UNDERSTANDING DETERMINANTS OF HEALTH IN TYPE 2 DIABETES

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ABSTRACT

Objective

To assess a broad range of determinants of health to determine which are most strongly associated with health-related quality of life (HRQL) in people with type 2 diabetes.

Methods

This study used respondents from Canadian Community Health Survey Cycle 1.1 who were over the age of 18 and were identified as having type 2 diabetes. Regression analyses were used to assess the relationships between the Health Utilities Index Mark 3 (HUI3) and determinants of health, including sociodemographics, comorbidities, health behaviors, physical and social environmental factors, and indicators of access to healthcare.

Results

The average age of the analysis sample (n = 4,678) was 61.6 (Standard Deviation (SD) 13.3), with an average duration of diabetes of 9.3 (9.8) years. Approximately, 51.7% of respondents were male. The average overall HUI3 score was 0.78 (0.26). Comorbidities had the largest impact on HRQL, with stroke (-0.11; 95% CI -0.17 to -0.06) and depression (-0.11; 95% CI -0.15 to -0.06) being associated with the largest deficits. Large differences in HRQL were also observed according to two markers of socio-economic status: social assistance (-0.07; 95% CI -0.12 to -0.03) and food insecurity (-0.07; 95% CI -0.10 to -0.04). Insulin use was associated with a clinically important HRQL deficit (-0.04; 95% CI -0.08 to -0.01), as was having less than secondary education, relative to having a university degree (-0.04; 95% CI -0.07 to -0.02). Overall, the determinants of health model explained 36% of the variance in HUI3.

Conclusions

These results demonstrated that while many social and environmental factors impact the health of individuals with type 2 diabetes, comorbidities such as cardiovascular disease and depression have the largest impact on HRQL for people with type 2 diabetes.

INTRODUCTION

Diabetes affects approximately 5% of all Canadians aged 20 years or older, with the prevalence rising with age (Health Canada 2003). Type 2 diabetes accounts for 90% of the diagnosed cases of diabetes in Canada and can be associated with a substantial burden for individuals with the disease and for their families. The health-related quality of life (HRQL) deficits reported by people with diabetes are generally attributed to the disease itself, its restrictive treatment regimens and its associated comorbidities. The observed heterogeneities in HRQL associated with diabetes, however, may be better explained in the context of a more holistic "determinants of health" framework since population health is not solely related to disease and treatment (Federal, Provincial and Territorial Advisory Committee on Population Health 1999; Evans 1990).

The Population Health Framework developed by the Canadian Institute for Advanced Research (CIAR) was designed as a means of conceptualizing the determinants of health and their causal linkages (Appendix 1) (Evans, 1990). It is intended to be a guideline for shaping policy and research (Health Canada, 2002), but due to the complexity of the specified relationships, operationalizing it from an analytical perspective is difficult. Based on CIAR's Population Health Framework, Hertzman, Frank, and Evans proposed a conceptual scheme for organizing and analyzing the relative importance of individual level determinants of health specified in the Population Health Framework (Hertzman 1994). Using this conceptual scheme, the determinants of health are grouped into three major dimensions or domains: Stage of the Life Cycle, Subpopulation Partitions, and Sources of Heterogeneity (Table 1) (Hertzman 1994). The dimensions relate to each other along three axes (Figure 1).

The Stage of the Life Cycle domain reflects that age, in part, determines an individual's vulnerabilities or susceptibility to disease. In the conceptual scheme, the Stage of the Life Cycle is divided into four age categories that generally reflect the underlying vulnerabilities (Table 1) (Hertzman 1994). In type 2 diabetes, the lower age boundary for the Chronic Disease Stage becomes less relevant as all individuals with type 2 diabetes have already developed a chronic disease. Further, comorbidities and complications occur frequently in people with type 2 diabetes, often even before diabetes is diagnosed, and negatively impact HRQL (Lloyd 2001; de Visser 2002). Approximately 60% of individuals have one or more complications, while almost one-quarter have two or more complications (Liebl 2002).

The second domain of determinants of health, Subpopulation Partitions (Table 1), are segments of the population across which heterogeneities in health status are observed (Hertzman 1994). Sex and socioeconomic status are examples of Subpopulation Partitions. Unique to type 2 diabetes, individuals who use insulin could be considered a Subpopulation Partition (specifically a special population) as they generally have HRQL deficits compared to those who do not use insulin.(Glasgow 1997; Keinanen-Kiukaanniemi 1996; Petterson 1998) The HRQL deficits associated with insulin use may simply relate to the observation that insulin users often have disease which has progressed further (Glasgow 1997; Keinanen-Kiukaanniemi 1996; Petterson 1998) or may relate to the increased treatment burden associated with insulin use (Redekop 2002).

Sources of Heterogeneity are considered mechanisms that operate across Subpopulation Partitions and Stages of the Lifecycle and are an attempt to understand why differences in HRQL are observed between Subpopulation Partitions. In the conceptual scheme, the Sources of Heterogeneity are quite diverse and include behavioral and social determinants of health, as well as aspects of the environment, genetic endowment, and differential access to health care (Table 1).

The general approach to studying factors associated with HRQL in diabetes has tended to focus on demographic and clinical factors (Lloyd 2001; Keinanen-Kiukaanniemi 1996; Petterson 1998; Redekop 2002; Rubin 1999; Hanninen 1998; Coffey 2002; Tabaei 2004; Wandell 2000; Camacho 2002; Aalto 1997; Klein 1998; Jacobson 1994; Maddigan 2003), There are few, if any studies that include individual life-style factors (such as stress), the social environment (such as social integration), and realized access to health care. Previous research has shown that demographic characteristics (i.e., age, sex, race, income, and education) and clinical factors (i.e., complications and comorbidities, duration of diabetes, insulin) impact HRQL in diabetes and that some heterogeneities in HRQL in diabetes can be explained by these factors (Rubin 1999). This is not surprising as a number of these variables are determinants of population health (Evans 1990), but perhaps heterogeneities in HRQL in type 2 diabetes could be better explained using the more comprehensive Population Health Framework (Appendix D), operationalized as in the Hertzman et al. conceptual scheme. With the Stage of Life Cycle, Subpopulation Partitions, and Sources of Heterogeneity taken together, perhaps a better understanding of the factors driving HRQL deficits in type 2 diabetes could be gained. Alternatively, it is possible that the inclusion of more broad determinants of health does not enhance our understanding and that focusing on demographic and clinical factors may be sufficient.

STUDY OBJECTIVE

The purpose of this analysis was to assess (1) the magnitude of HRQL deficits associated with determinants of health in type 2 diabetes and (2) the contribution of the Hertzman et al. Stage of Life Cycle, Subpopulation Partitions and Sources of Heterogeneities to the explained variance in HRQL in type 2 diabetes.

RESEARCH DESIGN AND METHODS

Survey Design

Data from the Canadian Community Health Survey (CCHS) Cycle 1.1 were used in this analysis. The CCHS is a cross-sectional survey carried out across the 10 provinces and three territories of Canada in the population over age 12 (Beland 2002). Data are collected on utilization of health services, determinants of health and health status on a two year cycle (Beland 2002). Cycle 1.1 had a large sample (N = 131, 535), sufficient in size to give reliable estimates at the level of the health region (Beland 2002). The survey excludes individuals living on crown or reserve land, in institutions, in some remote areas of the country, and members of the Canadian Armed Forces.. Approximately 98% of the Canadian population over 12 years of age is represented in the CCHS even with these exclusions (Beland 2002).

The CCHS has multiple sampling frames termed the *area frame* and *telephone frame*. For the area frame, the sample was drawn using a multistage stratified cluster design based on the sampling frame designed for the Canadian Labour Force Survey (Statistics Canada 1998). Approximately 83% of the sample was taken from the area frame; however, in some health regions, the telephone frame was also used, comprising the remaining 17% of the sample (Statistics Canada 2004). Within the area frame, in approximately 82% of households, one respondent was selected at random to be surveyed with an in-person interview, but in the remaining 18% of households, two respondents were randomly selected to be surveyed. Two respondents were chosen in order to over-represent individuals in the age group 12 to 19 years (Beland, 2002). In the telephone frame, random sampling was used and only one respondent was surveyed per household.

Data for Cycle 1.1 were collected between September 2000 and November 2001 using computer assisted interviewing. The interview took approximately 45 minutes to complete. Overall, including both sampling frames, 41.4% of respondents used in these analyses had telephone interviews, 56.7% had in-person interviews, and 1.9% had a combination of techniques.

Proxy reporting was permitted for certain components of the interview, but many components were deemed only appropriate for self response. Proxy reporting was permitted only if the selected respondent would not be available for the entire period of data collection, was unable to respond due to physical or mental illness preventing the interview, or had a language barrier (Statistics Canada 2004). At the end of Cycle 1.1, the overall response rate was 84.7% (Statistics Canada 2004).

Sample

Approximately 6361 respondents self reported having a diagnosis of diabetes, representing a weighted percentage of 4.1%. An algorithm based upon age, treatment regimen, duration of time from initial diagnosis to initiation of insulin therapy, and age at diagnosis was used to categorize individuals as having type 1 or type 2 diabetes (Figure 2). The criteria of less than 30 years old and being placed on insulin immediately has been used previously to classify individuals as having type 1 diabetes (Hahl 2002). Being on an oral agent to manage diabetes has previously been used to categorize respondents as having type 2 diabetes (Eurich 2004; Johnson 2002). Of the respondents who were categorized as having type 2 diabetes, 4678 (83.1%) had complete data and were included in this analysis (Figure 3).

