowed individuals was 0.103 higher ($p < 0.001$) than the score for those who were married. Consistent with findings from the community sample, those with chronic condition(s) had, on average, significantly lower overall HUI3 scores than those without any of the defined chronic conditions. In addition, the negative effect of having chronic condition(s) on HRQL was larger as the number of chronic conditions increased. Finally, consistent with findings from the community sample, the mean overall HUI3 score for current drinkers was significantly and importantly higher (0.096, $p < 0.01$) than that for former drinkers or abstainers, and the mean score for proxy reports was significantly and importantly lower (-0.377, $p < 0.001$) than that for self report.

3-4-3-3 Factors associated with the probability of being in an institution

We further assessed factors associated with the selection of being in an institution with a logistic regression. Table 3-4 shows results of the logistic regression. All variables except for gender were importantly associated with the probability of being in an institution. More specifically, we found that factors such as lower health status, advanced age, a higher number of chronic condition, lower education, lower financial status, not being married and smoking were all associated with greater odds of being in an institution. In particular, those with severe health (HUI3 ≤ 0.70) had almost 11 times greater odds of being in an institution compared with those with perfect health or mild disability (HUI3 ≥ 0.89), controlling for other determinants of health factors. In addition, as age increases, the odds of being in an institution also increased from 2.71 (age 65-74) to 5.45 (age 65-64) to 12.37 (age $\geq$ 85) compared with the youngest age group (age 40-64). Similar increasing trends were also found for impacts of the number of chronic conditions on the odds of being in an institution: Odds of being in an institution for individuals who were single, divorced, separated or widowed was 6.45 times as high as those who were married, common-law or with partner. Consistent with previous studies, controlling for other factors, our results showed no significant gender difference in the odds of being in an institution.

3-4-3-4 Model diagnostics

A series of model diagnostics indicated that the model specifications for final models were appropriate. For the linear regression models, potential existence of influential observation, outliers or collinearity was not evident. Results of informal endogeneity tests showed that our study implications did not change when income and marital status variables were excluded from stratified models. Therefore, these variables were treated as exogenous. For the logistic regression model, a plot of differences in observed and predicted probabilities showed large residuals for institutional sample relative to those for the community sample. The lack of fit of the institutional sample may be partly due to its small sample size (institutional sample consisted of approximately 4% of the total sample size). Plots of Pearson chi-square, deviance and estimated regression coefficients with deletion of the observation against predicted probabilities indicated a few potentially influential observations. Therefore, a sensitivity analysis was conducted by excluding these extreme observations. An exclusion of these observations altered the size of odds ratio estimates and/or their significance level for some variables (results not shown). However, these changes did not affect study implications.

3-5 Discussion

We found that the determinants of health models differed importantly between respondents living in the community and those living in long-term care institutions. Consistent with previous studies, lower health status, older age, lower education, lower financial status and not being married were all associated with a higher probability of being in an institution. We also showed that a higher number of chronic conditions, being a smoker and being a non-drinker were associated with higher probability of being in an institution. These results imply important heterogeneity in characteristics between those living in the community and those living in institutions. Based on stratified analyses, it was found that these factors (except for race) were also important determinants of HRQL of individuals living in the community. However, older age, lower education and lower financial status were not important in explaining variations in HRQL for those in institutions. In addition, not being married was found to have positive impacts on HRQL for the institutional subjects; these findings differed from results for those living in the community.

Contrary to usual observation of the negative association between age and HRQL, results from institutional sample showed that the overall HUI3 scores for ages 65-74 or 75-84 groups were importantly higher than scores for the youngest age group (40 to 64). Our finding is consistent with a recent Canadian study[1] that older individuals had greater odds of reporting good, very good or excellent self-perceived health. Ramage-Morin (2006) provided three possible explanations for this finding. First, it could be those who have attained older age perceive themselves as healthier than others, simply because they have lived longer than others. Second, it could be that individuals survive because they are healthy, the so called "healthy survivor effect".[1] Finally, *change* in health status, instead of its absolute level, may affect the subject's perception of their self-rated health. Younger individuals who were admitted to institutions may have experienced a rapid decline in their health status that necessitated institutionalization. Such younger individuals may evaluate their health more pessimistically than residents who were institutionalized at an older age. In our analysis, the youngest age group was defined as age 40 to 64 years old. Our finding indicated that the mean HUI3 score for those 40 to 64 years old was lower than the mean in the 65-84 age group, perhaps partly because those 40 to 64 years old were in long-term institutions because of their acute and/or severe health problems – a form of selection bias.

It was found from the stratified models that effect of alcohol consumption on HRQL was positive, which was opposite to our *a priori* expectation. Controlling for other factors, current drinkers on average had 0.038 (0.096) higher HUI3 scores compared with current non-drinkers for the community (institutional) sample (Table 3-4). Growing evidence shows beneficial effects of moderate alcohol consumption on health. Therefore, the observed positive effect may be due to the definition of alcohol consumption used in the analysis that did not differentiate light to moderate drinkers from those who are heavy drinkers.

Our results also showed that marital status had a negative association with HRQL for those living in institutions. This finding differs from the usual result of a positive impact of marriage on health.[38,39] It has been noted that marriage provides (1) economic advantage (e.g. a higher living standard), (2) emotional and instrumental support, and/or (3) a guard against risky behaviours, resulting in better health.[38] However, these mechanisms may not apply for those living in institutions. For example, those who are in institutions (even if they are married), may rely on other resources available in the institution to provide emotional/instrumental support and the monitoring of health behaviours. Results from Ramage-Morin (2006) are similar. Ramage-Morin found that those having at least one close staff member had significantly higher odds of reporting positive self-perceived health. In contrast, having at least one close relative or friend outside of the facility did not show any significant association with reporting positive self-perceived health. These results imply that having interactions with someone inside of the facility may be a more important factor than the existence or absence of spouses for residents in institutions. Exploring the differential roles of marriage and other types of social interaction/support on HRQL in institutional settings may warrant additional research.

We address five potential study limitations. First, comparisons of the two determinants of health models based on stratified analyses should be made with caution due to the differences in the proportion of variations explained for each model. The model for the institutional sample explained almost twice the variance (Weighted R^2 = 0.46) as was explained for the community sample (Weighted R^2 = 0.25). Although there was more variability in HUI3 scores among subjects in the institutional sample than in the community sample, the independent variables explained less of the variability in HUI3 scores in the community sample than in the institutional sample. One possible reason for the difference in variance explained may be that health status of respondents in institutions are, on average, so severe (shown by low overall HUI3 scores) that only a few key variables (e.g. the number of chronic conditions) may be sufficient to explain a large proportion of variations in the outcome variable. However, a stratified analysis has its advantage over the single model with interactions (i.e. equation 1) in terms of its simplicity in interpreting results.

Second, information on severity of chronic conditions was not available in NPHS. As a result, only the number of chronic conditions was controlled for in the model. The lack of information about disease severity prevented us from further investigating the association between age and health in these samples. Controlling for the number of chronic conditions, age was positively associated with health in the institutional sample. Further descriptive statistics of the mean number of chronic conditions by age group (40-65, 65-74, 75-84 and 85+) showed that, in general, the mean number of chronic conditions increased as age increased for both the community and institutional samples (mean number of conditions for the four age groups were 0.6, 1.4, 1.9, and 2.0 for the community sample and 1.8, 2.6, 3.2 and 3.1 for institutional sample). Therefore, it could be that not only the number of conditions but also the severity of illness accounts for the reported lower HRQL of the youngest age group in the institutional sample. Alternatively, it could be that the decline in health status experienced by those who entered institutions at a relatively young age, before age 65, triggered further declines in health and this accounts for the low HRQL observed in the younger group. Assessing such dynamic impacts of health conditions on the evaluation of health status requires the use of longitudinal data.

Third, the number of chronic conditions was calculated based on questions asking whether or not one had '…"long-term conditions" …that have lasted, or are expected to last, 6 months or more that have been diagnosed by a health professional'.[12] Responses were based on self or proxy reports and the accuracy of responses was not confirmed by objective sources. Therefore, the reported number of chronic conditions may be subject to bias. For example, respondents may not realize the existence of some conditions, or they may refuse to admit the existence of certain conditions. Moreover, subjective responses may also suffer from recall bias. These biases may over or underestimate the number of reported chronic conditions.

Fourth, unexpected findings, in particular age and marital status for institutional sample, may be spurious. For instance, the finding of positive effects of older age (or being not married) on mean HUI3 scores from the institutional sample may be due to selection bias; i.e. those who are older (or not married) may be more likely to become institutionalized possibly due to the lack of home support compared with others with the same level of HRQL. Hence, older (or not being married) individuals living in institutions may have higher HRQL than others in institutions. Similarly, observed association between tobacco or alcohol and HRQL may be confounded by factors such as institutional rules and restrictions. For example, the observed positive association between current drinker and HRQL may be due to limited access to alcohol for those with lower HRQL who are living in institutions.

Finally, variables indicating social interaction or social support beyond marital status (e.g. having close staff members, friends and/or relatives, frequencies of participation in activities) were not included in our analyses. This was because such questions were not asked in the community survey, or if asked, they were presented in different contexts. Our results, like results from several others, suggest the possibility of different roles for marriage and other forms of social supports in influencing the HRQL of institutionalized residents. Further exploration of relative importance of various forms of social interaction/support on HRQL may be warranted.

3-6 Conclusion

This paper reports on a unique study that formally tested the differences in the determinants of health factors between those living in the community and those living in long-term care institutions using representative samples of the Canadian population. Using merged data of the community and institutional population health surveys, we found that the determinants of health model importantly differed between those living in the community and those living in long-term care institutions. More specifically, our results indicated that the usual determinants of health such as advanced age, lower financial status, lower educational attainment and smoking were less important factors for those living in institutions. Instead, factors such as the number of chronic conditions and alcohol consumption seemed to be key determinants of HRQL of residents in institutions. The major implication of our study is that it is important to recognize heterogeneity in determinants of health factors among various types of populations, in our case, among those living in the community and those living in long-term care institutions.

Disclaimer

The research and analysis reported in this paper are based on data from Statistics Canada and the opinions expressed do not represent the views of Statistics Canada.

Table 3-1 Descriptive statistics for community and institutional samples

	Community (n = 34,763)	Institution (n = 1,349)
	Mean (SD)	Mean (SD)
Overall HUI3 scores	0.87 (0.208) [a]	0.17 (0.373)
Age	56.4 (12.55)	80.5 (12.25)
	Proportion (%) [b]	Proportion (%)
Age groups		
Age ≥ 85	2.0	44.8
Age 75 – 84	8.5	30.8
Age 65 – 74	16.8	14.0
Age 40 – 64 (Ref)	72.8	10.4
# of chronic conditions (groups)		
Has 1 condition	26.8	14.5
Has 2 conditions	13.1	21.4
Has 3 conditions	5.8	19.1
Has 4 conditions	2.5	15.1
Has > 4 conditions	1.5	20.6
No condition (Ref)	50.3	9.2
Gender		
Female	51.9	69.3
Male (Ref)	48.1	30.7
Education		
Less than high school	31.2	71.0
At least high school (Ref)	68.8	29.0
Race		
Non-white	7.7	3.0
White (Ref)	92.3	97.0
Social assistance		
Yes	4.9	8.2
No (Ref)	95.1	91.8
Marital status		
Single, divorced, widowed or separated	27.3	84.0
Married, common-law or with partner (Ref)	72.7	16.0
Alcohol		
Current drinker	73.5	27.0
Former drinker/abstainer (Ref)	26.5	73.0
Smoking		
Current or former smoker	61.2	48.9
Never smoked (Ref)	38.8	51.1
Information source		
Proxy	2.6	55.5
Self-report (Ref)	97.4	44.5

Note: Information source: for community sample, Proxy = proxy for health component questionnaire; for institutional sample, Proxy = staff or family proxy
Ref = Reference Group.

[a] Mean overall HU3 scores as well as mean age significantly differed between community and institutional samples ($p < 0.01$).

[b] Distributions of all the categorical variables significantly differed between community and institutional samples ($p < 0.01$).

Table 3-2 Multiple linear Regression Analysis of HUI3 scores for community and institutional sample combined (n=36,112)

Variable		Coeff	SE	p
Intercept		0.926*	0.005	<0.001
Institutionalization [a]	Yes (INST)	−0.454*	0.055	<0.001
Age	Age ≥ 85	−0.194*	0.027	<0.001
	Age 75-84	−0.046*	0.009	<0.001
	Age 65-74	0.006	0.006	0.32
# of chronic conditions [b]	Has 1 condition (NCC=1)	−0.047*	0.004	<0.001
	Has 2 conditions (NCC=2)	−0.104*	0.007	<0.001
	Has 3 conditions (NCC=3)	−0.164*	0.011	<0.001
	Has 4 conditions (NCC=4)	−0.273*	0.022	<0.001
	Has>4 conditions (NCC>4)	−0.382*	0.023	<0.001
Gender	Female (FEMALE)	0.003	0.004	0.40
Education	No high school (LOWEDU)	−0.023*	0.005	<0 .001
Race	Nonwhite (NONWHITE)	0.004	0.007	0.61
Receive social assistance	Yes (ASSIST)	−0.067*	0.012	<0.001
Marital status	Not married (NOTMARR)	−0.013*	0.004	0.003
Smoking	Ever smoked (EVERSMK)	−0.021*	0.004	<0.001
Alcohol	Current drinker (DRINK)	0.038*	0.005	<0.001
Information source	Proxy (PROXY)	−0.204*	0.020	<0.001

Table continued ...

Interaction terms	INST × Age			<0.001 [d]
	INST × Age ≥ 85	0.237*	0.055	<0.001
	INST × Age 75-84	0.126*	0.047	0.008
	INST × Age 65-74	0.089*	0.049	0.07
	INST × NCC			<0.001 [d]
	INST × NCC=1	−0.082*	0.039	0.036
	INST × NCC=2	−0.108*	0.037	0.003
	INST × NCC=3	−0.124*	0.038	0.001
	INST × NCC=4	−0.032	0.045	0.47
	INST × NCC>4	0.030	0.047	0.52
	INST × FEMALE	−0.032	0.019	0.09
	INST × LOWEDU	0.011	0.018	0.56
	INST × NONWHITE	0.013	0.041	0.75
	INST × ASSIST	0.137*	0.054	0.011
	INST × NOTMARR	0.116*	0.021	<0.001
	INST × EVERSMK	0.005	0.019	0.79
	INST × DRINK	0.058	0.033	0.08
	INST × PROXY	−0.173*	0.031	<0.001
Weighted R^2	0.35 [c]			

Notes: Dependent variable is overall HUI3 scores.

Abbreviations: Coeff, regression coefficients; SE, Taylor linearization standard errors; p, p-values

* statistically significant at 5%.

[a] A dichotomous variable indicating place of residency (=1 if institution, =0 if community).

[b] Target chronic conditions are conditions common to heath and institutional files: asthma, arthritis, high blood pressure, chronic bronchitis, diabetes, epilepsy, heart disease, ulcers, stroke, urinary incontinence, Crohn's disease, Alzheimer disease, cataracts, glaucoma, and thyroid conditions.

[c] Weighted R^2 reported here partially takes account of survey design, adjusted R^2 is lower than R^2 but was not calculated.

[d] A p-value for a joint significance.

Table 3-3 Regression results of HUI3 scores from independent multiple linear regression analysis (Stratified analyses)

	Community (n=34,763)		Institution (n=1,349)	
Variable	Coeff	95% CI [b]	Coeff	95% CI [b]
Intercept	0.926*	0.916, 0.936	0.472*	0.366, 0.578
Age [§]				
Age ≥ 85	−0.194*	−0.238, −0.150	0.044	−0.035, 0.123
Age 75-84	−0.046*	−0.061, −0.031	0.081 [c]	0.005, 0.157
Age 65-74	0.006	−0.004, 0.016	0.095	0.014, 0.176
Age 40-65 (ref)				
# of chronic conditions [a §]				
Has 1 condition	−0.047*	−0.054, −0.040	−0.129*	−0.193, −0.065
Has 2 conditions	−0.104*	−0.116, −0.092	−0.212*	−0.271, −0.153
Has 3 conditions	−0.164*	−0.182, −0.146	−0.288*	−0.349, −0.227
Has 4 conditions	−0.273*	−0.309, −0.237	−0.305*	−0.369, −0.241
Has > 4 conditions	−0.382*	−0.420, −0.344	−0.351*	−0.418, −0.284
Has no condition (ref)				
Gender				
Female	0.003	−0.005, 0.011	−0.029	−0.066, 0.008
Male				
Education [§]				
No high school	−0.023*	−0.031, −0.015	−0.012	−0.042, 0.018
At least high school (ref)				
Race				
Nonwhite	0.004	−0.010, 0.018	0.017	−0.063, 0.097
White (ref)				
Receive social assistance [§]				
Yes	−0.067*	−0.087, −0.047	0.070	−0.016, 0.156
No (ref)				
Marital status [§]				
Not married	−0.013*	−0.020, −0.006	0.103*	0.068, 0.138
Married (ref)				
Smoking [§]				
Ever smoked	−0.021*	−0.028, −0.014	−0.015	−0.046, 0.016
Never smoked (ref)				
Alcohol [§]				
Current drinker	0.038 [c]	0.030, 0.046	0.096 [c]	0.042, 0.150
Former drinker/abstainer (ref)				
Information source				
Proxy	−0.204*	−0.243, −0.165	−0.377*	−0.426, −0.328
Self-report (ref)				
Weighted R^2	0.25 [d]		0.46	

Notes: Dependent variable is overall HUI3 scores.

Abbreviations: Coeff, regression coefficients; 95% CI, 95% confidence intervals based on Taylor linearization.; * Statistically significant at 5%.; † Reference group.; § Hypothesis tests are based on one-sided tests.

[a] Target chronic conditions are conditions common to heath and institutional files: asthma, arthritis, high blood pressure, chronic bronchitis, diabetes, epilepsy, heart disease, ulcers, stroke, urinary incontinence, Crohn's disease, Alzheimer disease, cataracts, glaucoma, and thyroid conditions.; [b] 90% confidence intervals were calculated for one-sided tests.; [c] Coefficients on Age 75-84 and Age 65-74 for the institutional sample as well as coefficients on Alcohol are statistically significant but have opposite signs from *a priori* hypotheses.; [d] Weighted R^2 reported here partially takes account of survey design, adjusted R^2 is lower than R^2 but was not calculated.

Table 3-4 Adjusted odds ratios of institutionalization from multiple logistic regression (n=36,112)

Variable	Odds ratio	95% CI [b]
Overall HUI3 scores [§]		
Severe (HUI3 = < 0.70)	10.74*	7.57,15.24
Moderate (0.70 < HUI3 = < 0.88)	3.43*	2.45, 4.81
None/mild (HUI3≥ 0.89) [†]	1.00	—
Age [§]		
Age ≥ 85	12.37*	8.74, 17.51
Age 75-84	5.45*	4.04, 7.35
Age 65-74	2.71*	2.07, 3.56
Age 64 and under [†]	1.00	—
# of chronic conditions [a §]		
Has>4 conditions	1.74*	1.01, 3.00
Has 4 conditions	1.63*	1.11, 2.42
Has 3 conditions	1.51*	1.08, 2.11
Has 2 conditions	1.20	0.82, 1.77
Has 1 condition	0.97	0.69, 1.34
No condition [†]	1.00	—
Gender		
Female	1.04	0.74, 1.44
Male [†]	1.00	—
Education [§]		
No high school	1.33*	1.09, 1.63
At least high school [†]	1.00	—
Race		
Nonwhite	0.28*	0.13, 0.62
White [†]	1.00	—
Receive social assistance [§]		
Yes	1.97*	1.33, 2.90
No [†]	1.00	—
Marital status [§]		
Not married	6.45*	4.91, 8.47
Married/common-law/with partner [†]	1.00	—
Smoking		
Ever smoked	1.46*	1.09, 1.94
Never smoked [†]	1.00	—
Alcohol		
Current drinker	0.55*	0.41, 0.73
Current non-drinker [†]	1.00	——
Information source		
Proxy	10.19*	7.03, 14.77
Self report [†]	1.00	—

Note: Dependent variable =1 if institutional resident, =0 if community resident.

