

Unhealthy Longevity in the United States

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A Study of Mortality by Health Status

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Introduction

The purpose of this report is to quantify differences in mortality and disease prevalence by health status. This project was conducted in response to a request from the Society of Actuaries (SOA) Mortality and Longevity Steering Committee and is intended to assist both practicing actuaries and the public to better understand differences in mortality for people in good and poor health.

This project uses five definitions of unhealthy status, the first two of which are broad: (1) poor or fair self-rated health and (2) Frailty Index (FI) values equal to or higher than 0.2 ($FI \geq 0.2$). The three specific definitions included (1) mental conditions, (2) disability or activity limitations and (3) presence of chronic diseases (based on a list of nine diseases). A “healthy” group was also studied for comparison purposes.

The National Health Interview Survey (NHIS), one of the largest U.S. health surveys, was used as a source of data for the U.S. population health. Estimates of mortality rates for unhealthy and healthy groups of adults (ages 45 and over) were stratified by sex and period. Mortality estimates by health status were obtained for two recent periods: 2010–2014 and 2015–2018. Age-specific prevalence by health status was estimated for 2010–2021 to include years impacted by COVID-19.

The project results were expressed in the form of life expectancies and life tables using a spectrum of individual health measures.

Executive Summary

KEY TAKEAWAYS

1. In comparing the unhealthy and healthy groups, regardless of definition employed, mortality was much worse for the unhealthy group.
2. The mental conditions subgroup had worse life expectancy at age 45 versus the disability and the chronic disease subgroups.
3. Persons with three or more chronic diseases had a significant increase in mortality versus individuals with one or two chronic diseases.
4. The self-rated health definition proved to be just as good of a measure for being unhealthy as the more sophisticated Frailty Index definition, which is based on 64 health conditions.
5. A higher prevalence of poor health was found among respondents who have had COVID-19 versus respondents indicating they never had COVID-19.

ANALYSIS OF KEY TAKEAWAYS

Unhealthy groups have much higher mortality and shorter life expectancy than healthy groups. The difference in life expectancy at age 45 between healthy and unhealthy subgroups using both the Frailty Index and self-rated health measures exceeds 15 years for both sets of data periods and for both males and females.

Additionally in examining the three types of specific health impairments, mental health (memory impairments) resulted in the largest decrease in life expectancy at age 45. In 2015–2018, the life expectancy estimates at age 45 were 21 years for males and 25 years for females compared to 35 years for males and 44 years for females without memory impairments. Although disability accounted for the second largest portion of life expectancy decline, the presence of chronic diseases had a smaller effect on the life expectancy decrease among unhealthy subgroups. Life expectancy estimates at age 45 for persons having and not having chronic diseases were 31 versus 40 years for males and 39 versus 45 years for females (Table 7).

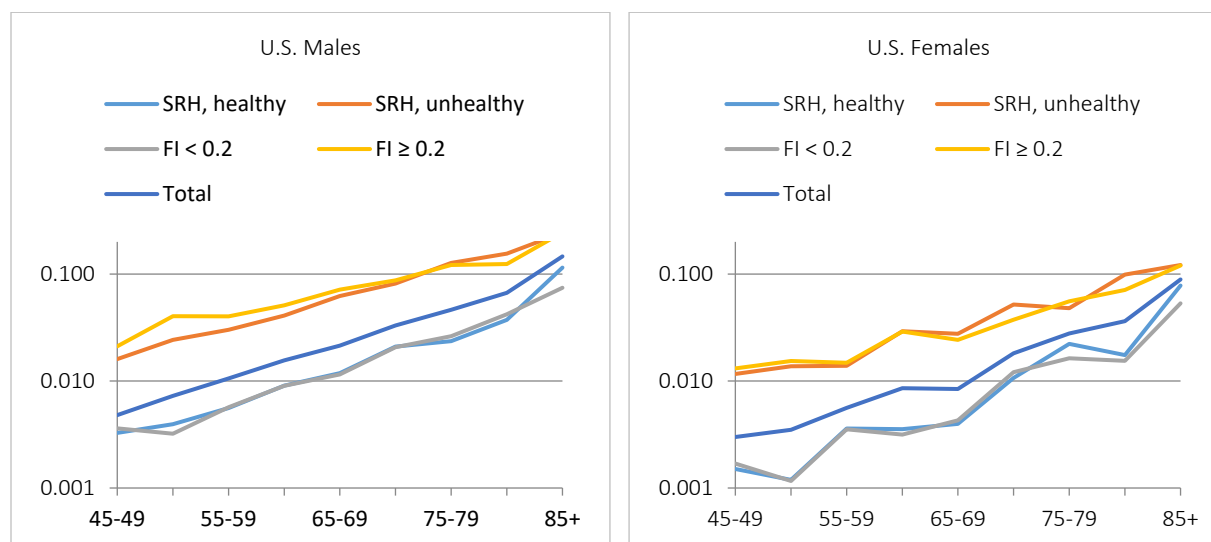
Analysis of mortality for persons having three diseases or more showed an association with a significant increase in mortality. In 2015–2018, life expectancy at age 45 dropped from 35 years for males with one disease to 22 years for males with three or more diseases. For females, life expectancy at age 45 dropped from 36 years to 28 years.

Life expectancy at 45 for unhealthy groups (according to self-rated health and Frailty Index [FI] measures) showed a decline over time with the exception of females having $FI \geq 0.2$. Males and females with memory impairments and females with chronic diseases demonstrated an increase of life expectancy at 45. Males and females with disability and males with chronic disease showed a decline in life expectancy at 45 over time. All changes of life expectancy over time were small and not statistically significant for all studied health groups.

The comparison of age-specific mortality trajectories found a remarkable similarity in trajectories between unhealthy groups based on self-rated health and Frailty Index definitions of health. It turns out that the very simple definition based on self-rated health produced virtually the same mortality trajectory as using a far more sophisticated definition based on the Frailty Index with 64 health-related questions (see Figure E1).

Figure E1

AGE-SPECIFIC MORTALITY IN LOG SCALE FOR MALES AND FEMALES IN 2015–2018 ACCORDING TO DIFFERENT DEFINITIONS OF HEALTH: (1) SELF-RATED HEALTH (SRH) AND (2) FRAILITY INDEX (FI) WITH CUTOFF EQUAL TO 0.2



This project analyzed newly released data on health distribution in the COVID-19 pandemic (2020–2021) and pre-pandemic (2019) years. The NHIS questionnaires in 2019–2021 are markedly different from the questionnaires in 2018 and earlier surveys. For this reason, only the trends in health indicators using 2019–2021 data were studied. This comparison showed a noticeable increase in the prevalence of mental conditions in 2021 compared to 2019 and 2020. No noticeable differences were observed for disability, chronic diseases, self-rated health and Frailty Index.

The direct effects of COVID-19 on health were analyzed by comparing COVID-19 survivors with respondents who had not had this disease. A significant increase was seen in poor health among respondents ever having COVID-19 for those with mental conditions, chronic diseases, self-rated health and frailty. For COVID-19 survivors with a disability, COVID-19 had no noticeable effect on health.

OTHER ANALYSIS HIGHLIGHTS

Changes in life expectancy of unhealthy groups between 2010–2014 and 2015–2018 were very small. Similarly, no difference was found in the order of the life expectancies for the three groups of unhealthy lives when moving from age 45 to age 65.

Utilizing 2015–2018 data, the total difference in life expectancy between healthy and unhealthy subgroups according to *self-rated health* at age 45 is 18 years. The decomposition of life expectancy at age 45 years showed that of these 18 years, deaths due to cancer contribute five years and deaths due to cardiovascular disease (CVD) contribute four years to the difference. Thus, in the case of self-rated health, cancer and CVD deaths combined represent half of the excess mortality at age 45.

The total difference in life expectancy between *disabled* and *not disabled* subgroups at age 45 is 23 years. Of these 23 years, deaths due to CVD contribute six years and deaths due to cancer contribute five years. Thus, in the case of disability, CVD contributes slightly more than cancer to differences in life expectancy between disabled and not disabled (unlike the self-rated health).

The comparison of the prevalence of poor health status by race showed that age-specific prevalence of the unhealthy group was almost always significantly higher among the Black or African American population (hereafter Black will be used for brevity) compared to the white population. Overall, age-specific prevalence of unhealthy groups is higher among the Black population compared to the white population for all studied definitions of health.

Differences in prevalence of poor health status between the Black and white populations were higher when using the self-rated health measure for unhealthy status than when using more objective measures of unhealthy status such as chronic diseases and disability. Prevalence of unhealthy status for the “Other” racial group tends to be closer to the white population at younger ages and to the Black population at older ages.

The study of prevalence according to health status by region showed somewhat higher prevalence of unhealthy groups in the South region compared to other regions. This observation agrees with existing reports of higher mortality and lower life expectancy in this region.



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Section 1: Definition of Healthy and Unhealthy Status

The purpose of this project was “to analyze differences in mortality patterns and trends between healthy and unhealthy lives in the U.S.” as formulated in the call by the Society of Actuary (SOA) for proposals. To analyze the mortality of healthy and unhealthy individuals it is important to define health. Many approaches could be found for such definitions. Definitions of health can consider multiple dimensions, or they can be based on a single dimension (Crimmins 2015). The Frailty Index (FI) is an example of a multidimensional measure of health encompassing indicators of disability, disease and risk factors. Similarly, self-rated health is a broad measure of health, but it is based on an individual’s perception, and we assume people include all of these factors in their assessment. Another approach is to consider one dimension of health at a time, such as disability, mental conditions or the presence of chronic diseases. For this report, we considered mortality of unhealthy and healthy groups of the U.S. population using both broader and specific definitions of health. A literature review of the existing measures of health status is available in Appendix B.1.

In this study we were limited by the available data in choosing how to define healthy and unhealthy status. We assessed the available information in the National Health Interview Survey (NHIS) and made choices that we think reflect healthy and unhealthy defined in multiple ways. We used the following definitions of poor general health:

- *Self-rated health as fair or poor.* This definition of poor health is often used in the scientific literature. It was used here for comparison with more sophisticated definitions. Self-rated health is one of the oldest measures of health status. Respondents are typically asked to rate their perceived health using a five-point Likert scale (excellent, very good, good, fair, poor). These five groups are often combined into three groups (very good/excellent, good, fair/poor). This is the simplest way to measure individual health status, and it was shown to be a good predictor of subsequent mortality (Idler and Kasl 1991, DeSalvo, Bloser, Reynolds, He and Muntner 2005).
- *Frailty Index equal to 0.2 or higher.* Empirical studies estimated that the cutoff value of 0.2 is recognized by multiple frailty measures as approaching a frail state (Rockwood, et al. 2005, Rockwood and Mitnitski 2006, Kulminski, Ukraintseva, Akushevich, Arbeevev and Yashin 2007), so that individuals can be classified as having no frailty ($FI < 0.2$) and frail ($FI = 0.2–1.0$). Calculations of the Frailty Index were based on questions available in the NHIS Sample Adult file, which provides index estimates comparable to the published estimates. Sixty-four questions reflecting three domains of health were used: (1) medical conditions (arthritis, cancer, diabetes mellitus and others), (2) health conditions causing difficulty with activity (hearing difficulties, poor cognition etc.) and (3) health-related behaviors such as smoking. Overall, the Frailty Index calculation was based on 64 possible health conditions (deficits) listed in Appendix B.3. Details of the calculation including treatment of missing values are described in Appendix B.2.

In addition to measures of general health this project studied mortality by health status using three more specific definitions of health. Specific definitions of health considered in this study include the following three groups of health impairment: (1) disability, (2) mental conditions and (3) presence of chronic diseases.

In this project mortality patterns were studied using the following specific definitions of health:

Disability. Disability was defined as having any limitation of activity mentioned by a NHIS respondent including activities of daily living (ADLs) and instrumental activities of daily living (IADLs) and difficulty remembering. This definition includes both physical and mental disability, which is in line with the definition applied by long-term care insurance (Stallard 2019).

Mental conditions. Mental conditions were defined as a positive answer to at least one of the questions: (1) Person is limited by difficulty remembering; (2) Intellectual disability causes difficulty with activity; (3) Senility causes difficulty with activity [ICD-9 code for senility is 797, Senility without mention of psychosis]; (4)

Depression/anxiety/emotional problem causes difficulty with activity; and (5) Other mental conditions/ADD[attention deficit disorder]/bipolar/schizophrenia causes difficulty with activity. Memory impairments (questions 1 and 3) were also studied separately. In the NHIS questionnaire all mentioned mental conditions were associated with difficulty of activity.

Presence of chronic diseases. Chronic diseases were defined as a positive response to at least one of nine questions whether respondent ever has been told that he or she has hypertension, coronary heart disease, angina pectoris, heart attack, heart condition/disease, stroke, emphysema, cancer or diabetes. These nine diseases were chosen out of 12 diseases mentioned in the NHIS because of their strong association with aging-related mortality.

For each of these health subgroups age-specific mortality and remaining life expectancy were estimated. Estimates were done for males and females separately.

Section 2: The Source of Information on Population Health

Several large nationally representative surveys collect individual health information such as National Health Interview Survey (NHIS), Health and Retirement Study (HRS), General Social Survey (GSS) and National Health and Nutrition Examination Survey (NHANES). Comparability of mortality estimates based on these surveys and the U.S. vital statistics demonstrated a good consistency across time in the NHIS and HRS but not GSS (Keyes, Rutherford, Popham, Martins and Gray 2018, Brown, Lariscy and Kalousová 2019). When comparing the NHIS and HRS surveys, it should be considered that the HRS collects data for respondents older than 50 years whereas the NHIS collects data for adults aged 18 years and older. Also, the NHIS is conducted every year rather than biannually as the HRS and has a larger sample size.

Comparison of several population surveys brought us to the conclusion that the NHIS is one of the best sources of data on U.S. population health. It is conducted by the Centers for Disease Control and Prevention's National Center for Health Statistics (Centers for Disease Control and Prevention 2016). This is an annual cross-sectional household interview survey, which provides demographic, socioeconomic and health characteristics of the civilian, noninstitutionalized population in the United States. Sampling and interviewing for the NHIS are continuous throughout each year. The NHIS is conducted in a face-to-face interview format. To increase the precision of estimates of the Black or African American (hereafter Black will be used for brevity), Hispanic/Latino and Asian American populations, the current NHIS sample design (starting in 2006) oversamples Black persons, Hispanic/Latino persons and Asian American persons.

The NHIS has rich information on the health status of respondents. It asks respondents about self-rated health and has a set of questions on health conditions and ADLs that allows researchers to estimate the Frailty Index. The NHIS has more than 64 questions on health status and limitation of activity and health behaviors. Summarizing, the NHIS provides all necessary information for calculating the Rockwood Frailty Index score, which is comparable to scores obtained in other studies (Biritwum, et al. 2016, Rockwood, et al. 2017, Mousa, et al. 2018). It also includes several questions on mental conditions.

The NHIS made significant changes of its questionnaire in 2019 so that definitions of mental conditions and disability in 2019 became incompatible with earlier NHIS questionnaires. Health measures for Frailty Index, disability and mental conditions were updated to reflect a new NHIS questionnaire introduced in 2019 (see Appendix B.4 and B.5). In 2020 and 2021 NHIS questionnaires asked respondents if they have had COVID-19. This information was used to compare health status among those who had COVID-19 with those who had not had this disease. This has been done for the whole spectrum of health status measures mentioned above.

In 2022 the NHIS released information on respondents' deaths in the form of 2019 Public-Use Linked Mortality files and allowed us to estimate mortality of respondents by health status. Mortality by health status was estimated for two recent periods corresponding to years when the survey was conducted: 2010–2014 and 2015–2018. In 2010–2014, 5,811 deaths were recorded out of 90,404 respondents surveyed in 2010–2014 and aged 45 years and over. In 2015–2019 there were 4,404 deaths out of 70,678 respondents aged 45 years and over and surveyed in 2015–2018.

Section 3: Construction of Period Life Tables

Unhealthy longevity in this project was analyzed by construction of cross-sectional or period life tables. Construction of period life tables is a standard way of presenting mortality data in demography (Preston et al. 2001). With this approach, period life tables and life expectancies in this report were calculated in a manner different from that with which some actuaries are accustomed. Period life tables show survival of hypothetical rather than real birth cohorts. Life expectancy of a hypothetical birth cohort shows the average number of years a baby born in a particular population can be expected to live if it experiences the current age-specific mortality rates of that particular population throughout its life. It does not reflect the expectations of life for a real cohort of individuals at a given age.¹

These tables are typically based on official governmental sources of population counts and death counts. Cross-sectional mortality rates can be estimated directly using a standard demographic approach when the annual number of deaths in a particular age group is divided by the exposure in this age group. This approach is applied less often to surveys data compared to a cohort approach, although examples of its successful application do exist (Manton, Stallard and Corder 1997, Arias, Escobedo, Kennedy, Fu and Cisewski 2018, Steensma, Choi, Loukine and Schanzer 2018). A cross-sectional life table approach to data on health was also applied in the study of multimorbidity and mortality using Medicare data (DuGoff, Canudas-Romo, Buttorff, Leff and Anderson 2014). This approach has not been widely applied to survey data although it may be promising for obtaining nationally representative mortality estimates.

A period life table is the most effective way of summarizing mortality experience of a population and can also be used to make statistical inferences and comparisons between mortality experience of different populations. The methodology used in this project applies life table construction for small areas with a small population size (Eayres and Williams 2004, Eayres 2017) and used methods described by Chiang (Chiang 1978, 1984). The methodology of period life table construction is described in Appendix C.1.

Construction of period life tables has certain advantages compared to a standard cohort approach:

- It is possible to study changes in mortality and life expectancy over time in a standard manner.
- It is possible to study mortality over longer age spans (e.g., from years 45 to 85 and older).

¹ Readers need to correctly interpret the life expectancies in this report. Two interpretations are considered:

1. For individuals matched on age, sex and other characteristics, life expectancy represents the average remaining number of years to be lived by such individuals. Generally, half live longer and half less than the indicated value.
2. For a population of individuals at different attained ages who are matched, at those ages, on sex and other characteristics, mortality over the next year can yield a set of age-specific death rates and an associated life expectancy that serves as a summarization of those age-specific death rates. In the second case, the life expectancy value is tied to the given set of mortality rates without assuming that the entire set of rates applies to any given individual or group.

The first interpretation applies to cohort life tables. The second interpretation applies to period life tables. The latter is the intended interpretation for the life expectancies in this report.

- It is possible to compare mortality in different subgroups in a standard manner using such conventional indicators as remaining life expectancy.

It is important to note that period life tables have certain limitations in the current application because they do not take into account possible transitions between the studied healthy and unhealthy statuses. The calculations assume that all initially healthy persons are exposed to the mortality schedules only for healthy persons, and all initially unhealthy persons are exposed to the mortality schedules only for unhealthy persons for all ages and durations. In actuality, substantial changes in group membership occur over time with the predominant direction of change being from healthy to unhealthy. The NHIS data do not permit us to study such transitions. Thus, it is important in interpreting the results to remember that such transitions are not included in the calculations. (see Appendix E for more details).

The NHIS has information about death counts for each survey cohort followed until 2019. This information can be used for cohort analysis of mortality. At the same time, these data can also be used for period life table construction using existing methods. In this project we used a standard method of life table construction with some modifications taking into account the relatively small size of the population and the way this survey has been conducted. The number of deaths was calculated as deaths occurring during the first four quarters after the survey interview in the age/health status/sex subgroup; this reflects the fact that NHIS interviews were conducted at different times during the survey year. The population under risk (exposure) included all respondents in a particular age and health subgroup minus one-half of deaths in this subgroup during one year (see Appendix C.1).

3.1 LIFE TABLE CONSTRUCTION FOR HEALTHY AND UNHEALTHY INDIVIDUALS

In this section we compare mortality and life table functions using two definitions of general health:

- Self-rated health as fair or poor (unhealthy) and very good, good or excellent (healthy).
- Frailty Index (FI) equal to 0.2 or higher (unhealthy) and $FI < 0.2$ (healthy). This cutoff point for the index was determined empirically in earlier studies (see Appendix B.1).

Abridged life tables have been constructed for each type of healthy and unhealthy status, separately for males and females for two periods: 2010–2014 and 2015–2018. Life tables for healthy and unhealthy subgroups of U.S. population were calculated using the methodology described in the life table calculator created by the South East Public Health Observatory (SEPHO) (Eayres 2017). These life tables are available as a supplement to this report in the form of an Excel file. The methodology of life table construction is described in Appendix C.1.

Table 1 presents life expectancy at age 45 for healthy and unhealthy females and males in 2010–2014 using two definitions of health, Frailty Index (FI) and self-rated health (SRH). It shows that at age 45, the remaining life expectancy of healthy and unhealthy individuals differs by more than 15 years.

Table 1

LIFE EXPECTANCY AT AGE 45 YEARS FOR HEALTHY AND UNHEALTHY MALES AND FEMALES IN 2010–2014 USING TWO DEFINITIONS OF GENERAL HEALTH: SELF-RATED HEALTH (SRH) AND FRAILITY INDEX (FI)

Group	Life Expectancy at 45	Standard Error	95% Confidence Interval
Males			
Total population	34.07	0.46	33.18–34.97
FI < 0.2, healthy	41.99	1.11	39.82–44.16
FI ≥ 0.2, unhealthy	20.89	0.87	19.19–22.60
SRH, healthy	40.78	0.80	39.21–42.35
SRH, unhealthy	22.53	0.75	21.07–23.99
Females			
Total population	40.99	0.55	39.92–42.06

FI < 0.2, healthy	54.04	2.19	49.75–58.33
FI ≥ 0.2, unhealthy	29.14	0.91	27.37–30.92
SRH, healthy	47.92	1.01	45.94–49.91
SRH, unhealthy	29.13	0.80	27.57–30.70

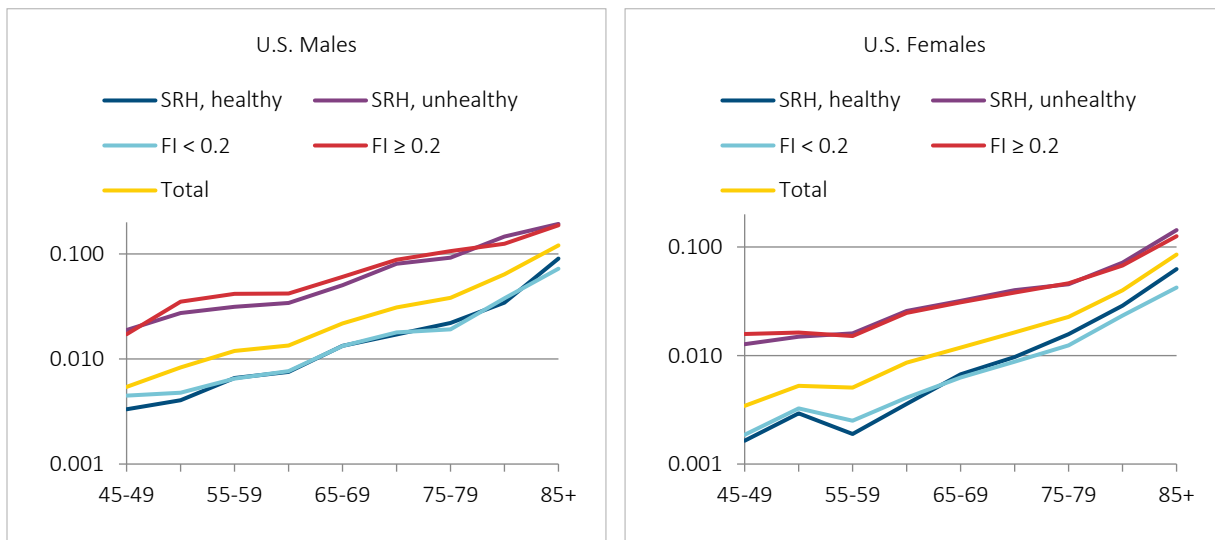
Life expectancy for U.S. males at age 45 in 2010–2014 is 34.14 years according to the official data provided by the National Center for Health Statistics (NCHS), which is close to life expectancy for NHIS total sample and falls into the 95% confidence interval (see Table 1). Life expectancy for U.S. females at age 45 in 2010–2014 according to the NCHS data is equal to 37.88 years, which is somewhat lower than the life expectancy for the NHIS total sample (40.99 years). The absence of institutionalized females in the NHIS sample may be one possible explanation of this difference because females are more prevalent in the nursing home facilities compared to males (Gurwitz 2005). Official U.S. data on life expectancy are taken from the Human Mortality Database (www.mortality.org).