HEALTH UTILITIES INDEX MARK 3 (HUI3)

HUI3 is a preference-based measure of HRQL that uses a multiplicative utility function to assign valuations to different health states (Feeny 2002; Feeny 1995). Using the multi-attribute approach, health states are defined by a classification system that includes a set of dimensions or attributes of HRQL, with a number of different levels of functioning for each attribute. In the HUI3 system, eight attributes (including vision, hearing, speech, ambulation, dexterity, emotion, cognition, and pain) define health status. Each attribute has five or six levels, creating 972,000 unique HUI3 health states (Appendix 2) (Feeny 2002). The overall utility function for the HUI3 was derived from visual analogue scale and standard gamble techniques and responses from random samples from the general population in Hamilton, Ontario, Canada (Feeny 2002). Overall scores on the HUI3 range from -0.36 to 1.0, with -0.36 representing the utility of the worst possible HUI3 health state, 0.0 representing dead, and 1.0 representing perfect health (Feeny, 2002). Differences of greater than 0.03 for HUI3 overall scores are considered to be clinically important (Horsman 2003). Assessment of health status using the HUI3 can be based upon current or usual health. In the versions of the questionnaire used to assess current health status, a specific duration of recall is given: one, two or four weeks. Population survey applications of the HUI3 typically assess usual health status, and no duration of recall is given (Horsman 2003). In the CCHS, the HUI3 was administered as a 31-item, questionnaire with no specific recall period (i.e., "Are you usually able to…").

DETERMINANTS OF HEALTH

Table 2 summarizes the independent variables used in the analysis, the manner in which they were operationalized and their categorization into the three domains in the Hertzman et al. conceptual scheme.

Stage of Life Cycle

Age

Consistent with the exponential increase in comorbid conditions over the age of 70 (Crimmins 2001), previous research using the HUI3 has detected a nonlinear relationship between age and HRQL (Maddigan 2005; Austin 2002). Thus, age was operationalized in the quadratic form (i.e. $b_1\text{age} + b_2\text{age}^2$). Due to collinearity between age and its square, age was analyzed as a deviation from its mean (i.e. mean centered: age - 61.55) and the square of this variable [$(\text{age} - 61.55)^2$] (Pedhazur 1997). This procedure has no effect on estimates of other variables in the analyses. It simply reduces the correlation between a variable and its square from approximately one to approximately zero (Pedhazur 1997), which can correct issues related to the high correlation, or collinearity, such as inflation of standard errors of a variable or its square and difficulties estimating the beta coefficient of either variable.

Sentinel Comorbid Medical Conditions

During the chronic disease Stage of Life Cycle, degenerative diseases such as heart disease, stroke, and arthritis are considered the primary threats to health in the Hertzman et al. conceptual scheme and as such, are of particular significance (Hertzman 1994). Moreover, heart disease and stroke are two common macrovascular comorbidities in diabetes (Lloyd 2001; de Visser 2002; Simpson 2003; James 1997) that are associated with large HRQL deficits (Lloyd 2001; de Visser 2002; Tengs 2003; Grootendorst 2000; Post 2001) It is also relatively common for individuals with type 2 diabetes to have osteoarthritis since both conditions are more common in older adults and those who are obese (Sturmer 2001). Past research has demonstrated that comorbid arthritis or osteoarthritis is associated with significant HRQL deficits in diabetes (Maddigan 2005; Maddigan 2003b). In addition to degenerative diseases, depression is a relevant comorbidity to consider since diabetes is associated with an approximately two-fold increased risk of depression (Anderson 2001) and depression has been associated with a significant additional HRQL deficits in diabetes (Maddigan 2003b; Goldney, 2004). Of the 25 chronic conditions included in the CCHS, stroke, heart disease, osteoarthritis and depression were of particular interest.

The presence of heart disease, stroke and arthritis was based upon self report from a direct question in the CCHS which asks: "We are interested in long term conditions that have lasted or are expected to last six months or more and that have been diagnosed by a health professional. Do you have…," followed by a list of common chronic conditions. Respondents who reported a diagnosis of arthritis were further asked the specific type of arthritis they had. For depression, the CCHS used the Composite International Diagnostic Interview Short Form for Major Depression (CIDI-SFMD) to assess the probability of a major depressive disorder. A probability of 0.90 is considered consistent with a diagnosis of a depression and is accordance with the DSM-IV diagnostic criteria for Major Depressive Disorder (Patten 2000).

Number of Medical Conditions

To assess the HRQL deficits associated with other medical conditions, the total number of self-reported medical conditions, other than heart disease, stroke, depression and osteoarthritis, were included.

Duration of Diabetes

Duration of diabetes was determined from the respondents' age and self-reported age of diagnosis of diabetes. Respondents were then grouped into quartiles of duration of diabetes: less than 2 years, 2.0 to 6.0 years, 6.0 to 13.0 years, and 13.0 years or greater.

Subpopulation Partitions

Socioeconomic Status

As a significant proportion of respondents (approximately 11%) were missing data on income, other markers were used to operationalize socioeconomic status in the conceptual scheme including education, household social assistance, and household food security. Highest level of education of each respondent was assessed in four categories: less than secondary graduation, secondary graduation, other postsecondary education (e.g. diploma/certificate from a trade school, some community college), and college or university degree. Receipt of social assistance was determined by self-reported social assistance as a source of total household income in the past 12 months. Three questions determined whether respondents had food insecurity in the past twelve months. Food insecurity was defined as (1) not having enough food to eat, or (2) not eating the quality or variety of foods that the respondent wanted due to lack of money.

Insulin Use

Questions regarding insulin use were included in the core survey content and in the optional survey content, making it possible to categorize almost all respondents as insulin users or nonusers.

Geographic Location – Rural vs Urban

An urban area was defined as a continuously built-up area with a population concentration of 1,000 or more, with a population density of 400 or more per square kilometre based on the previous census. To be considered continuous, the built-up area could not have a discontinuity exceeding two kilometres (Statistics Canada 2004).

Sex

Sex was included as a determinant of health in the model. Respondents were categorized as male or female.

Ethnicity or Race

Respondents were categorized as Aboriginal or Non-aboriginal, according to a question that asked respondents their cultural or racial background.

Sources of Heterogeneities

Individual Lifestyle Factors

Body mass index (BMI) was calculated from self-reported height in meters (m) and weight in kilograms (kg); specifically, BMI = kg/m^2. Respondents were categorized as obese (BMI ≥ 30.0) or not obese (BMI < 30.0) (Health Canada 2004). Smoking status was derived from responses to four questions pertaining to current and past smoking habits. Respondents were categorized as current smokers or nonsmokers. Respondents who consumed five drinks or more on one occasion more than once a month were considered heavy drinkers (Shields 2002). For physical activity, the CCHS categorizes respondents as inactive, moderately active, or active based on energy expenditure level. Energy expenditure level was derived from 47 questions regarding participation in specific activities and individual report on participation in other activities.

Self-perceived life stress was used as a measure of ability to cope. Respondents were asked to rate the amount of daily stress in their lives with response options ranging from “not at all stressful” to “extremely stressful” on a 5-point Likert scale. Response options were collapsed to create three categories: not at all stressful, not very stressful/a bit stressful, and quite a bit stressful or extremely stressful.

Physical Environment

The presence or absence of a family member who smoked inside the home was used as a measure of exposure to second-hand smoke.

Social Environment

Sense of belonging to the community and marital status were used to assess the social environment. Sense of belonging to the local community was assessed on a 4-point Likert scale with response options of “very strong”, “somewhat strong”, “somewhat weak” and “very weak”. This variable was operationalized in four categories. For marital status, respondents were categorized as “married/partnership” or “not married”. The married category included respondents who reported being married, common-law, or living with a partner, while not married included respondents who were single, widowed, separated, or divorced.

Differential Access to Health Care

Access to medical care was assessed using two variables: whether respondents had a regular medical doctor and self-perceived unmet healthcare needs. For self perceived unmet healthcare needs, respondents were asked, “During the past 12 months, was there ever a time when you felt the you needed health care but did not receive it?” with yes or no response options.

ANALYSIS

Analysis of Cases with Missing Data

Analyses were performed on cases with complete data; however, some of this data had been imputed by Statistics Canada during data processing. For interviews that were completed by proxy (6.3%), imputation using the “nearest neighbour” imputation method (i.e., hot-decking) was used to handle missing data for a pre-defined set of variables (Beland 2002). Certain modules or items were not considered appropriate for imputation and were therefore left as missing in the survey (e.g., distress, work stress). As well, when imputation could not improve data quality (i.e., produced poor estimates for those variables), responses were coded as missing (Statistics Canada 2004). Imputation was not used for non-proxy respondents who declined to answer particular questions. Thus, not all missing values were imputed by Statistics Canada. Additional imputation methods were not employed for variables where Statistics Canada had opted not to impute data.

T- and Chi-Square tests were used, where appropriate, to compare the demographic characteristics of respondents who were excluded from the analysis because they were missing only HUI3 scores (n = 76). These respondents had complete data on all other variables of interest (Figure 3). The overall HUI3 scores of the analysis sample (n = 4678) were compared to those of respondents who were excluded from the analysis due to missing data on either the Stage of Life Cycle variables, Subpopulation Partitions or Sources of Heterogeneity (n = 819).