Abbreviations: Coeff, regression coefficients; 95% CI, 95% confidence intervals based on Taylor linearization.

* Statistically significant at 5%

[†] Reference group

[§] Hypothesis tests are based on one-sided tests

[a] Target chronic conditions are conditions common to heath and institutional files: asthma, arthritis, high blood pressure, chronic bronchitis, diabetes, epilepsy, heart disease, ulcers, stroke, urinary incontinence, Crohn's disease, Alzheimer disease, cataracts, glaucoma, and thyroid conditions

[b] 90% confidence intervals were calculated for one-sided tests

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Chapter 4: Trajectories of health-related quality of life differ by age among adults: Results from an eight-year longitudinal study

4-1 Abstract

In this study, growth-curve models were used to investigate health-related quality of life (HRQL) trajectories among the general adult population and to determine the association between the individual characteristics and variations among trajectories.

The data from Cycles 2 (1996/97) to 6 (2004/05) of the Population Health Survey, a longitudinal survey conducted in Canada were used for the study. The target population was those aged 18 years and older in Cycle 2, including those who were subsequently institutionalized and/or died. Information for 13,665 respondents with 53,151 records in total was used in the analysis. Health Utilities Index Mark 3 (HUI3) was used as the HRQL measure. Separate HRQL trajectories were estimated for young (age 18-39), middle-aged (40-64) and seniors (65+). Socio-demographic and lifestyle factors were included as independent variables in the model. Dichotomous variables indicating institutionalization, death and cohort membership were also included.

Initially, unconditional models were fitted separately to determine unadjusted HRQL trajectories for the three age groups. In particular, significant cohort effects were observed in the middle-aged and senior groups. A typical life course trajectory was estimated as concave with a HUI3 score of around 0.95 at age 18 with a very slow decline until the age of 60 (HUI3 around 0.80), followed by a rapid decline. At the age of around 90, the predicted HUI3 was as low as 0.30. Results from conditional models showed that factors associated with trajectories differed substantially between the age groups. Receiving social assistance, not having a high school diploma and not being married had significant negative impacts on HRQL trajectories for young and middle-aged groups. These factors were not significant for seniors. However, unfavourable lifestyle factors (i.e. abstaining from alcohol, smoking and physical inactivity) had significant negative effects on HRQL trajectories for seniors. In particular, the average decrement in the HRQL trajectory when one became inactive was 0.05 for seniors, more than twice as great as was found for the young (0.02) and

middle-aged (0.02) ($p<0.01$ for all parameters). In contrast, having more chronic conditions lowered the mean trajectories by similar magnitudes regardless of age.

Important heterogeneities in life-course HRQL trajectories were found in the study. Understanding differential impacts of the determinants of health factors on trajectories is important in developing effective health policy for various life stages.

4-2 Introduction and background

In the typical framework, health is determined by a number of demographic, socio-economic and health behavioural factors that interact in a complex manner. Time is another dimension that adds within-individual changes in health through the aging process but also adds dynamics to the association between health determinants.[1] Although cross-sectional studies have shown that age is one of the important determinants of health factors, the impact of age on individual-level changes in HRQL over time for the general population has been under-investigated to date. Cross-sectional studies are useful to identify factors (including age) associated with varying levels of health at a certain point in time. However, in cross-sectional analyses, age and cohort effects are perfectly confounded, namely, the observed cross-sectional age difference in health may be due to the actual aging process and/or it could be as a result of factors other than age that are fundamentally different across individuals in different ages (or cohorts). Therefore, the analyses of longitudinal data is important to disentangle the phenomena.[2,3]

To date, only a few Canadian studies have examined longitudinal surveys to assess factors associated with general health status over time for general adult population[4], middle-aged to seniors[5], and seniors.[6,7] Shooshtari *et al* (2007)[4] used Cycles 1 (1994/95) to 3 (1996/97) of the National Population Health Survey (NPHS) household longitudinal data and assessed various determinants measured at Cycles 1 or 2 that predicted health outcome (self-rated health) at Cycle 3, as well as examined whether those factors differ for younger (age 25-54) and older adults (55+) (n=9,371). Using logistic regression analyses, the authors found that factors such as age, number of chronic conditions, functional limitations, income, education, social environment (social involvement and frequency of social contacts), genetic factors (premature death of parents), and health behaviours (self-esteem, alcohol, tobacco, physical activity, BMI) were important predictors of future health. On the other hand, chronic conditions and health behavioural factors were the important predictors for the older adults. Therefore, the authors concluded that compared with older adults, factors predicting future health for younger adults included a broader array and greater number of factors compared with those important for older adults.

Consistent findings with Shooshtari *et al* (2007) were reported in a study by Martel *et al* (2005)[5], which modeled changes in self-rated health over time more explicitly using five cycles of NPHS household longitudinal data. Their analysis was restricted to the middle-aged (age 45-64, n=2,498) and seniors (age 65+, n=1,310) who were in "good health" (based on the summary of four definitions of health: functional health, functional independence, mental health and self-rated health) and were residing in the community at Cycle 1. Using Cox proportional hazard models, the authors examined baseline determinants of health factors that were associated with declines in health status or maintaining good health by Cycle 5. For the middle-aged group, advanced age, not living with spouse, low income, low education, and having chronic conditions were important predictors of the incidence of declines in health status. On the other hand, in addition to older age and low education, factors associated with declines in health status over time for seniors were mainly chronic conditions and health behaviours (e.g. smoking, physically inactive, not having normal weight, never drank).

A study by Shields and Martel (2006)[6] also used NPHS household longitudinal data and focused on seniors (65+) who were initially in good health in Cycle 1 (n=1,309) to assess factors associated with maintaining good health over the eight-year follow-up period (Cycles 1 to 5). The authors used a Cox proportional hazard model with the same definition of "good health" as in Martel et al (2005). In addition to socio-demographic factors (such as advanced age), they found that living alone, low education and higher numbers of chronic conditions, and health behavioural factors (physical inactivity, being an abstainer or being a smoker) were associated with a higher risk of no longer being in good health over time. On the other hand, financial stress was not a significant risk factor.

Buckley et al (2004)[7] used three-year (1996-98) panel data from the Canadian Survey of Labour and Income Dynamics to examine the possible causal effects of socio-economic status (SES) on self-reported health for those aged 50 years and older. To assess temporal relationships between SES and health, the study focused on respondents who reported good health (i.e. excellent, very good or good) at baseline (1996). Using a probit model, they estimated the probability of remaining in good health in each of the following two years, conditional on being in good health at baseline. In independent analyses of males (n=7,752) and females (n=9,137), little differences were observed in factors associated with the incidence of declines in health status between males and females. For both groups, those with low income or low education in 1996 had a greater probability of declines in health status in 1997 and/or

1998. In addition, males who became non-married during the follow-up had a greater probability of declines in health; no such association was observed in females.

The above studies were predictive studies, which examined whether factors assessed at the beginning of the follow-up periods were associated with the incidence of the outcomes of interest. These studies importantly assess dynamic impacts of risk factors on health outcomes. However, they used only a few years of the follow-up data or used two extreme ends of the available data; information between the two cycles are often left unutilized.[8]

The health trajectory analysis approach examines changes in health over time from an alternative perspective. The approach recognizes a series of health transitions as a lifetime sequence[9] and analyzes dynamic associations between health and its determinants over time across various stages of the lifecycle.[1,8,10-13]

A study by McCullough and Laurenceau (2005)[11] was based on the Terman Life Cycle Study of Children with High Ability. The study was one of the longest longitudinal studies that followed a single cohort of children aged 11 and 12 years old in California, USA between 1921/1922 and 1999. Using 59-year data from 1940 to 1999 (n = 1,411 individuals with 9,022 records), the authors estimated trajectories of self-rated health (SRH) for males and females aged between 20 and 94 years old. Results from growth curve models showed that the trajectory was approximated by a curvilinear form; for both men and women, SRH was stable until the age of approximately 50. After the age of 50, the decline in SRH accelerated. Moreover, at age 20, males on average had higher SRH but, over time, SRH of males declined more rapidly and by the age of 80, trajectories of both males and females overlapped. The study provided important insight into the general shape of health trajectories that were estimated with a large sample size and with a long period of follow-up. However, several study limitations should be also noted. First, the study population was limited to intellectually bright children. As well, because only a single cohort of children was followed, the generalizability of study results was a potential concern. Second, sex was the only covariate used for the analyses. Therefore, the authors noted that the assessment of other individual characteristics that may influence trajectories is one of their future research interests.

Other studies investigating trajectories used accelerated longitudinal data[14,15], where individuals in a wide range of baseline ages are simultaneously followed for a relatively short time period. A study by McDonough *et al* (2005)[1] was based on annual waves (from 1968 to 1996) of the United States Panel Study of Income Dynamics that consisted of household heads and spouses (n=4,351). With the availability of long-term income information, the study investigated lagged impacts of income on the subsequent trajectories. More specifically, the authors examined whether or not different courses of poverty history (i.e. stable non-poor, exiting poverty, entering poverty, and stable poverty) during the first 14 years of the survey (1968 to 1982) were associated with the SRH trajectories for the subsequent 12 years (1984 to 1996), controlling for current income levels and other demographic and socio-economic factors. The trajectories were estimated separately for each of the four groups of poverty history. Results showed that SRH trajectory was generally represented as linear with slow decline over 12 years. However, the levels of trajectories also depended on various demographic and socio-economic characteristics. In particular, important differences in initial SRH levels between those who did not experience any poverty history (stable non-poor) and other groups were found among whites, older or less educated individuals. In addition, exiting from poverty during the 1960s to the early 1980s importantly raised the subsequent SRH trajectories, but such beneficial effects of becoming non-poor applied only to African-Americans, those with high education or younger respondents.

Sacker *et al* (2005)[12] focused their analyses on whether or not impacts of occupational classes on differences in health vary with age. Ten-wave follow-up data of the British Household Survey (1991-2001) was used in their analyses. Household residents with baseline ages between 21 and 59 years were followed for 10 years or until they reached 60 years in 2001. After excluding records with missing information for at least one of the important variables, 6,705 respondents were included in their analyses. Across the five occupational classes (professional/managerial, intermediate occupations, small employers/own account, lower supervisory/technical and semi-routine/routine), SRH declined with age with the rate of decline accelerating with age. However, heterogeneity in health among occupational classes was also found. For example, the health gap between professional/managerial and semi-routine/routine worker was not statistically significant in their 20s but the gap widened with age, showing that SRH for semi-routine/routine workers deteriorated more rapidly than that for individuals with professional/managerial occupations.

Herd (2006)[10] assessed how educational differences in health changed over time. The study was one of the few trajectory studies that explicitly took account of both cohort effects and mortality effects. In order to isolate cohort from age effects, the authors used a single cohort study, the six-wave (1992-2002) US Health and Retirement Study, a study that followed a single cohort of those aged between 51 and 61 in 1992 (n=9,825). Those who became institutionalized and/or died were retained in the analyses. The outcome of their interest was functional status, which was an ordered categorical variable based on seven functional categories. The challenge was to take account of mortality effects due to the absence of "real health value" after one dies. To assess mortality effects, the authors used sensitivity analyses by assessing impacts of excluding decedents from the analyses, performing a variety of imputations to retain health outcomes after death (e.g. last-observation carried forward, assuming linear rate of decline, imputing the worst possible health, multiple imputation). Results showed that the differences in functional status by education level widened until the age of 63. However, the gap diminished after the age of 63. Because sensitivity analyses showed little impacts on results, the authors concluded that their findings were not subject to mortality selection.

Finally, the objectives of a study by Shaw and Clause (2002)[13] were to model trajectories for seniors and to assess whether stress arising from various salient social roles was associated with varying trajectories. The representative US sample of the elderly (ages between 65 and 100 years old) was collected for three waves between 1992 and 1999 (n=605). After excluding individuals without complete information for any of the three waves, the SRH trajectories were estimated using 465 participants. Using a growth curve model approach, the SRH trajectory was estimated as a linear and downward-sloping curve. In addition, the statistically significant interaction term between age and salient stress indicated that the effects of salient stress on declining SRH worsened with age, controlling for various demographic and socio-economic factors. Therefore, the oldest old population was found to be more vulnerable to the salient stress. As the authors also noted, however, several important study limitations exist. First, the study used only three waves of the data. Therefore, the ability of the data to detect potential non-linear trajectories may be limited. In fact, a quadratic age term in their model was not statistically significant, possibly due to the short duration of follow-up. In addition, because the trajectories were estimated using data from respondents who had complete data for the three waves, the estimated trajectories and study results may be subject to sample selection.[14] In fact, in a separate logistic regression analysis by the study authors, older age, male sex, non-white, and lower baseline SRH were associated with the probability of being excluded from the analyses.

In summary, a review of existing studies provides at least two important considerations: there are important methodological complexities in estimating trajectories, and the existence of potential heterogeneity in trajectories. First, methodological challenges in analyzing longitudinal data are that cohort effects, mortality effects and other forms of sample selection are potential threats to the interpretation of results. Accelerated longitudinal data take less time to collect. However, the analysis of such data is subject to potential age-cohort effects. On the other hand, although the cohort effect is absent in a single age-cohort followed for a longer period, the results may not be generalizable to wider age-groups. Moreover, the issue of sample attrition is common to any types of longitudinal data, in particular, for those who died during the follow-up period. Previous studies tended to exclude individuals who died during the follow-up, which resulted in an important mortality bias.[16] The use of a growth curve model is one strategy to reduce potential selection bias because, for those who deceased, records prior to death for the decedents can be included in the analyses instead of excluding these individuals completely from the analyses. Nonetheless, such studies were still restricted to the analyses of samples excluding any records at the time of and after the incidence of death, implying that estimated trajectories from those studies still do not fully incorporate potential impact of death on trajectories. Even other studies that attempted to include health outcomes on or after death were challenged by the absence of valid values representing the state of being dead. Therefore, various imputation methods needed to be assessed. Second, a review of the literature earlier showed that estimated trajectories of general health are represented by a downward slope in which the rate of decline in health accelerates with age. However, many of the previous studies discussed earlier also found noticeable variations in the level as well as the shape of trajectories among various determinants of health factors.[3] Therefore, this study investigated these methodological issues as well as heterogeneities in trajectories.

In this study, longitudinal data from the National Population health Survey (NPHS) were used to investigate three research questions: What is the typical trajectory of HRQL and what does it look like? Does the cohort effect have an impact on HRQL trajectories? What factors are associated with variations among HRQL trajectories and does the importance of these factors differ by the phase of life?

4-3 Methods

4-3-1 Data

Statistics Canada NPHS household longitudinal data was used for the analyses. NPHS longitudinal data were collected to assess dynamic aspects of physical and mental health, health service utilization along with their demographic and socio-economic determinants. The target population of the NPHS longitudinal household data was those who resided in the community in ten provinces in Cycle 1 (1994/95). Those living on Indian reservations, Canadian Forces bases or in long-term care institutions were excluded from the household longitudinal data. Information for those who died in the subsequent cycles was retained in the household data. Once respondents moved to long-term care institutions, the NPHS institutional questionnaire was administered and information obtained by institutional questionnaire from these respondents were also included in the household data.[17]

In Cycle 1, 17,276 randomly selected individuals formed a longitudinal panel in 1994-95. The panel was followed every two years up to 20 years. No additional respondents were added to the longitudinal panel in the subsequent cycles. Except for Cycle 1, interviews were conducted mostly by telephone. For a respondent aged 12 years or older, proxy response was allowed only if the respondent was unable to conduct the interview due to illness or incapacity. For a respondent aged less than 12 years old, almost all information was provided by proxy respondents. At Cycle 6, the response rate was 77.4% (based on the initial longitudinal panel of 17,276 respondents).

Eight-year follow-up information from Cycles 2 (1996/97) to 6 (2004/05) was used for the analyses. The target population in the analyses was those who were 18 years and older in Cycle 2 (1996/97). Cycle 1 information was not included in the analyses for two main reasons. First, the mode of interview administration was changed from Cycle 1 (in-person interviews) to the subsequent cycles (telephone interviews). Although some studies found that respondents from telephone and in-person interviews showed only small differences when reporting socio-demographic, health indicators and lifestyle factors[18,19], others found important differences with respect to lifestyle variables such as physical activity, alcohol and tobacco[20], which were also variables of interest. Second, a list of physical activities to derive a physical activity index used in the analyses was importantly modified between

Cycles 1 and 2. Therefore, the use of Cycles 2 to 6 data helped minimize any impact of systematic differences in data collection and content over time.

4-3-2 Variables

Health Utilities Index Mark 3 (HUI3): HUI3 was used as the outcome measure in the analyses. HUI3 is a generic, multi-attribute utility-based HRQL measure capturing functional and emotional health. HUI3 is widely used in population health survey, clinical studies and cost-utility analyses.[21] HUI3 consists of eight attributes with five or six levels per attribute and it can describe up to 972,000 unique health states. HUI3 provides both overall and single-attribute utility scores. Overall scores range from 1.00 (perfect health) to -0.36 ("all-worst" HUI3 health state) where 0.00 is defined as the state of being dead. Single-attribute scores range from 1.00 (perfect level) to 0.00 (most disabled). Because the estimation of general health status was of interest, overall HUI3 scores were used for the analyses. HUI3 has been shown to be responsive under various clinical settings.[22] Overall HUI3 scores were able to predict five-year mortality in adults with brain tumors[23] and eight-year mortality in a representative sample of the general adult population (NPHS).[24] In addition, ceiling and floor effects are less evident for HUI3 compared with other utility measures.[25] Therefore, HUI3 was considered to be an appropriate measure in evaluating changes in general health status over time.

Cohort membership: To control for cohort membership, a set of dummy variables Cohort_i (i = individual) was also included in the cohort model. In order to estimate finer trajectories without sacrificing sample size for each cohort, cohort groups based on three-year bands for age were defined at baseline: (e.g., Cohort:18-28 for individuals with baseline age between 18 and 20 years old, which then ranges from age 18 to 28 years during the eight-year follow-up period).

Time: The variable, Time_{ti},was defined to indicate the person-median centered age which was obtained by subtracting the weighted median age of the particular cohort that person i belongs to from the age of the individual i at cycle t.[26] For example, if the age of a respondent (i) who joined the study was 20 years at Cycle 2, the respondent's age would be 22, 24, 26, and 28 at Cycles 3 to 6, respectively, and the respondent would belong to the Cohort 18 to 28 years. If the weighted median age for the cohort was, say, 22 years, then values for Time_{ti} for this respondent (i) were coded as -2, 0, 2, 4, 6, respectively at Cycles 2 to 6. Age of respondents at each cycle was calculated by subtracting their reported birth dates from their interview dates at each cycle. Quadratic and cubic variations of time were also considered in each model.