3.2 COMPARISON OF AGE-SPECIFIC DEATH RATES BY HEALTH STATUS

Figure 1 shows mortality of healthy and unhealthy males and females using two definitions of health: self-rated health (SRH) and Frailty Index (FI) with a cutoff equal to 0.2.

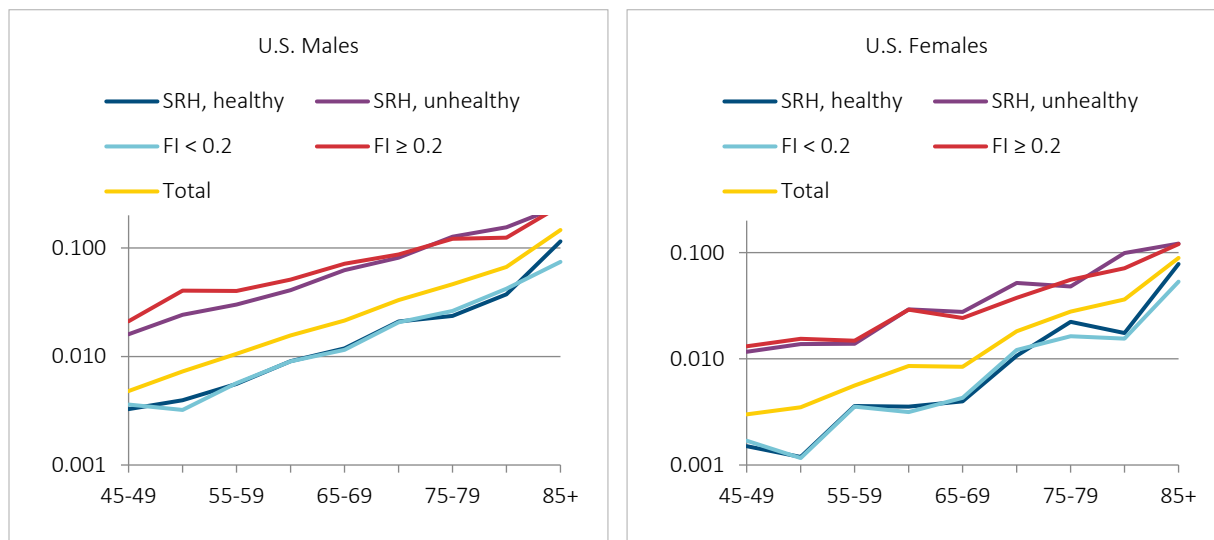
Figure 1

AGE-SPECIFIC MORTALITY IN LOG SCALE AFTER AGE 45 FOR MALES AND FEMALES IN 2010–2014 ACCORDING TO DIFFERENT DEFINITIONS OF HEALTH: (1) SELF-RATED HEALTH (SRH) AND (2) FRAILITY INDEX (FI) WITH CUTOFF EQUAL TO 0.2



Similar results are obtained for more recent years, 2015–2018 (see Figure 2).

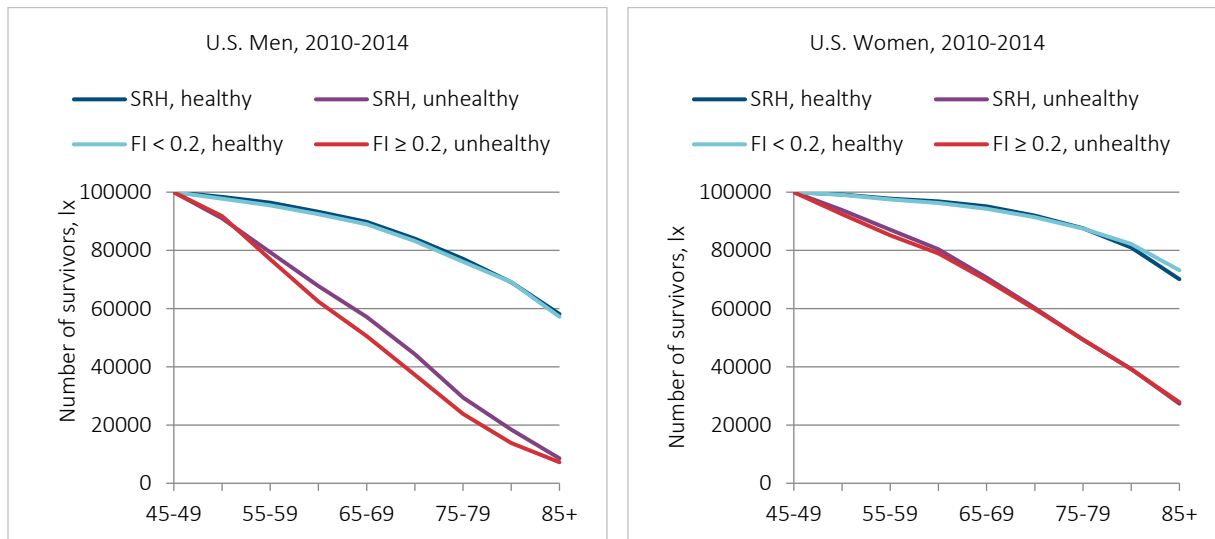
Figure 2
 AGE-SPECIFIC MORTALITY IN LOG SCALE AFTER AGE 45 FOR MALES AND FEMALES IN 2015–2018 ACCORDING TO DIFFERENT DEFINITIONS OF HEALTH: (1) SELF-RATED HEALTH (SRH) AND (2) FRAILITY INDEX (FI) WITH CUTOFF EQUAL TO 0.2



Despite a very simple definition of health based on self-rated health, this analysis produces virtually the same age-specific mortality trajectories as the much more sophisticated definition of health based on the Frailty Index (Figures 1 and 2). Thus, the definition of health based on the cutoff $FI = 0.2$ gives very reasonable mortality trajectories, which practically coincide with mortality trajectories based on self-rated health. This similarity in mortality trajectories obtained for two different definitions of health is the same for the two studied periods.

Figure 3 presents survival curves for healthy and unhealthy females and males in 2010–2014. Note that healthy females have more rectangular survival curves than healthy males, reflecting lower mortality before age 75. Figure 3 is presented here as an illustration of life table function. More information about life table functions can be found in the Excel supplement to this report (Abridged Life Tables, by Health Status; see also Appendix D).

Figure 3
SURVIVAL CURVES FOR FEMALES AND MALES IN 2010–2014 AS A FUNCTION OF AGE ACCORDING TO DIFFERENT DEFINITIONS OF HEALTH



This figure demonstrates very significant differences in survival between healthy and unhealthy females and males. Also note very similar survival curves for two different definitions of health.

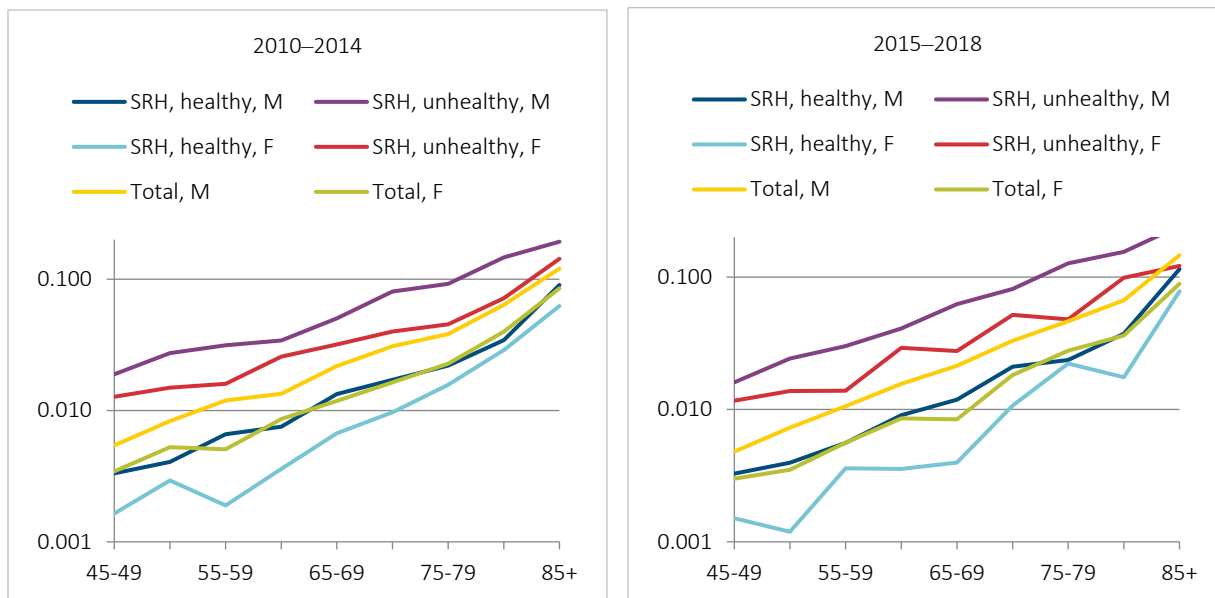
Section 4: Mortality and Life Expectancy of Healthy and Unhealthy Subgroups of the U.S. Population

4.1 GENERAL DEFINITIONS OF HEALTH: SELF-RATED HEALTH AND FRAILTY INDEX

Self-rated health is a simple integral health indicator. We define reporting fair or poor self-rated health as an indication of poor health. On the other hand, those individuals who report excellent, very good or good health are considered to be healthy. Figure 4 demonstrates mortality of healthy and unhealthy males and females in 2010–2014 and 2015–2018 according to their self-rated health.

Figure 4

AGE-SPECIFIC MORTALITY IN LOG SCALE OF HEALTHY AND UNHEALTHY U.S. MALES AND FEMALES IN 2010–2014 AND 2015–2018 ACCORDING TO THEIR SELF-RATED HEALTH, BASED ON THE NHIS SAMPLE ADULT FILE FOR U.S. MALES AND FEMALES

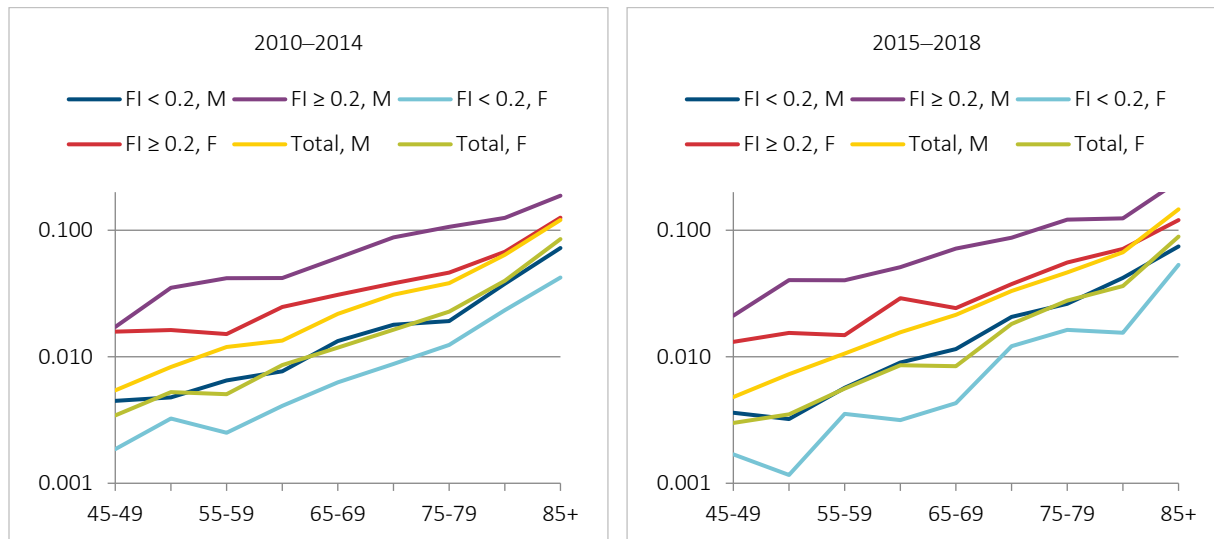


Mortality trajectories for both males and females were similar between 2010–2014 and 2015–2018.

Frailty Index. Here we show mortality of persons having $FI < 0.2$ (healthy) and those having $FI \geq 0.2$ and higher (unhealthy). Figure 5 presents age-specific mortality of healthy and unhealthy males and females in 2010–2014 and 2015–2018. Again, mortality trajectories for males and females were similar between 2010–2014 and 2015–2018.

Figure 5

AGE-SPECIFIC MORTALITY IN LOG SCALE OF HEALTHY (FI<0.2) AND UNHEALTHY (FI ≥ 0.2) U.S. MALES AND FEMALES IN 2010–2014 AND 2015–2018, BASED ON THE NHIS SAMPLE ADULT FILE FOR THE U.S. MALES AND FEMALES



Note that the mortality of unhealthy persons is much higher compared to the total population.

These mortality estimates allow us to calculate relative mortality risks for healthy and unhealthy individuals, which can be applied to other populations. Table 2 provides estimates of relative risk of healthy and unhealthy individuals for males and females in 2015–2018.

Table 2

RELATIVE MORTALITY RISK FOR HEALTHY AND UNHEALTHY INDIVIDUALS COMPARED TO TOTAL POPULATION, BASED ON THE NHIS SAMPLE ADULT FILE FOR 2015–2018

Age	Males		Females	
	Healthy	Unhealthy	Healthy	Unhealthy
45–49	0.75	4.40	0.56	4.38
50–54	0.44	5.55	0.33	4.40
55–59	0.54	3.80	0.63	2.64
60–64	0.58	3.27	0.37	3.39
65–69	0.54	3.34	0.51	2.88
70–74	0.62	2.64	0.67	2.06
75–79	0.57	2.62	0.59	2.00
80–84	0.63	1.86	0.43	1.96
85 and above	0.51	1.67	0.60	1.35

Note: Definition of healthy and unhealthy status is based on the cutoff FI= 0.2.

Age-specific relative risk presented in Table 2 may help to reconstruct mortality of unhealthy subgroups using information about the observed age-specific mortality of the total population.

4.2 SPECIFIC DEFINITIONS OF HEALTH: MENTAL CONDITIONS, DISABILITY AND CHRONIC DISEASES

The next step of the analyses was a study of mortality for three groups with different types of health impairments, having (1) mental conditions, (2) disability and (3) chronic diseases.

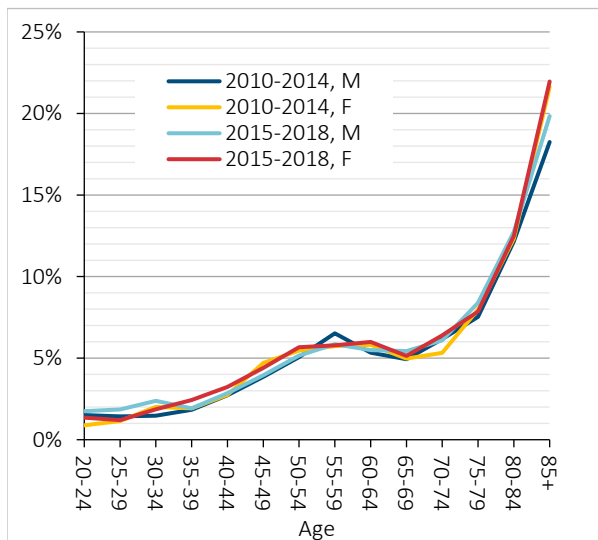
Mental conditions. Mental conditions were considered for two groups of mental impairments according to questions in the NHIS:

Group 1 considers memory impairments: (a) person is limited by difficulty remembering and (b) senility causes difficulty with activity (ICD-9-CM Diagnosis Code 797, Senility without mention of psychosis).

Group 2 considers all other mental conditions: (a) intellectual disability causes difficulty with activity, (b) depression/anxiety/emotional problem causes difficulty with activity and (c) other mental condition/ADD [attention deficit disorder]/bipolar/schizophrenia causes difficulty with activity.

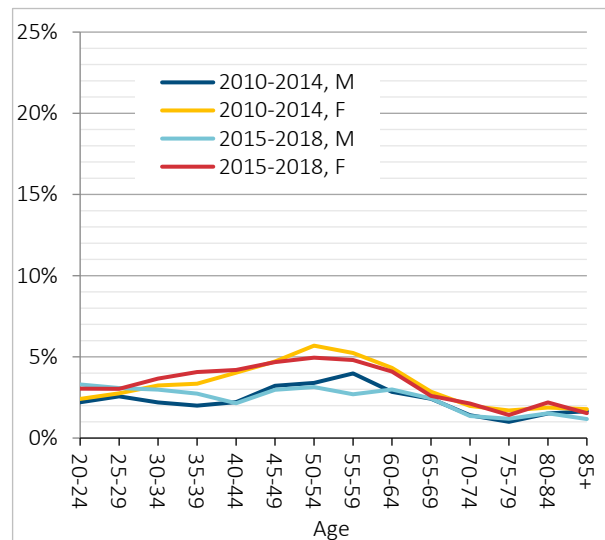
Figures 6 and 7 show prevalence of memory impairments (mental conditions, group 1) and other mental conditions (group 2) in 2010–2014 and 2015–2018.

Figure 6
PROPORTION OF U.S. MALES AND FEMALES REPORTING MEMORY IMPAIRMENTS (GROUP 1) AS A FUNCTION OF AGE BY SEX AND TIME PERIOD



Data source: NHIS sample adult file for U.S. males and females in 2010–2014 and 2015–2018.

Figure 7
PROPORTION OF U.S. MALES AND FEMALES IN OTHER MENTAL CONDITIONS (GROUP 2) AS A FUNCTION OF AGE BY SEX AND TIME PERIOD



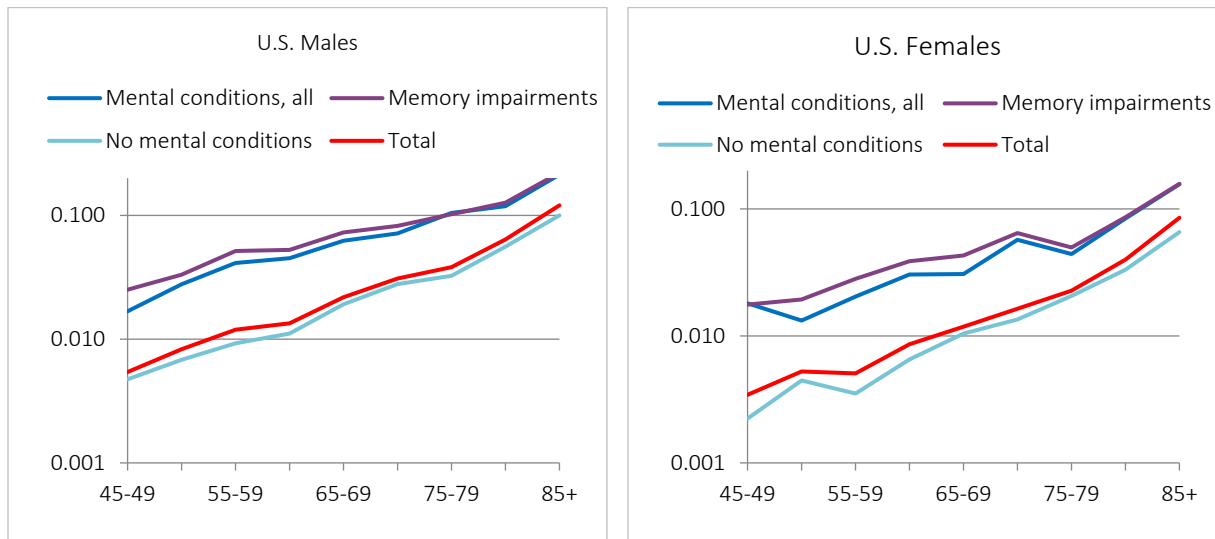
Data source: NHIS sample adult file for U.S. males and females in 2010–2014 and 2015–2018.

It looks like no noticeable difference exists in the prevalence of memory impairments between the two periods and between males and females for the first group. In the case of other mental conditions (group 2) only a small difference is seen in the prevalence of mental conditions between the two periods, but the prevalence of this type of mental condition for females is higher than that for males.

Note that the proportion of persons with the first group of mental conditions is small until the age of 70 years and then grows rapidly. Prevalence of the second group of mental conditions is rather low and has a peak at age 50–55. If we compare Figures 6 and 7 it is obvious that the prevalence of mental conditions is mostly determined by diseases of the first group.

Figure 8 shows mortality of males and females by mental conditions and memory impairments as the more prevalent group of mental conditions. Both groups of mental conditions demonstrate very high mortality compared to mortality of the total population.

Figure 8
 AGE-SPECIFIC MORTALITY IN LOG SCALE OF MALES AND FEMALES ACCORDING TO THE GROUP OF MENTAL CONDITIONS, BASED ON THE NHIS SAMPLE ADULT FILE FOR U.S. MALES AND FEMALES IN 2010–2014



Note that respondents with memory impairments have the highest mortality.

Figure 9 shows the mortality of persons with mental conditions and having memory impairments (group 1 of mental conditions) in 2015–2018. As in 2010–2014, the mortality of persons with mental conditions is very high compared to the total population (all respondents), and the group with memory impairments has the highest mortality.