Objective One – Determinants of Health

The clinical importance (i.e., magnitude of the unstandardized regression coefficients) and statistical significance of the HRQL deficits associated with each determinant of health were first assessed with bivariate regression analyses. The correlation between each determinant of health and overall HUI3 score was determined from these bivariate analyses. A multiple regression model that included all determinants of health was then used to operationalize the entire conceptual scheme and control for the relationships among determinants of health. The clinical importance and statistical significance of each determinant of health in the overall model was then assessed. A regression coefficient with a bootstrap confidence interval that excluded zero was considered statistically significant (i.e., P value < 0.05). To assess the degree of collinearity in the overall model, the tolerance of each independent variable was evaluated (i.e., the proportion of variance in the independent variables unexplained by the other independent variables). As a general guideline, when the tolerance of a variable is less than 0.20, collinearity may be a problem (Menard 1995). As each determinant of health had a tolerance that exceeded 0.20, collinearity in the overall model was not deemed to be problematic.

Objective Two – Contribution of Each Domain

The proportion of explained variance (i.e., R^2) in HRQL, explained by each domain, was determined from three regression models that each contained the determinants of health for their respective domains (Stage of Life Cycle, Subpopulation Partitions, and Sources of Heterogeneities). To determine the unique contribution to the explained variance of a particular domain, the R^2 change was calculated between a model containing the other two domains and a model with all three domains. For example, to determine the unique contribution of the Stage of Life Cycle Variables, thosey variables were added to a model containing Subpopulation Partitions and Sources of Heterogeneity, and the R^2 change between the two models was calculated. The same process was used to determine the unique contributions of the Sources of Heterogeneity and

Subpopulation Partitions. An R^2 change with an F-Statistic whose P value was less than 0.05 was considered statistically significant. Collinearity within each block was assessed in the same manner employed in the overall model and determined not to be problematic.

Weighting and Variance Estimates

The multistage stratified cluster design of the CCHS created an unequal probability of being selected for inclusion into the survey, which if unaccounted for, could bias point estimates (e.g., of regression coefficients, means, etc.) and underestimate the variance. Thus, normalized sampling weights were applied to the analysis in order to produce unbiased point estimates (Statistics Canada, 2004). Normalized sampling weights do not adjust for clustering or stratification (Statistics Canada 2004); thus, bootstrap variance estimates were used to estimate 95% confidence intervals for the regression coefficients (Rust 1996). Consistent with Statistics Canada's policies for disclosure, data pertaining to any cell with a weighted or unweighted frequency of less than five were suppressed.

RESULTS

Sample Characteristics

The average (SD) age of respondents included in the analysis was 61.6 (13.3), with an average duration of diabetes of 9.3 (9.8) years (Table 3). Heart disease and osteoarthritis were the two most common comorbidities of interest, with 20.6% of respondents affected by heart disease and 19.4% of respondents affected with osteoarthritis. Failure to complete high school was relatively common (42.4%). Only a small proportion of respondents were Aboriginals (1.8%). While approximately 7.5% of respondents reported receiving social assistance, 15.5% reported some food insecurity in the previous 12 months. Physical inactivity (64.6%) and obesity (36.4%) were prevalent in this sample. The vast majority of respondents had a regular medical doctor (96.0%), but 12.7% of the sample felt that they had unmet healthcare needs. The overall HUI3 score was 0.78 (0.26).

Missing Data

The HUI3 scores for respondents who were excluded from the analyses due to missing data on the determinants of health (n = 819) (Figure 3) were significantly lower than the overall HUI3 scores of respondents with complete data (n = 4678) (difference between groups = -0.14; 95% CI -0.17 to -0.10, P value < 0.05). The majority of differences for comparisons between respondents who had complete data on the determinants of health, but were missing data on the HUI3 (n = 76) (Figure 3) and respondents included in the analysis (n = 4678) were not statistically significant. Those who were missing HUI3 were, however, more likely to report a weak sense of belonging to the community (P value = 0.01), food insecurity in the past 12 months (P value = 0.001), heart disease (P value = 0.04), stroke (P value = 0.04) and osteoarthritis (P value = 0.02) and less likely to report being married (P value = 0.03).

Mean Centered Age

As previously explained, age was operationalized as a mean-centered variable to reduce problems with collinearity between itself and its square as a quadratic function in the regression models. Figures 4a and 4b demonstrate that mean centering had little effect on the overall nature of the nonlinear relationship between age and HRQL, i.e., the shape of the curves were basically the same, although not identical. The two quadratic equations result in predicted overall HUI3 scores that differ, on average, by approximately 0.024 units, with larger predicted differences observed for older ages. Collinearity was particularly problematic in the multiple regression analysis, where the tolerance of age and its square was 0.02 for each variable (a tolerance of less than 0.20 is a concern). In this analysis, collinearity also created problems in estimating the standard error of the age variable as evidenced by the fact that its standard error was five times higher prior to mean centering than after. Thus, it was apparent from both the bivariate and multiple regression analyses that mean centering was necessary.

OBJECTIVE ONE – DETERMINANTS OF HEALTH

Bivariate Associations

Stage of Life Cycle

All Stage of Life Cycle variables had statistically significant and clinically important bivariate associations with HRQL (Table 4). With the exception of number of medical conditions, the correlations between the Stage of Life Cycle variables and HRQL were weak. Of the Stage of Life Cycle variables, number of medical conditions was the variable that individually accounted for the most variance in HRQL. The comorbidities of interest were associated with clinically important deficits in HRQL, the largest of which were related to depression and stroke. Respondents who had the longest duration of diabetes had significantly worse HRQL than any other quartile (Table 4). The hypothesized non-linear association between age and HRQL was supported (Figure 4c). For interpretation purposes, in Figure 4c, the age variable was converted back to natural units and plotted against the predicted overall HUI3 obtained from the mean centered quadratic. The nature of the non-linear relationship between age and HRQL was interesting in that compared to respondents aged 18, HRQL was greater between the ages of 19 to 45 after which HRQL declined (Figure 4c).

Subpopulation Partitions

Weak correlations were observed between the Subpopulation Partitions and HRQL (Table 4). Food insecurity and social assistance were the Subpopulation Partitions that explained the largest proportion of variance in HRQL (6.0% and 4.0%, respectively). The largest HRQL deficits across Subpopulation Partitions were reported for respondents who reported food insecurity and receiving social assistance. A gradient was observed across level of education; respondents with less than secondary education had the largest HRQL deficits relative to respondents with university degrees (-0.11; 95% CI -0.14 to -0.07). Males reported better HRQL than females (0.06; 95% CI 0.03 to 0.08) and insulin use was associated with a clinically important deficit (-0.10; 95% CI-0.13 to -0.06).

Sources of Heterogeneity

Again, only weak correlations were observed among the determinants of health and HRQL, with relatively small proportions of variance explained by any single determinant of health. Many individual lifestyle factors had clinically important bivariate associations with HRQL. The largest deficits among the Sources of Heterogeneity were associated with high levels of stress, self-perceived unmet healthcare needs, and weak sense of belonging.

Overall Determinants of Health Framework

When the conceptual scheme was operationalized in its entirety (Stage of Life Cycle, Subpopulation Partitions, and Sources of Heterogeneity in a single model), the magnitude of a number of the coefficients decreased significantly, but the basic patterns within each domain persisted (Table 5). Across all of the determinants of health included in the model, stroke and depression were associated with the largest deficits and were nearly four times the clinically-important difference of 0.03. Clinically-important deficits were also associated with socioeconomic status (food insecurity, social assistance, and failure to complete a secondary education). Within the Sources of Heterogeneity, the largest differences between respondents were observed according to sense of belonging to the community, life stress, and self-perceived unmet healthcare needs. The variables in the conceptual scheme, as a whole, explained 36% of the variance in HRQL and had a strong association with HRQL (multiple correlation = 0.60).

OBJECTIVE TWO – CONTRIBUTION OF EACH DOMAIN

Taken together, the Stage of Life Cycle variables explained the most variance (27.0%) of the three domains and had a moderate, multiple correlation with HRQL (Models 1 through 3, Table 5). The Sources of Heterogeneity explained 16% of the variance in HRQL and also had a moderate multiple correlation with HRQL (Model 3, Table 5). The largest unique contribution to the explained variance in HRQL was that of the Stage of Life Cycle variables (15.0%), followed by Sources of Heterogeneity (6.0%) and Subpopulation Partitions (2.0%) (Table 5).

DISCUSSION

Type 2 diabetes is a chronic medical condition in which many factors potentially influence HRQL or health status. Some of these factors are disease related, but many relate to demographic, social characteristics and health behaviors. Using population-based data from the Canadian Community Health Survey, a model was constructed of the multiple determinants of health in type 2 diabetes.

The bivariate analysis explored heterogeneities in HRQL related to each variable that was used to operationalize the Population Health Framework. While the inter-relationships among determinants of health were not considered in the bivariate analysis, these analyses did confirm the hypothesized role of a number of determinants of health in type 2 diabetes. Subsequently operationalizing the conceptual scheme as a whole allowed control of potential confounding among determinants, enabling a better assessment of the magnitude of the deficits associated with particular determinants, which is the intent of the Hertzman et al. conceptual scheme.

It was evident from the overall model that several of the comorbidities of interest (i.e., stroke and depression) were associated with the largest HRQL deficits (-0.11 for each), even after considering the impact of socioeconomic and behavioral determinants of health. The clinically-important deficits associated with comorbidities demonstrate that prevention (where possible) and management of comorbidities could be vital to preserving or improving HRQL for people with type 2 diabetes. From a clinical perspective and a broader health policy perspective, efforts at primary and secondary prevention of heart disease and stroke could have a significant impact on HRQL. Better efforts may also be needed in screening and treatment of depression in diabetes, given the magnitude of the deficit associated with this comorbidity.