Demographic, socio-economic and health risk factors: The choice of the independent variables was informed by the determinants of health conceptual framework.[27,28] Variables of interest were: the number of chronic conditions (three dummy variables: no chronic condition (reference group), has one condition, has two conditions, has more than two conditions); *population characteristics:* sex (= 1 if female, = 0 if male), race (= 1 if non-white, = 0 if white), education (= 1 if no high school diploma, = 0 otherwise), income (= 1 if one receives social assistance, = 0 otherwise), marital status (=1 if single, divorced, widowed or separated, = 0 otherwise), and *health behavioural factors*: alcohol (two dummy variables: former drinker or abstainer (did not drink the last month or never drank), light to moderate drinker (drank in the past 12 months and zero to two drinks per day on average or daily/occasional drinker for those living in an institution; reference group), more than moderate drinker (drank in the past 12 months and more than three drinker per day on average), tobacco (= 1 if current or former smoker, = 0 otherwise), and physical activity index (= 1 if inactive, = 0 if active or moderately active). (Because information on a household income was frequently missing, income is represented in the model by the receipt or non-receipt of social assistance.) The variable on the number of chronic conditions was calculated by adding the number of long-term chronic conditions that an individual had or were expected to last for six months or more and had been diagnosed by health care professionals.[29] Because the list of chronic conditions differed throughout the cycles as well as between the household and institutional questionnaires, 13 conditions common across all of the questionnaires were selected (see Appendix F for the list of selected conditions). A finer categorization of the level of alcohol consumption was created to differentiate light to moderate drinkers from more frequent drinkers, as growing evidence shows beneficial effects of moderate alcohol consumption on various health outcomes.[5,24,30-33] Physical activity index was based on the total daily energy expenditure during the leisure time activities based on the frequency, duration and intensity of each activity.[34] Information on sex and race was measured at baseline (Cycle 2) and values for these were considered fixed at each cycle and referred to as time-invariant variables. Other variables were allowed to vary between Cycles 2 to 6 and hereafter referred to as time-varying variables.

Control variables: To control for potential impacts of death and institutionalization on trajectories, two time-varying variables were also included: DEAD = 1 for records indicating death, = 0 otherwise; INST = 1 for records indicating institutionalization, = 0 otherwise.

Missing information due to death or institutionalization: In the NPHS longitudinal survey, when an individual was reported to be deceased, his/her response on and the subsequent cycles were coded as missing ("not stated") for all the determinants of health variables. As mentioned earlier, information from the decedents up to the first record of death was retained by assigning HUI3 = 0.00. For the corresponding values for the determinants of health variables, last observed values for each decedent were carried forward (last observation carried forward, LOCF). For example, if a respondent was reported to be deceased at Cycle 4, then HUI3 was assigned "0" at Cycle 4 and values for other variables for Cycle 4 were carried forward from Cycle 3 for this respondent. Then HUI3 and all other independent variables were considered as missing for this respondent in Cycles 5 and 6 and only the information from Cycle 2 to Cycle 4 was included for this respondent in the analyses.

When an individual was institutionalized, the NPHS institutional questionnaire was administered. Then, responses obtained from the institutional survey were included in the NPHS longitudinal household data. However, the physical activity index was systematically coded as missing for those who were in institutions. Therefore, to retain records for those who were in institutions, the physical activity index for these records was imputed as "physical inactive", consistent with clinical observations that those who are in long-term institutions are generally physically inactive.

4-3-3 Statistical analysis

A mixed model approach was used to estimate trajectories and assess factors associated with variations among trajectories. Mixed models provide several important advantages over other methods with respect to the ability to incorporate repeated measures (correlated data within an individual), unequally spaced measurement occasions, and time-varying predictors[15,35], all of which are important characteristics of the NPHS longitudinal data. Mixed models are also flexible in handling unbalanced data (data missing for some cycles) provided that data are missing at random.[26]

As mentioned earlier, the survey design of NPHS is characterized as accelerated longitudinal design (i.e. wider age groups at baseline and shorter follow-up). To test whether there are non-ignorable cohort effects, cohort convergence tests[36] were conducted. These tests were done by comparing a model incorporating cohort effects ("cohort model" that generates segmented trajectories) with a model that estimates an overall trajectory (defined in Appendix G).

Statistical analyses were conducted in three steps. First, cohort effects were tested in the unconditional model using the convergence test described in Miyazaki and Raudenbush (2000).[36] Details of the methods for testing cohort effects are described in Appendix G. Secondly a conditional model was fitted with or without the cohort effects depending on whether they were significant or not in the unconditional model. Demographic and behavioral variables were tested in the conditional model. Only the significant variables were retained in the final conditional model. Finally, cohort effects were tested again in the conditional models using the convergence test. This was because even if cohort effects were statistically significant in the unconditional models, those cohort effects may be partially explained by variations in demographic or health behavioural variables and may disappear once these variables are controlled for.[36] If cohort tests were significant after controlling for these covariates, cohort effects were included in the final conditional model, otherwise, they were excluded. For all statistical analyses, to partially account for complex survey design, normalized sampling weights that represent the 1996/97 (Cycle 1) household population of Canadian provinces were used at an individual level. Statistical significance of each parameter was determined based on two-tailed tests, except that the significance of random effects were based on one-tailed tests.[37] With the use of normalized sampling weights, a p-value of less than 0.01 was considered as statistically significant for all statistical tests.[38]

In the preliminary descriptive statistics, the mean HUI3 scores over the five cycles for young to middle-aged groups (age of 18 to 64) were fairly stable over time compared with a noticeable concave decline in mean HUI3 scores for the senior group (age 65+ (results not shown)). Therefore, stratified analyses were conducted for the following three age groups: young (baseline ages between 18 and 39), middle-age (40-64) and seniors (65+). The approach was in line with the notion of the difficulty in estimating life-course trajectories.[14] Namely, changes in health during adulthood possibly take decades instead of years, and such changes may not occur until later in life, making it difficult to estimate appropriately the segments of trajectories where changes in health really occur. This is in contrast with trajectory studies for children and or adolescents for which the identification of the point of inflection and shape of trajectories are feasible because developmental patterns can be assessed in a relatively brief period of follow-up.

4-3-3-1 Statistical model

The following is a general formulation of the conditional cohort model used in the analyses:

$$Y_{ti} = \pi_{0i} + \pi_{1i}(TIME_{ti}) + \pi_{2i}(TIME_{ti})^2 + \varepsilon_{ti} \qquad \text{Equation 1}$$

$$\pi_{0i} = \gamma_{00} + \sum_{j=1}^{M} \gamma_{0j} Cohort_{ji} + \sum_{k=1}^{K} \delta_{0k} X_{ki} + \zeta_{0i} \qquad \text{Equation 2}$$

$$\pi_{1i} = \gamma_{10} + \sum_{j=1}^{M} \gamma_{1j} Cohort_{ji} + \sum_{k=1}^{K} \delta_{1k} X_{ki} + \zeta_{1i} \qquad \text{Equation 3}$$

$$\pi_{2i} = \gamma_{20} + \sum_{j=1}^{M} \gamma_{2j} Cohort_{ji} + \sum_{k=1}^{K} \delta_{2k} X_{ki} + \zeta_{2i} \qquad \text{Equation 4}$$

Where Y_{ti} is the HUI3 score of an individual *i* at time (cycle) *t*, *j*=1, …, M denotes the cohorts, and X_{ki} (*k*=1, …, K) denotes the determinants of health and control variables. $Time_{ti}$ is a cohort-median centered age defined earlier. For the young age group (18 to 39), seven dummy variables were defined ($Cohort_{ji}$, j=1 to 7) to define the seven age cohorts 18 to 28, 21 to 31, 24 to 34, 27 to 37, 30 to 40, 33 to 43 and 36 to 47 during the eight-year study period. These seven dummy variables are also referred to as Cohort1828 ($Cohort_{1i}$), Cohort2131 ($Cohort_{2i}$), … , and Cohort3647 ($Cohort_{7i}$) respectively. The baseline ages for these seven cohorts are from 18 years to 20 years for Cohort1828, from 21 years to 23 years for Cohort2131, … , and from 36 to 39 years for the final Cohort3647. Similarly, eight dummy variables were defined for the middle age group (Cohort4050, Cohort4353, … , Cohort6171), and nine dummy variables for the senior group (Cohort6575, Cohort6878, … , Cohort89+). Unconditional models are similar to the conditional models described in Equation 1 to 4 except that X variables are excluded in the unconditional models.

Equation 1 represents a within-individual level regression model, which is specified as a quadratic function of TIME. A cubic specification was also considered for each age group. However, none of the cubic terms were statistically significant or a model reached a boundary constraint with the inclusion of a cubic term.[15] Equations 2 to 4 specify between-individual level models. In equation 1, the parameter π_{0i} refers to the intercept of the model and interpreted as median HUI3 scores during the follow-up. The parameters π_{1i} and π_{2i} in equation 1 refer to the rate of change and the rate of acceleration of HUI3 scores, respectively. The parameters π_{0i}, π_{1i} and π_{2i} were considered as random and were modeled as functions of cohort and determinants of health variables. Within-individual residuals were denoted by ε_{ti}, which were assumed to be normally distributed and with constant variance. ζ_{0i}, ζ_{1i} and ζ_{2i} are between-individual intercept, slope and curvature residuals, respectively which are assumed to be multivariate normal and constant variance. The unconditional models were similar to the conditional models but did not include the variable X_{ki}.

4-3-3-2 Model diagnostics

Normality of error and homoskedasticity assumptions for conditional models were assessed following Singer and Willett (2003).[15] With the large sample size of NPHS, models used in this study may be robust to the normality assumption. Nonetheless, a highly skewed distribution of HUI3, often observed in data from general population, may be a potential concern. Therefore, a generalized linear mixed model approach was also used to estimate the models for comparisons. A gamma distribution was chosen as a comparison to the normal distribution. Because the distribution of HUI3 scores is positively skewed, a random variable with a gamma distribution possesses useful distributional characteristics, ranging from zero to positive infinity, which is a mirror image of the distribution of HUI3 in the general population.[39,40] To facilitate the gamma model, disutility scores of HUI3 plus one (i.e. (1-HUI3) + 1) was used as a dependent variable.[41] The gamma model was estimated with an identity link function so that the interpretations of estimated coefficients are analogous to those based on linear mixed models.[42]

A series of sensitivity analyses were also conducted to assess mortality selection and implication for imputing missing values of independent variables. To assess mortality selection, unconditional models were re-estimated by excluding records indicating the incidence of death (i.e. DEAD = 1). Plots of unconditional models with and without DEAD = 1 were compared to see if an inclusion of mortality events impacted trajectories. To assess potential impacts of the imputation, conditional models were re-estimated by excluding DEAD = 1 and compared any differences in parameter estimates and their significance levels between conditional models with and without DEAD = 1.

Linear mixed models were estimated by MLWin 2.02[43] with a full iterative generalized least squared method. Generalized linear mixed models were estimated by SAS 9.1 glimmix procedure.[44] Mode fit was assessed using deviance statistics. For HUI3, mean overall scores of 0.03 or greater were considered as definitely important and differences as little as 0.01 may be meaningful in some contexts.[45-48]

4-4 Results

4-4-1 Sample selection, assignment of HUI3 scores and imputation

Of the initial 17,276 respondents in the person-level data, 2,752 individuals who were younger than 18 years old in Cycle 2 were excluded. Data were then re-arranged as the person-period data contains 87,114 records (= 14,524 respondents × 6 cycles). Based on the person-period data, records obtained at Cycle 1 as well as records with missing overall HUI3 scores were excluded, resulting in 57,239 records. Further, records missing with at least one of the other important variables (4,088 records) were excluded. The final sample used in the analyses contains 13,665 respondents with 53,151 records. Based on the final sample 13,665 respondents, transition to institutions and/or death between Cycles 2 to 6 are summarized as the following: 145 individuals were institutionalized but did not die during the follow-up, 1,361 individuals died without being institutionalized during the follow-up; 191 individuals were institutionalized and subsequently died during the follow-up.

Baseline characteristics were compared between those who were included (n=13,665) and those who were excluded (n=859) from the analyses (data not shown). It was found that those who were excluded from the analyses were older (mean age for the excluded individuals was approximately 56 years old), the average HUI3 score was importantly lower (0.42 compared with 0.89 for the included respondents). Excluded individuals were also more likely to be institutionalized and/or deceased during the follow-up. Having more chronic conditions, less education and abstaining from alcohol were also associated with sample selection.

Table 4-1 summarizes baseline characteristics for samples used in the analyses. The average age of respondents was 45 years and the average HUI3 score was 0.89. The majority of respondents were White and the sample consisted of slightly more males (51%) than females (49%). Approximately 64% of respondents did not report any of the specified chronic conditions at Cycle 2. High proportions of respondents had at least a high school diploma (76%), did not receive social assistance (93%) and were married (64%). The majority of the respondents were light to moderate drinkers (76%), whereas many of respondents were current or former smokers (61%) and/or physically inactive (59%).

4-4-2 Estimation results

Estimation of trajectories and tests for cohort effects were conducted using stratified groups: young (5,672 respondents with 22,779 records), middle-aged (5,082 respondents with 20,833 records) and seniors (2,911 respondents with 9,539 records)

4-4-2-1 Assessment of general HRQL trajectories: unconditional models

The second column in Tables 4-2 to 4-4 summarizes results of unconditional models for the three groups: young, middle-aged and seniors. For young and middle-aged groups (Models Y1 and M1, respectively), approximately 50% of variance was attributed to within-individual variations (intra-class correlation coefficient (ICC) = 0.55 for young and ICC = 0.46 for middle-aged). For the senior group (Model S1), as much as 90% (ICC = 0.90) of total variation in HUI3 was attributed to within-individual variations. For the young group, the model intercept was 0.92, which is interpreted as the median HUI3 score for the follow-up period for the youngest cohort. Coefficients for Time as well as all of the coefficients for the Cohort by Time interaction were negative, indicating linear downward-sloping cohort trajectories. Coefficients for the Cohort and Cohort by Time interaction were, for the most part, non-significant and/or quantitatively unimportant. This indicates that there was no important difference in mean HUI3 scores over time across cohorts. Results were similar for the middle-aged group. Results from the senior group (Model S1) were noticeably different from those for the younger groups. The model for the senior group was estimated as quadratic trajectories. The model reached a boundary constraint when the random effect of the quadratic time term ($Time^2$) was included. Therefore, $Time^2$ was fixed in the final model. The intercept was 0.80, which was importantly lower than those for young and middle-age groups. The slope for the reference cohort (Cohort6575) and the curvature estimate were -0.02 and -0.002, representing a concave trajectory. Both Cohort and Cohort by Time interactions were negative and statistically significant for most cohorts. In addition, older cohorts had larger coefficients: the size of cohort dummy variables increased from |0.04| to |0.50| and, for Cohort by Time interactions, the size increased from |0.003| to |0.05|. These results indicated that not only the median HUI3 scores for older cohorts were lower but also their slopes were steeper.

Unconditional trajectories for young, middle-aged and senior groups were also plotted (Figure 4-1). To help visualize general trends of trajectories over time, overall trajectories were also superimposed.[49] Trajectories for the young group were flat and there was little difference in slopes among cohort trajectories. Trajectories for the middle-age group were also linear, but had steeper decline in trajectories over time compared with those for the youngest group. For the senior group, the trajectories were approximated by curvilinear trends. At age 65, the predicted HUI3 scores were around 0.80, which were comparable to scores for young and middle-age groups. However, as age increases, HRQL declines rapidly. When one reaches in his/her 90s, the predicted HUI3 score was as low as 0.20 and continued to decline over time. Another noticeable difference was variations in cohort trajectories. Cohort trajectories for young-senior cohorts (e.g. 65 to 68 years old) were closer to the overall trajectory. In contrast, large cohort variations as well as large deviations from the overall trajectory were apparent for the oldest old cohorts (e.g. 83 years and older). Cohort trajectories for young, middle-aged and senior groups significantly deviated ($p < 0.01$) from the overall trajectory for unconditional models (Table 4-5).

4-4-2-2 Factors associated with variations in HRQL trajectories: conditional models

After important demographic and health behavioural factors were controlled for, cohort effects were significant only for the middle-aged group and seniors. The full models with all the independent variables considered in the analysis are described in columns titled Y2, M2 and S2 in Tables 4-2 to 4-4 for three age groups. The model Y2 does not include the cohort effect because it was not significant after controlling for the independent variables (Table 4-5). The final most parsimonious conditional models were then chosen for the three age groups after excluding the non-significant variables.

These models are described in columns titled Y3, M3 and S3 in Tables 4-2 to 4-4. In these models interaction terms between time and covariates were also added to these models to examine if slopes were the function of the independent variables. However, none of the interaction terms were statistically significant. Therefore, for all models, it was assumed that only intercepts (i.e. levels of trajectories, not the rate of the change) were functions of the determinants of health variables.

For the young group, all the variables except for sex and race were statistically significant and quantitatively important (Model Y3). A dummy variable indicating the incidence of death showed a dominant (-0.87) and statistically significant ($p < 0.01$) effect. The number of chronic conditions was also significantly associated with levels of trajectories; compared with a trajectory when one did not have any chronic condition, the average differences in levels of trajectories for one, two or more than two chronic conditions were -0.04, -0.08 and -0.16, respectively, controlling for other variables. Demographic, socio-economic and health behavioural factors also importantly differentiated the level of trajectories; not having a high school diploma, receiving social assistance, current/former smoker, abstainer/former drinker and physical inactivity were all associated with lower trajectories compared with reference groups.

Results for the middle-aged group (Model M3) were similar to those for the young group (Models Y3). The size of the dummy variable indicating the incidence of death (DEAD) had a large impact to the trajectories. The coefficient on DEAD was -0.78, indicating that, on average, once an individual die, his/her trajectory drops, on average, by 0.78. The number of chronic conditions also importantly impacted within-individual change in the levels of trajectories; on average for those who did not have any chronic condition, development of a new condition lowered the trajectory by 0.03, developing an additional condition further lowered the curve by 0.05 (= 0.08-0.03). Further, when one developed more conditions the curve fell by an additional 0.07 (= 0.15-0.08). Consistent with results from the young group, having low education, receiving social assistant, being not married, current smoker, abstainer/former drinker and/or physically inactive had negative and statistically significant impacts on the level of trajectories. The difference in the level of trajectories when one was in the community and in an institution was not statistically significant. This may be due to the very small number of available records from the institutionalized individuals in the sample.

Results for the senior group (Model S3) differed from those shown for the young and middle-aged groups (Models Y3 and M3). Coefficient on institutionalization (INST) was -0.21 and the coefficient on DEAD was -0.70; both were statistically significant. This indicates that once an individual became institutionalized, the level of their trajectory dropped by 0.21 compared with the trajectory when he/she was in the community. Furthermore, if an institutional resident died, then the trajectory dropped further by 0.49 (= 0.70-0.21). In addition, having more chronic conditions, being non-white, current/former smoker, abstainer/former drinker and/or physically inactive had negative and statistically significant effects on the trajectories. However, in contrast with results from the younger groups, education, social assistance and marital status were not important factors in differentiating trajectories for seniors.

Differences in the size of coefficients across the three age groups (models Y3, M3 and S3) are also of interest. Although the magnitude of the coefficients on DEAD was large for all groups, the young group had a much larger coefficient (|0.87|) than for the older two groups (|0.78| for the middle-aged group and |0.70| the senior group). Impact of low education on trajectories was comparable for young (|0.02|) and middle-aged (|0.02|) groups. On the other hand, coefficients on socio-economic factors such as social assistance and marital status were greater for the middle-aged group (|0.06| and |0.03|, respectively) compared with those for the young group (|0.05| and |0.02|, respectively). Once individuals entered into their senior ages, however, these factors became less important. Opposite trends were found with respect to health behavioural factors; health behavioural factors such as tobacco, alcohol and physical activity showed greater impact in trajectories for seniors than for younger groups. In particular, the average decrement in trajectories when one became inactive was |0.05| for seniors, which was more than twice as the decrements estimated for young (|0.02|) and middle-aged (|0.02|) groups. However, it was found that the magnitude of coefficients on the number of chronic conditions was comparable across the three age groups.

