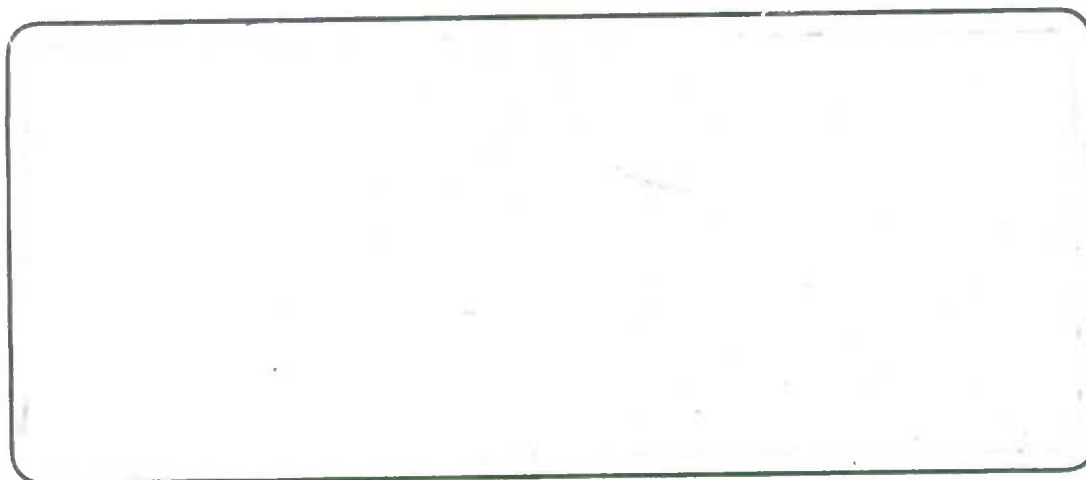




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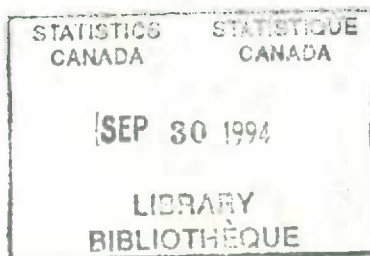
**THE CALCULATION OF HEALTH-ADJUSTED LIFE
EXPECTANCY FOR A CANADIAN PROVINCE USING A
MULTI-ATTRIBUTE UTILITY FUNCTION: A first Attempt**

by

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The Calculation of Health-Adjusted Life Expectancy for a Canadian Province Using a Multi-Attribute Utility Function: A First Attempt*

Jean-Marie Berthelot, Roger Roberge, and Michael C. Wolfson

ABSTRACT

Life expectancy of Canadians has increased by approximately 5 years in the last quarter century. It is not clear if the addition of quantity to life is also adding quality. In this paper we present the application of a health status index to calculate the Health-Adjusted Life Expectancy for the population of Ontario, Canada's largest province. Health-Adjusted Life Expectancy is calculated by combining a life table stationary population with cross-sectional population estimates of self-reported health status from the 1990 Ontario Health Survey. Health status is obtained from the Comprehensive Health Status Measurement System developed by McMaster University. It is based on eight health attributes and a multi-attribute utility function which produces an overall health status index score for each individual. It should be stressed that the index is provisional because it is based on a utility function estimated for an earlier study with a somewhat different set of health status measurement system, modified for use with the Ontario Health Survey. Health status for the household population was estimated by applying the provisional formula to the 1990 Ontario Health Survey. Health status for the institutionalized population was imputed using a combination of the 1990 Ontario Health Survey and the 1986-1987 Canadian Health and Activity Limitation Survey. Application of the Sullivan method to the 1985-1987 Ontario life table stationary population in conjunction with the provisional index, resulted in a Health-Adjusted Life Expectancy at age 15 of 53.6 years for men, 5.7 years less than their life expectancy, and of 57.9 years for women, 7.6 years less than their life expectancy.

Key Words: Comprehensive health status measurement system, health status index, Sullivan method



Introduction

Increased life expectancy is a continuing trend observed in much of the developed and developing world. In Canada, life expectancy increased by 4.6 and 5.5 years, respectively, for males and females between 1961 and 1986 (Nagnur, 1986; Statistics Canada, 1988). In the United States, the increases were 4.4 and 4.5 years between 1964 and 1985 (McKinlay et al., 1989), while in Australia, the increases were 5.4 and 5.3 years between 1965 and 1988 (Mathers, 1991). The simple increase in the quantity of life, however, does not give any indication of whether there is an accompanying increase, decrease or maintenance of the health-related quality of life. Many health indices and indicators have been developed to quantify the health status of a population. Sullivan (1971) was one of the first to develop and apply a health-adjusted indicator. His Disability-Free Life Expectancy (DFLE) indicator combines cross-sectional age/sex specific disability prevalence data with an appropriate life table. Two health states are used with a disability state having a value of 0 and a disability-free state a value of 1. Implicitly, each year of disability is assumed to be independent of any prior disability. The prevalence of the disability-free health state is applied to a stationary population from a life table resulting in an estimate of disability-free life expectancy.

Summary indices of population health have evolved in several directions from the original Sullivan work. These directions include indicators which identify various other health states such as impairment or handicap (Robine and Michel, 1992) while another provides explicit and more realistic descriptions of the health status dynamics (Wolfson, 1992) by modeling the underlying health and disability processes (incidence patterns and progression). These efforts are reviewed in Wolfson and Manton (1992).

The extension of Sullivan's binary representation of health status (e.g., disabled or not) to a continuum of health states is another direction being taken. Torrance (1976) suggested the use of a health expectancy index based on multi health states whereby each year of life would be weighted by a utility or value function. The reference values for the index are 0.0 for death and 1.0 for "fully healthy". States considered worse than death, such as very painful terminal cancer or total paralysis, may be valued at less than 0.0. While the conceptual framework for calculating Health-Adjusted Life Expectancy is well understood, the practical difficulties of measuring health state utilities are still being addressed. Wilkins and Adams (1983) derived the first estimates of the Health-Adjusted Life Expectancy for a national population, by combining the Sullivan method with the cross-sectional prevalence for six disability states and by assigning arbitrary values, corresponding to perceived health-related quality of life, to each of the six disability states.