When looking at the Subpopulation Partitions, the clinically-important deficits associated with the two markers of income (social assistance and food insecurity) were also of interest (-0.07 and -0.08, respectively). Income and social status have been recognized as two of the most important determinants of health in the Canadian population (Evans 1990; Federal, Provincial and Territorial Advisory Committee on Population Health 1999). Specifically in diabetes, income is an important predictor of social functioning and mental health; thus, this observation is consistent with previous research (Glasgow 1997). It was interesting to note, however, that the two markers appeared to capture somewhat different phenomena as they were both independently associated with clinically-important deficits that reached statistical significance. While social assistance may have captured respondents with low income as intended, it is possible that food insecurity reflected the impact of poor nutrition in diabetes on overall health, in addition to the impact of low socioeconomic status.

Education was also a clinically important variable in the multiple regression analysis, confirming that it is indeed an important determinant, even independent of its association with income (Evans 1990). A relationship between education and physical health, physical and social functioning, and mental health in diabetes has been demonstrated previously (Glasgow 1997; Rubin 1999). It has been suggested that the relationship between education and HRQL is in part attributable to the association between higher levels of education and healthier lifestyles, including refraining from smoking, higher levels of physical activity, and better access to healthy foods (Federal, Provincial and Territorial Advisory Committee on Population Health 1999). Despite controlling for a number of these factors, the relationship between education and HRQL persisted. It has been suggested with diabetes that education may also influence diabetes-related knowledge, ability to communicate with healthcare providers, treatment choices, and ability to adhere to complex self-care regimens, which in turn affect HRQL (Brown 2004). This could perhaps better explain why we found heterogeneities in HRQL according to education in type 2 diabetes.

The multiple regression analysis did reveal that a number of bivariate relationships between Subpopulation Partitions and HRQL were likely confounded. Heterogeneities in HRQL observed in the bivariate analysis according to Aboriginal Status, for example, did not persist in the overall model. This may seem counter-intuitive as Aboriginals are an ethnic group in Canada for whom disparities in health status are often observed (Health Canada 1999; Young 2000). In general, Aboriginals are more likely to rate their health as poor, and have shorter life expectancies, higher mortality rates, and higher rates of diabetes, hypertension, arthritis, and heart disease than the general Canadian population (Health Canada 1999; Young 2000). Aboriginal people with diabetes are more likely to develop macrovascular and microvascular complications and do so after shorter disease duration than the general population with diabetes (Health Canada 2000). However, controlling for comorbidities, socioeconomic status, and other behavioral determinants of health may have reduced the differences in HRQL according to this particular Subpopulation Partition.

The Sources of Heterogeneity produced interesting results. Sense of belonging to the local community and marital status were used to assess the respondents' social environment. While marital status was not associated with HRQL in the overall model, one of the largest differences in HRQL was observed between respondents who reported a weak sense of belonging to the local community and respondents who reported a strong or somewhat strong sense of belonging. Sense of belonging has been previously found to relate to self rated health in the Canadian population (Ross 2002), where Ross considered sense of belonging to be a measure of social capital, despite the fact that it was evaluated as an individual level variable, as it was in this study. This may not be consistent with the broader concept of social capital, though there is some debate over the level at which this variable should be analyzed (Harpham 2002). Perhaps when analyzed at the individual level, sense of belonging may better reflect social integration (i.e., a measure of the degree to which individuals are socially isolated) (House 1998). Marital status has also been considered a measure of social integration (House 1998), which may explain in part, why marital status was not associated with clinically important deficits in the overall model.

Life stress was another Source of Heterogeneity where clinically-important differences were observed between respondents. Respondents who felt their lives were 'quite a bit stressful' or 'extremely stressful' experienced HRQL deficits nearly three times the clinically-important difference relative to those who felt their lives were 'not at all stressful'. Stress is recognized as a determinant of health in the general population. High levels of stress may be particularly problematic, however, for individuals with diabetes as stress is associated with poor glycemic control (Kramer 2000; Jaber 1993). This might explain the magnitude of the deficit associated with high stress levels observed in this sample of respondents with type 2 diabetes.

Two markers were used to measure access to healthcare services: having a regular medical doctor and self perceived unmet healthcare needs. The vast majority of the sample (96.0%) had regular medical doctor. The health status of the small number of respondents who did not have a regular medical doctor did not appear to suffer as a result. Having a regular medical doctor did not guarantee that healthcare needs would be met, however, as almost 13% of respondents reported unmet needs, while only 4.0% reported that they did not have a regular medical doctor. Unmet healthcare needs were associated with clinically-important deficits in HRQL. This finding is important for health policy makers to consider, given that often the reasons that patients cite for unmet healthcare need are beyond the control of the patient and clinician, such as excessive wait times and services not being available in an area (Sanmartin 2002). Unmet health care needs increased in the Canadian population between the 1995 and 2001 (Sanmartin 2002). Increasingly, features of the healthcare system are cited as the reason for these unmet needs (Sanmartin 2002).

Overall, the multiple regression results demonstrated that a broad range of determinants of health is important in type 2 diabetes, but was associated with deficits of various magnitudes. Knowing the determinants of health associated with clinically-important HRQL deficits is relevant to researchers, health policy makers, and clinicians. The strategies that are developed to deal with the epidemic level of diabetes should consider the segments of the population with diabetes that experiences the greatest burden. Given that comorbidities and low socioeconomic status were particularly burdensome, these areas may warrant particular attention from a policy perspective.

The large number of determinants of health in the multiple regression analysis and the possibility of relationships between these determinants of health created the potential for collinearity in the overall model and within each block. The failure to confirm the bivariate associations between several of the determinants of health and HRQL in the overall multiple regression model suggested that there was, indeed, some degree of collinearity between determinants of health. However, collinearity was not felt to be problematic to the extent of creating estimation problems as the tolerance of all independent variables was well above the minimally-acceptable threshold.

Of the three domains of determinants of health in the conceptual scheme, Stage of Life Cycle variables alone accounted for the largest proportion of variance in HRQL. Stage of Life Cycle was operationalized in a manner somewhat specific to diabetes as this domain included the comorbidities that occur more frequently in diabetes, as well as duration of diabetes. It is therefore not clear if Stage of Life Cycle would be the dominant domain in the general population or in other chronic diseases. Further, using cross-sectional data precludes definitively stating that the Stage of Life Cycle variables were the most important determinants of health in diabetes, as causal relationships among variables could not be assessed. For example, cross-sectional data cannot capture the fact that Aboriginals, individuals who smoke or who are sedentary may be more likely to develop comorbidities such as heart disease (Health Canada 2000; Resnick 2002). Thus, the full explanatory power of the Subpopulation Partitions and Sources of Heterogeneity may not have been captured in this analysis.

Overall, Subpopulation Partitions accounted for the least variance in HRQL and explained little unique variance in HRQL despite the fact that clinically-important differences in HRQL were noted according to insulin use and socioeconomic status (social assistance, food insecurity and education). Sources of Heterogeneity accounted for less variance than Stage of Life Cycle, but it should be pointed out that the ability to operationalize this domain was somewhat limited. While the CCHS included detailed information on individual life-style factors, it did not contain much information on the physical environment, social environment, or differential access or response to health care services. Social support scales were included, but as optional content, limiting the usefulness of these data for our analyses. Perhaps if the Sources of Heterogeneity were more fully operationalized, the domain would have explained a larger proportion of the variance. As the conceptual scheme was currently operationalized, no treatment or clinical variables were included (other than insulin). Such variables (e.g., whether a patient was treated to a target for blood glucose or blood pressure or received appropriate drug therapy) would be considered differential access or response to therapy. These variables may have made a contribution to the Sources of Heterogeneity and the overall explained variance by the model.

A number of study limitations should be noted in this analysis. The algorithm used to distinguish between respondents with type 1 and type 2 diabetes has not been previously validated. A number of the criteria in the algorithm have been used previously (Eurich 2004; Johnson 2002; Hahl, 2002), but the algorithm as a whole has not. The algorithm appeared to accurately classify respondentsas categorization of type 1 and type 2 diabetes produced by the algorithm was 10% and 90%, which is generally recognized as the distribution of type 1 and type 2 diabetes in Canada (Center for Chronic Disease Prevention and Control 2002).

The cross-sectional nature of the data limited the ability to assess temporal relationships between HRQL and the determinants of health; thus, it is possible that a number of determinants of health were endogenous in the model. For example, in the analysis, social assistance (a marker of low socio-economic status) was modeled as a cause of poor HRQL. It is also possible that poor health and HRQL may cause low income, though past research has demonstrated that the effect of socioeconomic status on HRQL is the stronger relationship (Hertzman 1994; Smith 1999; McLeod 1990).

Another potential limitation was related to the accuracy of self-reported data on a number of determinants of health including medical conditions, alcohol use, BMI, duration of diabetes, and level of physical activity. Although the questions regarding medical conditions specified that the condition have been diagnosed by a health professional, there remained potential for individuals to over- or under-report any medical condition. BMI may have been subject to bias in that it was determined from self-reported height and weight. The accuracy of this data could be questionable; therefore we chose to operationalize BMI as a dichotomous variable, either above or below 30.0. As with any health behavior, questions regarding alcohol consumption may have been answered in a socially desirable manner. The validity of self-reported level of physical activity may be questionable, but it should be emphasized that the physical activity index was based on detailed responses to 47 questions on participation in specific activities and participation in other activities. This reduced the need to recall the activities in which the respondents participated; however, duration of time spent in each activity may have been subject to inaccurate recall or social desirability.