4-4-2-3 Model diagnostics

Based on normality plots, level-1 and level-2 residuals showed evidence of non-normal distribution in the main models (i.e. models with DEAD and INST as time-varying variables). Although normal plots of level-1 (within-individual) standardized residuals were reasonably symmetric for all groups, level-2 (between-individual) residuals were highly left skewed for most models (results not shown). Therefore, results from the linear mixed models (Tables 4-2 to 4-4) were compared with those from generalized linear mixed models (gamma models). Results based on the generalized linear mixed models are shown in Appendix H. First, impacts of normality assumptions on unconditional models were assessed by comparing plots of unconditional trajectories (Figure A-1 to Figure A-3). Comparisons of estimated trajectories between linear mixed models and generalized linear mixed models showed little differences in patterns with respect to the shape and cohort variations in trajectories for all age groups. Namely, results from both methods showed that estimated trajectories were linear for young and middle-aged groups and curvilinear for the seniors with a steeper decline in health over time, and cohort effects were more noticeable for older cohorts than younger cohorts. Comparisons of conditional models found negligible differences in parameter estimates and their significance level (Table A-1 to Table A-3). Therefore, little impact of the violation of the normality assumption for study results was found.

Scatter plots of unstandarized residuals against each level of the independent variables showed little evidence of heteroskedasticity (result not shown). A few exceptions were residual variations with respect to dummy variables for institutionalization (INST) and death (DEAD). Variations in residuals were much smaller for records with INST = 1 and/or DEAD = 1 compared with records with INST = 0 and/or DEAD = 0. However, smaller residual variations may be partly due to the small proportion of records with INST = 1 and/or DEAD = 1 in the total available records.

4-4-2-4 Sensitivity analyses

First, potential mortality effects were assessed by comparing estimated trajectories based on unconditional models with and without DEAD = 1 records for the main models (Appendix I). Comparisons of trajectories for the young group found few differences; for both cases, there was little cohort variation in trajectories and the rate of decline in health was very flat (Figure A-4). On the other hand, noticeable differences in trajectories were found for middle-aged and senior groups. For the middle-aged group (Figure A-5), cohort variations were greater for a model including DEAD = 1. The finding was in contrast with the existence of significant cohort effect for models with DEAD = 1. (Tests for cohort convergence for models without DEAD = 1 for middle-aged and senior groups were also conducted and there was no evidence of cohort effect (results not shown)). Compared with a model with DEAD = 1, slopes of trajectories based on a model excluding these records were also noticeably flatter. Impacts of the exclusion of DEAD = 1 records for the senior group were found to be much more profound (Figure A-6). In particular, after the age of around 70, the cohort variations in trajectories as well as the rate of change in trajectories were noticeably greater for the model with DEAD = 1 included. For example, based on the model with DEAD = 1 records, the predicted HUI3 score at the age of 80 was around 0.60, whereas it was estimated at around 0.75 based on the model without DEAD = 1 (Figure A-6). Moreover, at the age of 90, the predicted HUI3 score was around 0.30 for the former model whereas it was around 0.60 based on the latter model. Therefore, an exclusion of records with DEAD = 1 had important impacts in the middle-aged and senior groups, with the greatest impact for seniors.

A series of sensitivity analyses were also conducted to assess potential implications of imputing systematically missing values for independent variables. Conditional models shown in Tables 4-2 to 4-4 were re-estimated by excluding records that refer to the incidence of death (i.e. DEAD = 1, a total of approximately 1,550 records). These results are also summarized in Appendix I (Table A-4 to Table A-6). In general, little difference was found; comparisons of the size and significance of estimated coefficients for the determinants of health variables showed negligible differences. Therefore, study results were consistent.

4-5 Discussion

This study utilized longitudinal data from a representative sample of the Canadian population aged 18 years and older to investigate three research questions: What is the typical trajectory of HRQL and what does it look like? Does the cohort effect have an impact on HQRL trajectories? What factors are associated with variations among HQRL trajectories and does the importance of these factors differ by the phase of life?

To answer the first research question, unconditional HRQL trajectories were estimated. Results from stratified unconditional HRQL trajectories indicate that a typical life course trajectory was concave with a very slow decline in HRQL until the age of around 60. After one reaches his/her 60s, average health deteriorates more rapidly. To answer the second research question, tests for cohort convergence were conducted. Test results showed evidence of cohort effects for middle-aged and senior groups. In particular, cohort effects were noticeable for the senior group. Therefore, it was important to control for cohort effects for these groups.

With respect to the third question, results from conditional models revealed important heterogeneity in trajectories. Comparisons of the size of covariates across young, middle-aged and senior groups also provided a number of key findings. First, as would be expected, death affected the young group more than the older age groups, where the drop in the level of trajectories due to death was the greatest for the young. This partly reflects that, on average, young respondents who died had high HUI3 scores prior to death (a score of 0.00), which was a far more devastating event for the young than for older groups. Second, it was found that unfavourable socio-economic factors such as receiving social assistance or not being married had the greatest impact for the middle-aged (age 40-64), implying that the impacts of these socio-economic conditions were more important for middle-aged life stage than for the other two ends of the life stage. Third, impacts of unfavourable health behaviours increased with age. In particular, negative impact of physical inactivity on levels of health trajectories was noticeably greater for the senior group. Similar results were found in other Canadian studies. Shields and Martel (2006)[6] found that baseline health risk factors remained significant predictors of the subsequent incidence of declines in health status for seniors, even after controlling for demographic and socio-economic variables. Another study found that health risk factors were not important predictors for the middle-aged.[5] Results from the current study were consistent with these finding that, although health risk factors are significant for all age groups, the magnitude of the effect for these health risk factors was greater for seniors. As Martel et al (2005)[5] noted, the finding implies that the consequence of unhealthy behaviour may not appear until later in life.

Of course, health behavioural factors such as physical inactivity and abstaining from alcohol are potentially both a cause of subsequent declines in health status and an effect of the previous declines in health. Given that information on the severity of chronic conditions is not available in the NPHS data set, unfavourable health behaviours may also be a marker for the severity of various chronic conditions. It is important to realize that there is the potential for two-way causality between health behavioural factors and health status. Therefore, although results from the current study were consistent with previous predictive studies, they should be interpreted with caution.

It is notable that the effects of the number of chronic conditions on trajectories were surprisingly similar for young, middle-aged and seniors. Therefore, contrary to findings for other variables, negative impacts of having additional conditions persisted regardless of the life stage.

4-5-1 Impacts of mortality selection and imputation

Excluding decedents completely from the analyses is a threat to the study's generalizability because it is likely that decedents are systematically different from others. The mixed model is a useful method to retain decedents by incorporating their records until they die and estimating the within-individual level equations based on their available data obtained when they were alive.[16] Yet, there is another possible source of bias regarding exclusions of records after the death. For example, if prior health of the decedents was generally good and if many of the decedents had such a pattern (as was the case for many of decedents in samples used in the analyses), then the incidence of death occurred to these decedents will importantly impact the average trajectory. By ignoring records of death, trajectories estimated in this study may be unnecessarily inflated. However, because of the absence of a value representing the state of death, previous trajectory studies faced challenges in finding appropriate methods to incorporate the state of death.[10] In this study, it was possible to assign the state of being dead as 0.00, a defined health state in the HUI3 system and found that trajectories for middle-aged and senior groups were much steeper when the records of death were included in estimating their trajectories. Therefore, an exclusion of these records from the analyses resulted in higher estimated trajectories, suggesting the importance of an inclusion of death to estimate lifetime trajectories.

Assigning a value of zero to the dependent variable for the incident of death was reasonable and had little room for ambiguity. However, a potential concern was the appropriateness of imputing missing records for the corresponding independent variables. Sensitivity analyses showed little impact of the imputation of independent variables on study results. This may be because the proportion of records indicating the incidence of death consisted of less than 5% of the total number of records. Therefore, it could be due to that any carried-forward demographic and socio-economic status may be averaged out. Despite these results, one may still argue that it is not fundamentally appropriate to impute any determinants of health factors once an individual has died. This is because once dead, no one really possesses any demographic or behavioural status. Or it may also be unreasonable to impute values using information obtained as far back as six or eight years ago. This may be a concern especially when it comes to imputing values for time-varying variables such as chronic conditions or financial status. However, sensitivity analyses showed that an exclusion of the incidence of death importantly affected the estimated trajectories but the impact of LOCF imputation on study implication was negligible. Therefore, the importance of including the incidence of death surpassed the potential concerns associated with the feasibility of imputing values for the corresponding independent variables.

4-5-2 Study limitations

Several study limitations are also important to note in interpreting results. First, NPHS is based on self or proxy reports and no objective measures were used to confirm the accuracy of reporting. Therefore, inconsistency in reporting may arise over time. Although strategies were taken to ensure the consistency of reporting over time during the data collection, potential inconsistency in reporting is not always avoidable. The definition of the chronic condition variable is of a particular note. A number of potentially inconsistent cases were found over time for conditions that may be considered as irreversible, at least for the majority of cases (e.g. diabetes, dementia). In some longitudinal predictive studies, baseline impacts of several major chronic conditions were assessed separately[5] or chronic conditions were grouped according to the risk of mortality.[24] In this study, a rather crude measure was used by categorizing the number of chronic conditions into four groups (no condition, one condition, two conditions and more than two conditions) for simplicity. In this way, it was felt that misclassifications over time were minimized, assuming that it is more difficult for respondents to identify multiple chronic conditions. Despite being a crude measure, having more chronic conditions was found to have larger impacts on trajectories, as would be expected.

Second, with growing evidence of beneficial association of moderate drinking and health, differential effects of light-to-moderate drinkers and more than moderate drinkers on health were examined. However, there was no significant difference in trajectories between these two groups from all models. The observed indifference may be due to a lack of statistical power due to very few cases of more than moderate drinkers. It also could be that the definition of light-to-moderate drinking versus more than moderate drinking used in this study did not reflect the appropriate threshold level of alcohol consumption. The definition of alcohol consumption was informed by results from existing studies. However, these studies also showed lack of consensus on the standard definition of light-to-moderate drinking, making it difficult to define clear cut-offs.

Third, one of the important advantages of the growth curve model is the ability to incorporate respondents with at least one data point, provided that data is missing at random (MAR). MAR assumes that the probability of data missing can depend on any observed data but does not depend on unobserved concurrent data.[15,50] The violation of this assumption is unlikely in data used in the current analyses because past health states are likely to be related to current (but unobserved) health states.[35] It may be argued that this assumption reasonably holds for those who were alive and did not respond to the survey, but it does not hold for decedents because their health could be very poor had we have observed it.[16] In this study, however, because there is a valid score for the dependent variable for those who are dead, even though records after the first report of death are missing for decedents, these missing values are related to the past observed values (i.e. Dead = 0.00) as well. In this respect, MAR assumption is considered to be reasonable. Nonetheless, the analyses may still be subject to potential bias arising from systematic differences between those who remained in the survey and those who dropped out completely from the surveys (other than due to death). Therefore, a systematic assessment of the possibility of such attrition bias is warranted to minimize impacts of attrition on estimates. A method for testing and adjusting for potential attrition bias has been suggested in the context other than mixed models.[51,52] Therefore, the application of such methods to mixed models may be important to obtain more accurate estimates that take sample attrition into account.

Fourth, individuals who did not contribute any of their records were excluded completely from the analyses. Any non-random selection to be excluded from the analyses leads to a potential generalizability issue. Additional analyses of comparing characteristics of included and excluded samples for young, middle-aged and senior groups for each cycle showed statistically significant associations between determinants of health variables and the selection (results not shown). In particular, for the young, those who reported lower HUI3 scores, had low education, social assistance and/or being abstainer were likely to be excluded from the analyses. For the middle-aged, characteristics such as having lower HUI3, being not married, being non-smoker and/or being abstainer were significantly associated with the selection. For the senior group, in addition to HUI3, education and alcohol variables, those who were older, institutionalized (at least once during the follow-up), deceased and/or non-white race were also more likely to be excluded from the analyses. Implications are that the estimated trajectories and impacts of the determinants of health on the trajectories may be underestimated. However, the majority of these independent variables already had significant effects on trajectories. In addition, less than 5% of individuals among the target population were completely excluded from the analyses. Therefore, potential impacts of non-random sample selection are considered to be minimal.

Finally, NPHS longitudinal sampling weights represent baseline sample characteristics (i.e. Cycle 1) and no adjustment was made for sample non-response for the subsequent cycles.[6] Therefore, data used in the current analyses may not fully represent the Canadian population observed at Cycle 1 due to sample attrition in the subsequent cycles.

4-6 Conclusion and future direction

Understanding the process of health and aging is a complex matter because of the existence of a number of determinants of health factors that affect ones health in a dynamic way. It is also methodologically complex to assess because the countless patterns of health trajectories, time-varying covariates, cohort variations and attrition, making it difficult to generalize the dynamic process. Despite such complexities, this study provided an overview of life-time trajectories and factors associated with variations among trajectories. The key finding was that the socio-economic factors such as financial status, education and marital status were important factors that differentiate among trajectories for the young and middle-aged population. However, in the later life, lifestyle factors such as physical activity became a more important component. Moreover, the magnitude of the impacts of chronic conditions was important and similar throughout the life cycle. An implication of the study results is that it is important to recognize such heterogeneity in trajectories and focus on appropriate aspects of the determinants of health in various phases of life accordingly.

This study provided unique empirical and methodological contributions to existing Canadian longitudinal studies. To the author's knowledge, this study was among the first to estimate HRQL trajectories for the general adult Canadian population and compared potential differences in impacts of determinants of health factors on trajectories in various stages of life. Several methodological contributions are provided. First, the study utilized five waves of an accelerated longitudinal survey representing the entire Canadian population, including those in long-term care institutions. Therefore, results were generalizable to the adult population including those in institutions. Second, using five waves of data, it was possible to assess potential non-linear trajectories. Third, the study also explicitly tested and controlled for cohort effects, thus estimated trajectories were generalizable to a wider age and cohorts. Finally, the study incorporated a unique approach to retain decedents by assigning the utility of 0.00 for the incidence of death. Therefore, it was possible to overcome the difficulty of assigning values to the state of being dead.

This work was the initial investigation of HRQL trajectories of the Canadian general population and there are a number of potential extensions to the models. A few examples of future research interests are to incorporate social-environmental factors that affect health trajectories over and above individual-level effects, motivated by the growing interests of impacts of community-level factors on health.[53,54] Another application is to assess more complex pathways such as assessing the role of individual response (e.g. biological and behavioural (life-style) response) as mediating factors between social-environment and health.[27] Finally, the assessment of how health behaviour affects subsequent health trajectories by testing specific *a priori* hypotheses about differential rates of change in trajectories will be of important policy interest. The accumulation of evidence from longitudinal trajectory studies will complement our existing knowledge based on cross-sectional and predictive studies. It also will help policy makers to help achieve informed decision making based on a more comprehensive picture of the association between health and its determinants.

Disclaimer

The research and analysis reported in this paper are based on data from Statistics Canada and the opinions expressed do not represent the views of Statistics Canada.

Table 4-1 Selected sample characteristics of individuals at baseline (Cycle 2, 1996/97)

Mean age (standard deviation)	45.0 (17.47)
Mean HUI3 scores (standard deviation) [a]	0.89 (0.205)
	Frequencies (%)
Race	
White	90.3
Non-white	9.7
Sex	
Male	51.1
Female	48.9
Chronic conditions [a]	
No condition	63.9
One condition	22.1
Two conditions	8.6
More than two conditions	5.4
Education [a]	
No high school diploma	23.8
High school diploma	76.2
Receiving social assistance [a]	
Yes	6.6
No	93.4
Marital status [a]	
Not married	36.4
Married	63.6
Tobacco [a]	
Current or former smoker	61.3
Nonsmoker	38.7
Alcohol [a]	
More than moderate drinker	3.4
Former drinker or abstainer	20.4
Light to moderate drinker	76.2
Physical activity [a]	
Inactive	59.2
Active	40.8

Statistics are based on n = 13,665 individuals (age 18 years and older), weighted

[a]: Sample size varies due to missing records

Table 4-2 Estimation results for unconditional, full and parsimonious models for the young age group (18-39)

	Unconditional model		Conditional models			
Model #	Model Y1		Model Y2 [a]		Model Y3	
	b	SE	b	SE	b	SE
Fixed effects						
Intercept	0.923*	0.0050	0.961*	0.0028	0.964*	0.0024
time	-0.001	0.0009	-0.003*	0.0003	-0.003*	0.0003
Cohort 18-28 (ref)						
Cohort 21-31	0.006	0.0068				
Cohort 24-34	0.007	0.0072				
Cohort 27-37	0.002	0.0068				
Cohort 30-40	-0.005	0.0071				
Cohort 33-43	-0.004	0.0069				
Cohort 36-47	-0.015	0.0066				
Cohort 21-31*time	-0.001	0.0012				
Cohort 24-34*time	-0.003	0.0012				
Cohort 27-37*time	-0.002	0.0013				
Cohort 30-40*time	-0.003	0.0012				
Cohort 33-43*time	-0.002	0.0012				
Cohort 36-47*time	-0.004*	0.0011				
DEAD			-0.869*	0.0196	-0.868*	0.0195
Number of chronic conditions						
1 condition			-0.035*	0.0032	-0.035*	0.0032
2 conditions			-0.084*	0.0091	-0.084*	0.0091
> 2 conditions			-0.156*	0.0181	-0.156*	0.0181
no condition (ref)						
Sex						
Female			0.007	0.0032		
Male (ref)						
Race						
Non-white			-0.003	0.0052		
White (ref)						
Education						
No high school			-0.021*	0.0057	-0.021*	0.0057
High school (ref)						
Social assistance						
Received			-0.053*	0.0062	-0.054*	0.0062
Not received (ref)						
Marital status						
Single/divorced /separated/widowed			-0.016*	0.0025	-0.016*	0.0025
Married/with partner/common-law (ref)						
Smoking						
Current/former smoker			-0.013*	0.0027	-0.013*	0.0027
Non-smoker (ref)						

Table continued ...

Drinking						
Abstainer/former drinker			-0.0097	0.0039	-0.0103*	0.0039
More than moderate drinker			-0.005	0.0050		
Light/moderate drinker (ref)						
Physical activity						
Physically inactive			-0.015*	0.0019	-0.015*	0.0018
Physically active (ref)						
Random effects						
Within individuals	0.012*	0.0004	0.011*	0.0004	0.011*	0.0004
Between individuals						
Variances Intercept	0.009*	0.001	0.003*	0.0004	0.006*	0.0004
Time	3.E-05*	1.E-05	2.E-05*	4.E-06	2.E-05*	4.E-06
$Time^2$						
Covariance						
Intercept & Time	4.E-04*	4.E-05	2.E-04*	3.E-05	2.E-04*	3.E-05
# parameters	18		19		16	
Deviance (-2*LL)	-26212		-29755		-29750	

*: Significant at 1%
time: median weighted cohort centered age
INST was not included; there was no incidence of institutionalization for young group among records used in the analyses
[a]: Cohort dummy variables and interaction terms were excluded from conditional models because tests for cohort effect were not statistically significant (See Table 4-5).