Figure 9
 AGE-SPECIFIC MORTALITY IN LOG SCALE OF MALES AND FEMALES WITH MENTAL CONDITIONS AND HAVING DIFFICULTY REMEMBERING (GROUP 1 OF MENTAL CONDITIONS), BASED ON THE NHIS SAMPLE ADULT FILE FOR U.S. MALES AND FEMALES IN 2015–2018

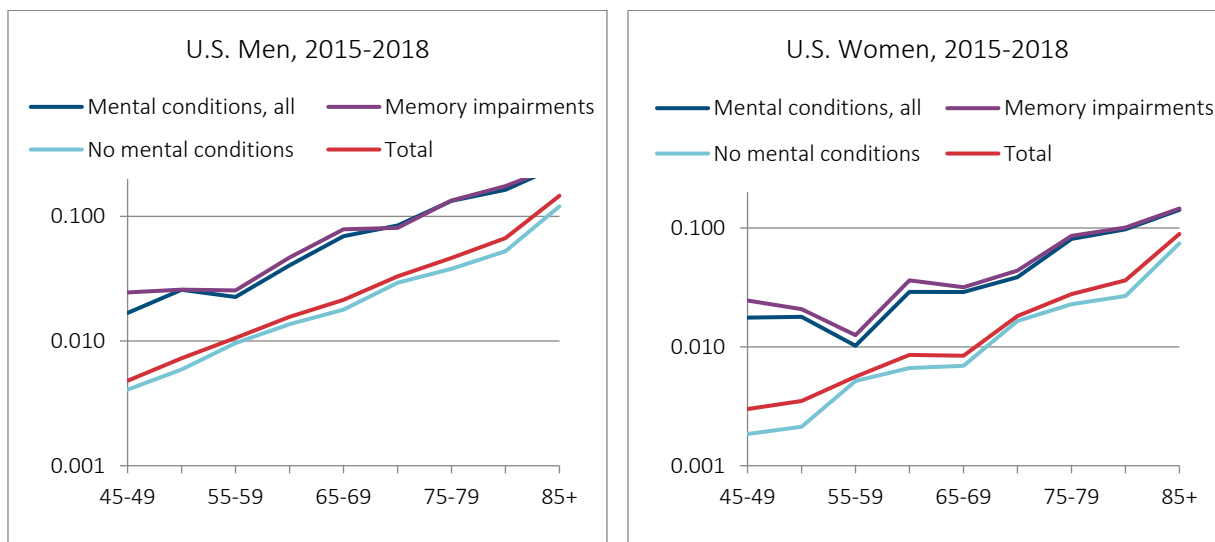


Table 3 demonstrates differences in life expectancy at age 45 according to the two groups of mental conditions. Life expectancy of the group 1 of mental conditions is similar to life expectancy of total mental conditions. Adding cases with the second group of mental conditions improves the accuracy of life expectancy estimates.

Table 3

LIFE EXPECTANCY AT AGE 45 YEARS IN 2010–2014 BY TWO GROUPS OF MENTAL CONDITIONS

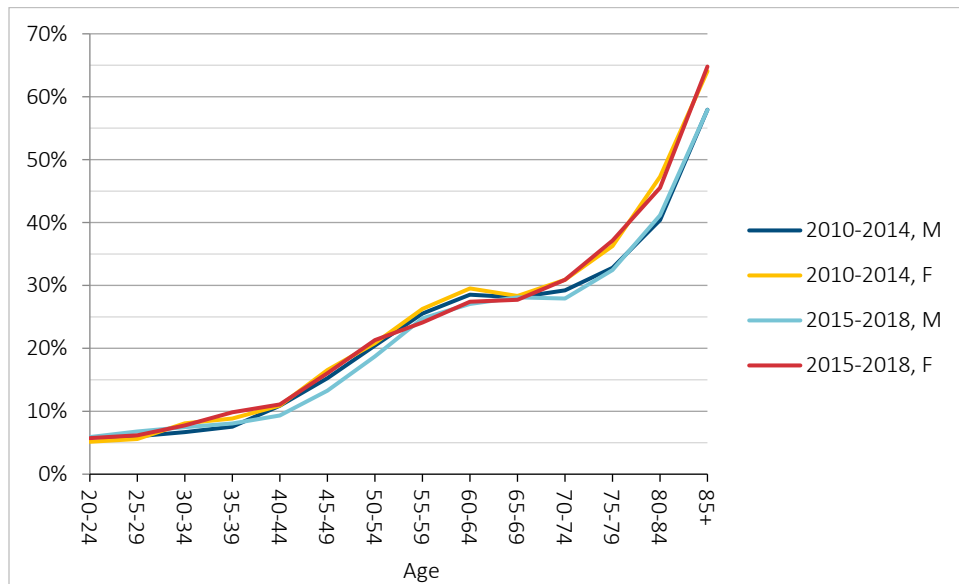
Group	Life Expectancy at 45	Standard Error	95% Confidence Interval
Total population, males (M)	34.07	0.46	33.18–34.97
Total population, females (F)	40.99	0.55	39.92–42.06
Group 1 of mental conditions, M	19.31	1.30	16.76–21.85
Group 1 of mental conditions, F	24.82	1.24	22.09–27.55
Group 2 of mental conditions, M	25.65	1.83	22.06–29.23
Group 2 of mental conditions, F	32.74	2.05	28.73–36.75
Mental conditions total, M	21.53	1.14	19.30–23.76
Mental conditions total, F	27.18	1.20	24.84–29.53

These results demonstrate that having mental conditions (both groups) is indeed detrimental for survival. These results also show that differences in life expectancy between the two groups of mental conditions are not significant despite existing differences in age-specific prevalence. Memory impairments (group1 of mental conditions) result in lower life expectancy compared to group 2 of mental conditions.

Disability. The definition of being disabled included a positive response to the questions about activity limitations (see Appendix B for definition). This definition includes both physical and mental disability. Long-term care insurance considers disability as both physical and mental impairment (Stallard 2016, 2019). We used here a similar approach, so questions applied for definition of mental conditions were also used as a part of definition for disability.

Figure 10 shows the proportion of persons with disability by age and sex in 2010–2014 and 2015–2018. Note that the proportion of persons with disability grows rapidly after age 70 years. Until age 70, no significant sex differences are seen in the proportion of disabled; after age 70, females appear to have a greater prevalence of disability than males.

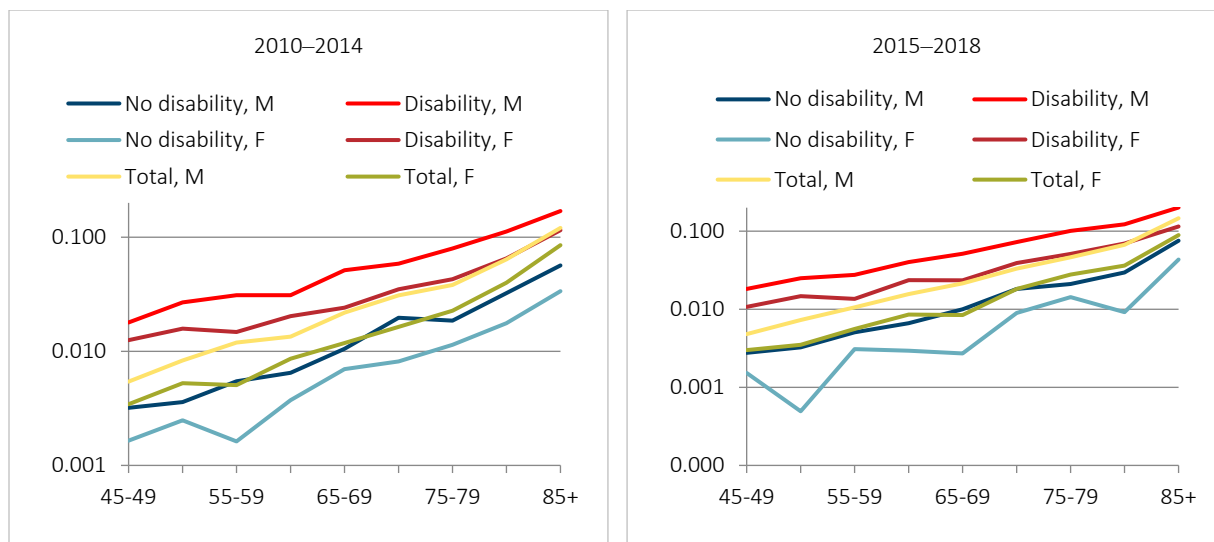
Figure 10
 PROPORTION OF MALES AND FEMALES REPORTING LIMITATION OF ACTIVITY AS A FUNCTION OF AGE



Data source: NHIS Sample Adult file for the U.S. males and females in 2010–2014 and 2015–2018

The mortality of disabled males and females is presented in Figure 11. Note that disability is causing a significant increase in mortality compared to the total population (all respondents), although this increase is not as big as the increase caused by mental conditions.

Figure 11
 AGE-SPECIFIC MORTALITY IN LOG SCALE OF MALES AND FEMALES ACCORDING TO THEIR DISABILITY STATUS IN 2010–2014 AND 2015–2018, BASED ON THE NHIS SAMPLE ADULT FILE FOR U.S. MALES AND FEMALES



Note the very low mortality of groups without disability. Also note that mortality in 2010–2014 and 2015–2018 shows similar results.

Table 4 presents data on life expectancy of disabled males and females in 2015–2018. It shows that differences in life expectancy at age 45 for disabled persons are significantly lower compared to the total population (all respondents).

Table 4

LIFE EXPECTANCY AT AGE 45 YEARS IN 2015–2018 BY DISABILITY STATUS

Health Group	Life Expectancy at 45	Standard Error	95% Confidence Interval
All respondents, males	33.34	0.44	32.47–34.21
All respondents, females	41.04	0.58	39.90–42.18
Disability, males	22.86	0.86	21.18–24.54
Disability, females	30.66	0.91	28.88–32.44

Chronic diseases as a measure of health status. Our definition of having chronic diseases included a positive response to at least one of the following nine questions:

- (1) "Ever been told you have hypertension"
- (2) "Ever been told you had coronary heart disease"
- (3) "Ever been told you had angina pectoris"
- (4) "Ever been told you had a heart attack"
- (5) "Ever been told you had a heart condition/disease"
- (6) "Ever been told you had a stroke"
- (7) "Ever been told you had emphysema"
- (8) "Ever told by a doctor you had cancer"
- (9) "Ever been told that you have diabetes"

The NHIS has questions about 12 chronic diseases. It was decided to remove three diseases (ulcer, arthritis and asthma) having weaker associations with mortality.

Figure 12 shows the proportion of persons having chronic diseases by age. Note that the proportions of persons with chronic diseases grow rapidly in the age window 40–70 years, and then they become relatively stable. By age 70, about 80% of the population has at least one chronic disease. This age dynamics is quite different from the age-specific proportions of disabled people, where the fastest growth of prevalence is observed after age 70.

Figure 12

PROPORTION OF MALES AND FEMALES REPORTING CHRONIC DISEASES, BASED ON THE NHIS SAMPLE ADULT FILE FOR U.S. MALES AND FEMALES IN 2010–2014 AND 2015–2018

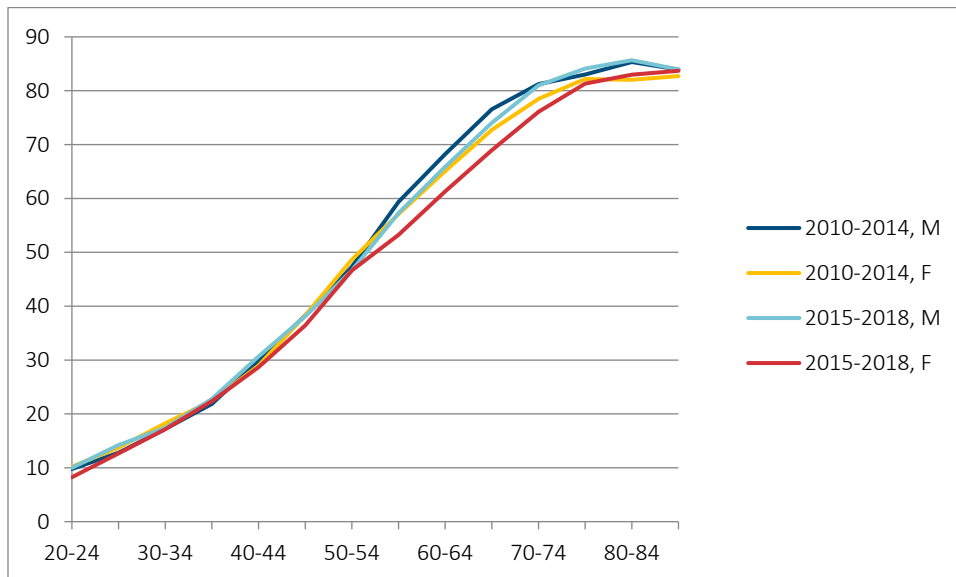
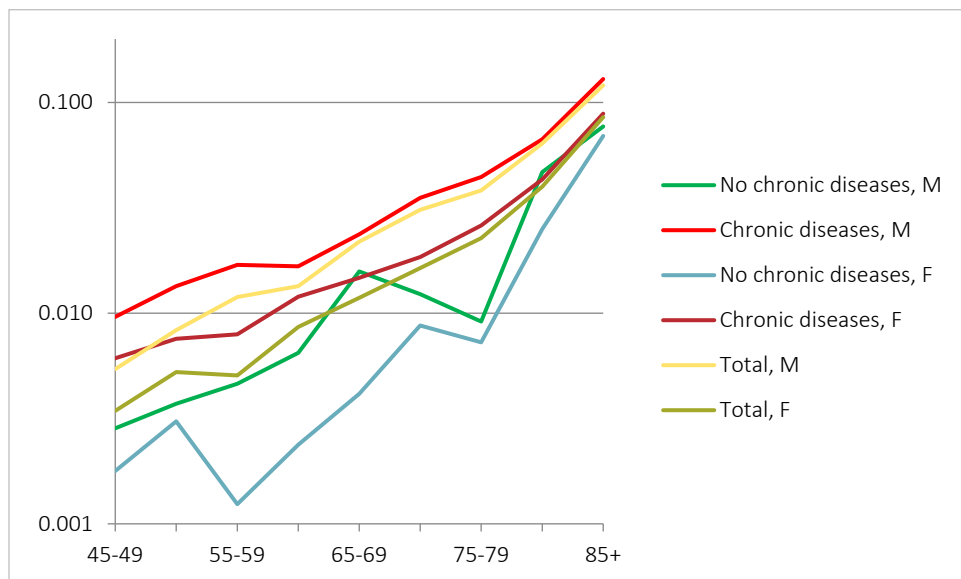


Figure 13 demonstrates age-specific mortality for males and females having and not having chronic diseases in 2010–2014. Figure 14 shows mortality using the same information in 2015–2018.

Figure 13

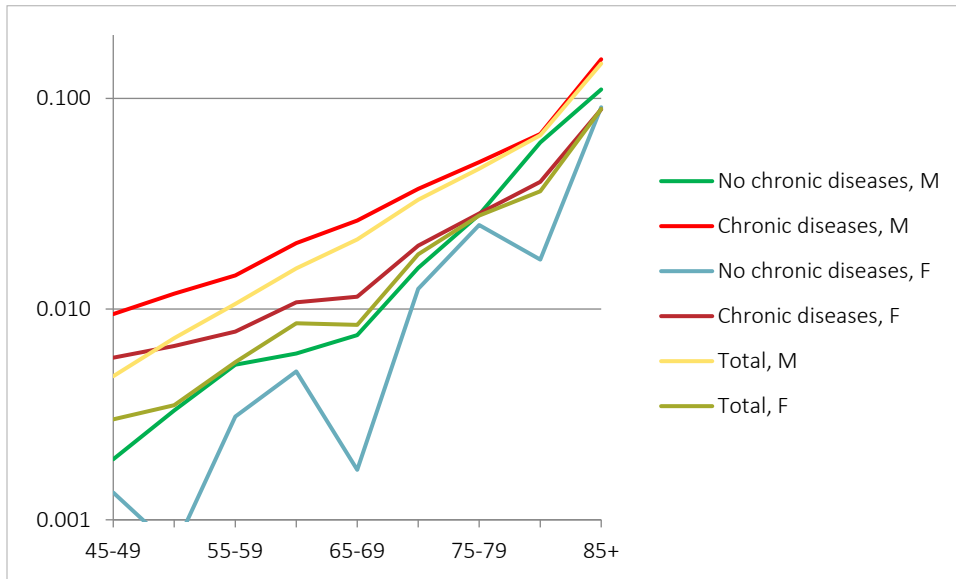
AGE-SPECIFIC MORTALITY IN LOG SCALE OF U.S. MALES AND FEMALES ACCORDING TO HEALTH STATUS BASED ON CHRONIC DISEASES IN 2010–2014, BASED ON THE NHIS SAMPLE ADULT FILE FOR U.S. MALES AND FEMALES.



Note that the mortality of persons with chronic diseases at older ages (after age 65) is similar to mortality of the total population.

Figure 14

AGE-SPECIFIC MORTALITY IN LOG SCALE OF U.S. MALES AND FEMALES ACCORDING TO REPORTING OR NOT REPORTING CHRONIC DISEASES IN 2015–2018, BASED ON THE NHIS SAMPLE ADULT FILE FOR U.S. MALES AND FEMALES



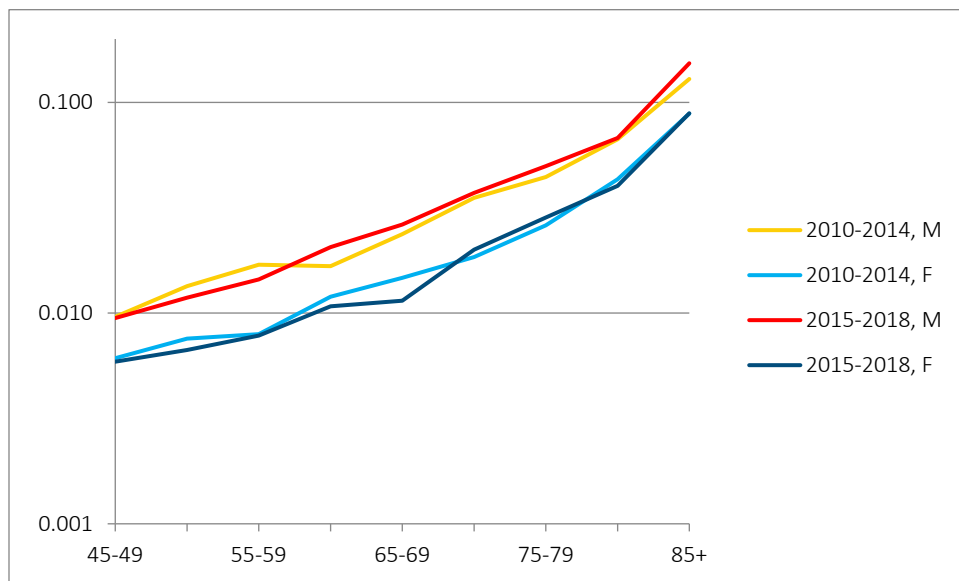
Figures 13 and 14 show mortality trajectories for males and females having and not having chronic diseases. Note that after age 70 mortality of persons having chronic diseases is close to mortality of the total population, perhaps because persons without chronic diseases are relatively rare at that age.

4.3 LIFE EXPECTANCY IN 2010–2014 AND 2015–2018 BY HEALTH STATUS

It is possible to compare mortality of unhealthy persons at different points of time: in 2010–2014 and 2015–2018. As an example of such a comparison we present the mortality of males and females having chronic diseases (Figure 15). Note that after age 45 no noticeable difference is seen in mortality trajectories between these two periods.

Figure 15

AGE-SPECIFIC MORTALITY IN LOG SCALE OF MALES AND FEMALES HAVING CHRONIC DISEASES IN 2010–2014 AND 2015–2018 BASED ON THE NHIS SAMPLE ADULT FILE FOR U.S. MALES AND FEMALES



To present results in a more compact manner, it is useful to construct abridged life tables for each group of healthy and unhealthy individuals in 2010–2014 and 2015–2018 and to compare values of life expectancy at these two points of time. Abridged life tables by health status are available as a supplement to this report (see Appendix D). Details on life table construction are available in Appendix C.1

Tables 5 and 6 show life expectancy at age 45 for males and females in 2010–2014 and 2015–2018 using two indicators of general health: Frailty Index and self-rated health.

Table 5

LIFE EXPECTANCY AT AGE 45 YEARS (LE45) FOR U.S. MALES IN 2010–2014 AND 2015–2018 USING TWO INDICATORS OF HEALTH: FRAILITY INDEX (FI) AND SELF-RATED HEALTH (SRH)

Group	LE45	2010–2014 Standard Error	95% Confidence Interval	LE45	2015–2018 Standard Error	95% Confidence Interval
Total population	34.07	0.46	33.18–34.97	33.34	0.44	32.47–34.21
FI<0.2, healthy	41.99	1.11	39.82–44.16	41.49	1.09	39.34–43.63
FI ≥ 0.2, unhealthy	20.89	0.87	19.19–22.60	19.59	1.05	17.53–21.65
SRH, healthy	40.78	0.80	39.21–42.35	39.09	0.65	37.82–40.36
SRH, unhealthy	22.53	0.75	21.07–23.99	22.18	0.85	20.52–23.85

Table 6

LIFE EXPECTANCY AT AGE 45 YEARS (LE45) FOR U.S. FEMALES IN 2010–2014 AND 2015–2018 USING TWO INDICATORS OF HEALTH: FRAILITY INDEX (FI) AND SELF-RATED HEALTH (SRH)

Group	LE45	2010–2014 Standard Error	95% Confidence Interval	LE45	2015–2018 Standard Error	95% Confidence Interval
Total population	40.99	0.55	39.92–42.06	41.04	0.58	39.90–42.18
FI < 0.2, healthy	54.04	2.19	49.75–58.33	51.04	1.80	47.51–54.57
FI ≥ 0.2, unhealthy	29.14	0.91	27.37–30.92	29.51	1.05	27.45–31.57
SRH, healthy	47.92	1.01	45.94–49.91	46.14	0.84	44.48–47.79
SRH, unhealthy	29.13	0.80	27.57–30.70	29.04	0.96	27.16–30.93

Note that unhealthy groups have a significantly lower life expectancy compared to healthy groups and the total population (all respondents). At the same time, life expectancy is remarkably stable over time: no statistically significant changes in life expectancy are seen between 2010–2014 and 2015–2018 within each health group taking into account overlapping 95% confidence intervals of life expectancy for two periods. These results are in line with the stability of U.S. life expectancy during these years: U.S. life expectancy in 2010–2014 and 2015–2019 is almost the same and equal to 36.08 and 36.29, respectively, for both sexes (data on U.S. life expectancy are taken from the [Human Mortality Database](#)).

Tables 7 and 8 present life expectancy at age 45 years for males and females using three specific groups of health impairment: memory impairments, disability and chronic diseases.