Missing data were somewhat problematic. Approximately 17% of respondents were missing data leading to their exclusion from the analysis. Certain covariates (i.e., sense of belonging, physical activity, and depression) had a relatively large number of respondents with missing data. Respondents who were missing data on covariates tended to have worse HRQL. Demographic differences also existed between respondents with complete and missing HUI3 scores. Regardless, it was decided that all of the variables originally proposed be included since the intent of this analysis was to operationalize the Hertzman et al. conceptual scheme as fully as possible. Missing data could be missing for a number of reasons. If a non-proxy respondent refused to answer, the response was not imputed. Some questions were not considered appropriate for interviews completed by proxy (approximately one-third of the survey). Data were then imputed for a number of those items, but not in all instances (e.g., physical activity) as Statistics Canada did not consider some variables appropriate for imputation or had attempted to do so, but had obtained unsatisfactory results. It is not clear what impact missing data had on the analysis, but it may limit the generalizability of the results.

In light of these limitations, the strengths of this analysis should also be noted. The determinants of health in type 2 diabetes were modelled using a large sample, representative of 98% of the

Canadian population. Further, we used a broad framework, rather than limiting our analysis to medical and disease-related factors. The framework facilitated the inclusion of a number of variables that were associated with clinically-important HRQL deficits; sense of belonging and life stress, in particular. Further, including multiple domains of determinants of health, confirmirmed that previously detected relationships, such as those seen between HRQL and comorbidities or insulin use were not merely confounded by socioeconomic or behavioral factors. A final strength of this analysis was the use of the HUI3 as the measure of HRQL, a measure that we have previously shown to have construct validity in this population (Maddigan 2003a; Maddigan 2004).

CONCLUSIONS

Overall the analysis confirmed that many of the determinants of health specified in the Population Health Framework were indeed important in type 2 diabetes. Clinically-important heterogeneities in HRQL were observed for people with diabetes and stroke or depression, emphasizing the importance preventing and managing comorbidities and complications in type 2 diabetes. Social and behavioral determinants of health (socioeconomic status, life stress, and sense of belonging) were also important in type 2 diabetes, however, demonstrating that more than purely medical factors impact the health of individuals with type 2 diabetes. Employing a Population Health Framework, operationalized with the broad determinants of health it encompasses, is an important and feasible approach to understanding HRQL in type 2 diabetes.

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Table 1: Conceptual Scheme for Operationalizing the Population Health Framework

Stage of Life Cycle	Subpopulation Partitions	Sources of Heterogeneities
Perinatal : preterm to 1 year	Socioeconomic status	Individual life-style
Misadventure: 1 to 44 years	Ethnicity/migration	Physical environment
Chronic disease: 45 to 75 years	Geographic	Social environment
Senescence: 75 years or older	Male/Female	Differential access or response to health care services
	Special Populations[A]	Reverse Causality
		Differential susceptibility

A Special populations include groups not defined by one of the other subpopulation partitions (i.e., socioeconomic status, ethnicity migration, geographic location, and sex), but who share a particular characteristic that is related to patterns in health status.

Table 2: Independent Variables and Their Operationalization in the Conceptual Scheme

Variable	Operationalization in the Analysis	Reference category
Stage of Life Cycle		
Age	Continuous – Mean Centered Quadratic	Not applicable
Heart Disease	Categorical – Dichotomous dummy	No heart disease
Depression	Categorical –Dichotomous dummy	No depression
Osteoarthritis	Categorical – Dichotomous dummy	No Osteoarthritis
Stroke	Categorical – Dichotomous dummy	No History of Stroke
Number of Other Medical Conditions	Continuous – Linear	
Duration of Diabetes	Categorical – Three dummy variables	Longer than 13 years
Subpopulation Partitions		
Socioeconomic Status		
Education	Categorical – Three dummy variables	College or University Degree
Social Assistance	Categorical – Dichotomous dummy	Not receiving social assistance
Food Insecurity	Categorical – Dichotomous dummy	No food insecurity
Ethnicity		
Aboriginal Status	Categorical – Dichotomous dummy	Non-aboriginal
Male/Female	Categorical – Dichotomous dummy	Male
Geographic Location		
Rural versus Urban	Categorical – Dichotomous dummy	Urban
Special Populations		
Insulin User	Categorical – Dichotomous dummy	Not using insulin
Sources of Heterogeneities		
Individual Life-Style		
Body Mass Index (BMI)	Categorical – Dichotomous dummy	BMI less than 30.0
Smoking status	Categorical – Dichotomous dummy	Non-smoker
Alcohol Use	Categorical –Dichotomous dummy	Not a heavy drinker
Physical Activity	Categorical – Two dummy variables	Inactive
Stress	Continuous – Two dummy variables	Not at all stressful
Physical Environment		
Smoking in house	Categorical – Dichotomous dummy	Family member does not smoke in house
Social Environment		
Sense of belonging	Continuous – Three dummy variables	Weak
Marital Status	Categorical – Dichotomous dummy	Not Married
Differential Access or Response to Health Care Services		
Regular medical doctor	Categorical – Dichotomous dummy	No regular medical doctor
Unmet Medical Need	Categorical – Dichotomous dummy	No Unmet needs

Table 3: Demographic Characteristics of Analysis Sample

	N=4678
Stage of Life Cycle	
Age – Mean (SD)	61.6 (13.3)
Duration of Diabetes – Mean (SD)	9.3 (9.8)
Median (Interquartile Range)	6.0 (2.0-13.0)
Number of Medical Conditions[A] – Mean (SD)	2.7 (1.7)
Has Osteoarthritis (% Yes)	19.4
Suffers the Effects of Stroke (% Yes)	4.8
Has Heart Disease (% Yes)	20.6
Predicted Probability of Depression > 0.90 - %	7.2
Subpopulation Partitions	
Sex – (% Male)	51.7
Level of Education - %	
Less than secondary	42.4
Secondary graduation	16.3
Some post-secondary, college, trade school	29.3
University degree	12.0
Aboriginal Status – (% Yes)	1.8
Some Food Insecurity – (% Yes)	15.5
Social Assistance – (% Yes)	7.5
Rural Geographic Location – (% Rural)	19.3
Insulin Use – (% Yes)	15.5
Sources of Heterogeneity	
Current Smoking Status – (% Current Smoker)	19.0
Heavy Drinkers – (% Yes)	6.9
BMI > 30.0 – (% Yes)	36.4
Physical Activity Index	
Active	14.5
Moderately Active	20.9
Inactive	64.6
Life Stress - %	
Not at all stressful	21.1
Not very stressful/a bit stressful	55.9
Quite a bit/extremely stressful	23.0
Family Member Smokes Inside House – (% Yes)	24.5
Marital Status – (% Married)	67.7
Sense of Belonging to the Community - %	
Strong	22.5
Somewhat strong	38.1
Somewhat weak	24.1
Weak	15.3
Regular Medical Doctor – (% Yes)	96.0
Self-Perceived Unmet Healthcare Needs	12.7
Health Utilities Index Mark 3 – Mean (SD)	0.78 (0.26)

A Number of medical conditions other than stroke, heart disease, osteoarthritis or depression

Table 4: Bivariate Associations between Determinants of Health and HRQL (N=4678)

	b	95% CI Lower Limit	95% CI Upper Limit	R	R^2_{adj}
Stage of Life Cycle					
Age[A]				0.14	0.02
Age	**-0.003***	-0.004	-0.002		
Age^2	**-0.0001***	-0.0001	-0.00004		
Osteoarthritis	**-0.13***	-0.16	-0.10	0.20	0.04
Stroke	**-0.21***	-0.27	-0.15	0.17	0.03
Heart Disease	**-0.14***	-0.17	-0.11	0.21	0.05
Depression	**-0.22***	-0.27	-0.17	0.21	0.05
Number of Medical Conditions[B]	**-0.07***	-0.07	-0.06	0.43	0.19
Duration of Diabetes[C]				0.17	0.03
Less than 2.0 years	**0.10***	0.06	0.13		
2.0 years to 6.0 years	**0.12***	0.09	0.15		
6.0 years to 13.0 years	**0.07***	0.04	0.10		
13.0 years or longer	-	-	-		
Subpopulation Partitions					
Level of Education[D]				0.15	0.02
Less than secondary	**-0.11***	-0.14	-0.07		
Secondary graduation	**-0.05***	-0.09	-0.01		
Some post-secondary, college, trade school	**-0.04***	-0.08	-0.01		
University degree	-	-	-		
Food Insecurity	**-0.18***	-0.21	-0.15	0.25	0.06
Social Assistance	**-0.21***	-0.26	-0.16	0.21	0.04
Aboriginal Status	-0.05	-0.12	0.02	0.03	0.01
Rural Geographic Location	0.004	-0.02	0.03	0.01	0.00
Male	**0.06***	0.03	0.08	0.11	0.01
Insulin Use	**-0.10***	-0.13	-0.06	0.13	0.02
Sources of Heterogeneity					
Current Smoker	**-0.05***	-0.08	-0.02	0.08	0.01
Heavy Drinker	**0.03***	-0.01	0.07	0.03	0.0
BMI > 30.0	**-0.06***	-0.08	-0.04	0.11	0.01
Physical Activity Index[E]				0.20	0.04
Active	**0.11***	0.08	0.14		
Moderately Active	**0.11***	0.09	0.13		
Inactive	-	-	-		
Life Stress[F]				0.22	0.05
Not at all stressful	-	-	-		
Not very stressful/a bit stressful	**-0.02***	-0.05	-0.0006		
Quite a bit/extremely stressful	**-0.15***	-0.19	-0.12		
Family Member Smokes Inside House	**-0.05***	-0.08	-0.02	0.08	0.01
Married	**0.08***	0.05	0.10	0.13	0.02
Sense of Belonging to the Community[G]				0.19	0.04
Strong	**0.14***	0.10	0.19		
Somewhat strong	**0.14***	0.10	0.18		
Somewhat weak	**0.09***	0.05	0.13		
Weak	-	-	-		
Regular Medical Doctor	-0.04	-0.09	0.01	0.03	0.00
Self-Perceived Unmet Healthcare Needs	**-0.18***	-0.22	-0.15	0.23	0.05