This paper presents an extension of the Sullivan method for the calculation of the Health-Adjusted Life Expectancy (HALE) at age 15 for the province of Ontario. HALE is computed by applying an age/sex specific average health status index score, based on a multi-attribute utility function, to a stationary population from a life table. The multi-attribute utility function employed in the calculation of the health status index is derived from the Comprehensive Health Status Measurement System (CHSMS) developed at McMaster University (Torrance et al., 1992a). Results from the 1990 Ontario Health Survey (OHS) and the 1986-1987 Canadian Health and Activity Limitation Survey (HALS) are used to estimate the prevalence of the different health states while the Childhood Cancer Study (Torrance et al., 1992b) is used to estimate provisional utility weights of each health state for the Ontario population. The results of this research are of a provisional nature.

Methods

The calculation of a health status index score for an individual requires that: i) health status be measured, and ii) that a score (or utility weight) be associated with each health state. Even though health status can be viewed in thousands of different facets, in practice it is based on a limited number of distinct attributes, with a limited number of functional levels within each attribute and is measured using a multi-attribute health status measurement system. In addition, Torrance (1986) required that "within each attribute, the function-levels must be mutually exclusive and exhaustive, so that at any point in time, each individual can be classified on each attribute into one, and only one, function-level. Each different combination of levels, one from each attribute, represents a unique health state." The Comprehensive Health Status Measurement System developed at McMaster University is used for this paper (Torrance et al., 1992a). It is comprised of eight attributes of health status with five to eight levels of functional ability within each attribute. These attributes consist of: Vision, Hearing, Speech, Mobility (ability to get around), Dexterity (use of fingers), Cognition (memory and thinking), Emotion (feelings) and Pain and Discomfort. The prevalence of each health state is obtained

from a representative sample of the population under study. For our application, the 1990 Ontario Health Survey (OHS) and the 1986-1987 Health and Activity Limitation Survey (HALS) are used to evaluate the prevalence, but not the utility weights, of the different health states of the Comprehensive Health Status Measurement System (CHSMS) for the province of Ontario.

The assignment of a score to each health state of the CHSMS is done by reflecting the preferences of individuals vis-à-vis the various health states. A utility weight is assigned to each health state on a scale that arbitrarily sets the reference state of death to 0.0 and the reference state of "fully healthy" to 1.0. In the case of the CHSMS, the evaluation of the preferences of individuals is a complex process: all health state outcomes within each attribute are ranked in order of preference by an individual, and cardinal utilities are assigned, using the visual analog scale method or the standard gamble method.

A visual analog scale process consists of measuring values for a number of health states by placing descriptions of them on a visual analog scale, using the subjective judgment of the individual. The standard gamble method is a process in which the subject is presented with two alternatives and asked to select the most preferred. One of the alternatives offers the subject a particular outcome with certainty (Alternative 1), while the other option offers a gamble with specified probabilities for two possible outcomes (Alternative 2). For example, Alternative 2 may be a treatment regime whereby either the patient is returned to normal health and lives for an additional t years (probability p), or the patient dies immediately (probability $1-p$). Alternative 1 has the certain outcome of chronic state i for life (t years). This particular variation of the technique is presented in Fig. 1. For a complete description of the use of the visual analog scale and the standard gamble method, see Torrance et al. (1992b).

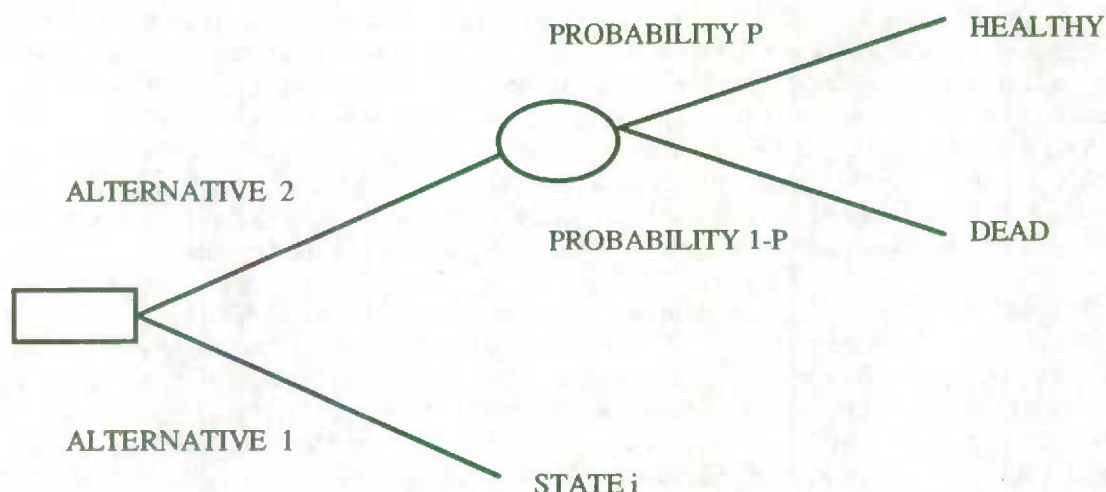


Fig. 1. Standard Gamble diagram for a chronic health state preferred to death, as extracted from Torrance (1986), p. 20.

The evaluation of the preference weights of individuals, specific to the CHSMS, is in development and will not be available before mid 1993 (telephone conversation with W. Furlong, July 1992). It is thus necessary to use the results of previous work to obtain provisional utility weights for the OHS. McMaster University had already developed a set of utility weights and a multi-attribute utility function (MAUF) to derive a health status index for a Childhood Cancer Study (Torrance et al., 1992b), using a precursor of the CHSMS. Statistics Canada commissioned McMaster University to adapt the results of the Childhood Cancer Study (CCS) utility weights and multi-attribute utility function to the OHS suite of questions, namely the CHSMS.