Table 7

LIFE EXPECTANCY AT AGE 45 YEARS (LE45) OF MALES IN 2010–2014 AND 2015–2018 FOR THREE GROUPS OF HEALTH IMPAIRMENT: MEMORY IMPAIRMENTS, DISABILITY AND CHRONIC DISEASES

Group	LE45	2010–2014 Standard Error	95% Confidence Interval	LE45	2015–2018 Standard Error	95% Confidence Interval
No memory impairments	36.37	0.58	35.24–37.50	35.34	0.54	34.29–36.39
Memory impairments	19.31	1.30	16.76–21.85	20.85	1.57	17.78–23.91
No disability	45.55	1.85	41.92–49.18	43.20	1.33	36.15–41.39
Disability	23.55	0.73	22.11–24.99	22.86	0.86	21.18–24.54
No chronic diseases	42.90	1.99	39.00–46.80	39.76	1.26	37.28–42.24
Chronic diseases	31.25	0.56	30.15–32.36	30.64	0.61	29.45–31.83

Note that values of life expectancy in 2010–2014 and 2015–2018 are very close to each other for all studied groups even if differences in life expectancy between groups are very large. This conclusion follows from overlapping 95% confidence intervals for life expectancy in 2010–2014 and 2015–2018 suggesting no statistically significant difference in life expectancy between the two periods.

Table 8
LIFE EXPECTANCY AT AGE 45 YEARS (LE45) OF FEMALES IN 2010–2014 AND 2015–2018 FOR THREE GROUPS OF HEALTH IMPAIRMENT: MEMORY IMPAIRMENTS, DISABILITY AND CHRONIC DISEASES

Group	LE45	2010–2014 Standard Error	95% Confidence Interval	LE45	2015–2018 Standard Error	95% Confidence Interval
No memory impairments	44.59	0.83	42.97–46.22	44.11	0.82	42.51–45.70
Memory impairments	24.82	1.39	22.09–27.55	25.49	1.77	22.02–28.97
No disability	59.81	3.66	52.64–66.98	56.19	2.95	50.42–61.96
Disability	30.83	0.80	29.27–32.39	30.66	0.91	28.88–32.44
No chronic diseases	48.43	1.86	44.79–52.08	44.76	1.40	42.00–47.51
Chronic diseases	38.37	0.63	37.13–39.61	38.85	0.73	37.41–40.29

These results confirm that our method of life table construction and life expectancy estimation produces stable results. Although some changes in life expectancy between two periods may be one year or more, in all cases 95% confidence limits of life expectancy for two periods overlap. Taking into account that we deal here with very small populations, all conclusions should rely on 95% confidence intervals for life expectancy.

These results demonstrate that memory impairments cause the largest decrease in life expectancy compared to total population for both males and females. Disability is the second largest cause of life expectancy decline. Persons with chronic diseases show the highest life expectancy among the three health impairment groups.

Section 5: Multimorbidity and Mortality

It is expected that having two or more diseases may have a significant impact on mortality. For this reason, we analyzed the mortality of persons having one, two and three or more diseases (out of a list of nine diseases used to define chronic diseases definition).

Figures 16 and 17 demonstrate the mortality of males and females, respectively, having one and three or more diseases compared to the total population (all respondents). Note that having three or more diseases results in a significant increase of mortality. Persons having one disease have mortality that is close to the total population. On the other hand, the mortality of persons having three or more diseases is significantly higher compared to the total population.

These results demonstrate that multimorbidity (having three or more diseases) greatly increases risk of death.

Figure 16
 AGE-SPECIFIC MORTALITY (LOG SCALE) OF MALES AND FEMALES HAVING DIFFERENT NUMBER OF DISEASES IN 2010–2014, NUMBER OF DISEASES BASED ON THE LIST OF NINE DISEASES AND BASED ON THE NHIS SAMPLE ADULT FILE

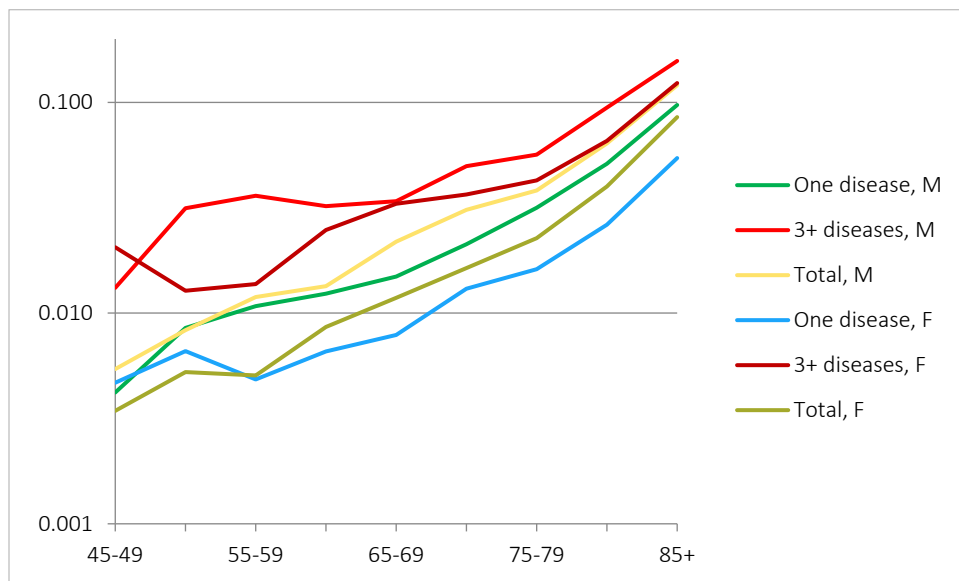
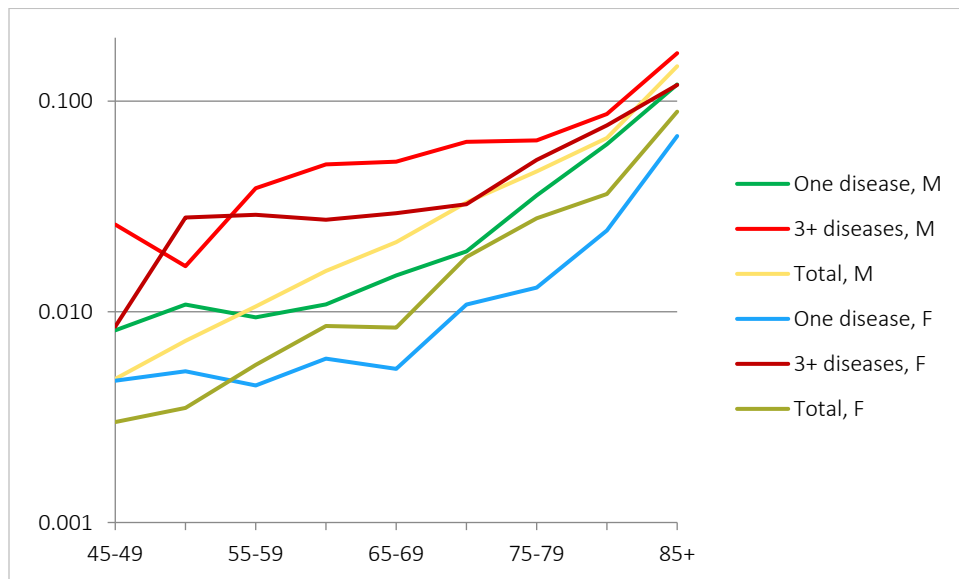


Figure 17
 AGE-SPECIFIC MORTALITY (LOG SCALE) OF U.S. MALES AND FEMALES HAVING DIFFERENT NUMBER OF DISEASES IN 2015–2018, NUMBER OF DISEASES BASED ON THE LIST OF NINE DISEASES AND BASED ON THE NHIS SAMPLE ADULT FILE



This conclusion can be confirmed by comparing life expectancy estimates at age 45 years for groups with a different number of diseases (Table 9). The life expectancy at age 45 years for persons having one disease is not significantly different from the life expectancy of the total population. At the same time, the life expectancy for persons having three or more diseases is significantly lower compared to the life expectancy of the total population.

Table 9
LIFE EXPECTANCY AT AGE 45 YEARS IN 2015–2018 BY NUMBER OF CHRONIC DISEASES

Group	Life Expectancy at 45	Standard Error	95% Confidence Interval
All respondents, males	33.34	0.44	32.47–34.21
All respondents, females	41.04	0.58	39.90–42.18
One disease, males	35.04	0.97	33.14–36.94
One disease, females	45.61	1.48	42.72–48.51
Two diseases, males	30.78	1.34	28.16–33.40
Two diseases, females	37.33	1.50	34.39–40.28
Three or more diseases, males	22.47	1.81	18.93–26.01
Three or more diseases, females	27.60	1.91	23.86–31.34

Note that having three or more chronic diseases significantly decreases life expectancy. At the same time, having only one disease results in higher life expectancy compared to the total population. Having one disease is associated with higher mortality at younger ages when most people are healthy. On the other hand, most respondents at older ages have two or more diseases, so that respondents with only one disease have lower mortality compared to the total population (Figures 16 and 17).

Section 6: Prevalence of Unhealthy Status by Race and Region

6.1 PREVALENCE OF UNHEALTHY STATUS BY RACE

We next decided to look at the prevalence estimation of healthy and unhealthy groups by race. Studies show that Black people have higher prevalence of poor or fair self-rated health compared to white people (Andrasfay and Goldman 2020).

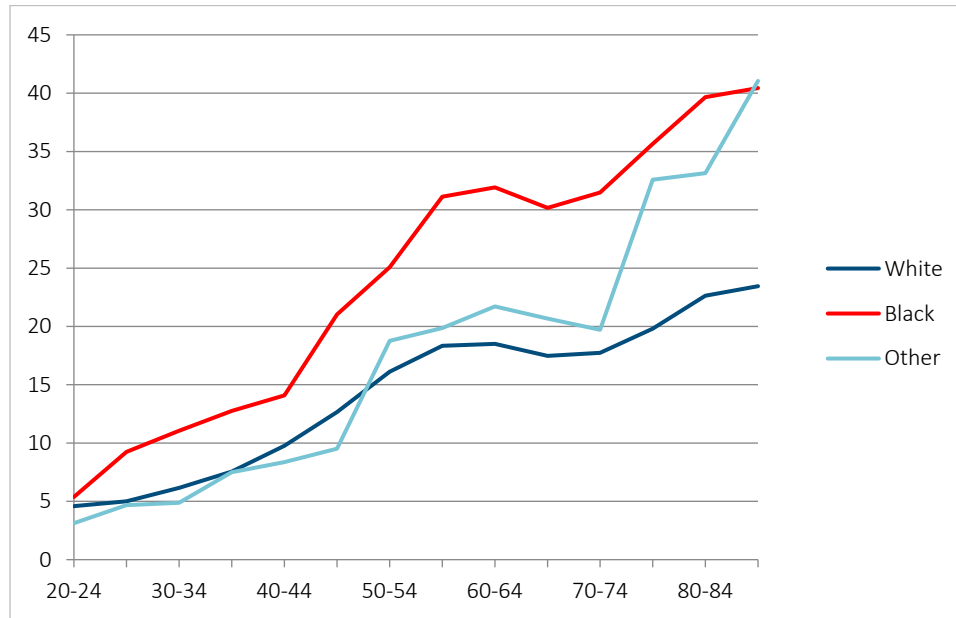
Data on race in the NHIS are based on self-identification. In this project three racial groups were considered: (1) white, for people having origins in any of the original peoples of Europe, the Middle East or North Africa; (2) Black or African American, for persons having origins in any of the Black racial groups of Africa; (3) Other, for people having other races (Native American and Alaska Native, Asian American, Native Hawaiian and other Pacific Islander or reporting two or more races). In the 2015–2018 survey, white people made up 80.2%, Black people 12.5% and the Other racial group 7.3% of the NHIS total sample aged 20 years and over.

In this report we consider age-specific prevalence by racial group using both general (self-rated health, Frailty Index) and specific (mental conditions, disability, chronic diseases) measures of health.

Self-rated health. Figure 18 shows age-specific prevalence of poor or fair self-rated health by racial group.

Figure 18

PROPORTION OF PERSONS REPORTING POOR OR FAIR HEALTH AS A FUNCTION OF AGE BY RACE, BASED ON THE NHIS IN 2015–2018

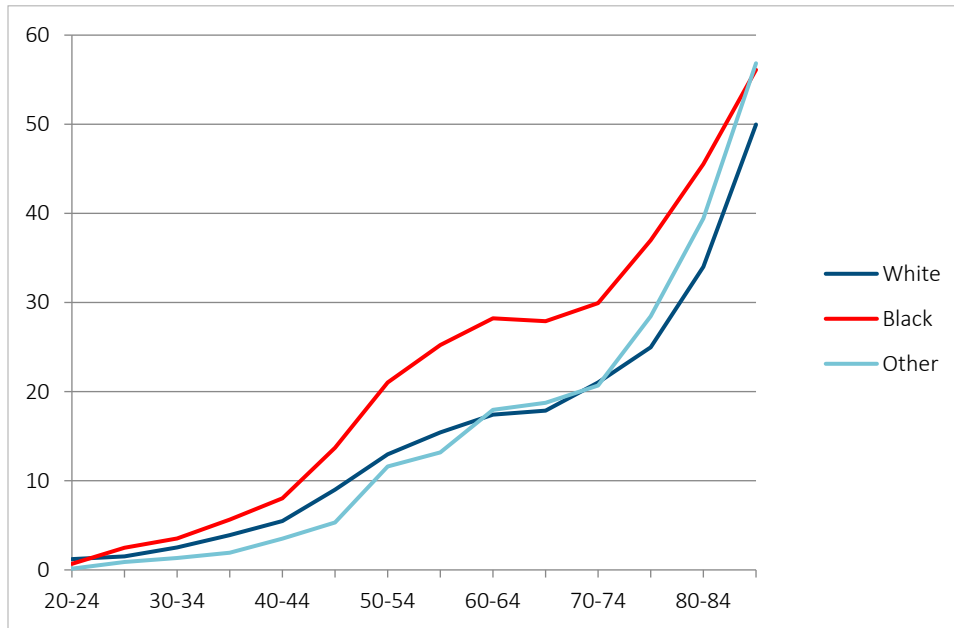


Note a substantially higher proportion of respondents reporting poor or fair health among Black people compared to white and Other people. The difference in proportion of respondents with poor or fair health is particularly high for Black people compared to white people after age 55. Prevalence of poor health in the Other racial group is close to the white group at younger ages and to the Black group at older ages.

Frailty Index. Figure 19 shows proportion of unhealthy Black, white and Other racial groups having FI = 0.2 or higher. Differences in the proportion of unhealthy respondents are particularly high around age 60, although these differences are not as high as in the case of self-rated health.

Figure 19

PROPORTION OF PERSONS WITH FRAILTY INDEX EQUAL TO 0.2 OR HIGHER AS A FUNCTION OF AGE BY RACE, BASED ON THE NHIS IN 2015–2018

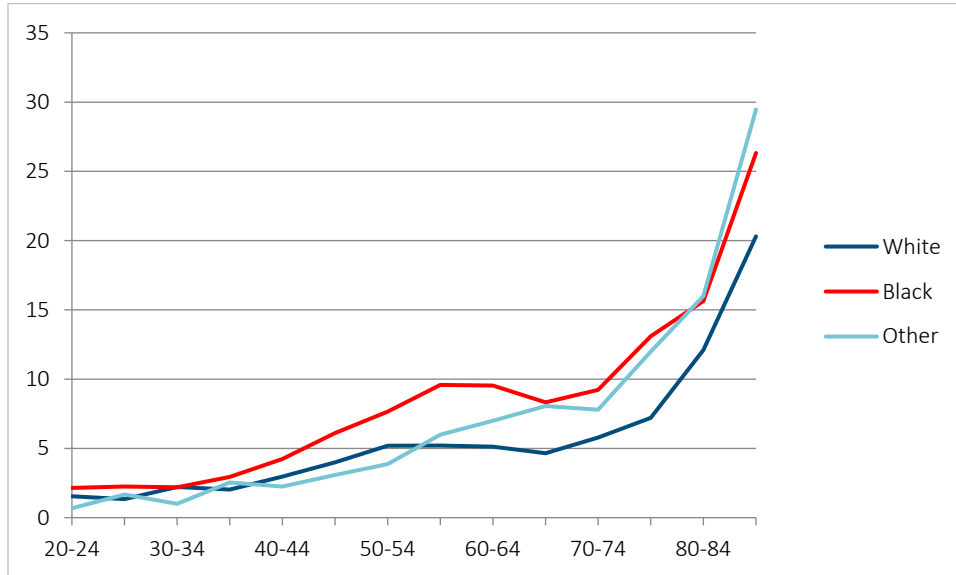


The next step of the analyses was to study prevalence for three groups with different types of health impairments, having (1) mental conditions, (2) disability and (3) chronic diseases.

Mental conditions. Definition of mental conditions is provided in section 4.2 of the report. We found that more reliable estimates of mental conditions can be obtained for memory impairments (difficulty remembering and senility causing difficulty with activity, see section 4.2

Figure 20 shows prevalence of memory impairments in 2015–2018 by racial group.

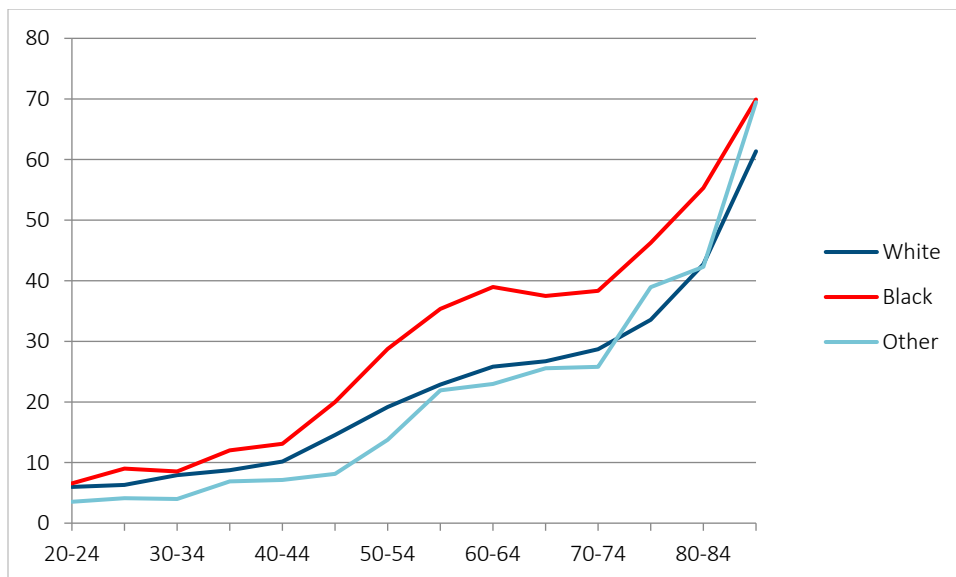
Figure 20
 PROPORTION OF PERSONS REPORTING MEMORY IMPAIRMENTS AS A FUNCTION OF AGE
 BY RACE, BASED ON THE NHIS IN 2015–2018



Substantial differences were manifest between Black and white racial groups in the prevalence of memory impairments after age 50 with Black persons having higher prevalence. As in the case of self-rated health, prevalence of memory impairments in the Other racial group is close to the white group at younger ages and to the Black group at older ages.

Disability. Definition of being disabled included positive response to any question about having activity limitation including problems with ADLs or IADLs and difficulty remembering. Figure 21 presents an age-specific prevalence of persons with disability by racial group in 2015–2018.

Figure 21
 PROPORTION OF PERSONS WITH DISABILITY BY RACE AS A FUNCTION OF AGE, BASED ON
 THE NHIS IN 2015–2018



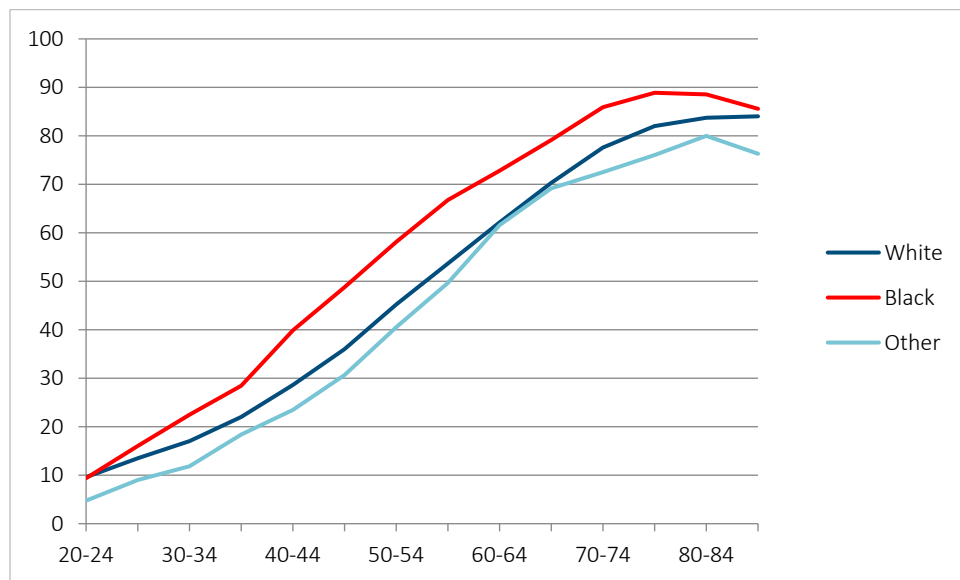
The proportion of persons with disability grows rapidly after age 70. Until age 45 we find only small differences in the proportion of disabled by racial group. At later ages and particularly between ages 55 and 65, differences in the proportion of disabled between the Black and white groups become very large. The proportion of disabled among the Other racial group is close to the proportion of the white group.

Chronic diseases. The definition of having chronic diseases included a positive response to at least one of the nine questions about having hypertension, coronary heart disease, angina pectoris, heart attack, heart condition/disease, stroke, emphysema, cancer and diabetes. The list of questions asked by the NHIS is presented in Appendix B.4.

Figure 22 presents an age-specific prevalence of persons with chronic diseases by racial group in 2015–2018.

Figure 22

PROPORTION OF PERSONS WITH CHRONIC DISEASES AS A FUNCTION OF AGE BY RACE, BASED ON THE NHIS IN 2015–2018



The Black group still has a higher prevalence of chronic diseases compared to the white group. The Other racial group has prevalence of chronic diseases similar to the white group. The difference in the prevalence is approximately the same between ages 40 and 75 years and is substantially lower than the difference between the prevalence of persons reporting poor or fair self-rated health.

Overall, the age-specific prevalence of unhealthy subgroups is higher among the Black group compared to the white group and Other group for all studied definitions of health. Differences in prevalence between the Black and white groups are higher for subjective measure of health (self-rated health) than for more objective measures such as chronic diseases or disability.