*P value < 0.05 (Significance based on bootstrap variance estimate); A Age was operationalized as a mean-centered quadratic (b_1(age-61.55) + $b_2(\text{age-61.55})^2$); thus, bivariate analysis included both (age-61.55) + $b_2(\text{age-61.55})^2$; B Number of medical conditions other than stroke, heart disease, osteoarthritis or depression; C The bivariate analysis for duration of diabetes included three dummy variables to represent the first three quartiles of duration; the fourth quartile of duration was the reference category (i.e. greater than 13.0 years).; D The bivariate analysis for education included three dummy variables for the lower levels of education; college or university degree was the reference category.; E The bivariate analysis for physical activity included two dummy variables to represent active and moderately active; inactive was the reference category.; F In the bivariate analysis for life stress, dummy variables were used to represent not very stressful/a bit stressful and quite a bit/extremely stressful; not at all stressful was the reference category.; G The bivariate analysis for sense of belonging to the community included three dummy variables to represent strong, somewhat strong, and somewhat weak; weak was the reference category.

Table 5: Unstandardized Regression Coefficients for Each Domain Alone and Overall Model (N=4678)

	Model 1 (Stage of Life Cycle)	Model 2 (Subpopulation Partitions)	Model 3 (Sources of Heterogeneity)	Model 4 (Overall model)
Stage of Life Cycle				
Age[A]				
Age	-0.001*			-0.003*
Age^2	-0.0001*			-0.0001*
Osteoarthritis	-0.08*			-0.06*
Stroke	-0.14*			-0.11*
Heart Disease	-0.07*			-0.05*
Depression	-0.16*			-0.11*
Number of Medical Conditions[B]	-0.05*			-0.04*
Duration of Diabetes[C]				
Less than 2.0 years	0.05*			0.03*
2.0 years to 6.0 years	0.07*			0.04*
6.0 years to 13.0 years	0.02*			0.01
13.0 years or longer	-			-
Subpopulation Partitions				
Level of Education[D]				
Less than secondary		-0.09*		-0.04*
Secondary graduation		-0.03		-0.03
Some post-secondary, college, trade school		-0.04*		-0.02
University degree		-		-
Food Insecurity		-0.13*		-0.08*
Social Assistance		-0.12*		-0.07*
Aboriginal Status		0.02		-0.01
Rural Geographic Location		0.00		0.00
Male		0.03*		-0.01
Insulin Use		-0.08*		-0.04*
Sources of Heterogeneity				
Current Smoker			-0.01	-0.02
Heavy Drinker			0.04*	-0.01
BMI > 30.0			-0.04*	-0.03*
Physical Activity Index[E]				
Active			0.08*	0.06*
Moderately Active			0.09*	0.06*
Inactive			-	-
Life Stress[F]				
Not at all stressful			-	-
Not very stressful/a bit stressful			-0.02	-0.02
Quite a bit/extremely stressful			-0.11*	-0.08*
Family Member Smokes Inside House			-0.01	0.01
Married			0.06*	0.00
Sense of Belonging to the Community[G]				
Strong			0.11*	0.09*
Somewhat strong			0.11*	0.08*
Somewhat weak			0.07*	0.05*
Weak			-	-
Regular Medical Doctor			-0.06*	-0.01
Self-Perceived Unmet Healthcare Needs			-0.14*	-0.08*
	R=0.52	R=0.33	R=0.40	R=0.60
Variance Explained by Domain Alone	R^2_{adj}=0.27	R^2_{adj} =0.11	R^2_{adj} =0.16	R^2_{adj} =0.36
Unique Variance Explained by Domain[H]	R^2=0.15	R^2=0.02	R^2 =0.06	

* P value < 0.05 (Significance based on bootstrap variance estimate); A Age was operationalized as a mean centered quadratic (b_1(age-61.55) + b_2(age-61.55)^2); B Number of medical conditions other than stroke, heart disease, osteoarthritis or depression; C Duration of diabetes > 13 years was the reference category; D College or university degree was the reference category. E Inactive was the reference category; F Not at all stressful was the reference category; G Weak was the reference category; H For example, R^2 change when Stage of Life Cycle variables are added to a model containing Subpopulation Partitions and Sources of Heterogeneity

Figure 1: Relationship between Stage of Life Cycle, Subpopulation Partitions, Sources of Heterogeneity

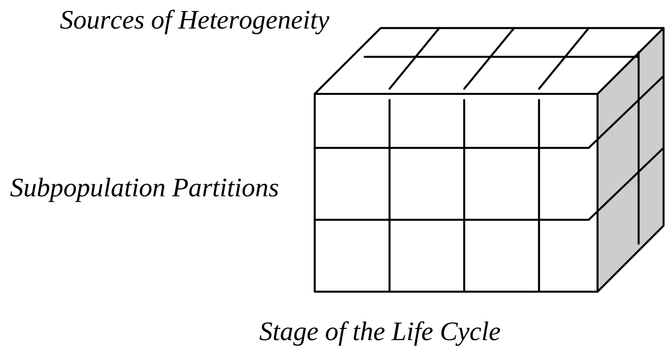


Figure 2: Algorithm for Differentiating between Individuals with Type 1 and Type 2 Diabetes

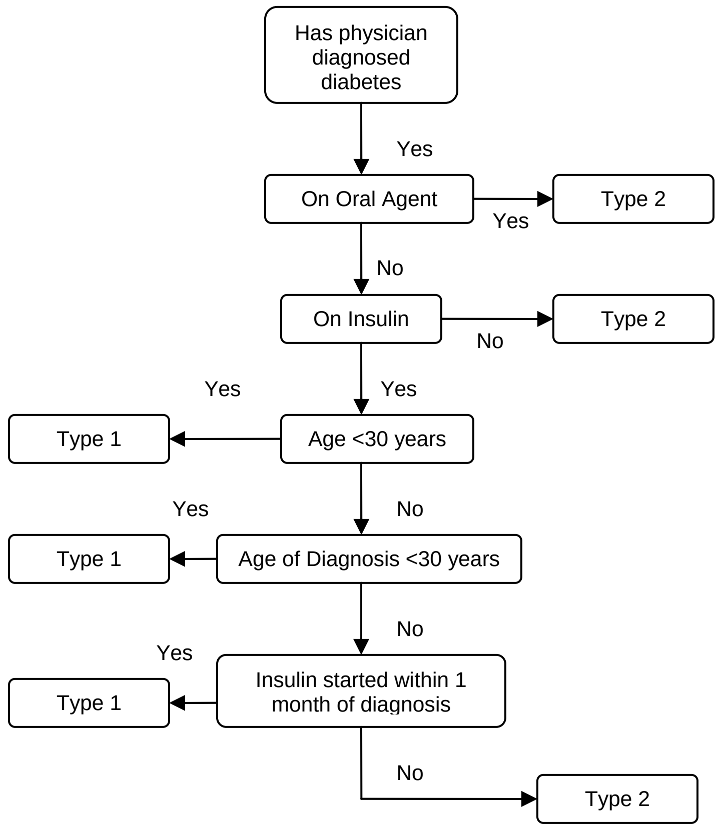
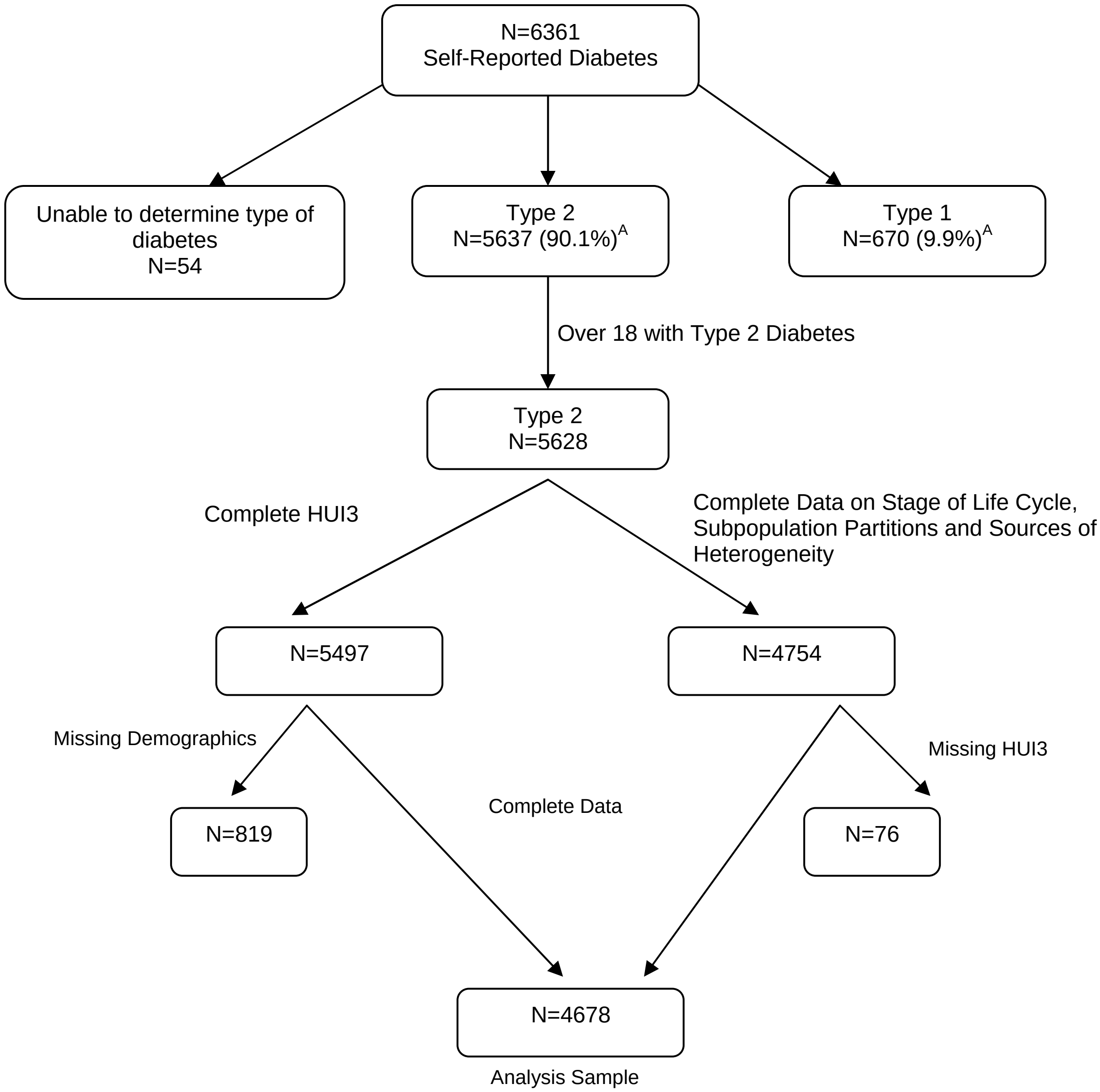