The CCS surveyed 200 parents of school children in kindergarten to grade 5 in the city of Hamilton, Ontario. The survey was developed to evaluate the preferences of parents towards different health levels defined in terms of 7 attributes. This involved both estimating preferences for levels within each attribute (vary levels within 1 attribute while assuming that all other attributes are fixed at a "fully healthy" level) and obtaining the preferences for combinations of attributes in which one attribute is placed in its "worst" health level and the others fixed at a "fully healthy" level. (Torrance et al, 1992b, p. 26.) The 7 attributes for which preferences were measured are: sensation (hearing, vision and speech),

mobility, emotion, cognition, self-care, pain and fertility. The standard gamble and visual analog scale techniques obtain parent's utility weights for the different health states. These preferences (or utility) weights were measured by asking each participant to imagine that they were a child of age 10 and would have to live in the state described until death at age 70. The participants were told to make all decisions on the basis of what would be best for themselves as a child (Torrance et al, 1992a, p. 29).

The individual OHS attribute levels were mapped to a unique CCS attribute level by members of the McMaster research team. A best estimate, a minimum and a maximum level for each CCS attribute were provided, with the best estimate used in the mapping process to derive utility weights for the OHS (Torrance et al., 1992a, p. 33-35). This mapping resulted in a number of compromises to the original OHS CHSMS method. The first of these was the combining of the three OHS sensation variables (Vision, Hearing, Speech) into one overall sensation variable. The OHS also contains an attribute for dexterity, whereas the closest counterpart in the CCS is the self-care attribute. Finally, the CCS contains an attribute for fertility whereas the OHS has none. Because of these and other compromises, it must be emphasized that the mapping method used results in a provisional index and that the results presented in this paper are best considered preliminary and approximate estimates.

With the mapping from the health states in the OHS into the CCS, the OHS CHSMS questionnaire response combinations are transformed into the format used in the CCS to provide health state levels for each CCS attribute. Utilities derived for the CCS are then combined through the CCS-MAUF to produce an overall individual health status index score. Possible functional forms for the MAUF are additive, multiplicative and more complex non-linear. Keeney and Raiffa (1976) determined that in the interests of practicality, for four or more attributes, only the additive and the multiplicative models should be considered. Previous work conducted by Torrance (1982) examined the independence conditions and the predictive validity of the additive and multiplicative forms, and determined that the multiplicative form was the most appropriate. Consequently, the CCS-MAUF, used to compute an individual's health status index score, is in the form of a multiplicative utility function and is defined as:

$$HSI_i = (\alpha * \prod_{k=1}^7 w_k(h_{i,k})) - \beta$$

where HSI_i is the health status index utility score for individual i , and $w_k(h_{i,k})$ is the preference weight associated with the observed health status level $h_{i,k}$ of the i^{th} individual for attribute k . The values α and β are parameters determined by the data and provide the range for the index scores. For the calculation of the provisional index, α was 1.06 and β was 0.06, such that the resulting health status index scores ranged from -0.02 to 1.0, where -0.02 is the worst state of health and 1.00 is the fully healthy state. Torrance et al. (1992a) state that "the negative score for the worst health state reflects the fact that on average respondents judged it to be worse than death."

The health status index derived from the OHS represents only the household population for Ontario. Since people residing in institutions are more likely to be disabled (Adams et al., 1991) and the proportion of people residing in institutions increases with age (less than 1% at age 15-24 and more than 30% at age 85 and over), the impact of the institutionalized population on the calculation of HALE for Ontario can be important, especially at older ages. With no survey providing data on health status compatible with the CHSMS for the institutionalized population, an imputation methodology was derived to reflect the health status of this segment of the population in the overall results.

The methodology consists of combining results from the OHS and the 1986-1987 HALS, to provide health status index scores for people residing in institutions. The HALS was a post-censal survey of approximately 200,000 persons designed to provide a comprehensive picture of persons with disabilities in Canada. The survey covered persons with disabilities in both households and health-related institutions (Statistics Canada, 1990). The adult institutionalized portion of HALS consisted of a sample of approximately 18,000 persons 15 years of age and over. Health status index estimates for the institutionalized portion of HALS were obtained by relating similar individuals in the OHS to those in the HALS.

The mean health status index score for the entire Ontario population by 10 year age groups and by sex was then derived by taking the weighted average of the mean health status index scores for households and institutions, given the proportions of people residing in institutions and households by age group and sex for Ontario (See appendix I). The

1985-1987 Ontario life table stationary population person years were multiplied with the population average health status index score by age group and sex resulting in Health-Adjusted Person Years. The HALEs at age 15 for each sex are calculated using the Health-Adjusted Person Years.

Application of the method

Responses from the 1990 OHS were used to estimate the population prevalence of the different health states. The OHS measured, using an interview and self completed questionnaire, the health status for a sample of over 62,000 individuals residing in households (OHS, 1992). The eight attributes of the CHSMS were measured in the OHS for all sampled persons aged 15 and over. All of the questions comprising the CHSMS were examined for a basic consistency before being combined into functional levels within each of the health status attributes. Taking the survey design into account, the percentage of respondents assigned to the "fully healthy" category or state was calculated by attribute for the Ontario household population and is presented in Fig. 2.