6.2 PREVALENCE OF UNHEALTHY STATUS BY REGION

Regional differences in the prevalence of unhealthy persons were studied using information for four U.S. Census Bureau regions:

Northeast Region: Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island and Vermont

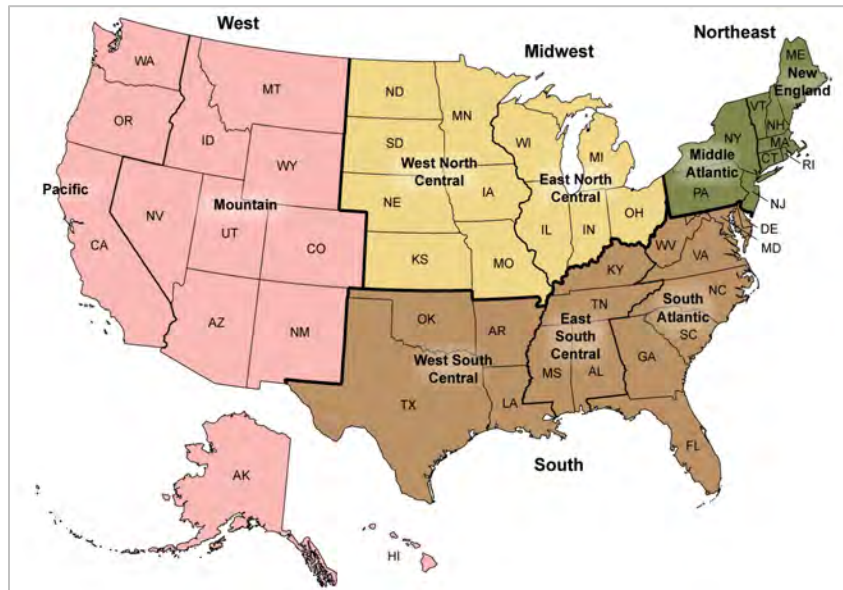
Midwest Region:, Illinois, Indiana, Iowa, Kansas, Michigan, Missouri, Minnesota, Nebraska, North Dakota, Ohio, South Dakota and Wisconsin,

South Region: Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia and West Virginia,

West Region: Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington and Wyoming

Figure 23

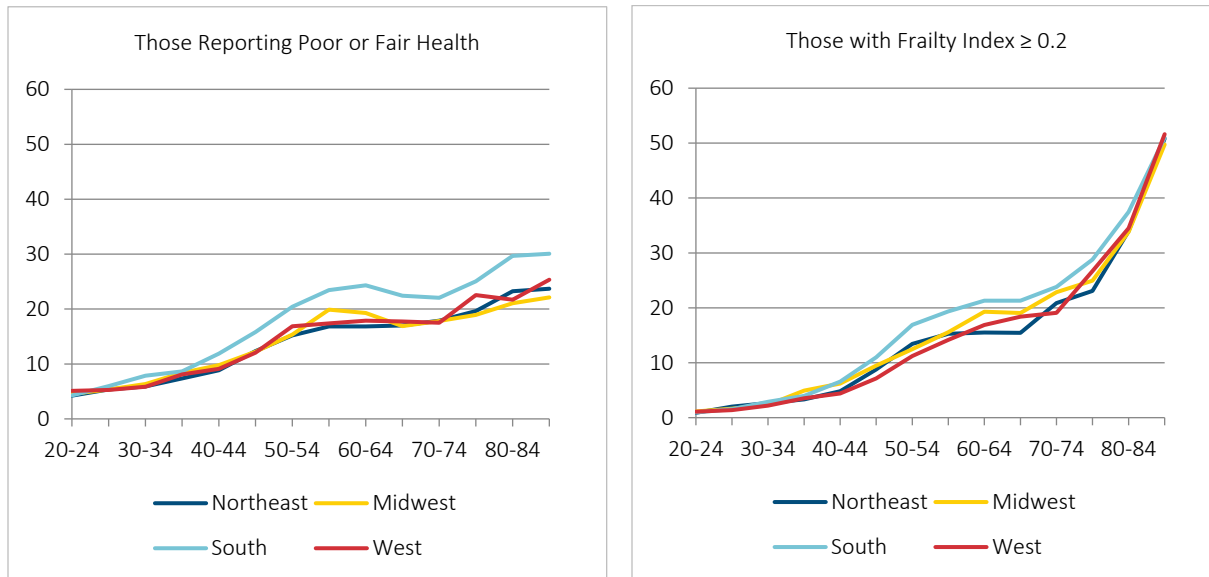
U.S. CENSUS BUREAU FOUR GEOGRAPHIC REGIONS



Source: <https://www.cdc.gov/nchs/hus/sources-definitions/geographic-region.htm>.

General definitions of health. Figure 24 presents the proportion of respondents reporting poor or fair health and FI \geq 0.2 for the four Census Bureau regions (males and females together).

Figure 24
 PERCENT OF PERSONS REPORTING POOR OR FAIR HEALTH AND FRAILITY AS A FUNCTION OF AGE BY REGION, BASED ON THE NHIS IN 2015–2018



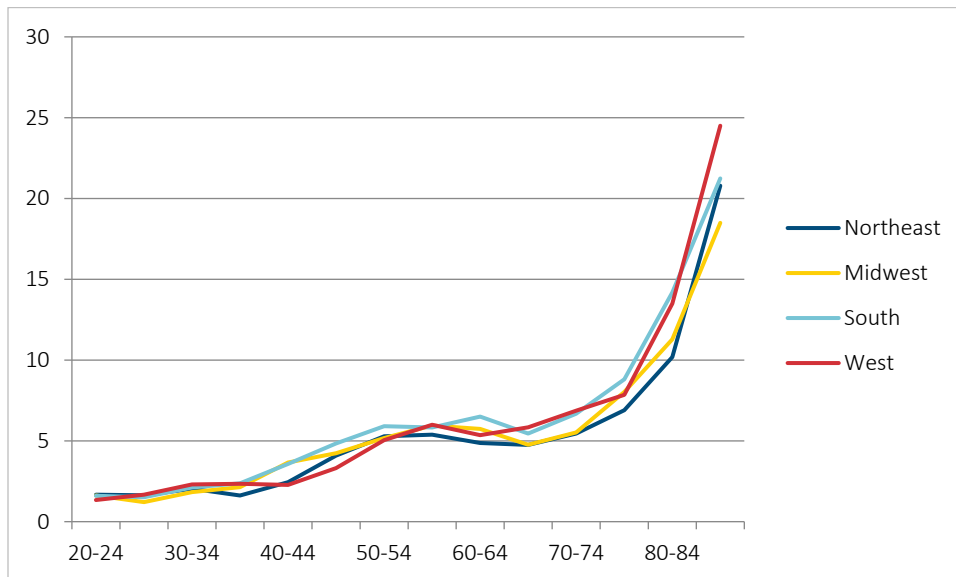
It is clear from this figure that the South region has a markedly higher proportion of unhealthy persons, although this effect is smaller in the case of the Frailty Index. The South is known for its higher mortality and lower life expectancy among U.S. regions (Fenelon 2013).

The next step of the analyses was a study of age-specific prevalence for three groups with different types of health impairments: (1) mental conditions, (2) disability and (3) chronic diseases.

Mental conditions. As in Section 3, here we analyzed age-specific prevalence of respondents reporting memory impairments.

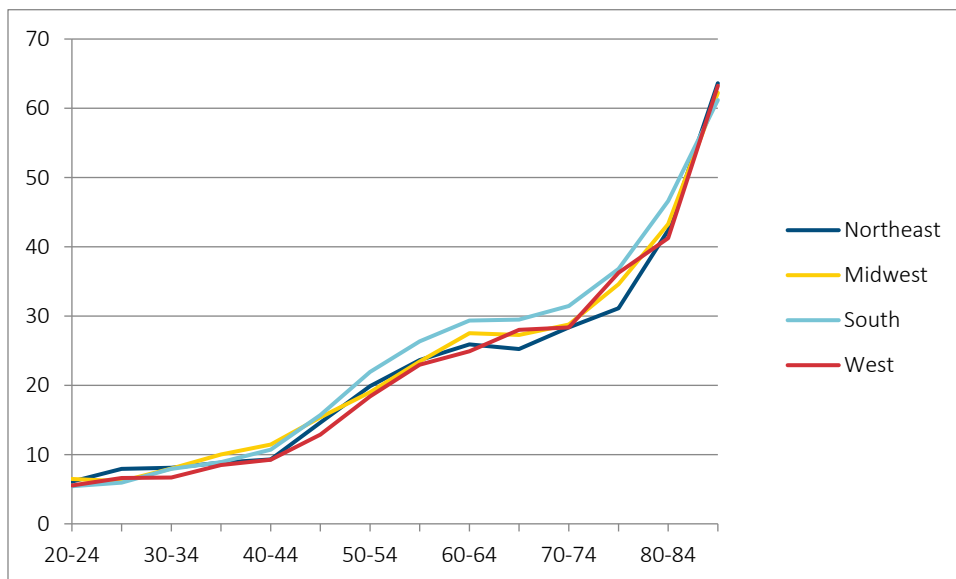
Figure 25 shows age-specific prevalence of memory impairments for the four Census Bureau regions. It looks like in this case differences between regions are not large. The West region shows a similar level of prevalence of memory impairments as the South region.

Figure 25
 PROPORTION OF PERSONS REPORTING DIFFICULTY REMEMBERING AS A FUNCTION OF AGE BY REGION, BASED ON THE NHIS IN 2015–2018



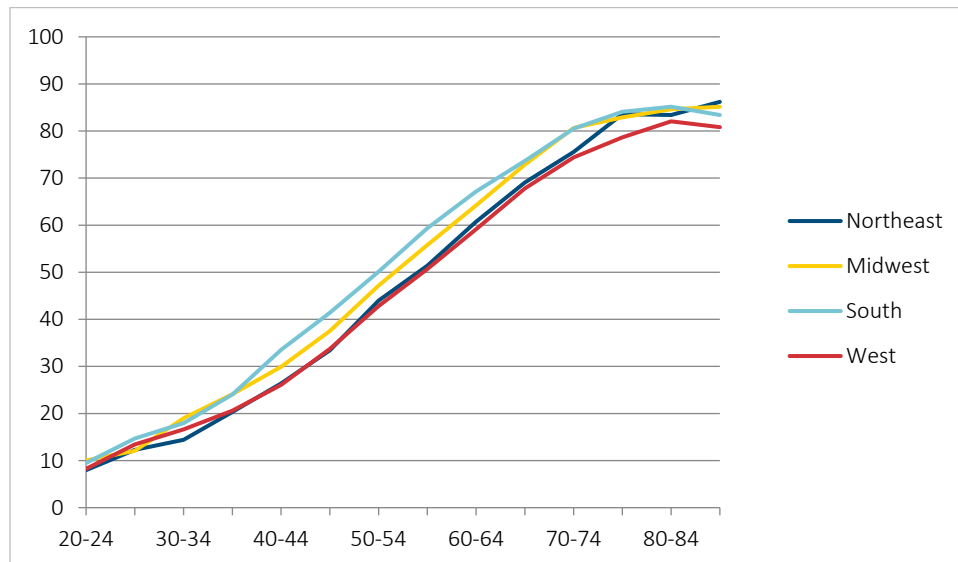
Disability. Figure 26 shows the age-specific proportion of persons with disability by region. Here again differences in disability prevalence between regions are not particularly large, although the South region has a somewhat higher prevalence.

Figure 26
 PROPORTION OF PERSONS WITH DISABILITY AS A FUNCTION OF AGE BY REGION, BASED ON THE NHIS IN 2015–2018



Chronic diseases. Figure 27 shows the age-specific prevalence of respondents with chronic diseases by region. Note that the differences in prevalence are not particularly large. The South and Midwest regions have a higher prevalence of chronic diseases than the Northeast and West regions.

Figure 27
 PROPORTION OF PERSONS WITH CHRONIC DISEASES AS A FUNCTION OF AGE BY REGION,
 BASED ON THE NHIS IN 2015–2018

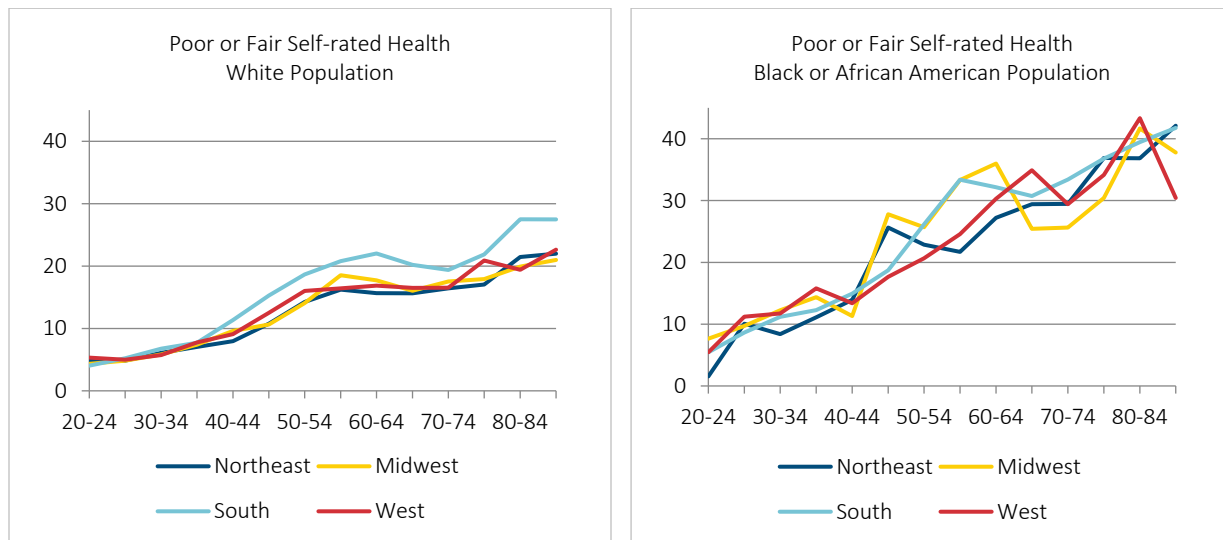


Overall, regional analysis of the proportion of unhealthy persons demonstrates that the South region generally has a higher prevalence of unhealthy persons compared to other regions for all studied definitions of health.

6.3. PREVALENCE OF UNHEALTHY STATUS BY REGION AND RACE

For almost all studied definitions of health, the South region demonstrated a higher percentage of unhealthy persons compared to other regions. We explored whether a higher prevalence of unhealthy individuals in the South may be associated with a higher percent of the Black population having a higher prevalence of poor health (as demonstrated in section 6.1). Indeed, the South region had the highest percentage of the Black population compared to other regions: 19.2% of the U.S. population compared to 11.8% in the Northeast, 10.4% in the Midwest and 4.8% in the West (U.S. Census Bureau 2014). However, it is possible that the higher prevalence of poor health is also caused by environmental or lifestyle factors. In this case, the white population in the South would also experience a higher prevalence of poor health. Figure 28 shows the age-specific prevalence of poor or fair self-rated health for white and Black populations by region. Note that for the white group the prevalence is similar in the Northeast, Midwest and West regions, whereas in the South region this prevalence is notably higher. This result suggests that environmental and lifestyle factors are not critically different in the three regions for the white population. However, the South region has certain factors that increase poor health among the white population. For the Black group, the prevalence of poor health is similar in all four regions, although this demonstrates very high variation.

Figure 28
 PERCENT OF PERSONS WITH POOR OR FAIR HEALTH BY REGION AND RACE, BASED ON THE NHIS IN 2015–2018



Thus, the higher prevalence of poor health in the South can be explained by both a higher percentage of the Black population in the South with a generally higher proportion of poor health and a higher percentage of unhealthy persons among the white population living in the South. Similar results were obtained for other measures of health (data not shown). Existing studies show an increasing concentration of health and mortality disadvantage in the South since the mid-twentieth century. States with higher mortality and slow improvement during this period were located almost exclusively in the South, whereas states in the Northeast, Upper Midwest and West performed relatively well. These adverse trends were partially related to smoking (Fenelon 2013).

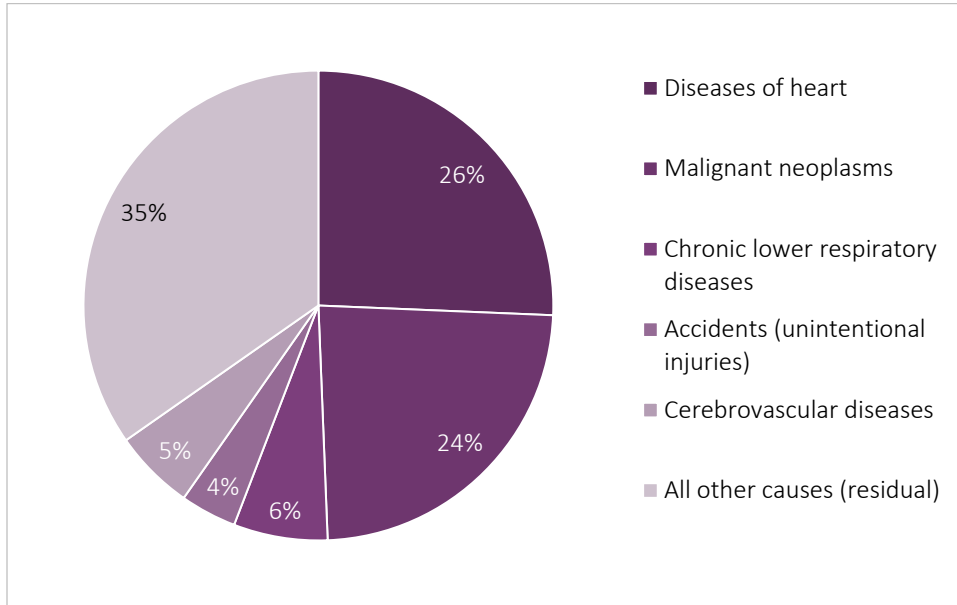
Section 7: Health Status and Causes of Death

7.1 MORTALITY BY CAUSES OF DEATH

The National Center for Health Statistics (NCHS) has linked data collected from several NCHS population surveys (including the NHIS) with death certificate records from the National Death Index. The Public-Use Linked Mortality files (LMFs) include a limited set of variables for adult participants only and were subjected to data perturbation techniques to reduce participant disclosure risk. The NHIS has information about five specific underlying causes of death (listed in Table 10) with diseases of heart and cancer making up about half of all deaths.

Distribution by causes of death for NHIS respondents aged 45 and over is presented in Figure 29. Diseases of heart and malignant neoplasms are the top two major causes of death.

Figure 29
 DISTRIBUTION BY CAUSES OF DEATH FOR NHIS RESPONDENTS AGED 45 AND OLDER, BASED ON THE NHIS SAMPLE ADULT FILE FOR U.S. MEN AND WOMEN IN 2015–2018



To provide an external validation of the data on causes of death available in NHIS, the distribution of causes of death for persons aged 45 years and over was compared to the respective U.S. vital statistics data in the pre-pandemic year 2019 (Xu, Murphy, Kochanek and Arias 2021). The results of this comparison are presented in Figure 30 and Table 10.

Figure 30
 PERCENT DISTRIBUTION OF CAUSES OF DEATH IN NHIS (2015–2018) AS COMPARED TO THE U.S. VITAL STATISTICS DATA IN 2019, AGE 45 YEARS AND OVER

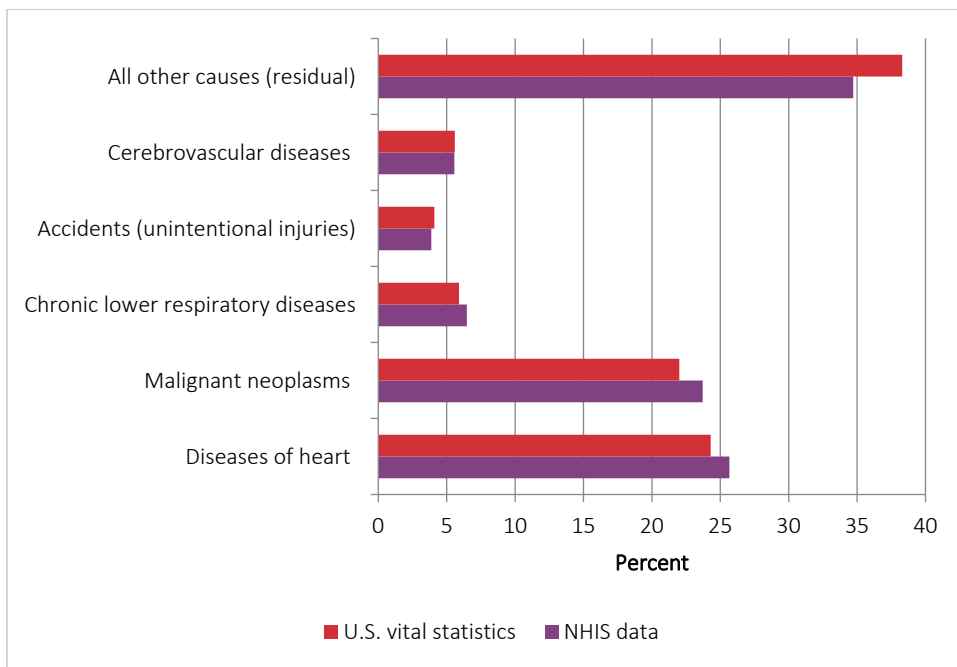


Table 10

DISTRIBUTION OF CAUSES OF DEATH IN NHIS (2015–2018) COMPARED TO U.S. VITAL STATISTICS IN 2019, AGE 45 YEARS AND OVER

Cause of Death (ICD10 Code)	Percent Distribution NHIS	Vital Statistics (2019)
Diseases of heart (I00–I09, I11, I13, I20–I51)	25.66	24.3
Malignant neoplasms (C00–C97)	23.71	22.0
Chronic lower respiratory diseases (J40–J47)	6.47	5.9
Accidents (unintentional injuries) (V01–X59, Y85–Y86)	3.88	4.1
Cerebrovascular diseases (I60–I69)	5.56	5.6
All other causes (residual)	34.72	38.3

Note that the percent distribution of causes of death in the NHIS is similar to the percent distribution reported in the U.S. vital statistics (Xu, et al. 2021).

Mortality from cardiovascular diseases (diseases of heart plus cerebrovascular diseases) and cancer may help us to identify the most serious disease with the highest mortality in both healthy and unhealthy persons. Figure 31 shows mortality from cardiovascular diseases and from cancer among healthy and unhealthy individuals according to their self-rated health.

In each health status group mortality from cardiovascular diseases (CVD) is almost the same as mortality from cancer with exception of very old ages (80 and above). However, this cause-specific mortality is significantly lower in the healthy group compared to the unhealthy group. Both CVD and cancer are almost equally important in each health status subgroup. The only notable observation is higher mortality at younger ages and slower mortality growth from cancer in the unhealthy subgroup.