Figure 3: Survey Sample, Analysis Sample and Missing Data



A Percentage represents the weighted population percentage based upon respondents who could be categorized as having type 1 or type 2 diabetes.

Figure 4a: Nonlinear Bivariate Association between Age and HRQL Prior to Mean Centering

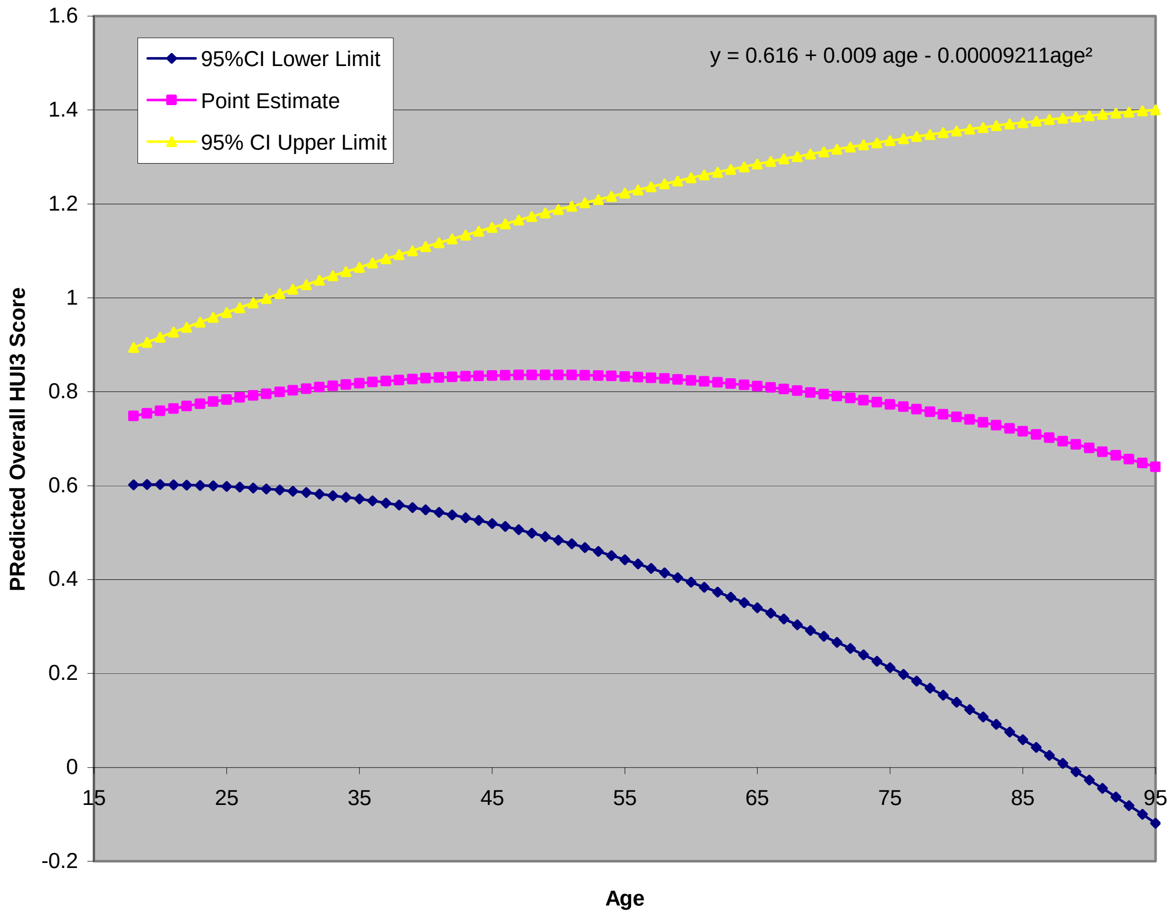
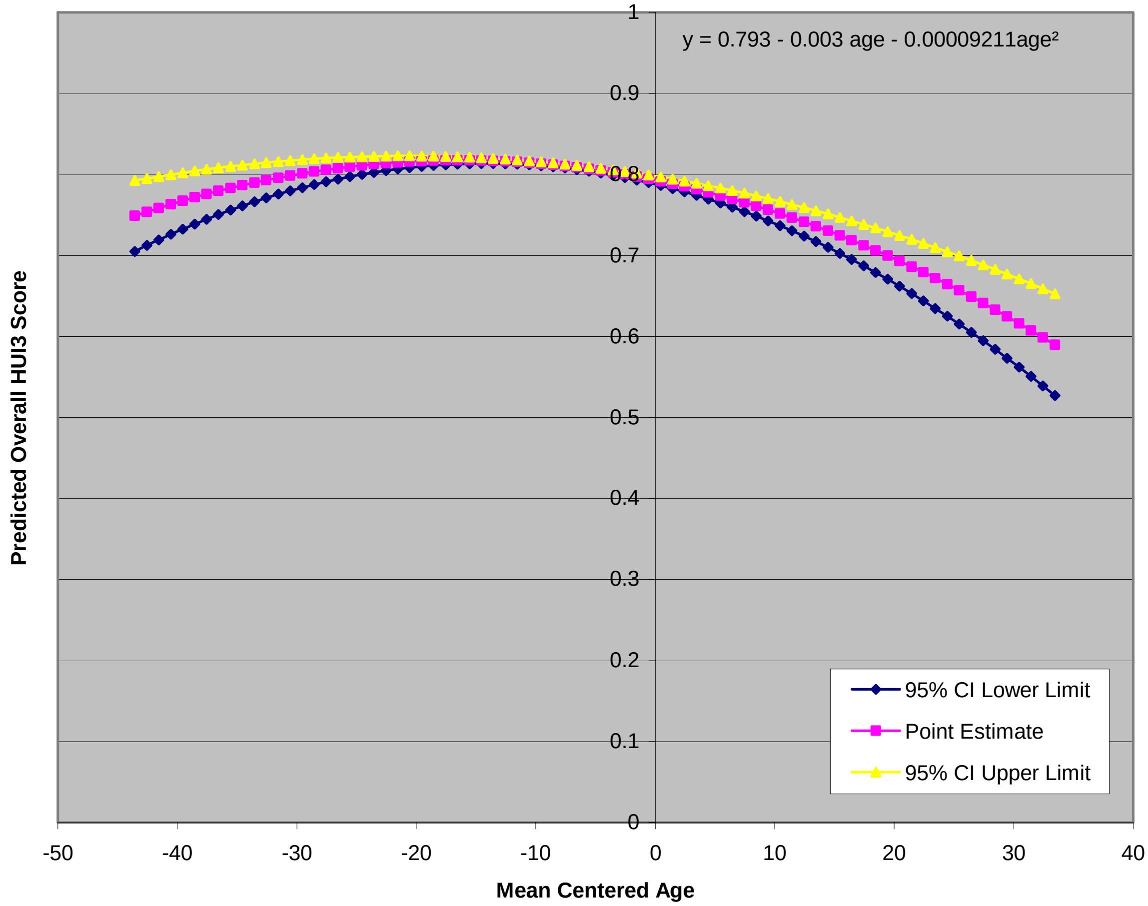
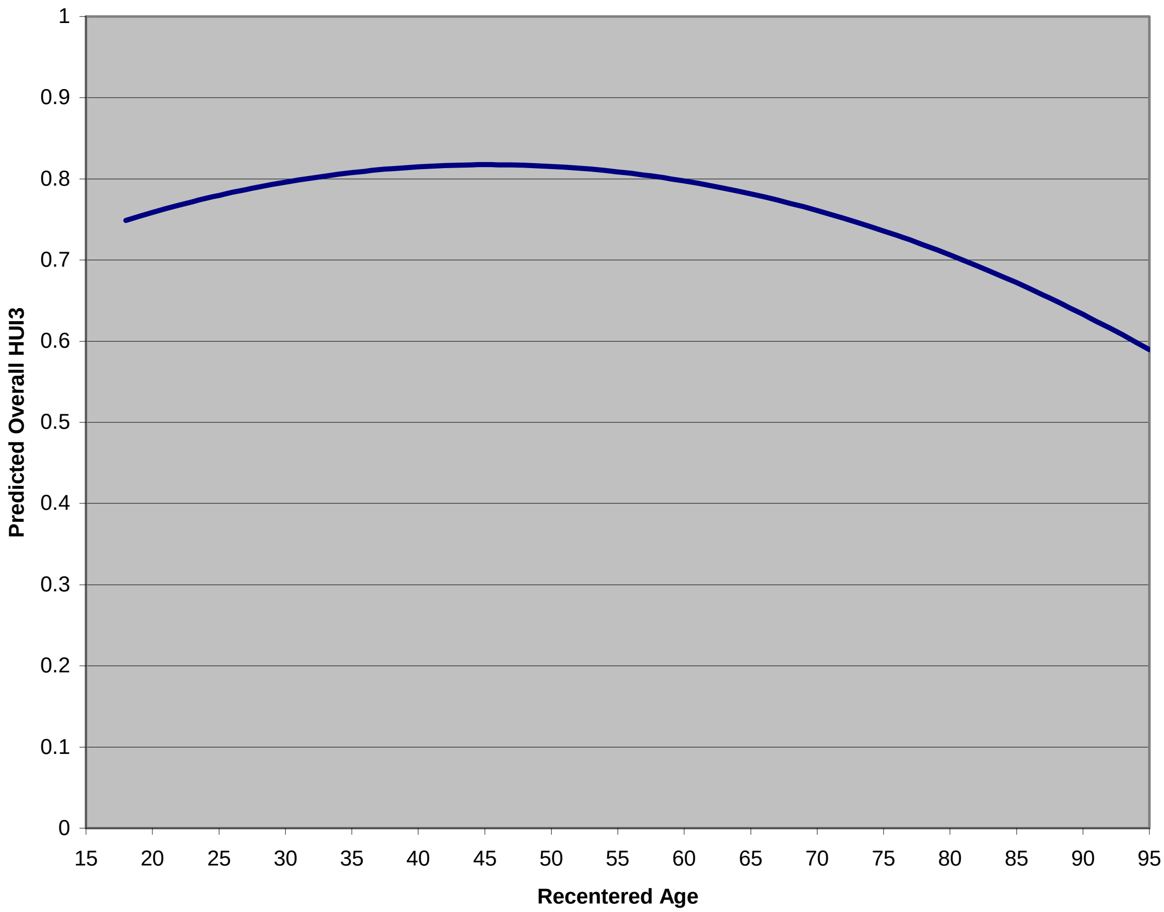