Table 4-3 Estimation results for unconditional, full and parsimonious models for the middle-age group (40-64)

	Unconditional model		Conditional models			
Model #	Model M1		Model M2		Model M3	
	b	SE	b	SE	b	SE
Fixed effects						
Intercept	0.900*	0.0058	0.958*	0.0057	0.961*	0.0056
time	-0.005*	0.0009	-0.004*	0.0008	-0.004*	0.0008
Cohort 40-50 (ref)						
Cohort 43-53	-0.013	0.0087	-0.007	0.0069	-0.007	0.0069
Cohort 46-56	-0.019	0.0088	-0.007	0.0070	-0.007	0.0070
Cohort 49-59	-0.042*	0.0098	-0.012	0.0077	-0.012	0.0077
Cohort 52-62	-0.043*	0.0107	-0.009	0.0081	-0.008	0.0081
Cohort 55-65	-0.059*	0.0112	-0.012	0.0082	-0.012	0.0082
Cohort 58-68	-0.081*	0.0121	-0.009	0.0084	-0.009	0.0085
Cohort 61-72	-0.097*	0.0114	-0.012	0.0081	-0.012	0.0082
Cohort 43-53*time	-0.001	0.0013	0.001	0.0012	0.001	0.0012
Cohort 46-56*time	-0.002	0.0014	-0.00005	0.0012	-0.0001	0.0012
Cohort 49-59*time	-0.0003	0.0014	0.003*	0.0012	0.003*	0.0012
Cohort 52-62*time	-0.0004	0.0015	0.003	0.0013	0.003	0.0013
Cohort 55-65*time	-0.001	0.0019	0.004*	0.0015	0.004*	0.0015
Cohort 58-68*time	-0.003	0.0018	0.003	0.0015	0.003	0.0015
Cohort 61-72*time	-0.005*	0.0018	0.004*	0.0014	0.004*	0.0014
INST			-0.078	0.0478		
DEAD			-0.781*	0.0109	-0.781*	0.0109
Number of chronic conditions						
1 condition			-0.032*	0.0028	-0.033*	0.0028
2 conditions			-0.076*	0.0049	-0.076*	0.0049
> 2 conditions			-0.146*	0.0083	-0.146*	0.0083
no condition (ref)						
Sex						
Female			0.008	0.0041		
Male (ref)						
Race						
Non-white			-0.005	0.0094		
White (ref)						
Education						
No high school			-0.019*	0.0049	-0.019*	0.0049
High school (ref)						
Social assistance						
Received			-0.064*	0.0087	-0.064*	0.0087
Not received (ref)						
Marital status						
Single/divorced/separated /widowed			-0.027*	0.0040	-0.028*	0.0040
Married/with partner/common-law (ref)						
Smoking						
Current/former smoker			-0.019*	0.0035	-0.018*	0.0036
Non-smoker (ref)						

Table continued ...

Drinking						
Abstainer/former drinker			-0.029*	0.0042	-0.029*	0.0042
More than moderate drinker			-0.009	0.0070		
Light/moderate drinker (ref)						
Physical activity						
Physically inactive			-0.021*	0.0023	-0.022*	0.0030
Physically active (ref)						
Random effects						
Within individuals	0.020*	0.0006	0.015*	0.0004	0.015*	0.0004
Between individuals						
Variances Intercept	0.022*	0.001	0.010*	0.0006	0.010*	0.001
Time	1.E-04*	1.E-05	4.E-05*	1.E-05	4.E-05*	1.E-05
$Time^2$						
Covariance						
Intercept & Time	1.E-03*	1.E-04	2.E-04*	4.E-05	2.E-04*	4.E-05
# parameters	20		34		30	
Deviance (-2*LL)	-12073		-19651		-19649	

*: Significant at 1%

time: median weighted cohort centered age

Table 4-4 Estimation results for unconditional, full and parsimonious models for the senior group (65+)

	Unconditional model		Conditional models			
Model #	**Model S1**		**Model S2 [a]**		**Model S3**	
	b	**SE**	**b**	**SE**	**b**	**SE**
Fixed effects						
Intercept	0.800*	0.0119	0.975*	0.0098	0.960*	0.0088
Time	-0.015*	0.0020	-0.002	0.0012	-0.002	0.0012
$time^2$	-0.002*	0.0003				
Cohort 65-75 (ref)						
Cohort 68-78	-0.038	0.0173	-0.017	0.0100	-0.019	0.0100
Cohort 71-81	-0.088*	0.0190	-0.039*	0.0111	-0.040*	0.0112
Cohort 74-84	-0.123*	0.0199	-0.044*	0.0113	-0.048*	0.0113
Cohort 77-87	-0.231*	0.0238	-0.081*	0.0128	-0.084*	0.0127
Cohort 80-90	-0.280*	0.0270	-0.094*	0.0144	-0.099*	0.0141
Cohort 83-93	-0.314*	0.0297	-0.104*	0.0144	-0.110*	0.0142
Cohort 86-96	-0.435*	0.0356	-0.151*	0.0199	-0.156*	0.0197
Cohort 89	-0.503*	0.0483	-0.154*	0.0196	-0.162*	0.0192
Cohort 68-78*time	-0.003	0.0031	-0.001	0.0019	-0.001	0.0019
Cohort 71-81*time	-0.008	0.0033	-0.001	0.0020	-0.001	0.0020
Cohort 74-84*time	-0.015*	0.0035	-0.002	0.0022	-0.002	0.0022
Cohort 77-87*time	-0.030*	0.0045	-0.004	0.0027	-0.004	0.0027
Cohort 80-90*time	-0.034*	0.0048	-0.009*	0.0031	-0.010*	0.0031
Cohort 83-93*time	-0.059*	0.0056	0.003	0.0034	0.003	0.0034
Cohort 86-96*time	-0.050*	0.0064	0.002	0.0052	0.002	0.0052
Cohort 89*time	-0.030*	0.0080	0.009	0.0046	0.008	0.0046
INST			-0.212*	0.0784	-0.211*	0.0767
DEAD			-0.698*	0.0038	-0.699*	0.0067
Number of chronic conditions						
1 condition			-0.035*	0.0051	-0.035*	0.0051
2 conditions			-0.074*	0.0063	-0.073*	0.0063
> 2 conditions			-0.140*	0.0075	-0.140*	0.0075
no condition (ref)						
Sex						
Female			-0.013	0.0076		
Male (ref)						
Race						
Non-white			-0.063*	0.0237	-0.067*	0.0240
White (ref)						
Education						
No high school			-0.014	0.0067		
High school (ref)						
Social assistance						
Received			-0.018	0.0207		
Not received (ref)						
Marital status						
Single/divorced/separated/ widowed			-0.014	0.0067		
Married/with partner/common-law (ref)						

Table continued ...

Smoking						
Current/former smoker			-0.025*	0.0065	-0.029*	0.0062
Non-smoker (ref)						
Drinking						
Abstainer/former drinker			-0.033*	0.0057	-0.034*	0.0057
More than moderate drinker			-0.013	0.0202		
Light/moderate drinker (ref)						
Physical activity						
Physically inactive			-0.048*	0.0043	-0.049*	0.0042
Physically active (ref)						
Random effects						
Within individuals	0.053*	0.001	0.028*	0.001	0.028*	0.001
Between individuals						
Variances Intercept	0.004*	0.002	0.008*	0.0005	0.008*	0.0005
Time	2.E-04*	2.E-05	1.E-05	1.E-05	1.E-05	1.E-05
Covariance						
Intercept & Time	2.E-03*	1.E-04	-2.E-04*	4.E-05	-2.E-04*	4.E-05
# parameters	23		36		31	
Deviance (-2*LL)	3818		-3958		-3941	

*: Significant at 1%

time: median weighted cohort centered age

[a]: After controlling for covariates, variable $time^2$ became non-significant. Deviance statistics for a model including $time^2$ and the model without $time^2$ were -3961 and -3958, respectively. Likelihood ratio tests showed no significant difference in model fit between the two models (chi-square = -3958 – (-3961) = 3.00 with d.f. = 1 (p = 0.083). Therefore, $time^2$ variable was excluded.

Table 4-5 Test of cohort effects

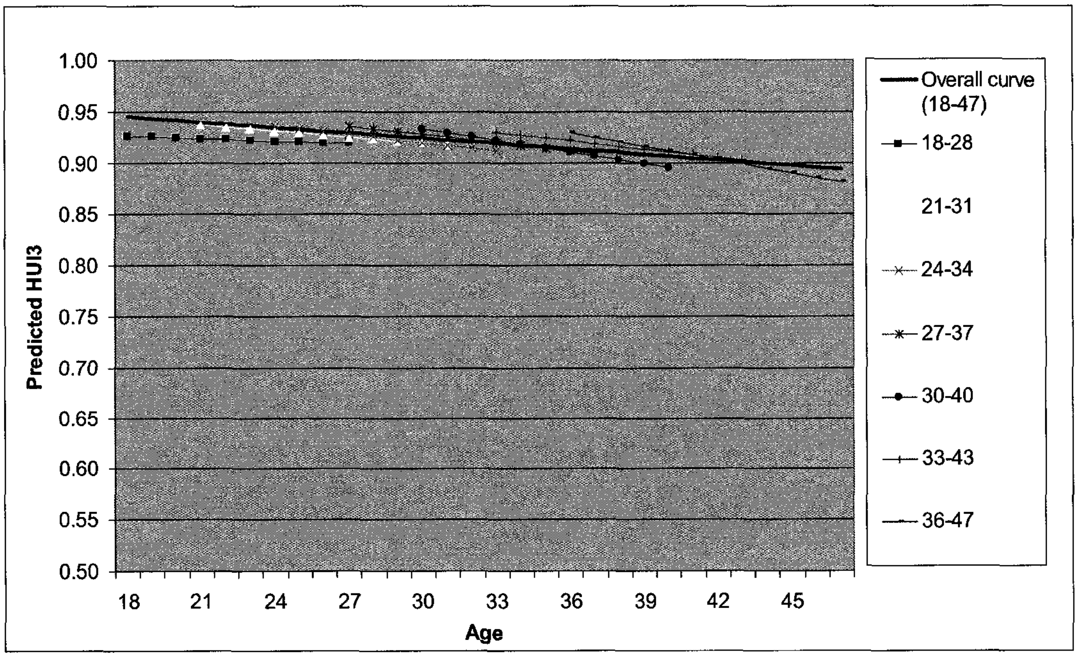
Unconditional models						
	Young (18-39)		Middle-aged (40-64)		Senior (65+)	
Model type [a]	Model Y1	Model excluding cohort effects	Model M1	Model excluding cohort effects	Model S1	Model excluding cohort effects
Number of parameters	18	6	20	6	23	7
Deviance	-26212	-26162	-12073	-12022	3818	4046
χ^2, d.f. (p-value)	50, 12 ($p < 0.001$)		51, 14 ($p < 0.001$)		228, 16 ($p < 0.001$)	
Conclusion	Significant cohort effect		Significant cohort effect		Significant cohort effect	

Conditional models [b]						
	Young (18-39)		Middle-aged (40-64)		Senior (65+)	
Model type	Model Y3 (with cohort effect)	Model excluding cohort effects	Model M3	Model excluding cohort effects	Model S3	Model excluding cohort effects
Number of parameters	28	16	30	16	31	15
Deviance	-24104	-24081	-19649	-19607	-3941	-3894
χ^2, d.f. (p-value)	24, 12 ($p = 0.020$)		42, 14 ($p < 0.001$)		47, 16 ($p < 0.001$)	
Conclusion	Non-significant cohort effect		Significant cohort effect		Significant cohort effect	

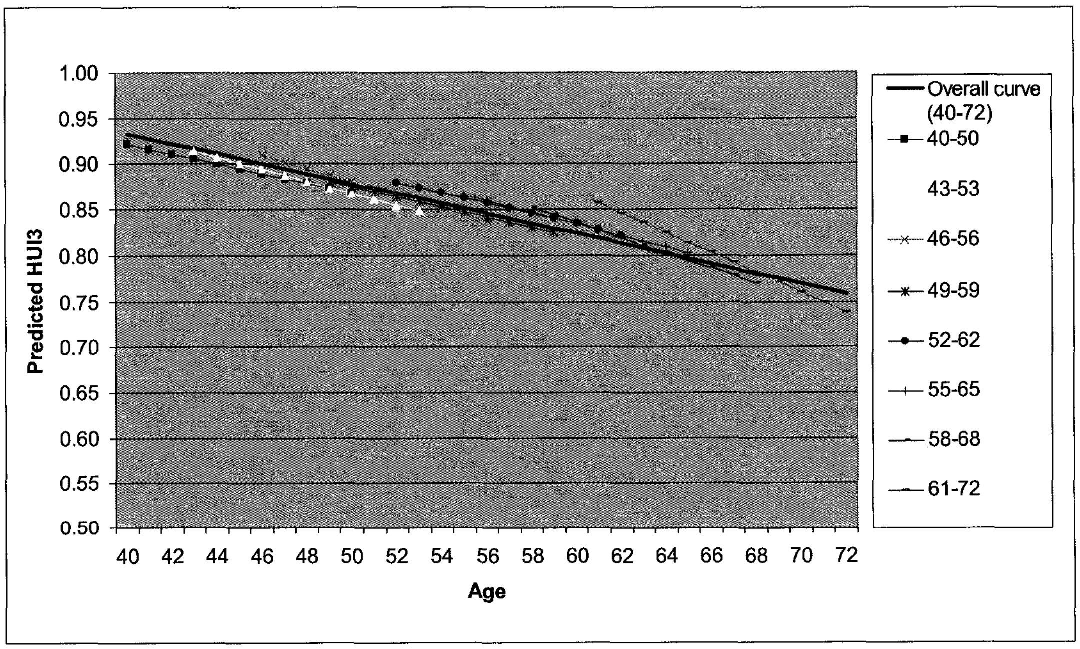
[a] "Model excluding cohort effects" refers to overall model in Appendix G (Equation A-7).
[b] Conditional models refer to the most parsimonious models. Cohort effect was tested for young group by adding cohort dummy variables in Model Y3.

Figure 4-1 Plots for unconditional models

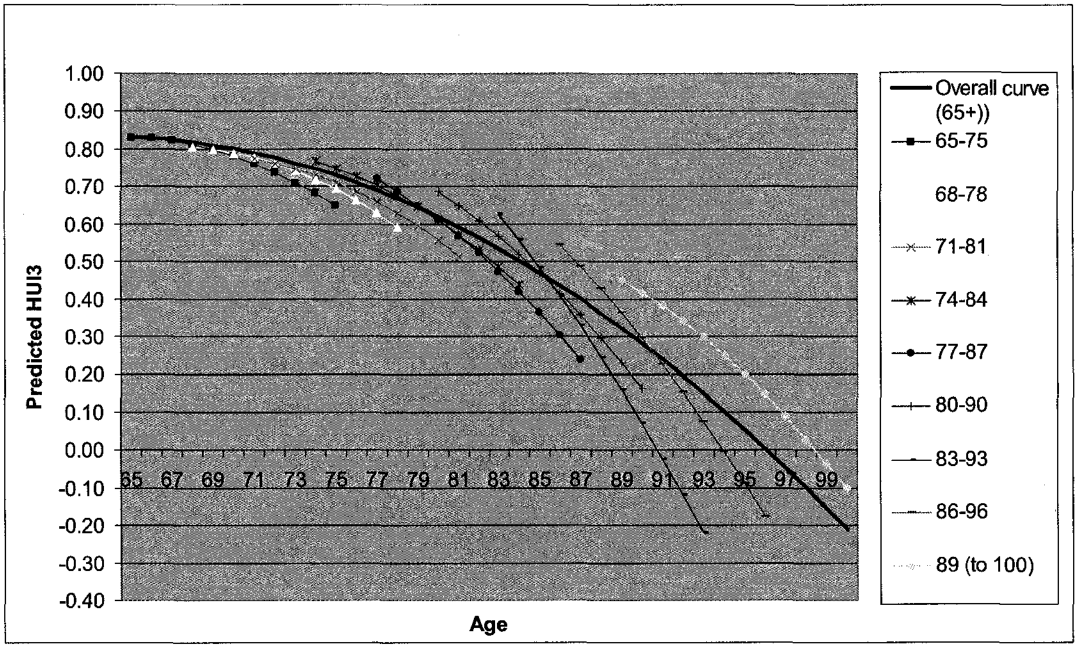
Young



Middle-aged



Senior


1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
-0.20
-0.30
-0.40
Predicted HUI3
65 67 69 71 73 75 77 79 81 83 85 87 89 91 93 95 97 99
Age
Overall curve (65+))
65-75
68-78
71-81
74-84
77-87
80-90
83-93
86-96
89 (to 100)

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Appendix F A list of chronic conditions used in the analyses

The following are the 13 chronic conditions that were included throughout Cycles 1 to 6 as well as in both the household and institutional surveys:

Asthma

Arthritis or rheumatism

High blood pressure

Chronic bronchitis or emphysema

Diabetes

Epilepsy

Heart disease

Stomach or intestinal ulcers

Effects of stroke

Urinary incontinence

Alzheimer disease or other dementia

Cataracts

Glaucoma

Appendix G Test for cohort convergence

Our objective for testing cohort convergence was to assess whether or not it is reasonable to assume that there is no important cohort effect. Namely, the study examined if cohort trajectories "converge" to an overall trajectory for each group (young, middle-age and senior groups) by comparing the cohort model (Equations 1 to 4) with overall trajectory model (to be specified below). The cohort convergence hypothesis is defined as:

- H_0: Cohort model and overall model are not different (i.e. cohort trajectories converge to an overall trajectory)
- H_1: Cohort model and overall model are different (i.e. cohort trajectories importantly deviate from an overall trajectory)

A rejection of H_0 indicates that that there is non-ignorable cohort effect. Therefore, cohort effects need to be included. A failure to reject H_0 indicates that the deviation of cohort trajectories from the overall trajectory can be considered as chance departure. Therefore, we are able to exclude cohort effects.

As described in Miyazaki and Raudenbush (2002), tests for cohort convergence are conducted in two steps: estimation of cohort and overall trajectory models and tests of model equivalence.

Estimations of cohort and overall trajectory models: Model specification for the cohort model is the same as in Equations 1 to 4. Model specification for the overall model is defined as following:

$$Y_{ti} = \pi'_{00} + \pi'_{10}(AGE_{ti}) + \pi'_{20}(AGE_{ti})^2 + \pi'_{30}(TIME_{ti}) + \pi'_{40} * (TIME_{ti})^2 + \varepsilon'_{it}$$

Equation A- 1

$$\pi'_{oi} = \gamma'_{00} + \sum_{k=1}^{K} \delta_{0k} X_{ki} + \zeta'_{0i}$$ Equation A- 2

$$\pi'_{1i} = \gamma'_{10}$$ Equation A- 3

$$\pi'_{2i} = \gamma'_{20}$$ Equation A- 4

$$\pi'_{3i} = \zeta'_{3i}$$ Equation A- 5

$$\pi'_{4i} = \zeta'_{4i}$$ Equation A- 6

Or equivalently,

$$Y_{ti} = \gamma'_{00} + \gamma'_{10}(AGE_{ti}) + \gamma'_{20}(AGE_{ti})^2 + \sum_{k=1}^{K} \delta_{0k} X_{ki} + \zeta'_{0i} + \zeta'_{3i} * (TIME_{ti}) + \zeta'_{4i} * (TIME_{ti})^2 + \varepsilon'_{it}$$

Equation A- 7

Where AGE is a grand-median centered age calculated by subtracting the weighted baseline sample median age from the age of individual *i* at time *t*.

Test the model equivalence of the two models using likelihood ratio tests by calculating the difference in deviance statistics between cohort and overall models.