Figure 31

MORTALITY BY CAUSES OF DEATH IN LOG SCALE FOR HEALTHY AND UNHEALTHY NHIS RESPONDENTS WITH SELF-RATED HEALTH, BASED ON THE NHIS SAMPLE ADULT FILE IN 2015–2018

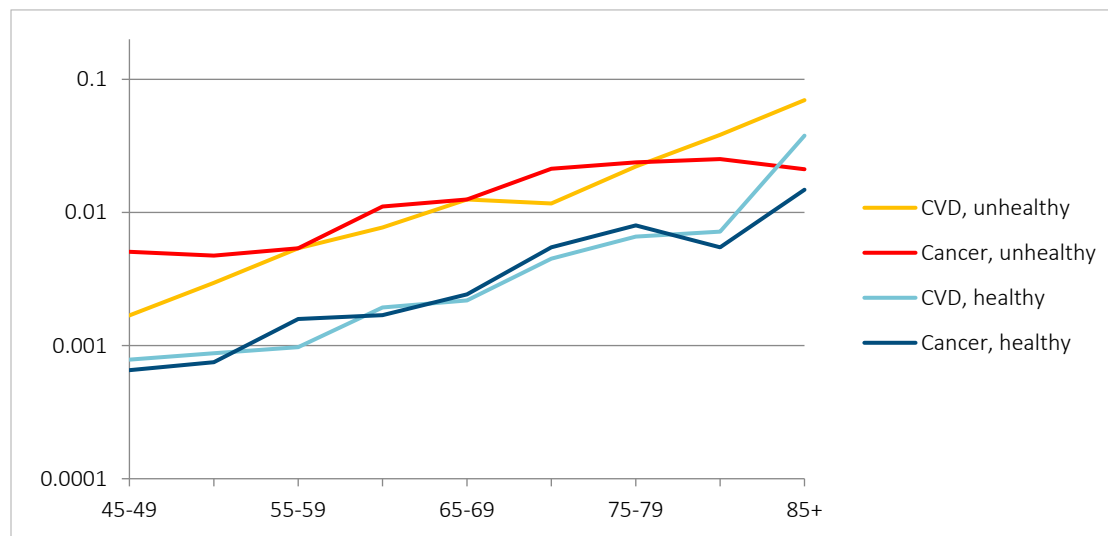
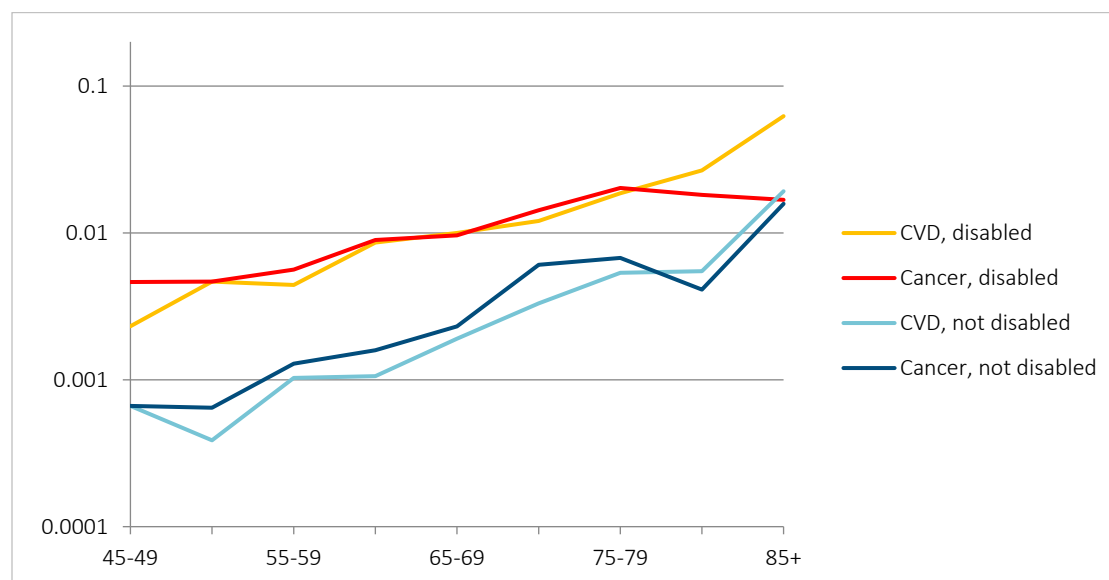


Figure 32 shows mortality trajectories from CVD and cancer for the disabled and not disabled health status subgroups.

Figure 32

MORTALITY BY CAUSES OF DEATH IN LOG SCALE FOR DISABLED AND NOT DISABLED NHIS RESPONDENTS, BASED ON THE NHIS SAMPLE ADULT FILE IN 2015–2018



The results for disability look similar to the results obtained for self-rated health. Again, mortality from CVD and cancer is similar to each other in disabled and not disabled subgroups with the exception of very old ages. As in the previous case, mortality from cancer among the disabled group shows higher mortality at younger ages and slower growth with age compared to mortality from cancer among the not disabled. Mortality from cancer in the not disabled group is notably higher than mortality from CVD up to age 75.

Thus, it is possible to conclude that mortality differences between the healthy and unhealthy subgroups cannot be explained by differences in mortality from one specific cause. In other words, all causes of death contribute almost equally to these differences.

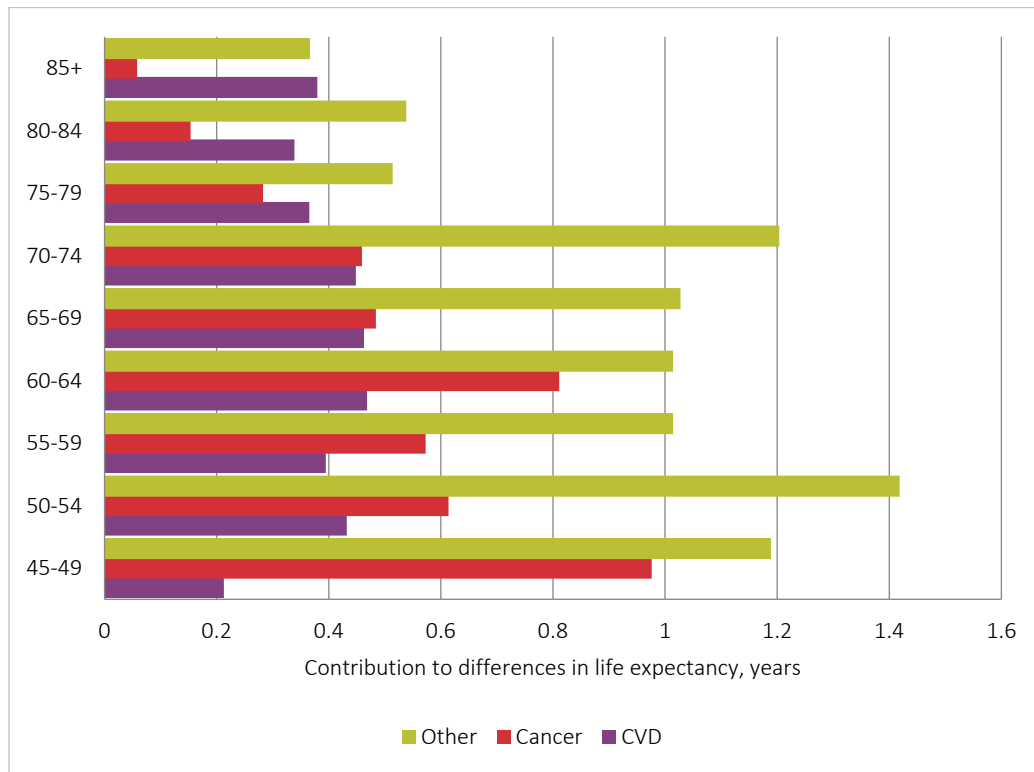
7.2 CONTRIBUTION OF CVD AND CANCER TO DIFFERENCES IN LIFE EXPECTANCY

When studying changes in life expectancy in a given population over time or when comparing life expectancy in two different populations, it is often useful to know which age groups or which causes of death contribute most to the observed differences in life expectancy. The answer to this question is provided by the life expectancy decomposition method, proposed by Pollard, and by Arriaga almost at the same time (Pollard 1982, Arriaga 1984). Pollard gives a description of the method for continuous time age (Pollard 1982, White, et al. 2013). However, the method proposed by Arriaga (Arriaga 1984) for the discrete case is the most popular among demographers because it is more consistent with the real data that demographers encounter. Later demographers developed decomposition methods further and suggested approaches that can be applied to decomposition of other demographic indicators (not only life expectancy) (Horiuchi, Wilmoth and Pletcher 2008). The decomposition method proposed by Arriaga does not differ in principle from Pollard's method, but it is easier to apply to traditional life tables. The decomposition method for life expectancy is described in Appendix C.

Figure 33 shows the contribution of different age groups and causes of death to differences in life expectancy at age 45 between healthy and unhealthy groups according to self-rated health. The total difference in life expectancy between healthy and unhealthy subgroups is 17.5 years. Of these 17.5 years, deaths due to CVD contribute 3.7 years and deaths due to cancer contribute 4.9 years. Thus, in the case of self-rated health, contribution of cancer to the differences in life expectancy is higher than contribution of CVD. Deaths at younger ages usually contribute more to

the difference in life expectancy. In the case of self-rated health, deaths at ages between 45 and 64 contribute 9.7 years, whereas deaths at ages 65 to 85 and above contribute 7.8 years.

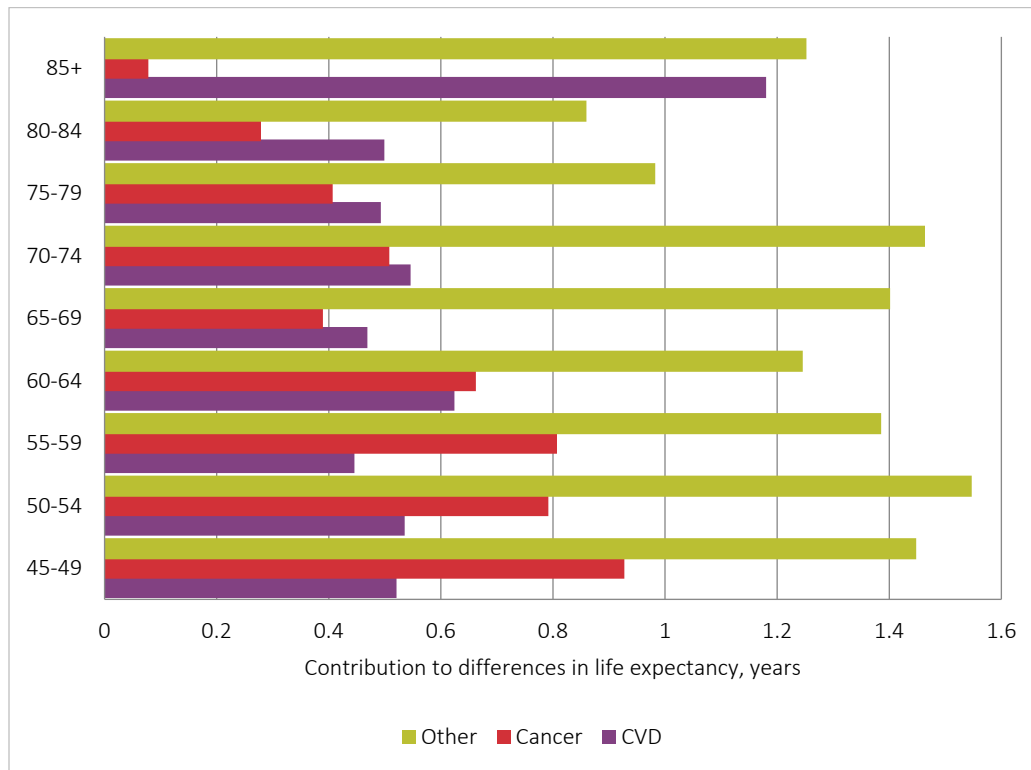
Figure 33
 CONTRIBUTION BY AGE AND CAUSE OF DEATH TO DIFFERENCES IN LIFE EXPECTANCY AT AGE 45 BETWEEN HEALTHY AND UNHEALTHY SUBGROUPS ACCORDING TO SELF-RATED HEALTH



Based on Figure 33, it can be seen that deaths due to cancer contribute to the differences in life expectancy mostly at younger ages, whereas the contribution of deaths due to CVD is more uniform across age groups.

Figure 34 shows the contribution of different age groups and causes of death to differences in life expectancy at age 45 between disabled and not disabled subgroups.

Figure 34
CONTRIBUTION BY AGE AND CAUSE OF DEATH TO DIFFERENCES IN LIFE EXPECTANCY AT AGE 45 BETWEEN DISABLED AND NOT DISABLED SUBGROUPS



The total difference in life expectancy at age 45 between the disabled and not disabled subgroups is 22.7 years. Of these 22.7 years, deaths due to CVD contribute 6.0 years, and deaths due to cancer contribute 5.3 years. Thus, in the case of disability, CVD contributes slightly more than cancer to differences in life expectancy between disabled and not disabled (in contrast to self-rated health). In the case of disability, deaths at older ages contribute more to the difference in life expectancy compared to self-rated health: 11.6 for ages 45–64 and 11.1 for ages 65–85 and above. It follows from Figure 34 that the contribution of deaths due to cancer is higher at younger ages, whereas the contribution of deaths due to CVD is particularly high after age 80.

Section 8: Prevalence by Health Status during the COVID-19 Pandemic Years

8.1 PREVALENCE OF UNHEALTHY STATUS IN 2020 AND 2021 YEARS COMPARED TO PRE-PANDEMIC 2019 YEAR

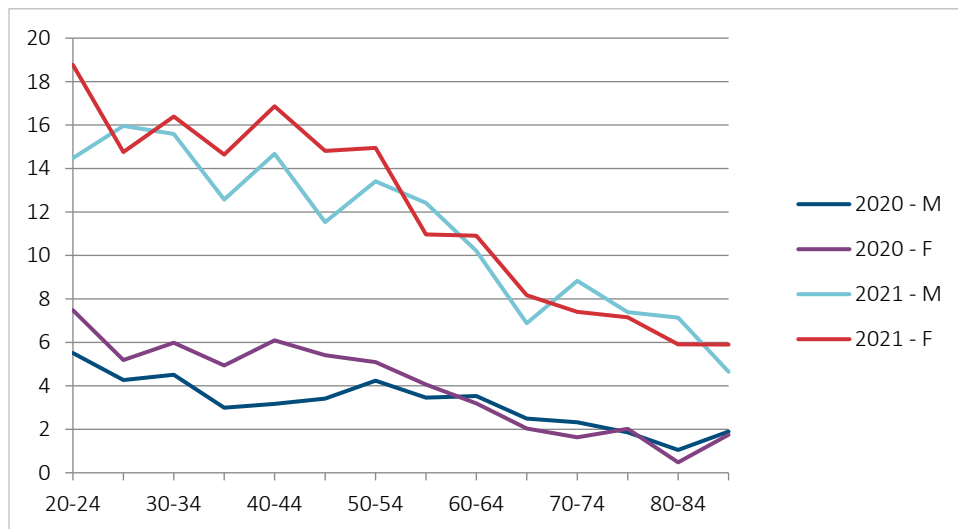
The NHIS made significant changes in its questionnaire in 2019, so that definitions of mental conditions and disability in 2019 became incompatible with earlier NHIS questionnaires. The NHIS explains this step in the following way: “The content and structure of the NHIS were updated in 2019 to better meet the needs of data users. Aims of the questionnaire redesign were to improve the measurement of covered health topics, reduce respondent burden by shortening the length of the questionnaire, harmonize overlapping content with other federal health surveys, establish a long-term structure of ongoing and periodic topics, and incorporate advances in survey methodology and measurement. “In particular, questions about ADLs and IADLs were removed from the questionnaire. Thus, the prevalence of health indicators in 2015–2018 cannot be compared with 2019–2021 data (see also Appendix B.4 and B.5).

Data for 2019–2021 are presented in the form of the Sample Adult files. Sample Adult files include 31,568 completed interviews in 2020 and 29,482 interviews in 2021. The sample size was significantly reduced compared to the previous years.

The 2020 and 2021 surveys had a question about COVID-19, and 635 respondents of the 2020 survey and 3,494 of the 2021 survey reported that they had had COVID-19. Figure 35 shows the percent distribution of those having COVID-19 in 2020 and 2021 by age.

Figure 35

PROPORTION OF MALES AND FEMALES REPORTING THAT THEY EVER HAD COVID-19 AS A FUNCTION OF AGE, BASED ON THE NHIS SAMPLE ADULT FILE FOR U.S. MALES AND FEMALES IN 2020 AND 2021



This figure shows that younger respondents report more COVID-19 infections compared to older respondents, and more COVID-19 infections were reported in 2021 than 2020. The latter result is likely because of the nature of the question being asked, if they “ever had” COVID-19, which would include both 2020 and 2021 in the 2021 survey. It might be surprising that the younger ages had a higher percentage of COVID-19 survivors than the older ages; this may be because of better isolation and a smaller number of contacts for seniors who knew that they were at higher risk.

Mental conditions in 2019–2021. The definition of mental conditions in 2019–2021 surveys changed compared to 2018 and earlier surveys.

In the 2019–2021 surveys, *mental conditions* are defined as positive responses to at least one of the following questions: (1) “Difficulty remembering/concentrating”; (2) “Ever had dementia”; (3) “Ever had anxiety disorder”; (4) “Ever had depression”; (5) “Currently receiving counseling/therapy from mental health professional.”

Definitions of mental conditions for questionnaires used before and after 2019 are available and can be compared in Appendix B.4.

Memory impairments are defined as a positive response to at least one of the following two questions: (1) “Difficulty remembering/concentrating” and (2) “Ever had dementia.”

Figure 36 shows percent of males and females with mental conditions in 2019–2021 by age.

Figure 36
 PROPORTION OF MALES AND FEMALES (%) REPORTING MENTAL CONDITIONS AS A FUNCTION OF AGE, BASED ON THE NHIS SAMPLE ADULT FILES FOR U.S. MALES AND FEMALES IN 2019–2021

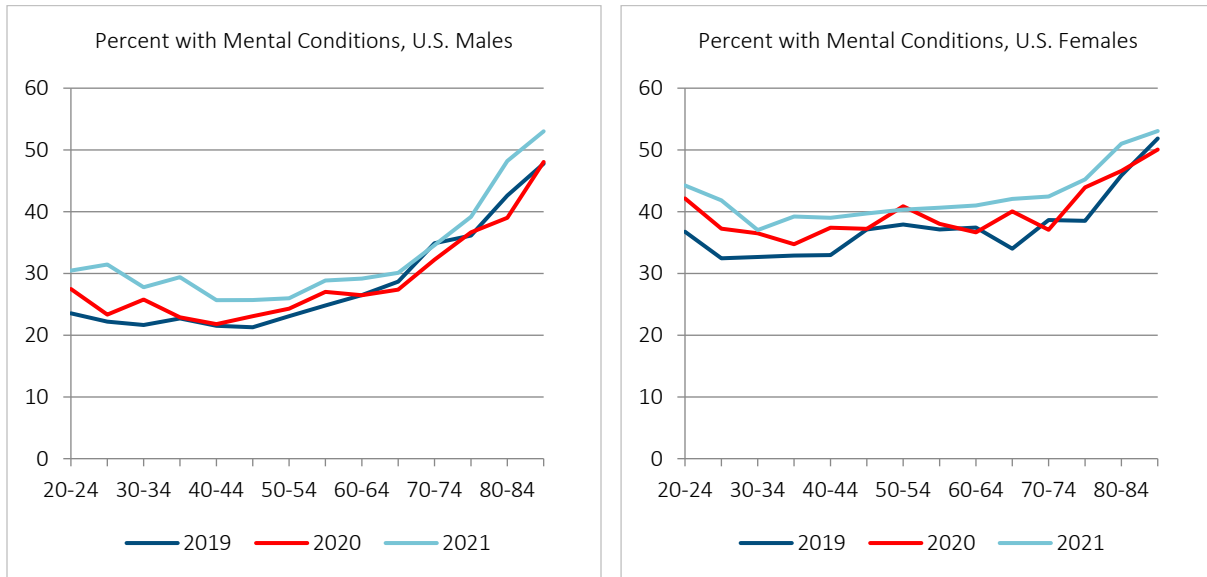


Figure 36 shows that the prevalence of mental conditions was notably higher in 2021 compared to the previous years. This increase of mental conditions in 2021 is observed for both males and females. This increase in the prevalence of mental conditions over time is also visible in Figure 37.

Figure 37
 PROPORTION OF MALES AND FEMALES HAVING MENTAL CONDITIONS AT AGE 40–44 OVER TIME, BASED ON THE NHIS SAMPLE ADULT FILES FOR U.S. MALES AND FEMALES IN 2019–2021

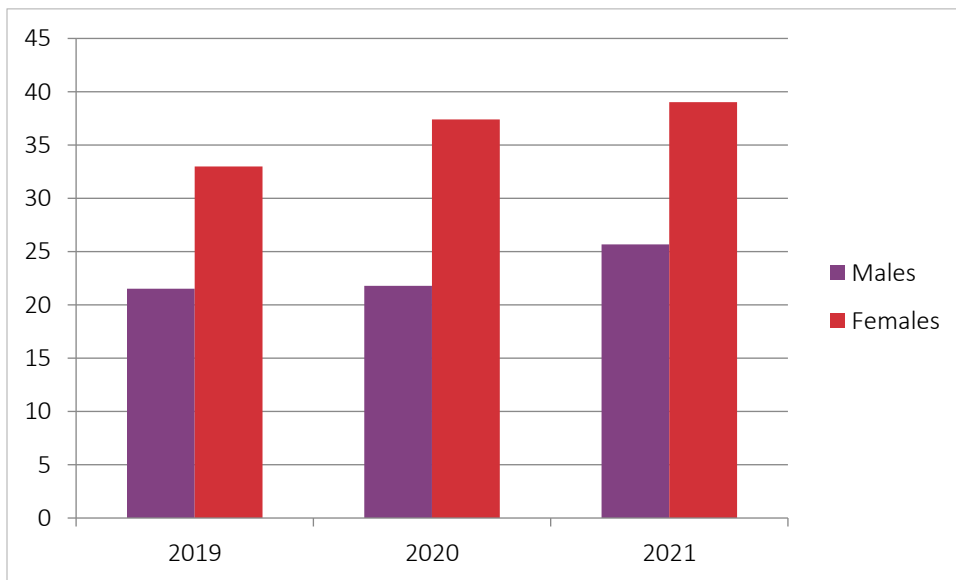
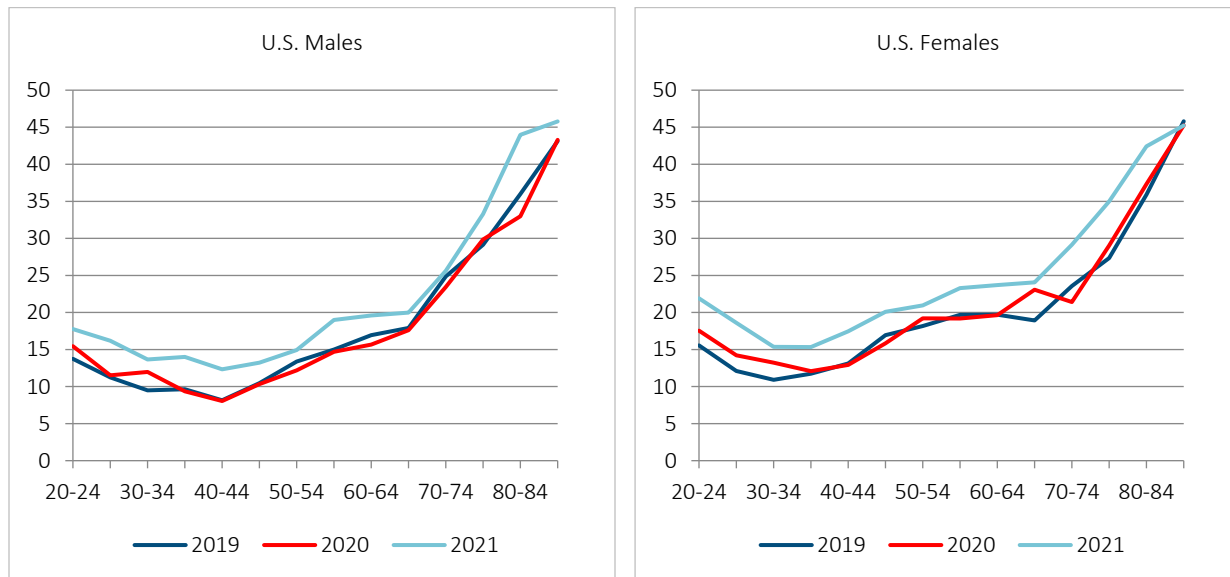


Figure 38 shows the prevalence of memory impairments in 2019–2021 by age.