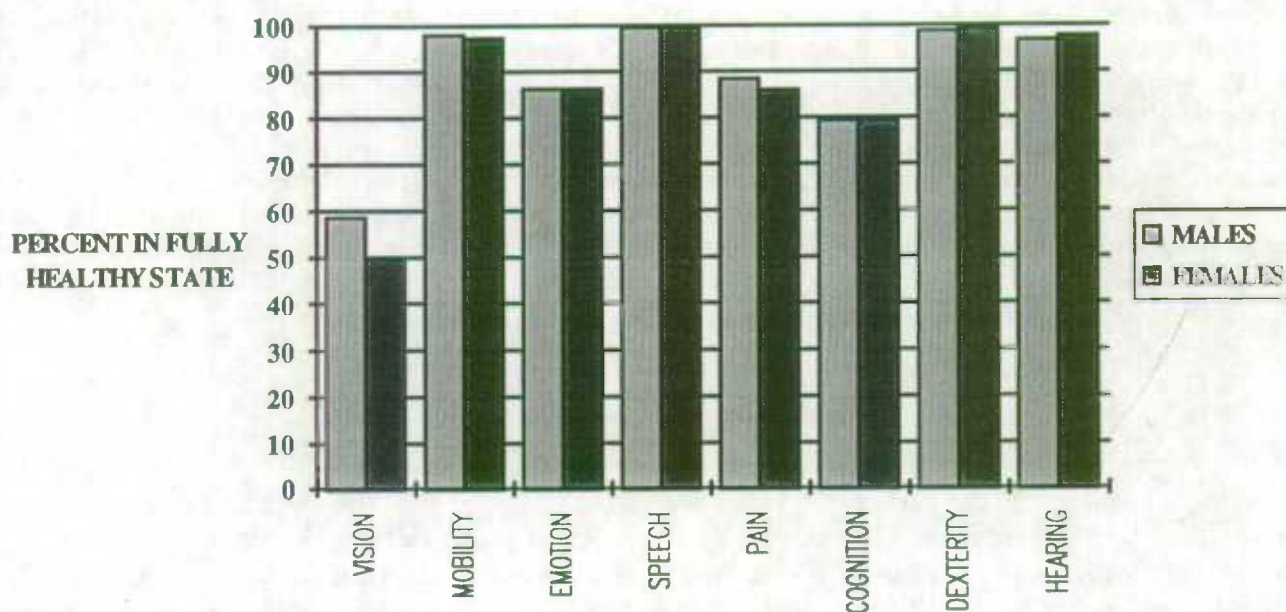


Fig. 2. Percentage of household population assigned to "fully healthy" in each health attribute, Ontario 1990, by sex, estimated from a sample of 21,315 males and 24,411 females aged 15 and over.

This graph shows that most people in the Ontario household population are assigned to a "fully healthy" state for each of the attributes, except for vision. The vision attribute, however, is explained by the fact that people wearing corrective glasses are not considered to be "fully healthy" on that dimension (over 44% of the population required glasses to correct their vision).

The health status index score was calculated for each individual in the OHS. Figure 3 shows the health status index distribution observed in the OHS for males and females, all ages combined. It can be observed from this figure that the majority of the individuals in the household population enjoy a relatively high level of health. Approximately 73% of males and 70% of females are in a health state valued at more than 0.9., with a large proportion (35.2% for males and 29.6% for females) fully healthy. It should also be noted that nobody was assigned to a state worse than death.

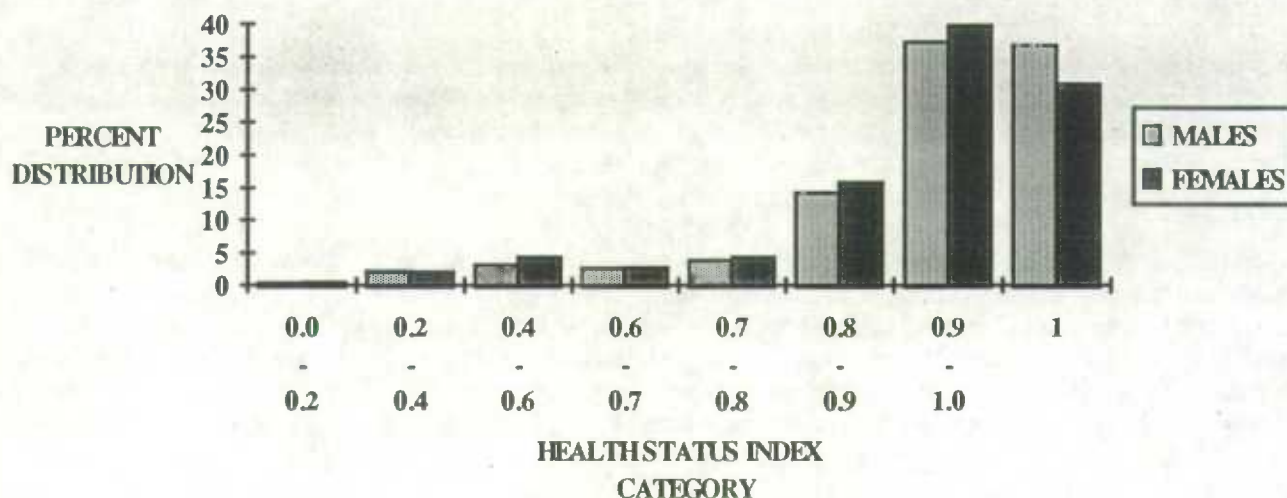


Fig. 3. Health status index distribution for males and females in the household population, Ontario 1990, estimated from a sample of 21,315 males and 24,411 females aged 15 and over.

The health status index distribution was compared to the well-being index derived from the self completed portion of the OHS. The well-being index provides a subjective measure of well-being known to be positively correlated with physical health. It is derived from a well-being score developed by Dupuy (1978) and has been used in many health surveys (OHS, 1992). The well-being index values range from a low of 1 (poor) to a high of 4 (excellent). The sex specific distribution of the health status index by the well-being index is presented in Fig. 4.