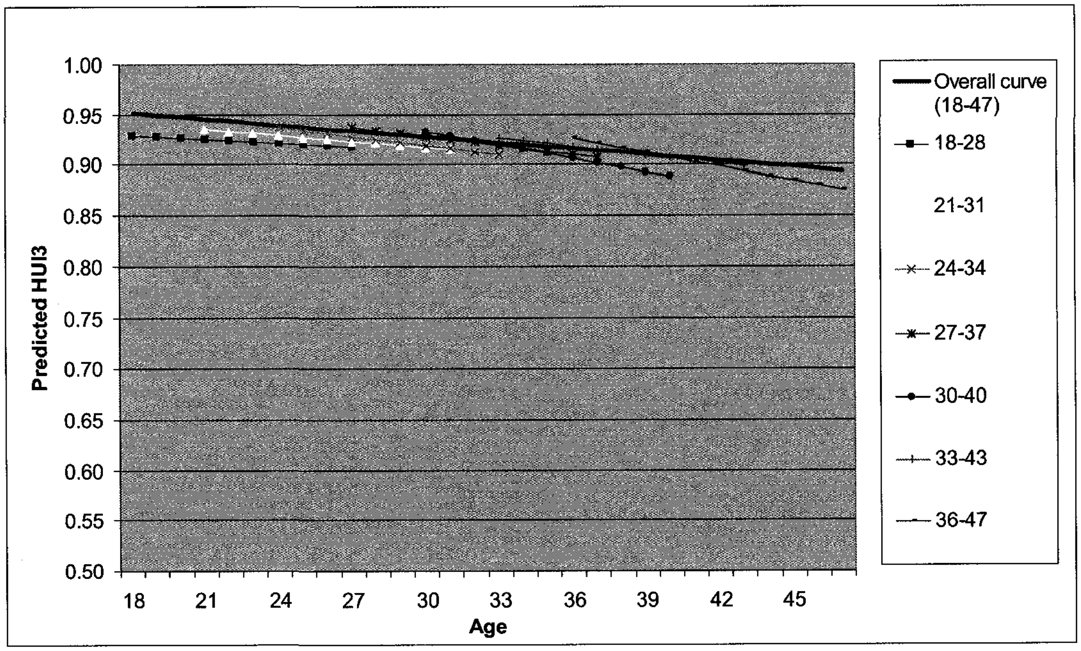
Cohort effect was examined for both unconditional (excluding covariates X from the above models) and conditional models. Tests for three separate groups were performed: young (18-39), middle-age (40-64) and seniors (65+).

Appendix H Generalized linear mixed models: results

<u>Plots of unconditional models based on generalized linear mixed model</u>

Figure A-1 Generalized linear mixed models - Young

Generalized linear mixed model



Linear mixed model (Original model)

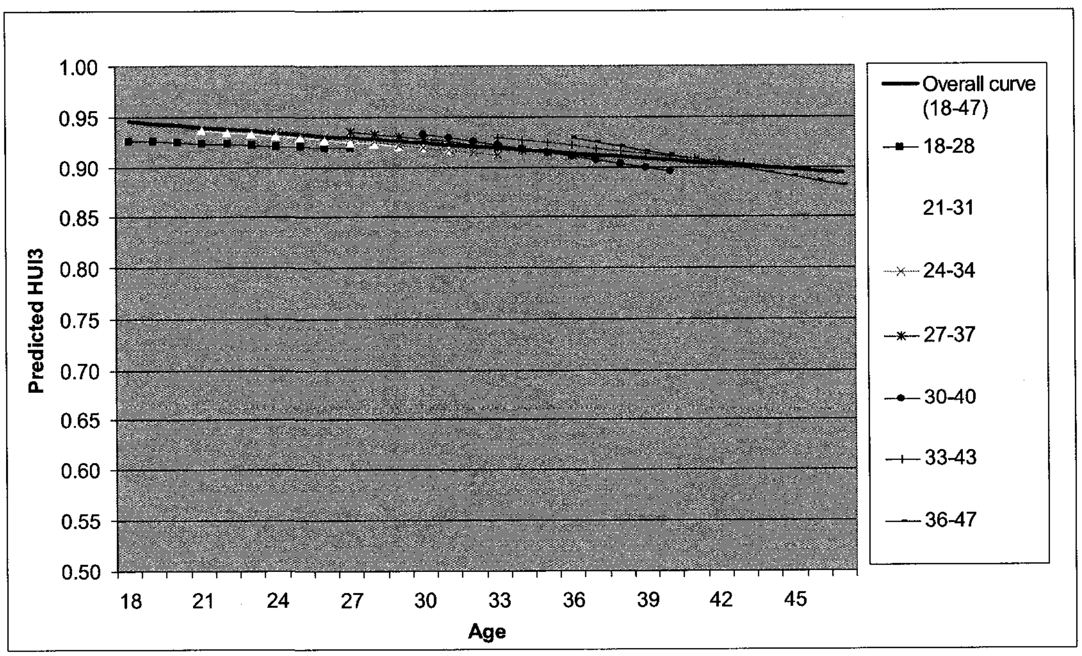
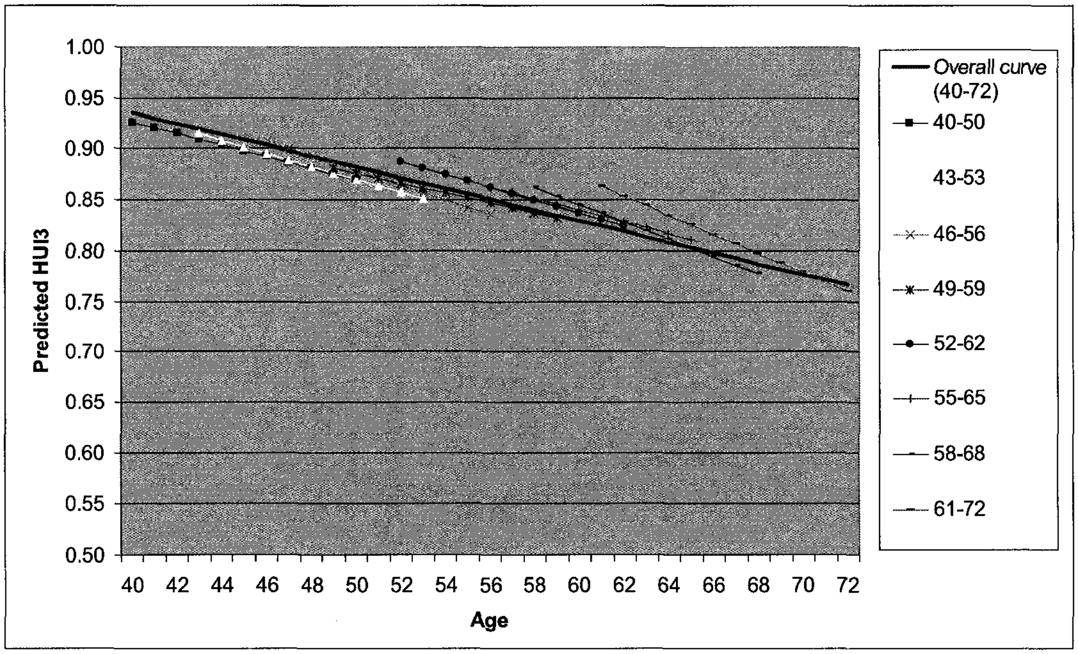


Figure A-2 Generalized linear mixed models - Middle-aged

Generalized linear mixed model



Linear mixed model (Original model)

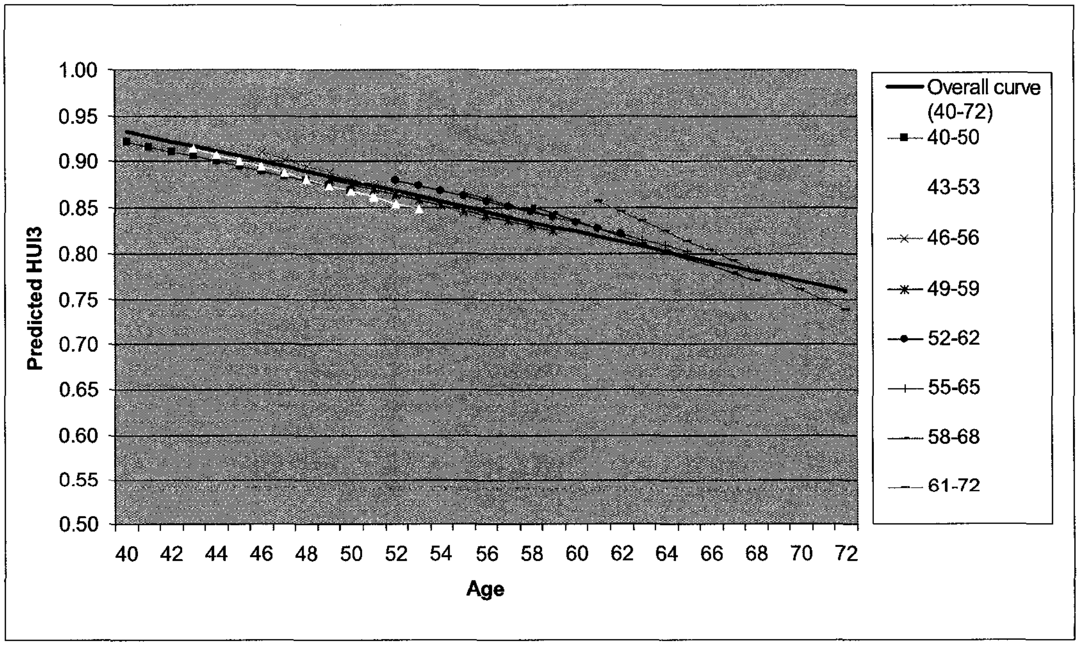
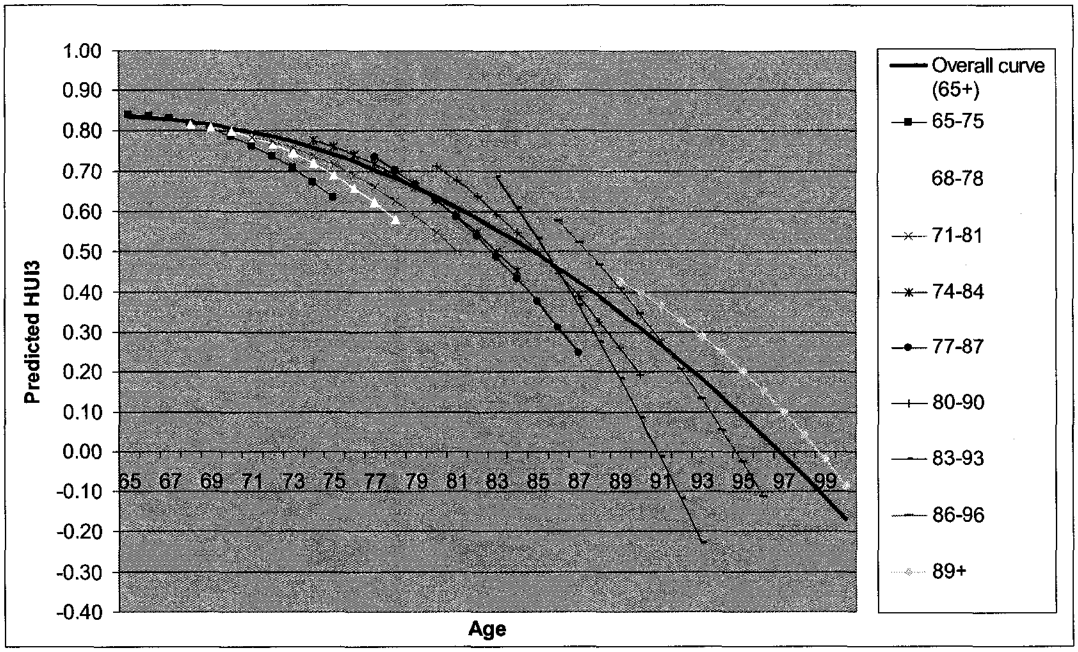
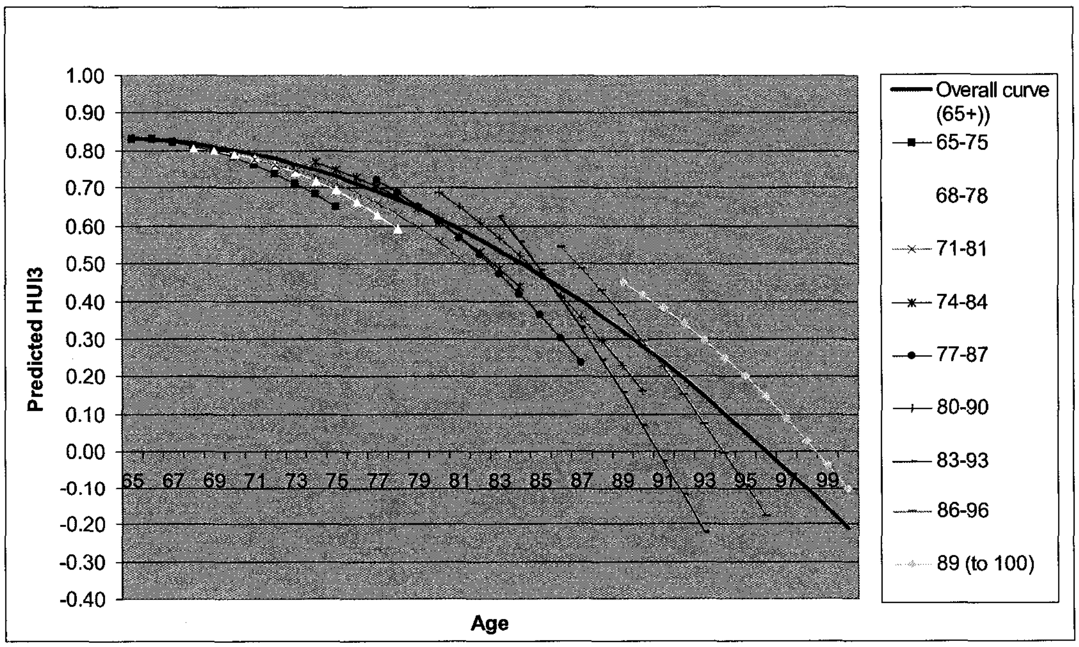


Figure A-3 Generalized linear mixed models - Seniors

Generalized linear mixed model



Linear mixed model (Original model)



Estimation results for conditional models based on generalized linear mixed model

Table A-1 Estimation results based on generalized linear mixed model - Young

		Generalized linear mixed model		Linear mixed model (Original)	
		b	SE	b	SE
Fixed effects	Intercept	0.960*	0.0024	0.964*	0.0024
	time	-0.003*	0.0003	-0.003*	0.0003
	DEAD (time-varying dummy)	-0.913*	0.0254	-0.868*	0.0195
Number of chronic conditions					
	1 condition	-0.029*	0.0024	-0.035*	0.0032
	2 conditions	-0.080*	0.0051	-0.084*	0.0091
	> 2 conditions	-0.154*	0.0098	-0.156*	0.0181
	no condition (ref)				
Education					
	No high school	-0.018*	0.0038	-0.021*	0.0057
	High school (ref)				
Social assistance					
	Received	-0.046*	0.0036	-0.054*	0.0062
	Not received (ref)				
Marital status					
	Single/divorced/separated/widowed	-0.015*	0.0020	-0.016*	0.0025
	Married/with partner/common-law (ref)				
Smoking					
	Current/former smoker	-0.012*	0.0023	-0.013*	0.0027
	Non-smoker (ref)				
Drinking					
	Abstainer/former drinker	-0.007*	0.0028	-0.010*	0.0039
	More than moderate drinker				
	Light/moderate drinker (ref)				
Physical activity					
	Physically inactive	-0.009*	0.0016	-0.015*	0.0018
	Physically active (ref)				
Random effects					
Within individuals		0.007*	0.0001	0.011*	0.0004
Between individuals					
Variance	Intercept	0.007*	0.0002	0.006*	0.0004
	Time	0.0001*	0.00001	0.00002*	0.000004
	$Time^2$				
Covariance	Intercept & Time	0.0002*	0.00003	0.0002*	0.00003
# parameters		16		16	
Deviance (-2*LL)		-28232		-29750	

*: Significant at 1%
time: median weighted cohort centered age

Table A-2 Estimation results based on generalized linear mixed model - Middle-aged

		Generalized linear mixed model		Linear mixed model (Original)	
		b	SE	b	SE
Fixed effects	Intercept	0.962*	0.0052	0.961*	0.0056
	time	-0.004*	0.0008	-0.004*	0.0008
	Cohort 43-53	-0.009	0.0063	-0.007	0.0069
	Cohort 46-56	-0.010	0.0064	-0.007	0.0070
	Cohort 49-59	-0.014	0.0065	-0.012	0.0077
	Cohort 52-62	-0.011	0.0069	-0.008	0.0081
	Cohort 55-65	-0.015	0.0072	-0.012	0.0082
	Cohort 58-68	-0.010	0.0073	-0.009	0.0085
	Cohort 61-72	-0.011	0.0069	-0.012	0.0082
	Cohort 43-53*time	0.001	0.0012	0.001	0.0012
	Cohort 46-56*time	0.0002	0.0012	-0.0001	0.0012
	Cohort 49-59*time	0.004*	0.0012	0.003*	0.0012
	Cohort 52-62*time	0.003	0.0013	0.003	0.0013
	Cohort 55-65*time	0.004*	0.0013	0.004*	0.0015
	Cohort 58-68*time	0.003	0.0013	0.003	0.0015
	Cohort 61-72*time	0.004*	0.0013	0.004*	0.0014
	DEAD (time-varying dummy)	-0.813*	0.0119	-0.781*	0.0109
Number of chronic conditions					
	1 condition	-0.029*	0.0025	-0.033*	0.0028
	2 conditions	-0.064*	0.0036	-0.076*	0.0049
	> 2 conditions	-0.142*	0.0050	-0.146*	0.0083
	no condition (ref)				
Education					
	No high school	-0.017*	0.0041	-0.019*	0.0049
	High school (ref)				
Social assistance					
	Received	-0.055*	0.0054	-0.064*	0.0087
	Not received (ref)				
Marital status					
	Single/divorced/separated/widowed	-0.028*	0.0033	-0.028*	0.0040
	Married/with partner/common-law (ref)				
Smoking					
	Current/former smoker	-0.017*	0.0032	-0.018*	0.0036
	Non-smoker (ref)				
Drinking					
	Abstainer/former drinker	-0.029*	0.0031	-0.029*	0.0042
	More than moderate drinker				
	Light/moderate drinker (ref)				
Physical activity					
	Physically inactive	-0.017*	0.0020	-0.022*	0.0030
	Physically active (ref)				
Random effects					
Within individuals		0.008*	0.0001	0.015*	0.0004
Between individuals					
Variance	Intercept	0.011*	0.0003	0.010*	0.001
	Time	0.0001*	0.00001	0.00004*	0.00001
	$Time^2$				
Covariance	Intercept & Time	0.0002*	0.00004	0.0002*	0.00004
# parameters		30		30	
Deviance (-2*LL)		-19488		-19649	

*: Significant at 1%; time: median weighted cohort centered age

Table A-3 Estimation results based on generalized linear mixed model - Seniors

		Generalized linear mixed model		Linear mixed model (Original)	
		b	SE	b	SE
Fixed effects	Intercept	0.938*	0.0096	0.960*	0.0088
	time	-0.002	0.0015	-0.002	0.0012
	Cohort 68-78	-0.015	0.0105	-0.019	0.0100
	Cohort 71-81	-0.037*	0.0106	-0.040*	0.0112
	Cohort 74-84	-0.045*	0.0109	-0.048*	0.0113
	Cohort 77-87	-0.081*	0.0121	-0.084*	0.0127
	Cohort 80-90	-0.099*	0.0139	-0.099*	0.0141
	Cohort 83-93	-0.111*	0.0157	-0.110*	0.0142
	Cohort 86-96	-0.162*	0.0191	-0.156*	0.0197
	Cohort 89	-0.202*	0.0238	-0.162*	0.0192
	Cohort 68-78*time	-0.0004	0.0022	-0.0008	0.0019
	Cohort 71-81*time	-0.003	0.0023	-0.001	0.0020
	Cohort 74-84*time	-0.003	0.0024	-0.002	0.0022
	Cohort 77-87*time	-0.004	0.0028	-0.004	0.0027
	Cohort 80-90*time	-0.012*	0.0032	-0.010*	0.0031
	Cohort 83-93*time	-0.003	0.0044	0.003	0.0034
	Cohort 86-96*time	-0.004	0.0053	0.002	0.0052
	Cohort 89*time	0.007	0.0060	0.008	0.0046
	INST (time-varying dummy)	-0.169*	0.0763	-0.211*	0.0767
	DEAD (time-varying dummy)	-0.712*	0.0083	-0.699*	0.0067
Number of chronic conditions					
	1 condition	-0.021*	0.0056	-0.035*	0.0051
	2 conditions	-0.059*	0.0062	-0.073*	0.0063
	> 2 conditions	-0.124*	0.0069	-0.140*	0.0075
	no condition (ref)				
Race					
	Non-white	-0.078*	0.0199	-0.067*	0.0240
	White (ref)				
Smoking					
	Current/former smoker	-0.020*	0.0058	-0.029*	0.0062
	Non-smoker (ref)				
Drinking					
	Abstainer/former drinker	-0.025*	0.0048	-0.034*	0.0057
	More than moderate drinker				
	Light/moderate drinker (ref)				
Physical activity					
	Physically inactive	-0.036*	0.0041	-0.049*	0.0042
	Physically active (ref)				
Random effects					
Within individuals		0.009*	0.0002	0.028*	0.001
Between individuals					
Variances	Intercept	0.018*	0.0008	0.008*	0.0005
	Time	0.0004*	0.00003	0.00001*	0.00001
	$Time^2$				
Covariance	Intercept & Time	-0.0002	0.0001	-0.0002*	0.00004
# parameters		32		32	
Deviance (-2*LL)		-2487		-3941	