Figure 4b: Nonlinear Bivariate Association between Mean Centered Age[A] and HRQL

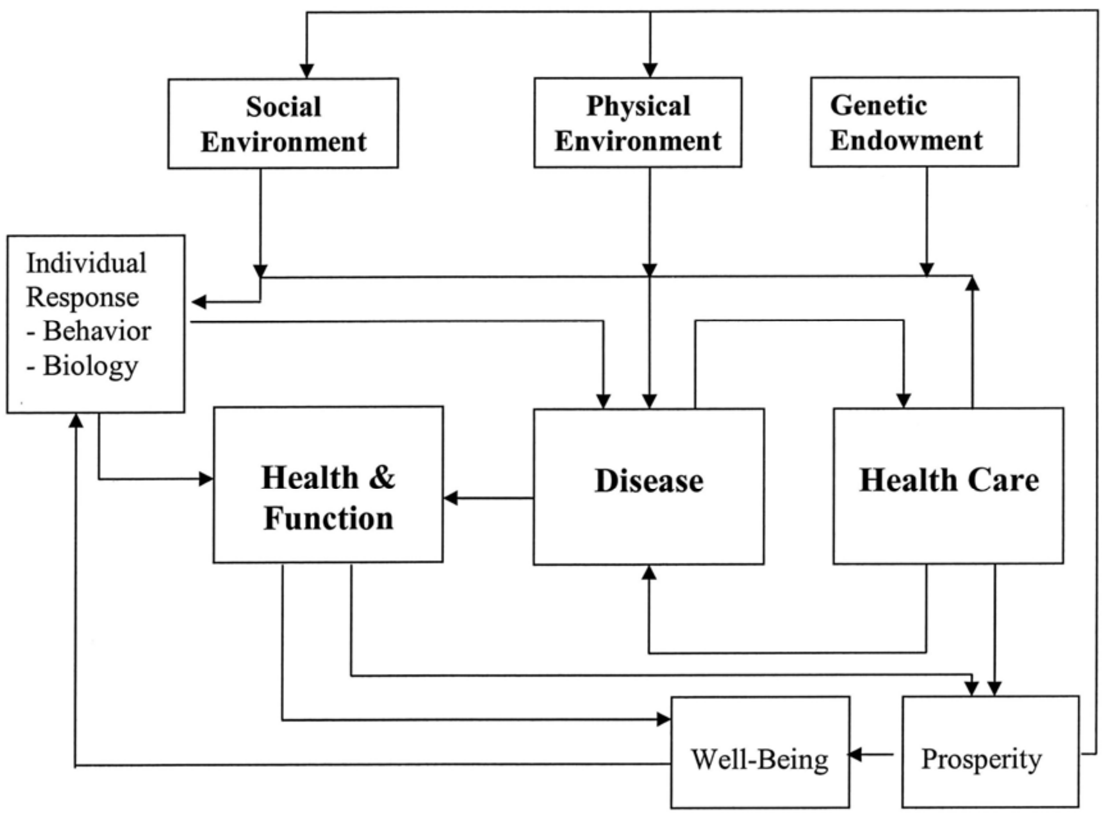


A Mean Centered Age = Age minus 61.55

Figure 4c: Bivariate Association between Age and Predicted Overall HUI3 Scores from Mean Centered Quadratic



Appendix 1
CIAR Population Health Framework[1]



[1] Evans RG, Stoddart GL. Producing health, consuming health care. Social Science and Medicine 1990; 31: 1347-63.

Appendix 2
HUI3 Health Status Classification System

Attribute	Level	Utility[A]	Level Description
Vision	1	1.00	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	0.95	Able to see well enough to read ordinary newsprint and recognize a friend on the other side of the street, but with glasses
	3	0.73	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	0.59	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	0.38	Unable to read ordinary newsprint and unable to recognize a friend on the other side of the street, even with glasses
	6	0.00	Unable to see at all
Hearing	1	1.00	Able to hear what is said in a group conversation with at least three other people, without a hearing aid
	2	0.86	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	0.71	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	0.48	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	0.32	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	0.00	Unable to hear at all
Speech	1	1.00	Able to be understood completely when speaking with strangers or friends
	2	0.82	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	0.67	Able to be understood partially when speaking with strangers or people who know the respondent well
	4	0.41	Unable to be understood when speaking with strangers but able to be understood partially by people who know the respondent well
	5	0.00	Unable to be understood when speaking to other people (or unable to speak at all)
Ambulation	1	1.00	Able to walk around the neighborhood without difficulty and without walking equipment
	2	0.83	Able to walk around the neighborhood with difficulty, but does not require walking equipment or the help of another person
	3	0.67	Able to walk around the neighborhood with walking equipment, but without the help of another person
	4	0.36	Able to walk only short distances with walking equipment and requires a wheelchair to get around the neighborhood
	5	0.16	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	0.00	Cannot walk at all

Dexterity	1	1.00	Full use of two hands and ten fingers
	2	0.88	Limitations in the use of hands or fingers, but does not require special tools or help of another person
	3	0.73	Limitations in the use of hands or fingers, is independent with use of special tools (does not require the help of another person)
	4	0.45	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	0.20	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	0.00	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	1.00	Happy and interested in life
	2	0.91	Somewhat happy
	3	0.73	Somewhat unhappy
	4	0.33	Very unhappy
	5	0.00	So unhappy that life is not worthwhile
Cognition	1	1.00	Able to remember most things, think clearly and solve day to day problems
	2	0.86	Able to remember most things, but have a little difficulty when trying to think and solve day to day problems
	3	0.92	Somewhat forgetful, but able to think clearly and solve day to day problems
	4	0.70	Somewhat forgetful, and have a little difficulty when trying to think or solve day to day problems
	5	0.32	Very forgetful, and have great difficulty when trying to think and or solve day to day problems
	6	0.00	Unable to remember anything at all, and unable to think or solve day to day problems
Pain	1	1.00	Free of pain and discomfort
	2	0.92	Mild to moderate pain that prevents no activities
	3	0.77	Moderate pain that prevents a few activities
	4	0.48	Moderate to severe pain that prevents some activities
	5	0.00	Severe pain that prevents most activities

Source: http://www.fcs.mcmaster.ca/hug/index.htm
A Single Attribute Utility Score