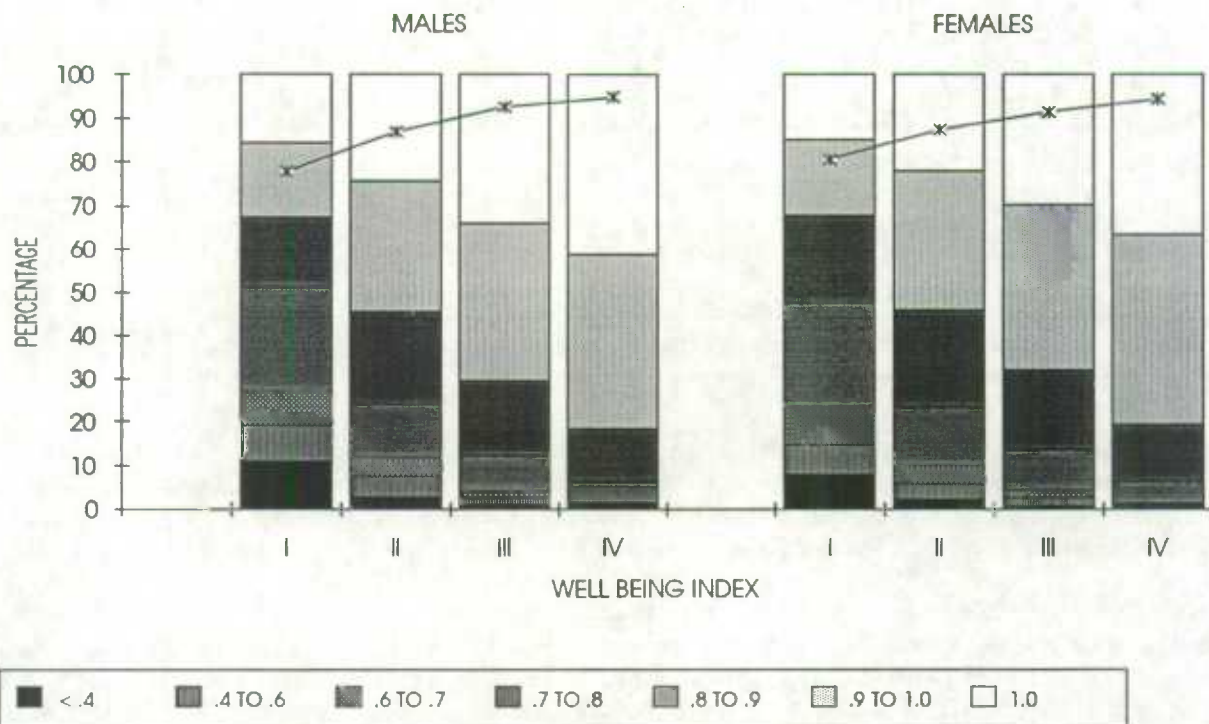


Fig. 4. Health status index distribution by Well-Being Index for the household population of Ontario 1990, by sex, estimated from a sample of 21,315 males and 24,411 females aged 15 and over. The number of respondents by well-being index was: 229 males and 376 females for index I, 2,357 males and 3,265 females for index II, 3,508 males and 4,184 females for index III, and 11,057 males and 11,356 for females for index IV. The well-being index was not available for 4,164 males and 5,230 females of the sample.

The different grey shading represents ranges of health status index scores; the darker the shading, the smaller the score of the health status index. The individual health status index scores were averaged within each well-being level and are represented in Fig. 4 by a line connecting asterisks in each vertical bar. This figure shows that the distribution of the health status index scores is broadly consistent with the well-being index: the mean health status index score increases when the well-being index increases, and the proportion of people in the darker (lower) category of health status index decreases when the well-being index increases. At the same time, it is evident that within each level of the well-being scale there is considerable dispersion among health status scores.

The OHS health status index distribution by 10 year age groups for males and females is presented in Fig. 5. This figure illustrates the well known declines in health with respect to aging. A relatively high proportion of the household population is fully healthy (around 60%) in the age group 15-24, while a very small proportion (around 3%) is fully healthy in the 85 + age group. Also, the proportion of the household population in the darker (lower health status) areas increases with age. The individual health status index scores were averaged to provide a mean health status index score by sex for 10 year age groups. These mean scores are represented in Fig. 5 with a line connecting asterisks in each vertical bar.

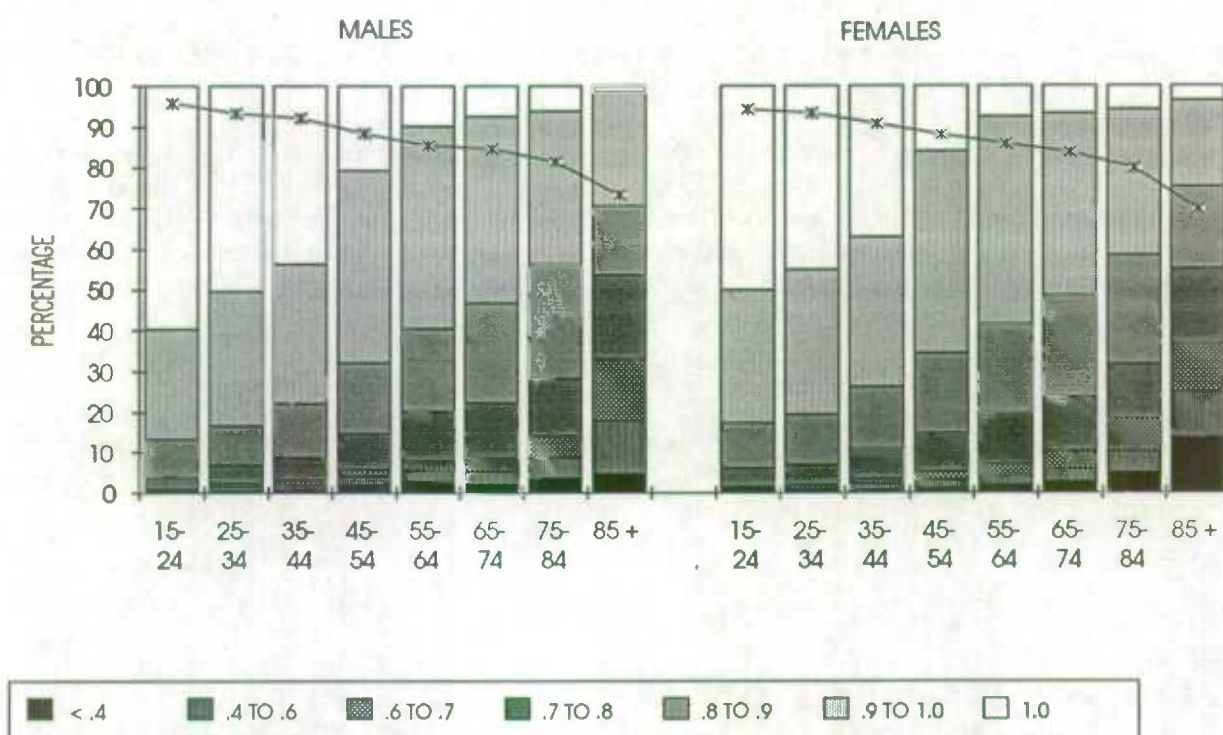


Fig. 5. Health status index distribution within age groups for the household population of Ontario 1990, by sex, estimated from a sample of 21,315 males and 24,411 females aged 15 and over. Each health status index distribution within an age group is based on a minimum of 2,000 individuals, except for the last 2 age groups with 866 males and 1187 females for age group 75-84 and 112 males and 222 females for age group 85 +.