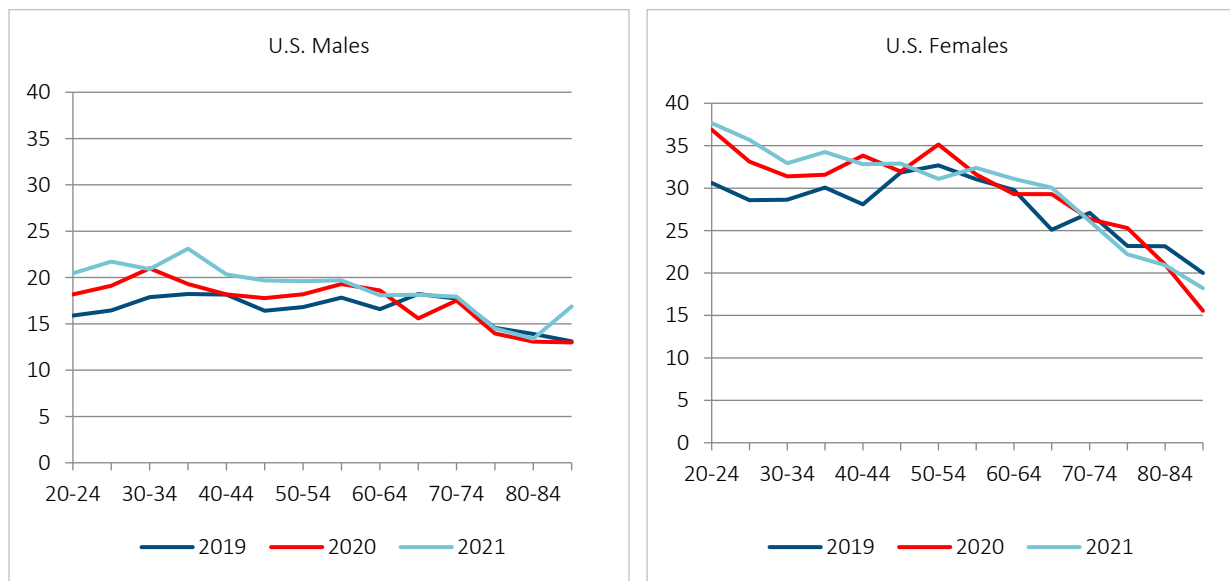
Figure 38
 PROPORTION OF MALES AND FEMALES (%) REPORTING MEMORY IMPAIRMENTS AS A FUNCTION OF AGE, BASED ON THE NHIS SAMPLE ADULT FILES FOR U.S. MALES AND FEMALES IN 2019–2021



Note that the proportion of memory impairments in 2021 is notably higher compared to 2019 and 2020. This increase in the prevalence of memory impairments is observed for both males and females.

Finally it is possible to look at other mental conditions (mostly depression and anxiety) as shown in Figure 39.

Figure 39
 PROPORTION OF MALES AND FEMALES (%) REPORTING OTHER MENTAL CONDITIONS AS A FUNCTION OF AGE, BASED ON THE NHIS SAMPLE ADULT FILES FOR U.S. MALES AND FEMALES IN 2019–2021



In the case of other mental conditions an increase of prevalence occurs in 2020 and 2021 compared to 2019, but mostly at younger ages.

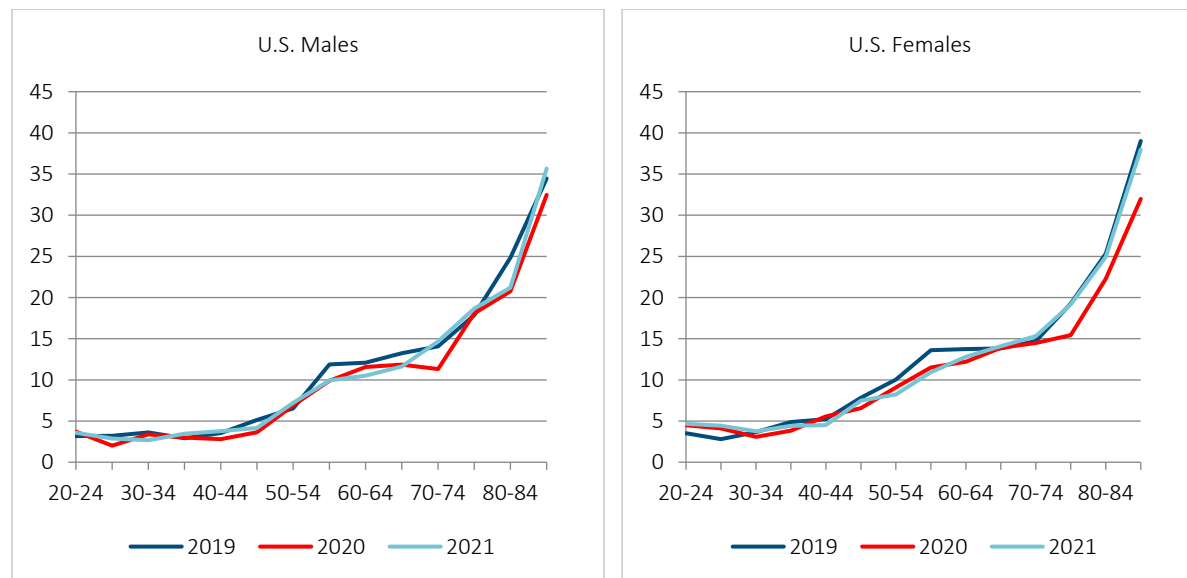
Thus, an increase of mental conditions prevalence is seen in 2021 compared to previous two years. The highest increase in prevalence occurred between 2020 and 2021, whereas the prevalence of mental conditions in 2019 and 2020 was closer to each other (with the exception of younger ages).

Disability in 2019–2021. In 2019–2021 many questions related to limitation of activity (including questions about ADLs and IADLs) were removed from the questionnaires. For this reason, we used the Washington Group Short Set Composite Disability (WG-SS) Indicator for definition of disability. The definition of this disability indicator is available in Appendix B.4 and can be compared with the definition of disability used for surveys conducted before 2019. This indicator identifies adults who are at greater risk than the general population for experiencing restrictions in participation because of difficulties doing certain universal, basic actions. If a sample adult reported “a lot of difficulty” or “cannot do at all” for at least one question, they were classified as having a disability. This definition of disability is different from the definition used for the NHIS conducted before 2019.

Figure 40 shows the prevalence of disability in 2019–2021 according to the WG-SS indicator.

Figure 40

PROPORTION OF MALES AND FEMALES REPORTING DISABILITY ACCORDING TO THE WG-SS INDICATOR AS A FUNCTION OF AGE, BASED ON THE NHIS SAMPLE ADULT FILES FOR U.S. MALES AND FEMALES IN 2019–2021



The WG-SS indicator produces a lower percentage of disabled persons compared to the earlier definition based on limitation of activity and used for NHIS 2010–2018 questionnaires. However, the age-specific pattern of prevalence is similar for both the earlier and the current definition.

Figure 39 demonstrates that the prevalence of disability is similar in 2019, 2020 and 2021 for both males and females. This is different from with mental conditions, where a notable increase is found in the prevalence of mental conditions in 2021 compared to previous years. For females, prevalence of disability at older ages in 2019 and 2021 is almost the same and higher than in 2020.

Chronic diseases in 2019–2021. The definition of chronic diseases is based on a set of eight questions “Ever been told you had ...” as in the case of 2018 and earlier surveys. However, the list of diseases in 2019–2021 was slightly different, and some diseases such as COPD (chronic obstructive pulmonary disease) were added (see Appendix B.4).

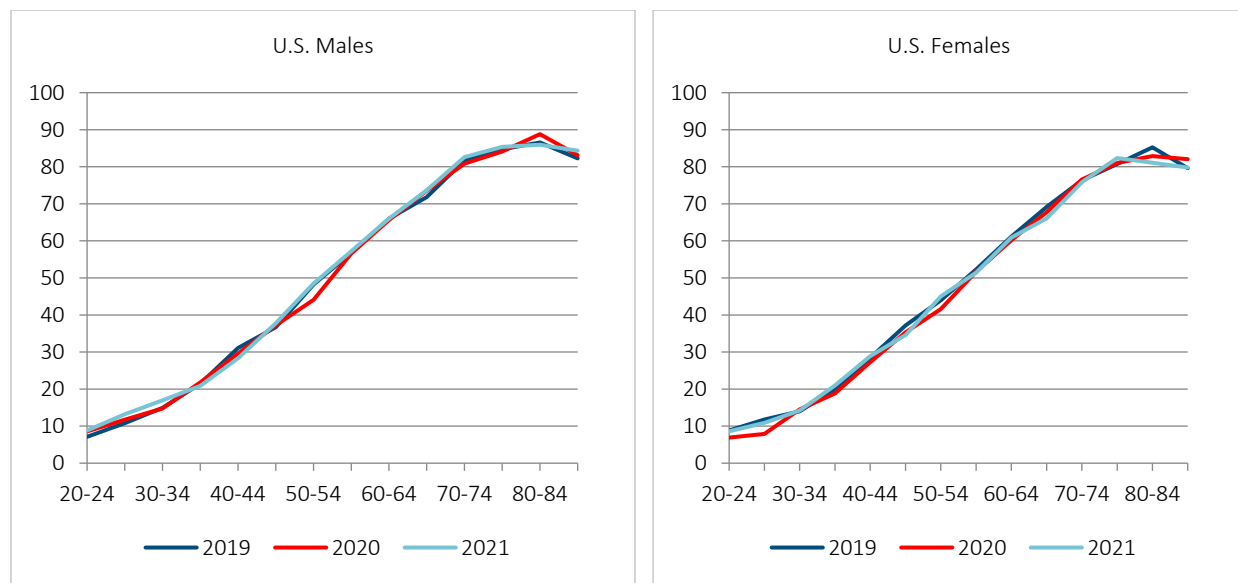
The definition of chronic diseases includes positive response to at least one of the following eight questions:

1. “Ever been told you have hypertension”
2. “Ever been told you had coronary heart disease”
3. “Ever been told you had angina pectoris”
4. “Ever been told you had a heart attack”
5. “Ever been told you had COPD, emphysema, or chronic bronchitis”
6. “Ever been told you had a stroke”
7. “Ever told by a doctor you had cancer”
8. “Ever been told that you have diabetes”

Figure 41 shows the prevalence of chronic diseases in 2019–2021 by age.

Figure 41

PROPORTION OF MALES AND FEMALES REPORTING CHRONIC DISEASES AS A FUNCTION OF AGE BASED ON THE NHIS SAMPLE ADULT FILES FOR U.S. MALES AND FEMALES IN 2019–2021



Practically no differences are seen in the proportion of chronic diseases between 2019 and 2021. Females have a lower prevalence of chronic diseases (according to this definition) compared to males.

Analysis of prevalence using different definitions of poor health shows that only mental conditions (including memory impairments) saw a notable increase in 2021 compared to previous years. These small changes in prevalence may be caused by a relatively low proportion of persons having COVID-19 in the population (less than 20%; see Figure 35). Thus, it would be more reasonable to make a direct comparison of respondents having COVID-19 with those not having COVID-19.

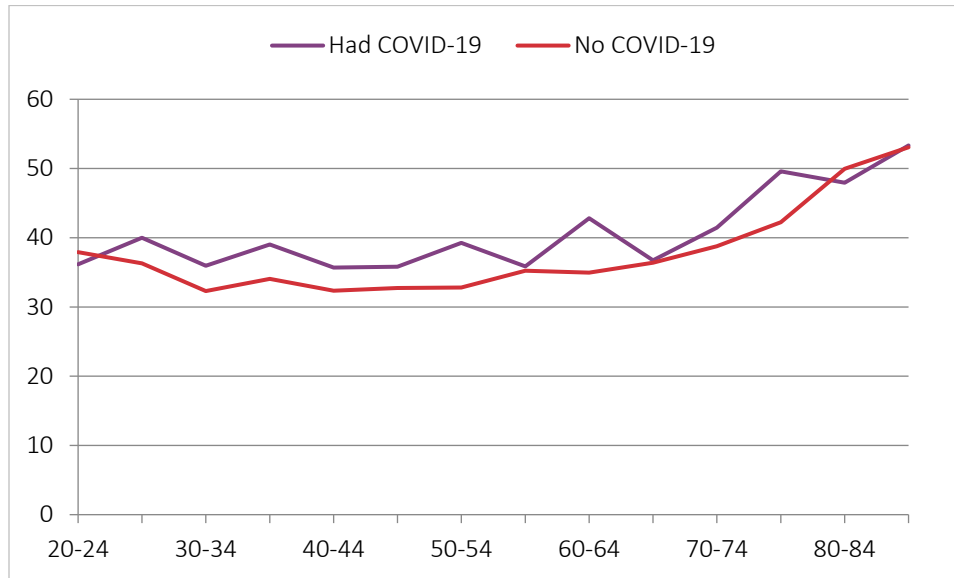
8.2 PREVALENCE OF POOR HEALTH AMONG COVID-19 SURVIVORS

Data from the 2021 NHIS show that the proportion of ever having COVID-19 was relatively small by the time it was taken. For this reason, effects of the COVID-19 epidemic on health at the population level were not particularly strong (with the exception of mental conditions). To analyze the direct effect of COVID-19 on health we compared the prevalence of poor health (using several definitions of health) among respondents having COVID-19 with those who had not had this disease.

Mental conditions. Figure 42 shows the proportion of persons reporting mental conditions among two studied groups of 2021 NHIS respondents, having and not having COVID-19.

Figure 42

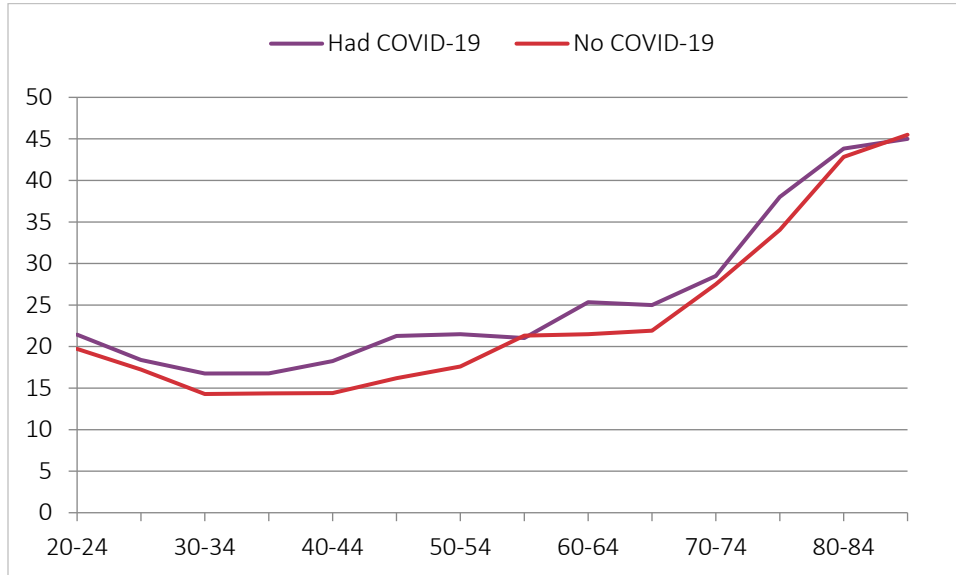
PROPORTION OF RESPONDENTS WITH MENTAL CONDITIONS BY COVID-19 STATUS, BASED ON THE 2021 NHIS SAMPLE ADULT FILE



Note that respondents ever having had COVID-19 demonstrate a higher prevalence of mental conditions compared to respondents not having had COVID-19. This difference is observed at all ages except for the oldest age group (80 and above). This result is similar to the result obtained when comparing the prevalence of mental conditions across 2019–2021 (section 8.1). The prevalence of mental conditions in 2021 (when prevalence of having COVID-19 was the highest) was significantly higher compared to 2019 and 2020.

The proportion of respondents having memory impairments (difficulty remembering or dementia) by their COVID-19 status is demonstrated in Figure 43.

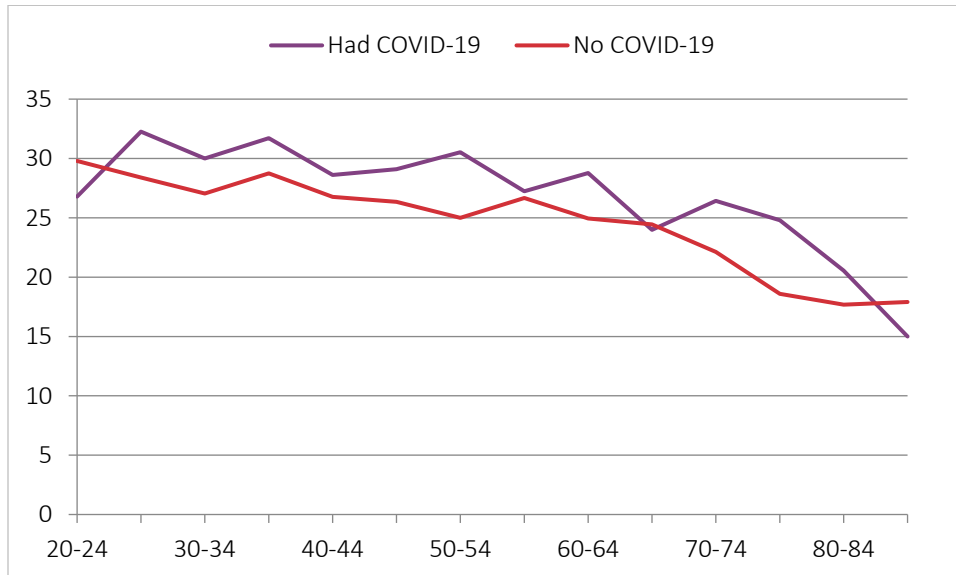
Figure 43
 PROPORTION OF RESPONDENTS WITH MEMORY IMPAIRMENTS, BY COVID-19 STATUS,
 BASED ON THE 2021 NHIS SAMPLE ADULT FILE



As in the case of mental conditions, COVID-19 is associated with the prevalence of memory impairments (with the exception of the oldest age group).

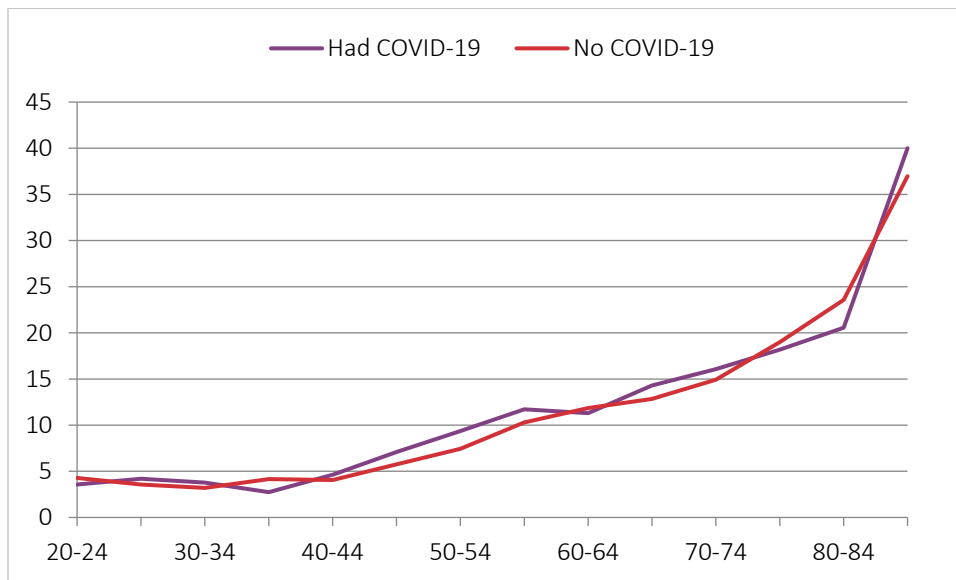
Other mental conditions (mostly depression and anxiety) are significantly more common among respondents ever having had COVID-19 (see Figure 44).

Figure 44
 PROPORTION OF RESPONDENTS WITH OTHER MENTAL CONDITIONS (MOSTLY DEPRESSION
 AND ANXIETY) BY COVID-19 STATUS, BASED ON THE 2021 NHIS SAMPLE ADULT FILE



Disability. In contrast to mental conditions, the prevalence of disability is not much associated with COVID-19 status (see Figure 45).

Figure 45
 PROPORTION OF RESPONDENTS WITH DISABILITY BY COVID-19 STATUS, BASED ON THE 2021 NHIS SAMPLE ADULT FILE



Chronic diseases. The list of diseases used to define chronic diseases includes diseases having a significant impact on mortality. Figure 46 presents the prevalence of chronic diseases according to COVID-19 status.