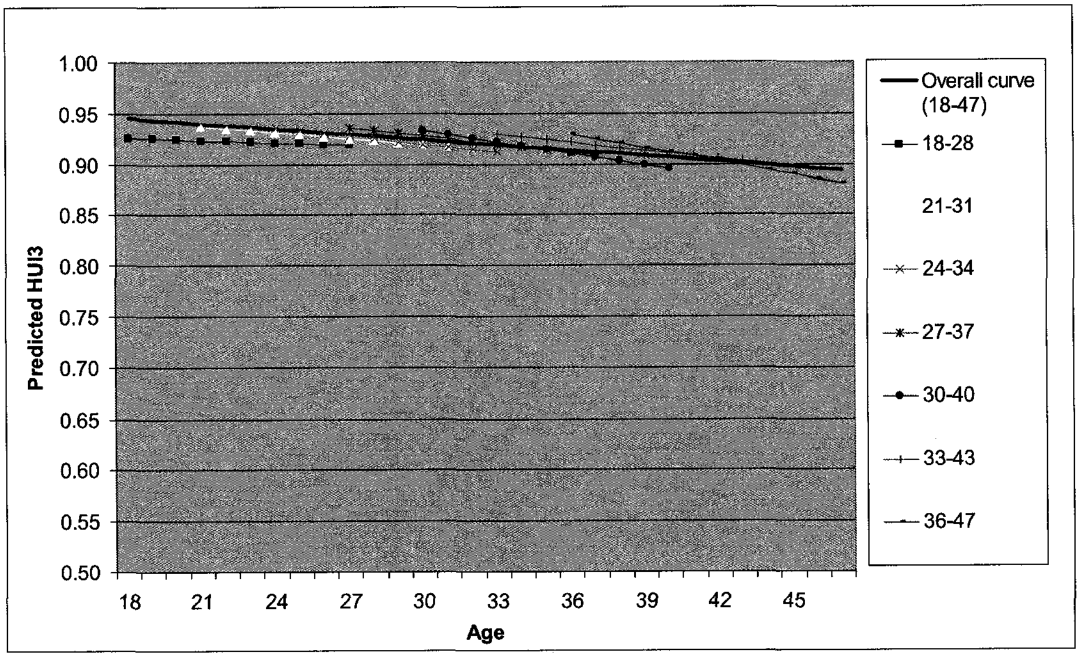
*: Significant at 1%; time: median weighted cohort centered age

Appendix I Sensitivity analyses: results

Unconditional models: Plots of predicted trajectories excluding records with DEAD=1

Figure A-4 Sensitivity analyses (unconditional models) - Young

DEAD=1 included



DEAD=1 excluded

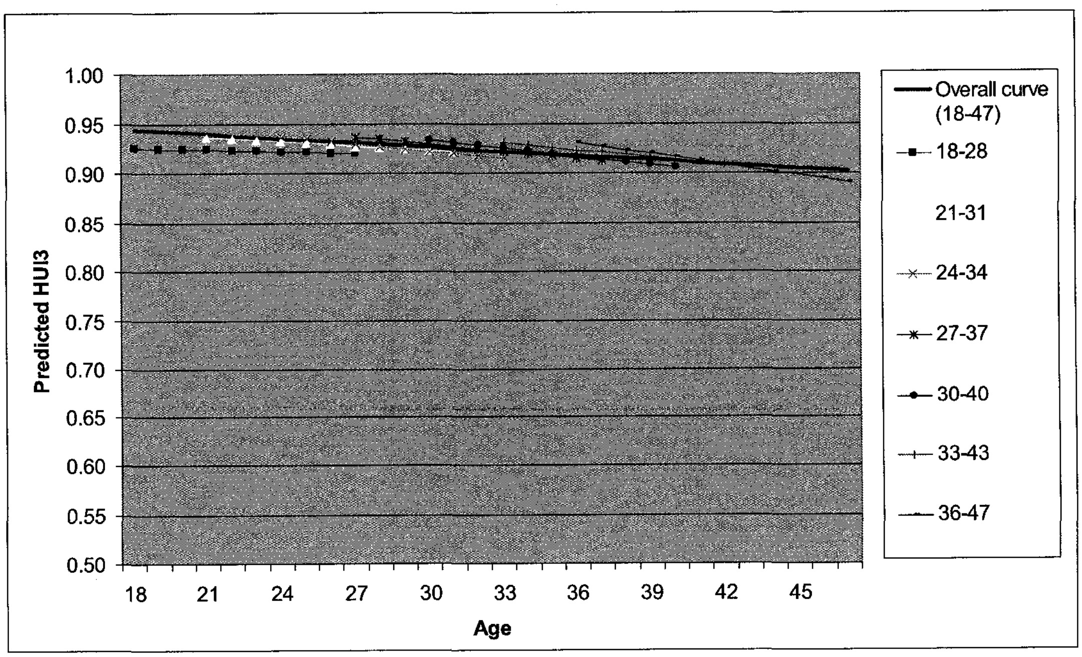
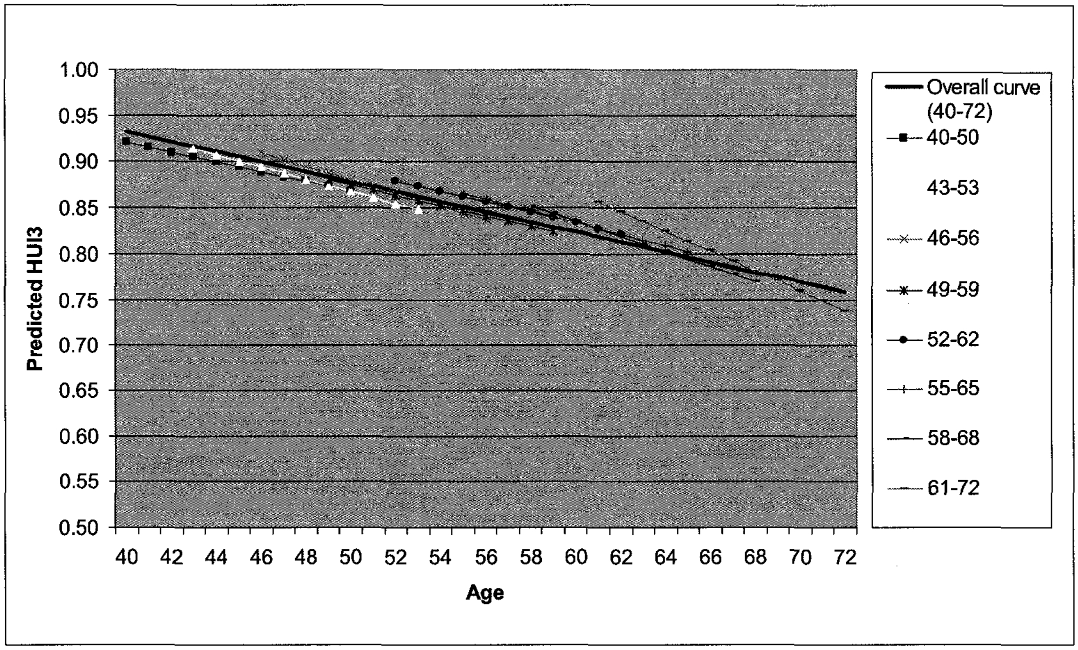


Figure A-5 Sensitivity analyses (unconditional models) - Middle-aged

DEAD=1 included



DEAD=1 excluded

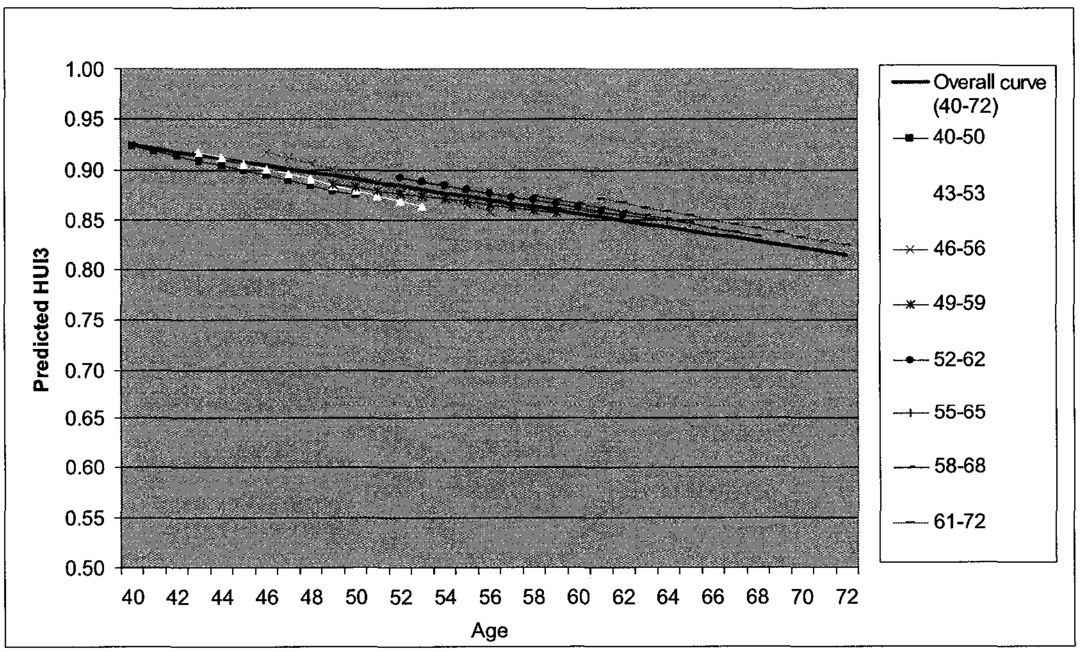
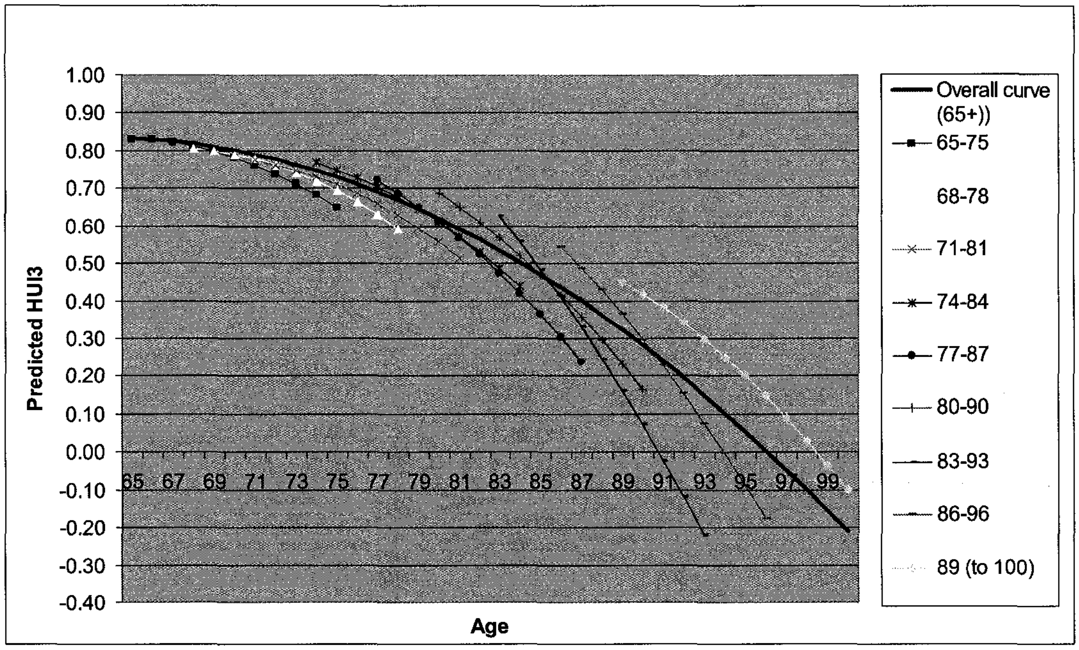
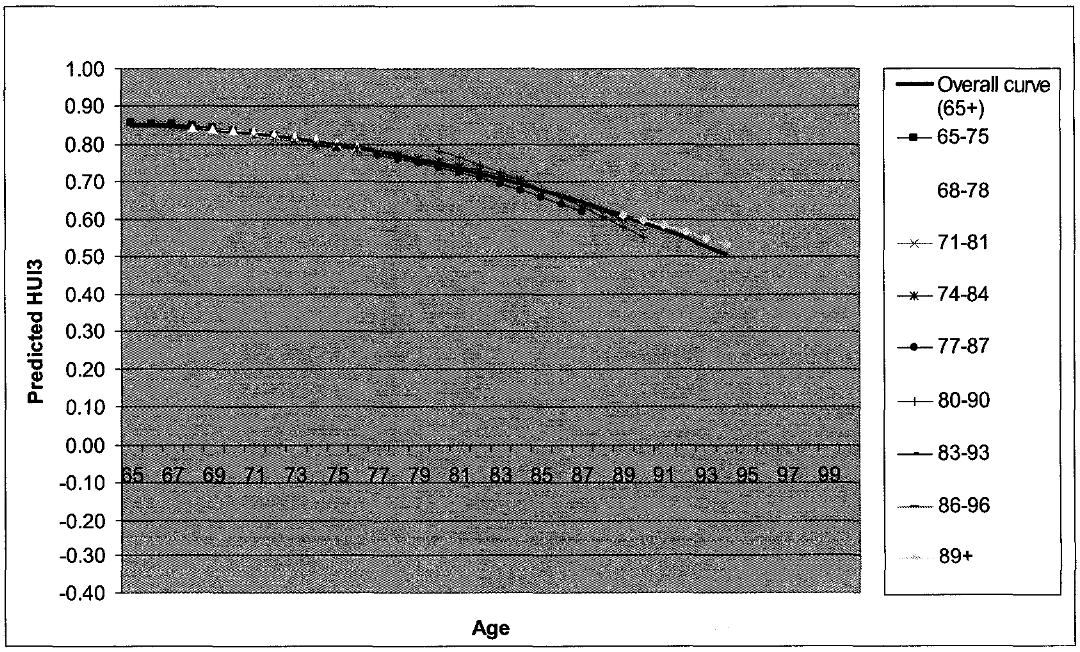


Figure A-6 Sensitivity analyses (unconditional models) - Seniors

DEAD=1 included



DEAD=1 excluded



__Note:__ Predicted values beyond 94 years old are not stated due to small sample size to calculate these values (however, records for age 94+ were included to estimate models)

Conditional models: Estimation results excluding records with DEAD = 1

Table A-4 Sensitivity analyses (conditional models) - Young

	Model Y2"		Model Y3"	
	b	**SE**	**b**	**SE**
Fixed effects				
Intercept	0.961*	0.0028	0.964*	0.0024
time	-0.003*	0.0003	-0.003*	0.0003
Number of chronic conditions				
1 condition	-0.035*	0.0032	-0.035*	0.0032
2 conditions	-0.083*	0.0091	0.084*	0.0091
> 2 conditions	-0.157*	0.0182	-0.157*	0.0182
no condition (ref)				
Sex				
Female	0.007	0.0032		
Male (ref)				
Race				
Non-white	-0.003	0.0052		
White (ref)				
Education				
No high school	-0.022*	0.0057	-0.021*	0.0057
High school (ref)				
Social assistance				
Received	-0.053*	0.0062	0.054*	0.0062
Not received (ref)				
Marital status				
Single/divorced/separated/widowed	-0.016*	0.0025	-0.016*	0.0025
Married/with partner/common-law (ref)				
Smoking				
Current/former smoker	-0.013*	0.0027	-0.013*	0.0027
Non-smoker (ref)				
Drinking				
Abstainer/former drinker	-0.010	0.0039	-0.011*	0.0039
More than moderate drinker	-0.006	0.0050		
Light/moderate drinker (ref)				
Physical activity				
Physically inactive	-0.015*	0.0019	-0.015*	0.0019
Physically active (ref)				
Random effects				
Within individuals	0.011*	0.0004	0.011*	0.0004
Between individuals				
Variances Intercept	0.006*	0.0005	0.006*	0.0005
Time	0.00002*	0.000004	0.00002*	0.000004
$Time^2$				
Covariance Intercept & Time	0.0002*	0.00003	0.0002*	0.00003
# parameters	18		15	
Deviance (-2*LL)	-29697		-29690	

Table A-5 Sensitivity analyses (conditional models) - Middle-age

	Model M2"		Model M3"	
	b	SE	b	SE
Fixed effects				
Intercept	0.958*	0.0058	0.961*	0.0057
time	-0.004*	0.0008	-0.004*	0.0008
Cohort 40-50 (ref)				
Cohort 43-53	-0.007	0.0071	-0.007	0.0071
Cohort 46-56	-0.006	0.0071	-0.006	0.0071
Cohort 49-59	-0.012	0.0078	-0.011	0.0079
Cohort 52-62	-0.008	0.0083	-0.008	0.0083
Cohort 55-65	-0.012	0.0084	-0.012	0.0085
Cohort 58-68	-0.007	0.0087	-0.007	0.0087
Cohort 61-72	-0.011	0.0085	-0.011	0.0086
Cohort 43-53*time	0.0004	0.0012	0.0004	0.0012
Cohort 46-56*time	0.00003	0.0012	0.00004	0.0012
Cohort 49-59*time	0.003*	0.0012	0.003*	0.0012
Cohort 52-62*time	0.003	0.0013	0.003	0.0013
Cohort 55-65*time	0.004*	0.0015	0.004*	0.0015
Cohort 58-68*time	0.003	0.0015	0.003	0.0015
Cohort 61-72*time	0.003	0.0014	0.003	0.0014
INST (time-varying dummy)	-0.081	0.0464		
Number of chronic conditions				
1 condition	-0.032*	0.0029	-0.032*	0.0029
2 conditions	-0.076*	0.0049	-0.077*	0.0049
> 2 conditions	-0.146*	0.0085	-0.147*	0.0084
no condition (ref)				
Sex				
Female	0.008	0.0042		
Male (ref)				
Race				
Non-white	-0.005	0.0096		
White (ref)				
Education				
No high school	-0.020*	0.0051	-0.020*	0.0051
High school (ref)				
Social assistance				
Received	-0.063*	0.0087	-0.063*	0.0087
Not received (ref)				
Marital status				
Single/divorced/separated/widowed	-0.027*	0.0041	-0.028*	0.0041
Married/with partner/common-law (ref)				
Smoking				
Current/former smoker	-0.019*	0.0035	-0.017*	0.0036
Non-smoker (ref)				
Drinking				
Abstainer/former drinker	-0.029*	0.0042	-0.029*	0.0043
More than moderate drinker	-0.007	0.0071		
Light/moderate drinker (ref)				
Physical activity				
Physically inactive	-0.021*	0.0023	-0.021*	0.0023
Physically active (ref)				

Table continued ...