These results represent the health status index for the Ontario household population only and do not incorporate those persons residing in institutions. For the institutionalized portion of the population, the methodology consists of combining results from the OHS and the 1986-1987 HALS. Health status index scores were estimated by relating "similar" individuals in the OHS to those in the HALS. "Similar" was defined by the number of disabilities. This process can be summarized in three steps: i) compute from the OHS CHSMS procedure, using the maximum score from the CCS-CHSMS mapping method, the mean age/sex specific health status index score by number of disabilities, ii) assign (impute) the calculated mean to each individual in the institutionalized portion of HALS that has the same number of disabilities, age and sex; and 3) compute a mean health status index score for the institutionalized portion of HALS by age and sex, using the individual imputed health status index scores.

In order to provide for a common basis between the OHS and HALS, the HALS definition of disability was used: individuals were not considered disabled if they used a technical aid that completely eliminated the limitation (Adams et al., 1991, p. 7). In HALS, a temporal condition is also factored in with the requirement that a disability or limitation be a minimum duration of 6 months. OHS disabilities for the 8 attributes of the CHSMS were standardized to the HALS definition of a disability by considering each attribute's health status level. Each health status level by attribute was labeled with a '1' indicating fully healthy, '2' a problem that is fully correctable with aid, '3 to 6' varying levels of disability. An individual was considered disabled if he/she was labeled at 3.0 or below for any attribute, with the exception of the cognition attribute, where the cut-off was set at 5.0 and below¹. The comparison between the OHS and HALS could only accommodate 6 of the 8 OHS attributes: Vision, Hearing, Speech, Mobility (ability to get around), Dexterity (use of fingers), and Cognition (memory and thinking). HALS had no counterpart for the OHS pain and discomfort, and emotion attributes. Also, the concept of the duration of a disability is not applicable to the OHS and, as such, has been ignored for both surveys.

An initial match between the two surveys proved to be inadequate, as a large number of HALS institutionalized respondents (approximately 40%) were found to have no counterpart in the OHS: those with more than 4 disabilities. This underscored the dramatic difference between the two populations and the obvious need for more information on the institutionalized segment of the population. In order to complete the imputation, the HALS populations were aggregated to 3 age groups (15-44, 45-64, 65+). The matching process varied by number of disabilities: those with 1 to 2 disabilities were matched on the basis of the new age group and sex; those with 3 disabilities on the basis of sex; and those with 4 or more disabilities an overall average. This was required to ensure that the mean health status index scores derived from the OHS were based on a sufficient number of OHS respondents. This procedure resulted in an imputed health status index score for each HALS respondent. The individually imputed HALS health status index scores were averaged to provide a mean health status index score for the residents of institutions, by sex for 10 year-age groups.

The use of a general household population to impute health status index scores for people residing in institutions has many limitations. The household and institutional populations are very different. Most of the severely disabled people reside in institutions, while most of the mild and moderately disabled people reside in households. Even though the methodology partially takes the number of disabilities into account, it does not fully consider severity or disabilities that are not captured by the CHSMS. The mean health status index scores imputed for people in institutions are therefore likely to be inflated.

The mean health status index scores for the combined household and institutionalized populations by age group and sex are presented in Fig. 6. Figure 6 demonstrates that although there might be concern that health status index scores for institutions have been over-estimated, they are still relatively low as compared to the household ones. Health status index scores for the combined population are nearly equal to the household population, except in older age categories, where institutionalization begins to have a greater impact.

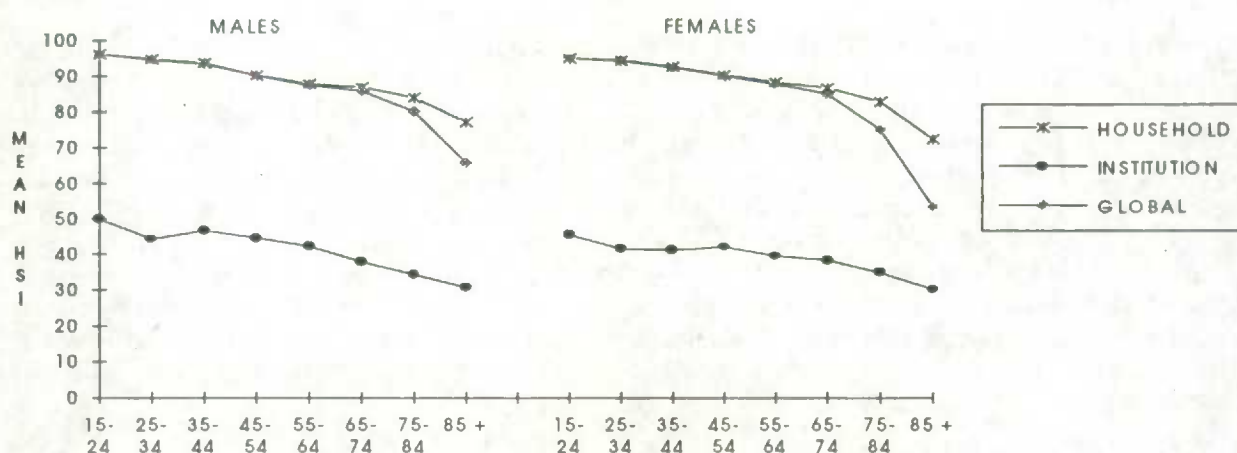


Fig. 6. Mean health status index scores by 10 Year Age Group. The household mean health status index scores are estimated from a sample of 21,315 males and 24,411 females aged 15 and over.

¹This labeling system was developed by the General Social Survey, Statistics Canada and Torrance et al., at McMaster.

The HALEs at age 15 for the Ontario population by sex were obtained by applying the average population health status index scores by ten year age group to a 1985-1987 life table stationary population for Ontario. Figure 7. presents the survival and the health-adjusted survival curves, in addition to the difference between the two curves. The ten year age grouping for the health status index scores combined with the single year population data from the life table account for the "saw tooth" patterns in the HALE and LE - HALE curves. The differences between the survival and health-adjusted survival curves increase with age for males until age 65 and then decrease. For females, the phenomenon is quite distinct, since the differences are increasing until the last age group. This reflects the fact that, beginning at the age group 65-74, the proportion of females residing in institutions is nearly twice that of males (Jamieson et al., 1992). This results in a HALE for males at age 15 of 53.6 years, 5.7 years less than their life expectancy, and a HALE for females at age 15 of 57.9 years, 7.6 years less than their life expectancy. The relative HALE, expressed as a percentage of remaining life expectancy, is 90.4% for males and 88.4% for females. These provisional results, though not directly comparable, are consistent with Wilkins and Adams (1983) in that females have a higher absolute HALE, but a smaller relative HALE; the difference between the males' and females' relative HALEs at age 15 is approximately 2%.

SURVIVAL AND HEALTH-ADJUSTED SURVIVAL CURVES

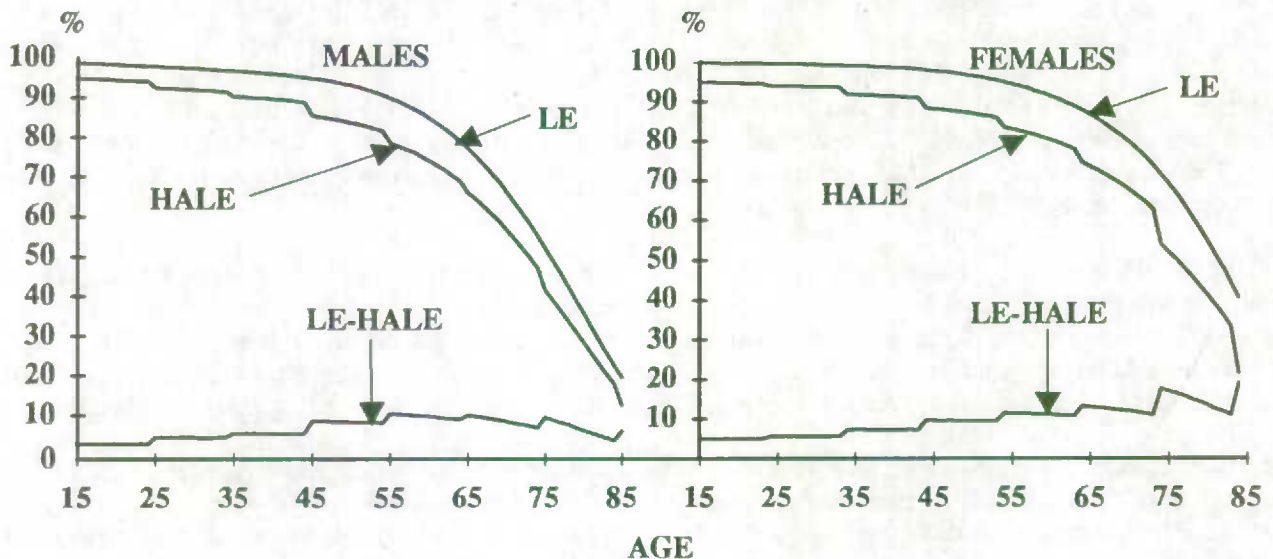


Fig. 7. 1985-1987 Survival Curve and Health-Adjusted Survival Curve for Ontario, by sex. The survival curve is truncated at age 85, since only aggregate estimates exist for ages over 85.

The reduction in health-related quality of life (i.e., LE - HALE) was disaggregated into the 6 attributes (excluding fertility), using a cause-deleted technique. For each individual in the sample, a given attribute is set to its fully healthy level, with the remaining attributes allowed to remain in their originally observed levels. Health status index scores are then re-computed individual by individual and re-averaged. This hypothetical "attribute-deleted" health status index calculation thus indicates the effect of each attribute on the overall HALE. Figure 8 shows that the pattern is relatively similar for males and females: the sensation attribute explains approximately 30% of the difference between life expectancy and HALE, followed by the pain attribute (25%) and the emotion and cognition attributes (12%). Given the non-linear character of the multi-attribute utility function that underlies the health status index, there is a residual -- that is, the difference between life expectancy and HALE not explained by the sum of the individual attribute-deleted calculations. This residual reflects the interaction of the level of one health status attribute with another. Since females generally have higher levels of disability than males, these interaction effects are more significant and the residual is therefore somewhat higher for females (14%) than for males (10%).

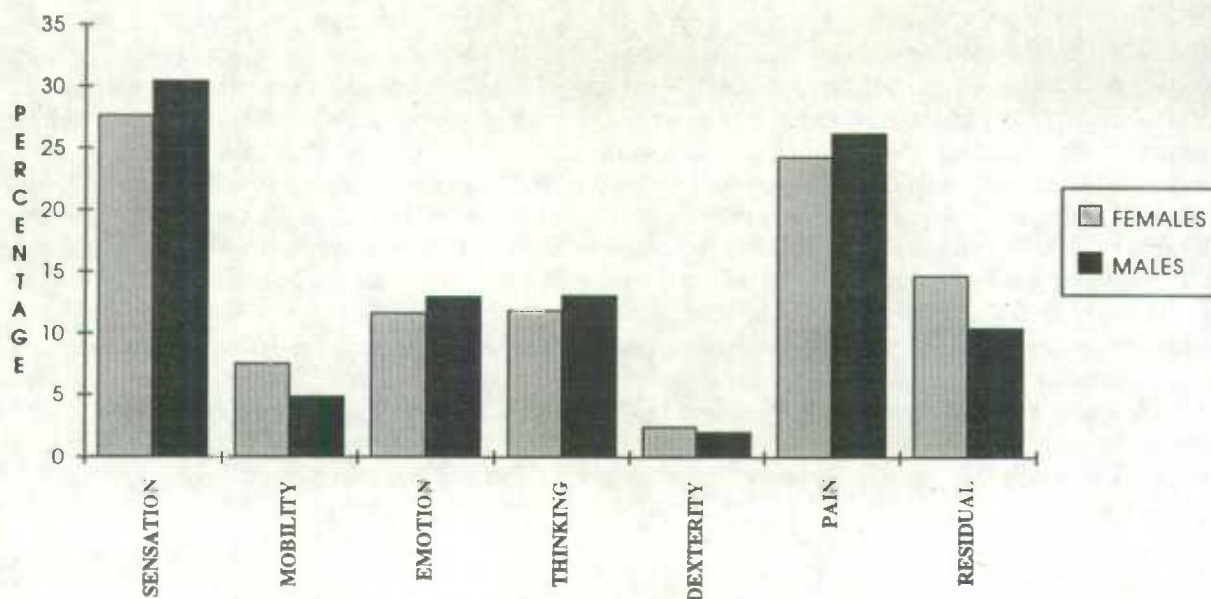


Fig. 8. Reduction in HALE by Attribute and sex, based on 1985-1987 life table for Ontario.