Random effects					
Within individuals		0.015*	0.0004	0.015*	0.0004
Between individuals					
Variances	Intercept	0.011*	0.0006	0.011*	0.0006
	Time	0.00004*	0.00001	0.00004*	0.00001
	$Time^2$				
Covariance	Intercept & Time	0.0003*	0.00004	0.0003*	0.00004
# parameters		33		30	
Deviance (-2*LL)		-19515		-19515	

Table A-6 Sensitivity analyses (conditional models) - Seniors

	Model S2"		Model S3"	
	b	SE	b	SE
Fixed effects				
Intercept	0.977*	0.0111	0.962*	0.0098
time	-0.001	0.0012	-0.001*	0.0012
Cohort 65-75 (ref)				
Cohort 68-78	-0.013	0.0111	-0.015	0.0110
Cohort 71-81	-0.037*	0.0128	-0.039*	0.0128
Cohort 74-84	-0.047*	0.0134	-0.051*	0.0133
Cohort 77-87	-0.078*	0.0157	-0.081*	0.0156
Cohort 80-90	-0.091*	0.0189	-0.096*	0.0183
Cohort 83-93	-0.131*	0.0231	-0.136*	0.0229
Cohort 86-96	-0.192*	0.0304	-0.196*	0.0303
Cohort 89	-0.253*	0.0474	-0.261*	0.0467
Cohort 68-78*time	-0.001	0.0020	-0.001	0.0020
Cohort 71-81*time	-0.003	0.0021	-0.003	0.0021
Cohort 74-84*time	-0.003	0.0023	-0.003	0.0023
Cohort 77-87*time	-0.009*	0.0032	-0.009*	0.0032
Cohort 80-90*time	-0.018*	0.0038	-0.018*	0.0038
Cohort 83-93*time	-0.012	0.0057	-0.011	0.0056
Cohort 86-96*time	-0.022*	0.0065	-0.022*	0.0065
Cohort 89*time	-0.013	0.0091	-0.013	0.0090
INST (time-varying dummy)	-0.195*	0.0710	-0.194*	0.0696
Number of chronic conditions				
1 condition	-0.035*	0.0054	-0.035*	0.0054
2 conditions	-0.078*	0.0068	-0.078*	0.0068
> 2 conditions	-0.151*	0.0085	-0.151*	0.0085
no condition (ref)				
Sex				
Female	-0.014	0.0093		
Male (ref)				
Race				
Non-white	-0.068*	0.0260	-0.070*	0.0263
White (ref)				
Education				
No high school	-0.016	0.0083		
High school (ref)				
Social assistance				
Received	-0.003	0.0216		
Not received (ref)				
Marital status				
Single/divorced/separated/widowed	-0.012	0.0078		
Married/with partner/common-law (ref)				
Smoking				
Current/former smoker	-0.020*	0.0073	-0.023*	0.0071
Non-smoker (ref)				
Drinking				
Abstainer/former drinker	-0.037*	0.0064	-0.037*	0.0063
More than moderate drinker	-0.016	0.0224		
Light/moderate drinker (ref)				
Physical activity				
Physically inactive	-0.045*	0.0044	-0.045*	0.0044
Physically active (ref)				

Table continued ...

Random effects					
Within individuals		0.026*	0.0008	0.026*	0.0008
Between individuals					
Variances	Intercept	0.014*	0.0007	0.014*	0.0007
	Time	0.00001	0.00001	0.00001	0.00001
	$Time^2$				
Covariance	Intercept & Time	0.0004*	0.00004	0.0004*	0.00004
# parameters		35		30	
Deviance (-2*LL)		-3227		-3216	

Chapter 5: Summary

5-1 Introduction

This thesis was motivated by the population health approach, which has been widely recognized in Canada as a research and policy framework. A focus of the thesis was on the Health Utilities Index Mark 3 (HUI3), one of the generic, multi-attribute and utility-based health-related quality of life (HRQL) measures and its usefulness in population health research. Generic measures are useful in population health research because they can be used to compare individuals with a variety of chronic conditions. Multi-attribute measures are useful in assessing various aspects of morbidity burdens that general population and patients may experience. Furthermore, the use of utility-based measures allows us to use the health outcome measurements in resource allocation decisions. All of these are important for agendas in population health research.

The general objective of this thesis was to assess the determinants of health of Canadians. In order to achieve this objective, the usefulness of HUI3 in population health research was assessed for four key aspects: instrument validation, assessing factors associated with heterogeneities in health outcomes, assessing longitudinal determinants of health, and deriving policy implications. In particular, this thesis was developed in two major parts. The first part (Chapter 2) was to assess the validity of HUI3 and the second part (Chapters 3 and 4) was to investigate cross-sectional and longitudinal determinants of health. In each chapter, relevant policy implications were addressed.

5-2 The validity of HUI3 – summary

Chapter 2 focused on the assessment of the validity of three chronic conditions common to the middle-aged to elderly populations: Alzheimer Disease (AD), arthritis, and cataracts. Known-group comparisons of predicted overall as well as single-attribute HUI3 scores were conducted among five subgroups: those with AD only, arthritis only, cataracts only, at least two of the three conditions, and none of the three conditions. The paper demonstrated the validity of HUI3 in assessing HRQL of AD, arthritis and cataracts for those living in the community as well as those living in long-term care institutions. In particular, it was shown that HUI3 was able to differentiate overall burdens associated with the three chronic conditions. As well, HUI3 was able to describe speech and cognition burdens known to be associated with AD, ambulation and pain burdens with arthritis, and vision burdens associated with cataracts. Therefore, it was concluded that the evidence supports the usefulness of HUI3 in assessing HRQL burdens in these chronic conditions for middle-aged to senior populations.

5-3 The validity of HUI3 – implications and future research

Chapter 2 provided two major implications for investigators and policy makers. First, as Kindig and Stoddart noted, the instrument validation "… is a crucial task for the field of population health research."[1] For investigators and policy makers who attempt to use and interpret HRQL measures for various purposes, it is important to be aware of the existing evidence and advantages and disadvantages of each HRQL measure. It is also important to recognize that resource allocation decisions are based on evidence derived using appropriate and validated HRQL measures for the target population. For example, Chapter 2 showed that HUI3 was able to discriminate major burdens unique in each of the three targeted chronic conditions: AD, arthritis and cataracts. However, the current study also showed that HUI3 was not able to identify, cross-sectionally, ambulation problems hypothesized to be relevant in those with AD and, similarly, dexterity problems with arthritis. Therefore, the assessment of HRQL for those with AD and arthritis with respect to these attributes using HUI3 should be made with caution. Moreover, the seemingly unexpected results with respect to ambulation and dexterity attributes mentioned above may be unique to the current study design (e.g. the creation of "Combined" group (i.e. those with at least two of the three conditions)) and/or available information. In this study, the major study considerations were the lack of sample size in defining finer comparison groups for the "Combined" group, and the absence of information with respect to severity of each condition in NPHS data. For instance, results from Neumann et al (2000) that compared HUI3 scores for various stages of AD patient showed lower ambulation scores for those with more severe AD.[2] In this respect, future research might compare results of the current study with other studies using population surveys with larger sample size (for example, Canadian Community Health Survey, a more recent cross-sectional survey containing representative sample of community residents in

Canada[3]). In addition, the inclusion of information on severity in major chronic condition in population health surveys would be useful for future validation studies. Using information on disease severity, validity can be examined in a more precise manner.

Second, instrument validation is an on-going process. In particular, when measuring HRQL, the accumulation of evidence of validity plays an important role for the instrument validation. The validation of an instrument in one clinical condition does not necessarily imply the validity of the instrument in measuring HRQL for other conditions. For example, evidence of the validity of HUI3 was reported for stroke and arthritis using the 1990 Ontario Health Survey, a community survey targeting residents of Ontario.[4] However, this does not necessarily imply the validity of HUI3 in measuring HRQL of individuals with, for example AD. Nor do the results necessarily imply the validity of HUI3 for elderly population and/or for those who are living in long-term care institutions. Furthermore, HRQL can be used in a variety of purposes: for instance, discrimination, evaluation and prediction.[5] This study demonstrated the ability of HUI3 to discriminate burdens associated with AD, arthritis and cataracts. However, to the author's knowledge, evidences of the evaluative and predictive ability of HUI3 in assessing these three conditions have not yet demonstrated to date. Therefore, future studies investigating longitudinal validity of these conditions are also important.

5-4 Determinants of health – summary

The second major objective of this thesis was to investigate factors associated with variations in HRQL. This objective was assessed in Chapters 3 and 4. Chapter 3 investigated cross-sectional comparisons of the determinants of health of those living in the community and in the long-term care institutions. Chapter 4 assessed HRQL longitudinally by estimating health trajectories.

Results from the cross-sectional study showed that the determinants of health equations statistically differed between those living in the community and those living in institutions. Regression results showed two important findings. First, consistent with existing studies, logistic regression results showed that current health status, socio-demographic factors (e.g. age, education, sex, marital status, income) and health risk factors were all important determinants of the probability of being in a long-term care institution. However, there is little evidence on the important determinants of health factors among institutionalized individuals. Do the determinants of health of people in institutions differ from those living in the community? Linear regression results comparing the determinants of health of those living in the community and in institutions showed that, for those who were in institutions, determinants of health factors such as advanced age, lower education, financial status, not being married, and smoking were no longer important health determinants. Instead, only chronic conditions and alcohol use were found to be important factors for individuals in institutions.

Chapter 4 estimated HRQL trajectories of the general adult population and explored factors associated with heterogeneities in trajectories using growth-curve models. Separate HRQL trajectories were estimated for young (age 18-39), middle-aged (40-64) and seniors (65+) taking account of mortality and cohort effects. Results based on unconditional models showed that a typical health trajectory was represented by a concave curve (starting with the HUI3 score of approximately 0.90 at age 18) with a very slow decline in HRQL until the age of 60, followed by a rapid decline in HUI3 score. Conditional trajectories estimated separately for the three age groups showed important heterogeneities in trajectories across the three age groups. In particular, trajectories for seniors (age 65+) were distinctly different from those for young and middle-aged groups. For seniors, contrary to findings in young and middle-aged groups, financial status (whether or not one received social assistance), education and marital status were unimportant in explaining heterogeneities in trajectories. Instead, unfavourable lifestyle factors (i.e. abstaining from alcohol, smoking and physical inactivity) had important negative effects for seniors. Another interesting finding was that the magnitude of effects of the number of chronic conditions on variations in trajectories was comparable across age groups. Although the impacts of most of the demographic, socio-economic and health risk factors on HRQL trajectories changed over time, there was consistent negative association between the number of chronic conditions and levels of HRQL trajectories throughout the life course.

5-5 Determinants of health – implications and future research

Results from the determinants of health studies provide research and policy implications. Implications from the cross-sectional determinants of health study (Chapter 3) are that the usual determinants of health factors found from the community-based samples are less important for individuals in institutions. Hence, there appeared to be important differences in determinants of health between these two groups. In addition, risk factors for institutionalization and factors associated with HRQL of those who were already institutionalized differed. The finding implies that evidence used for the management of HRQL of those who are institutionalized and evidence required for the reduction of the incidence of institutionalization may differ. More specifically, logistic regression results from this study showed that all the usual determinants of health factors (i.e. age, sex, marital status, income and health risk factors) and health status were important predictors of institutionalization. Therefore, policies aiming at the prevention of institutionalization need to take account of a wide variety of factors. However, according to the current study results, only a few of these determinants (i.e. chronic conditions and alcohol) were found to be important for those living in institutions. Therefore, the result implies that policies targeting at the management of HRQL for individuals already living in long-term care institutions can be achieved by focusing on a narrower set of determinants.

There are several methodological and policy implications from the longitudinal determinants of health study (Chapter 4). Two major methodological implications are with respect to mortality and cohort effects. Chapter 4 showed that the use of HUI3 as a health outcome measure is a useful alternative to the existing methods for incorporating dead into the trajectory models. It was shown that an exclusion of the incidence of death in the trajectory model importantly affected the estimated trajectories. Therefore, instead of imputing alternative values for the state of being dead and conducting sensitivity analyses, the use of HUI3 can effectively incorporate dead into the estimation of trajectories. The second methodological implication is with respect to the use of accelerated longitudinal data. When using data based on accelerated longitudinal design, it is important to acknowledge that we are in fact estimating trajectories for overlapping cohorts and these trajectories are combined to provide "composite image" of life-course trajectory.[6,7] Therefore, in estimating trajectories, it is important to test for potential cohort effects. If cohort effects exist, we need to control for the effect in order to distinguish age effects from cohort effects. Based on the current study, cohort effects were particularly evident for trajectories for seniors (65+), suggesting important cohort-related heterogeneities in trajectories.

A major policy implication from Chapter 4 is that, in understanding factors that affect heterogeneities in trajectories, there are differential determinants of health factors for each phase of life. The findings from the current study are useful for the efficient allocation health resources in maintaining and improving HRQL over time. For young and middle-aged, lack of financial resources, low education and not being married had important impact on lowering the level of HRQL trajectories. In contrast, for seniors, lifestyle factors were more important determinants of the trajectories. Therefore, focusing on the improvement in socio-economic factors could efficiently attain higher trajectories for young-adult and middle-aged groups, whereas, for seniors, focusing on the improvements in life-style factors maybe more efficient in achieving the same goal. Moreover, given that the effects of chronic condition on HRQL trajectories were found to be persistent regardless of age groups, the reduction in the incidence as well as effective management of chronic conditions will be important throughout the life cycle.

A number of future applications of the work presented here can be also addressed. Two potential methodological extensions common to both cross-sectional and longitudinal determinants of health studies are to explore multilevel as well as mediation analyses. First, a number of existing studies show that community-level factors are important determinants of health (examples are positive effects of regional economic prosperity[8], higher proportion of educated individuals in regions[9], and community belonging[10]). Supported by growing evidence of community-level impact on health, it has been recognized that the improvements in social environment contribute to the effective delivery of public health policy.[11-13] Such multilevel mechanism has been also recognized in the Canadian Institute of Advanced Research (CIAR) determinants of health framework, which includes a pathway from social and physical environment to health. Moreover, the assessment of dynamic effects of community-level factors on health is another topic of the research agenda. Past multilevel studies used group-level variables but they were typically only measured at one point in time.[14] Therefore, the importance of the use of longitudinal data has been emphasized to explore lagged effects of community-level exposures on outcomes[15,16] as well as effects of changes in community-level variables on health outcomes.[14,17] Understanding dynamic effects on health will provide additional important implications for formulating effective health policy.[18,19]

Second, another key development in the CIAR framework was an introduction of "Individual (biological and behavioural (lifestyle)) response" as a potential mediator between a pathway from the "Social environment" to "Health". Therefore, implicit in the model is that an individual's choice may be "… conditioned by the social environment of the individual, whose behaviour then constitutes a 'host response' to environmental stimuli … such social environmental risk factors can then operate to produce a pattern of negative health habits in a particular subgroup, greatly influencing their average health status."[20] The existence of mediating factors associated with health status and/or risky behaviour has been previously studied in the context of multilevel framework.[21-23] However, the mediation path proposed in the CIAR framework has not been well explored to date.

Other future research interests unique to longitudinal studies are: the assessment of interaction effects among the determinants of health trajectories, and the integration of research evidences associated with childhood and adult trajectories. The determinants of health studies presented in this thesis concerned with the assessment of systematic heterogeneities in the levels of trajectories across populations. Taking a step further, the assessment of interaction effects on trajectories is of important policy interests. One of the study limitations for the trajectory study presented in Chapter 4 was that two-way (time by determinants of health factors) or three-way (time by determinants of health factors by cohort) interactions were not incorporated due to statistical non-significance. Therefore, trajectory models estimated in Chapter 4 assumed that only levels, not the rate of change in HRQL, differed by various levels of the determinants of health variables. An inclusion of these complex interaction terms will allow researchers to test a variety of interesting hypotheses.[24-26] For example, questions such as "does HRQL of individuals who have been smoking deteriorate at a faster rate than the HRQL of those who do not smoke?", or "do the differences in trajectory levels by socio-economic status diverge or converge over time?" may provide more directly policy-related evidence.

The final issue is the potential for integrating findings based on child health trajectories (i.e. developmental health trajectories) with those based on adult health trajectories. The focus of this thesis was on identifying the source of heterogeneities HRQL for the adult population. Therefore, these studies mainly concerned with identifying factors that differentiated health outcomes. The identification of such factors is an important first step in disentangling the complex mechanism of the association between health and its determinants. However, the ultimate policy question may be to ask "why" such differences are apparent in adult populations. The recent development of the Life Course Health Development (LCHD) framework may be useful to help explore the question in future studies. The LCHD framework suggests the integration of childhood and adult trajectories. One of the mechanisms proposed in the LCHD framework is so called the programming mechanism. The programming mechanism emphasizes impacts of early childhood exposures on health outcomes in adulthood.[27] The mechanism suggests that the early childhood exposures to social and physical environment (e.g. maternal and family environments, exposure to allergens) are programmed into the body through "... permanent changes in an organism's functional system"[27], and such early childhood exposures subsequently impact health in later life. Therefore, it may be that observed heterogeneities in HRQL trajectories found in the current studies are fundamentally a consequence of physiological changes formulated in early childhood; investigations of such mechanism will be useful. An inclusion of information on biological factors in empirical analyses is challenging, especially at the population level. Nonetheless, the importance of collecting information on biological markers in a large-scale survey has been recognized. The recent launch of the Canadian Health Measures Survey (CHMS) by Statistics Canada (which collects information on various biological markers as well as usual socio-economic and health-related information, including HUI3)[28] is one example that represents the trend. Although CHMS is a cross-sectional survey, it is an important addition to the existing Canadian health surveys. Information collected in the CHMS will allow population health investigators to expand their research horizons in exploring pathways by which various levels of health determinants impact health outcomes.

5-6 Conclusion

To conclude, this thesis showed that HUI3 is a useful health outcome measure in population health research. The current work provided evidence that HUI3 is able to measure and discriminate disease burdens across populations. It was also demonstrated that HUI3 is useful in identifying factors associated with heterogeneities in the determinants of health both cross-sectionally and longitudinally. This thesis provided important results that, in assessing determinants of health of population, it is important to investigate not only those living in the community but also those living in long-term care institutions. It was also shown that HUI3 is useful in longitudinal trajectory studies where non-ignorable mortality effects exist. Moreover, the use of generic, utility-based HRQL measures such as HUI3 in population health research allows investigators to compare results obtained from different populations and chronic conditions, making it possible to integrate existing evidence. In addition, the use of utility-based HRQL measures allows resource allocation decision through cost-utility analyses. It is, therefore, the authors' hope that the work presented here motivates investigators and policy makers to acknowledge the usefulness of HUI3 in population health research.

The accumulation of empirical evidence is an important aspect of the population health research. However, the ultimate goal of the population health research is to influence public health policy through resource allocation decisions[1]. Hays and Dunn (1998) referred to the work by Saunders et al (1996) that noted several reasons why the existing population health research has limited influence on health policy: lack of understanding in relative importance of the determinants of health factors, lack of understanding of the pathways through which the determinants of health influence health, and the lack of initiative in synthesizing evidence generated from population health studies.[29,30] During the past decade, a growing number of empirical studies, especially longitudinal studies, have become available for evaluation. For the population health research to be useful for decision making, however, all aspects of population health research need to be addressed. HUI3 is one useful tool in every phase of population health research: from measurement to resource allocation.

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