Discussion

The use of a multi-attribute health status measurement system in conjunction with a utility function provides a valuable framework for estimating Health-Adjusted Life Expectancy based on the Sullivan method. In our application of this approach, several important data limitations were encountered. One is temporary, due to the use of a provisional multi-attribute utility function for computing health status index scores for the Ontario Health Survey. This should be remedied by the forthcoming development of a utility function explicitly based on the OHS-CHSMS.

A second concern is the lack of appropriate health attribute information for the institutionalized population. It is clear that more information on the institutionalized population is required to improve this method. The measurement of the health status of the institutionalized population, using a health status measurement system like the CHSMS is required. The CHSMS used for the household population is not necessarily appropriate for the institutionalized population. For example, it is not clear if the emotion and cognition attributes capture properly the mental health states of persons with learning disabilities, mental handicaps and/or any physical conditions that resulted in an emotional or nervous disability. This could be an important factor for the institutionalized population, since 71 % of the persons aged 15 and over were diagnosed under this type of disability in the institutional portion of the 1986-1987 HALS. Research should also be initiated to adapt the CHSMS so that it can be used for both the institutionalized and the household populations. The measurement of the health status of the institutionalized population using a CHSMS like instrument is required in order to calculate reliable health status index scores and, consequently, reliable HALEs for the elderly. In addition, the use of proxy responses during the data collection has to be evaluated. It is unlikely that proxy responses are appropriate for subjective attributes such as emotion, pain and cognition (Feeny et al. 1991). However, proxy responses may be the only means available to elicit responses for those with severe disabilities.

The availability of a health status measurement system, integrated within traditional health statistics reporting, is important to monitor the changes of the health-related quality of life of the Canadian population over time. In Canada, a new National Population Health Survey (NPHS) is under development and should be operational by 1994. It will be a longitudinal survey of around 22,000 households, and will be conducted every two years over a 20 year period. The goal of the National Population Health Survey is to provide more comprehensive information on current population health status (Catlin and Will, 1992). In addition to providing the basis for monitoring health trends over time, the inclusion of a health status measurement system in the NPHS provides a baseline estimate for the distribution of health status in the general population. The same suite of questions can then also be included in clinical randomized and case-control studies to place such studies in a broader population context.

Finally, it is important to note the limitations in the Sullivan method implicit in the results reported here. This method, by using only cross-sectional prevalence data on health status, takes absolutely no account of the dynamics of health and disease processes. As a consequence, the "attribute-deleted" results presented above, while indicative of the relative importance of various health problems, probably do not represent realistic scenarios. Still, as a first estimate, the Sullivan approach is computationally straightforward, widely used, and not very data demanding. The results presented here, however, would be far more useful if they were derived from realistic models of the underlying dynamics. More explicit modeling is essential to move beyond the dynamics implicit in life table approaches like that of Sullivan by modeling the underlying health and disability processes (incidence patterns and progression) in order to allow for more detailed health states and greater underlying realism. Such results will be possible with the Population Health Model (POHEM) under development at Statistics Canada. This model can take into account multivariate demographic, economic and health processes. The demographic module includes nuptiality and labour market dynamics; the economic module includes income; and the health module includes multivariate risk factor dynamics, disease-specific morbidity and treatment techniques, and mortality processes (Wolfson, 1992). This new integrated approach is intended to join the multi-attribute utility function and OHS health status attributes used in this paper with explicit dynamics for the underlying population. It will thus provide a framework for generalizations and extensions of the concept of health-adjusted life expectancy.

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APPENDIX I: DATA USED FOR THE CALCULATION OF HEALTH ADJUSTED LIFE EXPECTANCY FOR THE PROVINCE OF ONTARIO.

Table A1: DATA USED FOR MALES

AGE GROUP	MEAN HSI SCORE IN % HHLDS INST		% RESIDING IN INSTITUTIONS	OVERALL HSI AVERAGE IN %	STATIONARY POPULATION PY'S (LL)	HEALTH ADJUSTED PY'S (HALL)
15-24	96.10	49.83	0.16	96.03	996,704	957,090
25-34	94.70	44.24	0.36	94.52	984,998	931,012
35-44	93.60	46.66	0.24	93.49	971,497	908,209
45-54	90.20	44.58	0.27	90.08	941,859	848,397
55-64	87.80	42.17	0.87	87.40	861,248	752,756
65-74	86.90	37.83	2.39	85.73	680,263	583,157
75-84	84.00	34.26	7.57	80.23	384,376	308,397
85 +	77.20	30.74	28.30	64.05	111,971	71,719
EXPECTANCY					59.33	53.61

Table A.2: DATA USED FOR FEMALES

	MEAN HSI SCORE IN % HHLDS INST		% RESIDING IN INSTITUTION S	OVERALL HSI AVERAGE IN %	STATIONARY POPULATION PY'S (LL)	HEALTH ADJUSTED PY'S (HALL)
15-24	95.00	45.55	0.08	94.96	998,268	947,949
25-34	94.40	41.51	0.21	94.29	994,306	937,509
35-44	92.60	41.10	0.17	92.51	987,464	913,544
45-54	90.30	42.15	0.24	90.19	971,694	876,323
55-64	88.30	39.60	0.54	88.04	921,857	811,565
65-74	86.60	38.45	2.32	85.48	814,979	696,669
75-84	82.90	34.91	12.41	76.94	588,064	452,473
85 +	72.50	30.09	40.45	55.35	270,505	149,712
EXPECTANCY					65.47	57.86

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