Figure 46
 PROPORTION OF RESPONDENTS WITH CHRONIC DISEASES BY COVID-19 STATUS, BASED ON THE 2021 NHIS SAMPLE ADULT FILE

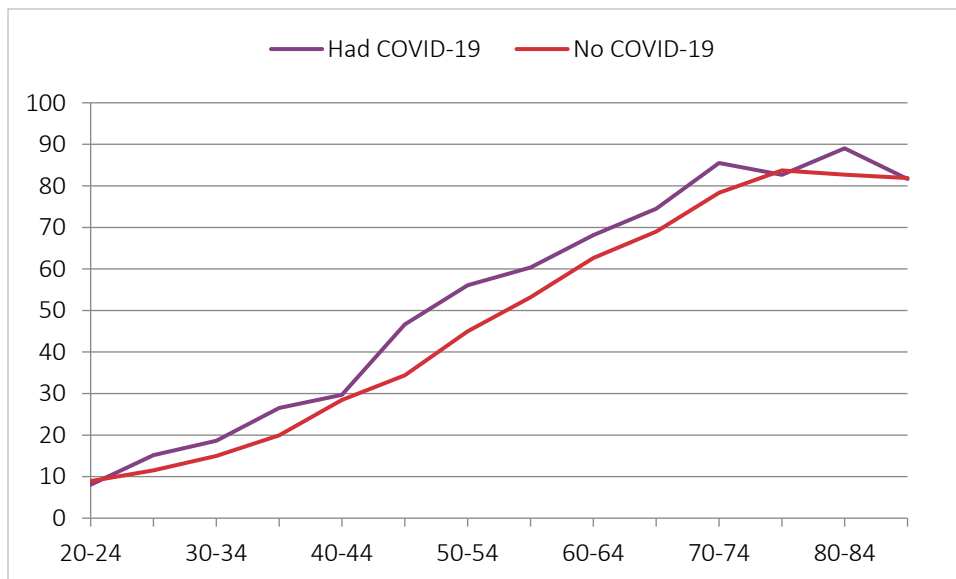
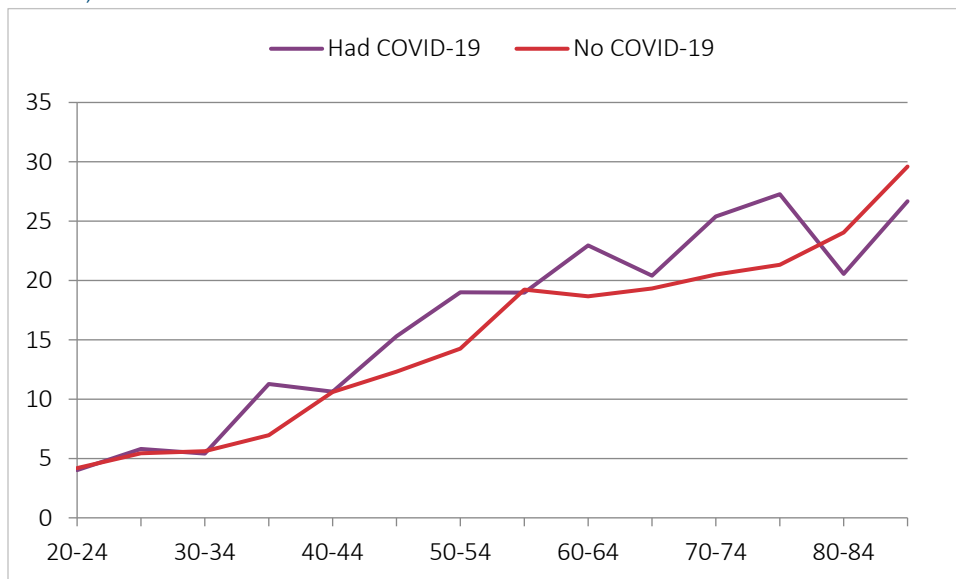


Figure 46 shows that COVID-19 status has a significant association with the prevalence of chronic diseases. This association is observed practically in all age groups.

Self-rated health. Study of self-rated health showed that COVID-19 status is associated with increased reporting of poor or fair health (see Figure 47). This effect is not observed for very young (under 35) and very old (over 80) age groups.

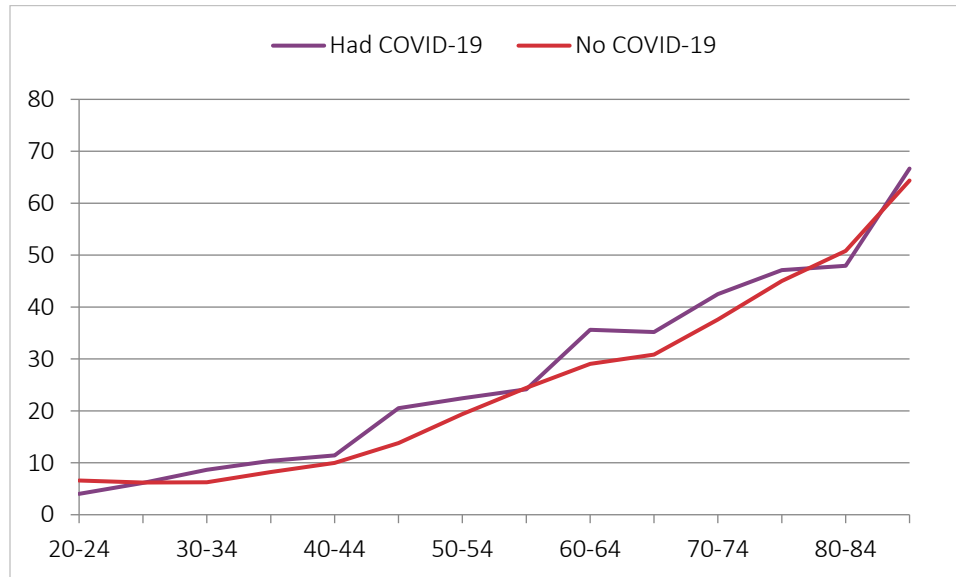
Figure 47
 PROPORTION OF RESPONDENTS WITH POOR OR FAIR SELF-RATED HEALTH BY COVID-19 STATUS, BASED ON THE 2021 NHIS SAMPLE ADULT FILE



Frailty in 2021 among COVID-19 survivors. Finally, we compared the proportion of those having a high Frailty Index (FI ≥ 0.2) for respondents ever having and not having had COVID-19 using the Frailty Index definition in Appendix B.5 (Figure 48).

Figure 48

PROPORTION OF RESPONDENTS WITH FRAILITY ($FI \geq 0.2$) BY COVID-19 STATUS, BASED ON THE 2021 NHIS SAMPLE ADULT FILE



Note that COVID-19 status is associated with a higher proportion of frailty in all age groups with the exception of very young and very old ages.

Summarizing, we can conclude that having had a COVID-19 infection is associated with a higher prevalence of poor health according to different definitions of health with the exception of disability.



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Section 9: Acknowledgments

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Appendix A: Data Source and Data Preparation

The National Health Interview Survey (NHIS) is the main data source for this project. The NHIS is the largest health survey of the U.S. population.

A.1 NHIS OVERVIEW

The description provided here was adapted from the description of the National Health Interview Survey available at the NHIS website: https://www.cdc.gov/nchs/nhis/about_nhis.htm.

The National Health Interview Survey (NHIS) is a cross-sectional household interview survey. The NHIS is conducted by the U.S. Census Bureau on behalf of the National Center for Health Statistics (NCHS). The NCHS is part of the U.S. Centers for Disease Control and Prevention (CDC). The NHIS is a national survey that has been conducted since 1957. The target population for the NHIS is the civilian noninstitutionalized population residing in the United States at the time of the interview. Sampling and interviewing for the NHIS are continuous throughout each year. The sample design follows a multistage area probability design that permits the representative sampling of households and noninstitutional group quarters (e.g., college dormitories). The NHIS is conducted in a face-to-face interview format. To increase the precision of estimates of the Black, Hispanic/Latino and Asian American populations, the current NHIS sample design (starting in 2006) oversamples Black persons, Hispanic/Latino persons and Asian American persons. In addition, the sample adult selection process is undertaken so that when Black, Hispanic/Latino or Asian American persons aged 65 years or older are present, they have an increased chance of being selected as the sample adult.

The core questionnaire (which remained unchanged from 1997 until 2018) consists of four main components: the Household Composition section, the Family Core, the Sample Child Core and the Sample Adult Core. The Family Core questionnaire, which is administered separately for each family in the household, collects information on all persons in the family. Topics on the Family Core include sociodemographic characteristics, basic indicators of health status, activity limitations, injuries, health insurance coverage and access to and utilization of health care services.

For the Sample Adult questionnaire, one adult per family (the “sample adult”) is randomly selected, with increased chances of selection for any Black, Hispanic/Latino or Asian American persons aged 65 years or older. The sample adult responds for him- or herself to the questions in that section unless he or she is physically or mentally unable to do so, in which case a knowledgeable proxy is allowed to answer for the sample adult. Because some health issues are different for children and adults, these two questionnaires differ in some items, but both collect basic information on health status, health care services and health-related behaviors. When fielded, supplementary questions about the sample child and sample adult provide additional information.

The publicly released data files (also called “public use data files”) for the 2014 NHIS have data for 44,552 households containing 112,053 persons in 45,597 families. The number of sample children is 13,380, and the number of sample adults is 36,697. In 488 cases, a knowledgeable proxy answered for the sample adult. The total household response rate was 73.8%: 17.6 percentage points of the 26.2% noninterview rate were the result of respondent refusal and unacceptable partial interviews. The remaining 8.6 percentage points were primarily the result of failure to locate an eligible respondent at home after repeated contact attempts.

In this report variables and composition of the NHIS have been analyzed for yearly surveys from 2010 to 2018 (the last year for which information on mortality is available). The NHIS collects various types of data that are presented in several data files. The most informative files for health analysis are the Person file (personx) and Sample Adult file (samadult). For each studied survey year (from 2010 to 2018), the Person file has been merged with the Sample Adult file and then with the Mortality file using the special “PersonId” variable.

The Person file variables are derived from the sections making up the Family Core of the NHIS. The information in the Family Core questionnaire is collected for all household members. Any adult household members who are present at the time of the interview may take part; information regarding adults not participating in the interview, as well as about all household members under age 18, is provided by a knowledgeable adult member of the household. (If more than one family is found in the household, then these procedures are followed for each family in the household.) Thus, the Person file contains data for both children and adults (18 and older).

The Sample Adult section of the NHIS covers many of the subject areas included in the Family Core. However, the questions in the Sample Adult section are more specific and are intended to gather more detailed information. In addition, sample adults generally respond for themselves, although in a small number of cases, proxy responses are allowed if the selected adult had a physical or mental condition prohibiting him or her from responding.

The number of adults (18 and older) in the Person file is about two times higher than the number in the Sample Adult file. However, questions in the Sample Adult file provide more accurate information about the health of individual.

2019 Public-Use Linked Mortality Files (LMFs)

The National Center for Health Statistics (NCHS) has linked data collected from several NCHS population surveys with death certificate records from the National Death Index. The public-use LMFs include a limited set of variables for adult participants only and were subjected to data perturbation techniques to reduce participant disclosure risk. Synthetic data were substituted for follow-up time or underlying cause of death for select records. Information regarding vital status was not perturbed. The public-use LMFs provide mortality follow-up data from the date of survey participation through December 31, 2019. Information about public-use LMFs is available at <https://www.cdc.gov/nchs/data-linkage/mortality-public.htm>.

A.2 OVERVIEW OF VARIABLES COLLECTED IN THE NHIS

The description of variables provided here was adapted from the description of NHIS questionnaire files available at the NHIS website: <https://www.cdc.gov/nchs/nhis/1997-2018.htm>.

Person File

Health Status and Limitation of Activity. The Health Status and Limitation of Activity section of the Family Core (FHS) contains information addressing respondent-assessed disabilities, disability-associated conditions and overall health status for all family members.

Limitation of Activity at the Person Level. Information on activity limitations, including questions about work limitations; the need for personal assistance with personal care needs such as eating, bathing, dressing and getting around inside the home; and the need for personal assistance with handling routine needs such as everyday household chores, doing necessary business, and shopping or running errands is collected for each family member (with some exclusions for children and youth). Since the questions in the FHS section allow only for “yes” or “no” responses, the degree to which a person is limited is not determined.

Since cognitive impairment is increasingly recognized as a source of activity limitations among older adults, the FHS section includes an indicator that identifies persons who are limited because of difficulty remembering or periods of confusion. Other indicators in this section identify persons who have difficulty walking without any special equipment or limitations related to specific personal care needs.

Conditions Leading to Limitations of Activity. For each person with a limitation, the respondent was asked about the condition or health problem associated with that limitation, as well as the length of time he or she has had the

condition. Respondents were then handed one of two flash cards listing various condition categories. These categories are broad in scope and vary according to age.

The fixed response categories in the instrument for adults age 18 or older were broad: “vision/problem seeing,” “hearing problem,” “arthritis/rheumatism,” “back or neck problem,” “fracture, bone/joint injury,” “other injury,” “heart problem,” “stroke problem,” “hypertension/high blood pressure,” “diabetes,” “lung/breathing problem (e.g., asthma and emphysema),” “cancer,” “birth defect,” “intellectual disability, also known as mental retardation,” “other developmental problem (e.g., cerebral palsy),” “senility,” “depression/anxiety/emotional problem” and “weight problem.” If an adult family member was limited by a condition not listed in one of the 18 fixed categories mentioned above, the interviewer accessed a second screen containing 17 additional condition categories and two “other impairment problem” categories.

Each condition reported as a cause of an individual’s activity limitation has been classified as “chronic,” “not chronic” or “unknown if chronic” based on information obtained about the condition and/or the duration of the condition.

None of the FHS condition variables (the 34 adult variables) should be used to estimate prevalence for the conditions they represent, because only those persons with a previously reported limitation were eligible for the condition questions that followed. Analysts who are interested in estimating the prevalence of particular conditions should use the Sample Adult file to evaluate variables that may be more appropriate.

Sample Adult File

The Sample Adult section of the NHIS covers many of the subject areas included in the Family Core. However, the questions in the Sample Adult section are more specific and are intended to gather more detailed information.

Adult Conditions Section. The Adult Conditions (ACN) section contains information about whether the sample adult has, or has had, a selected number of medical conditions. In most instances, sample adults were asked whether a doctor or other health professional had told them that they had the condition in question (joint symptoms, pain, hearing, vision impairment and tooth loss are the exceptions). Sample adults are also asked about head colds and intestinal conditions that began in the two weeks before the interview, and females aged 18–49 are asked about recent and current pregnancy status.

Adult Health Status and Limitation of Activity Section. The 2014 Adult Health Status and Limitation of Activity section (AHS) contains information from sample adults on behavior, health status, use of special equipment, limitations in functional activities and the conditions underlying such limitations.

Although the functional limitation questions in the AHS section may seem similar to questions in the FHS section in the Family Core, the questions in these sections have a somewhat different focus. For example, both sections ask about the ability to walk without special equipment. However, the walking limitation question in the FHS section () captured only whether a person has difficulty walking without using special equipment. In contrast, the Sample Adult question on walking asks about the degree of difficulty the sample adult has walking a specified distance (a quarter mile, or about three city blocks) by him- or herself and without using any special equipment.

The functional limitation questions in the AHS section asks the sample adult to indicate the degree of difficulty he or she would have in performing specific physical tasks (e.g., walking up 10 steps, standing for two hours or carrying a 10-pound object) and engaging in social activities and recreation (e.g., going shopping, attending club meetings, visiting friends, sewing or reading) without the assistance of another person or using special equipment.

Each sample adult indicating any functional limitation (regardless of the degree of the limitation) is asked about the condition(s) or health problem(s) associated with that limitation, as well as the amount of time he or she has had

the condition. Respondents were handed a flash card listing various condition categories: “vision/problem seeing,” “hearing problem,” “arthritis/rheumatism,” “back or neck problem,” “fracture, bone/joint injury,” “other injury,” “heart problem,” “stroke problem,” “hypertension/high blood pressure,” “diabetes,” “lung/breathing problem (e.g., asthma and emphysema),” “cancer,” “birth defect,” “intellectual disability, also known as mental retardation,” “other developmental problem (e.g., cerebral palsy),” “senility,” “depression/anxiety/emotional problem” and “weight problem.”

Adult Health Behaviors Section. The Adult Health Behaviors section (AHB) contains information on questions related to an adult’s cigarette smoking, leisure-time physical activity, alcohol use, height and weight. The same questions have been included in the Sample Adult core every year since 1997 with only minor changes. The sleep question, added in 2004, was removed from AHB in 2013 and moved to the Adult Selected Items (ASI) section.

Publication

2014 National Health Interview Survey (NHIS). Public Use Data Release. Survey Description. Division of Health Interview Statistics, National Center for Health Statistics, Hyattsville, Maryland, June 2015.

https://ftp.cdc.gov/pub/Health_Statistics/NCHS/Dataset_Documentation/NHIS/2014/srvydesc.pdf

A.3 DATA PREPARATION

This project relies predominantly on data available in the Sample Adult file. Some information (questions on self-rated health and activity limitation) was taken from the Person file. Life tables and mortality were calculated using surveys conducted in the periods 2010–2014 and 2015–2018. 2019NHIS Public-Use Linked Mortality files for deaths of NHIS respondents that occurred between 2010 and 2019 were released in 2022.

Person file and Sample Adult file were merged for each year between 2010 and 2018. Then the resulting files were merged with Public-Use Linked Mortality files using the personal ID. After that, files for 2010–2014 and 2015–2018 were combined to create files with a sufficiently large sample size. A large sample size is needed to obtain stable estimates of age-specific death rates and then calculate cross-sectional or period life tables.

Numbers of respondents and deaths for each period used in this project are presented in Table A1.

Table A1

NUMBER OF RESPONDENTS AND DEATHS IN NHIS SURVEYS

	2010–2014	2015–2018
Number of respondents aged 20 and older	159,276	114,251
Number of respondents aged 45 and older	90,404	70,678
Deaths at ages 20 and older	6,301	4,584
Deaths at ages 45 and older	5,811	4,404

To study age-specific prevalence, we used information on respondents aged 20 years and older. It follows from Table A1 that almost all deaths occur after age 45. For this reason, the main focus of this study was on mortality after age 45 when mortality estimates are more stable and reliable. Therefore, for mortality studies we used information on respondents aged 45 years and older.

For the NHIS conducted after 2018 mortality data are not available yet, only information about the number of respondents. The number of respondents aged 20 years and older is 31,467 in 2019, 31,227 in 2020 and 29,009 in 2021. The same number of respondents aged 45 years and older is 19,973 in 2019, 20,684 in 2020 and 18,555 in 2021.

Information on NHIS data, questionnaires and related documentation is available at the following URL:

<https://www.cdc.gov/nchs/nhis/data-questionnaires-documentation.htm>

Information on NHIS Public-Use Linked Mortality files is available at the following URL:

<https://www.cdc.gov/nchs/data-linkage/mortality-public.htm>

Appendix B: Measures of Health. Literature Review and Definitions

In this project the main focus was given to individual (rather than population) health and to the most appropriate instruments of its measurement because the insurance industry is most interested in individual characteristics of its clients. Taking into account that the existing definition of health by the World Health Organization is formulated as “a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity” (Parkerson, Eisenson and Campbell 2019), we used definitions of healthy and unhealthy status that would cover a wide scope of existing health impairments. We defined healthy and unhealthy groups in the population based on adverse health outcomes, which cover at least three domains of health: (1) medical conditions (heart disease, cancer, stroke, diabetes, hypertension etc.); (2) mental conditions; and (3) disability (IADLs/ADLs and any limitation of activity). Measures of social adversity such as loneliness were not considered. Exceeding the established threshold or percentile of health deficiencies would separate unhealthy from healthy individuals. Each domain of health was studied separately and then combined into one broader index. Definitions of healthy and unhealthy status were based on health outcomes and followed from the main objective of the SOA call, which expressed interest in analyzing effects of “a variety of impairments, such as physical disability, mental health conditions, and chronic disease” on mortality.

This project reviewed, used and compared several existing instruments to measure individual health status including self-rated health, the Rockwood Frailty Index, disability, mental conditions and chronic diseases.

B.1 MEASURES OF GENERAL HEALTH: SELF-RATED HEALTH

Self-rated health (SRH) is one of the oldest measures of health status. Respondents are typically asked to rate their perceived health using a five-point Likert scale (excellent, very good, good, fair, poor). This is the simplest way to measure individual health status, and it was demonstrated to be a good predictor of subsequent mortality (Idler, et al. 1991, DeSalvo, et al. 2005). It was shown that mortality strongly depends on health status (Bundgaard, et al. 2020).

The SRH already categorizes individuals into healthy (good/very good/excellent SRH) and unhealthy (fair/poor SRH) groups. This is a time-tested measure, which was shown to be a surprisingly good predictor of mortality (Goldman, Gleib and Weinstein 2016, 2017, Andrasfay, et al. 2020). We believe that this measure can be used in actuarial practice in those cases when introducing long health questionnaires is not feasible. A limitation of this health status measure is its simplistic and subjective nature, which is unable to capture all aspects of health status including both physical status and mental status. Also, this measure is difficult to interpret because it is not linked to any specific health condition.

B.2 MEASURES OF GENERAL HEALTH: ROCKWOOD FRAILITY INDEX

The Rockwood Frailty Index or simply Frailty Index (FI) is probably the most comprehensive measure of health status. It is now widely used in clinical and demographic studies. The idea of the Frailty Index comes from the reliability theory of aging (Gavrilov and Gavrilova 2001, Mitnitski, Song, Skoog and Rockwood 2004), which considers aging as a process of accumulating damage and loss of reserves leading to a state of increased vulnerability for adverse health outcomes (Rockwood and Mitnitski 2007, Rockwood, et al. 2017, Mousa, et al. 2018). The FI is used to measure health of individuals and counts the number of deficits related to health and well-being. It calculates a frailty score by dividing the number of deficits present by the total possible number of deficits and has a tendency to grow with age. The FI remains a robust predictor of mortality and is widely used in gerontological and demographic literature (Rockwood, Song and Mitnitski 2011, Rockwood, Hubbard, Eeles, Mitnitski and Rockwood 2012, Theou, Rockwood, Mitnitski and Rockwood 2012, Rockwood, et al. 2017). Deficits selected for inclusion in the FI are specifically selected to reflect the process of aging with their risk increasing with age. Empirical studies estimated that the cutoff value of 0.2 is recognized by multiple frailty measures as approaching a frail state (Rockwood, et al.

2005, Rockwood, et al. 2006, Kulminski, et al. 2007), so that individuals can be classified as healthy (FI = 0–0.2) and unhealthy or frail (FI = 0.2–1.0). Limitation of this index is its requirement to collect exhaustive set of questions about health, which may take a significant amount of time and be difficult for frail respondents. On the other hand, questions used to measure deficits represent a standard set of instruments to measure health and activities of daily living applied in many population surveys.

The advantages of the Frailty Index are the following:

1. *Inclusiveness*. The Frailty Index includes information from several domains of health including diseases, disability, loss of function and mental health conditions.
2. *Flexibility*. The number of total counted deficits is quite flexible, and the Frailty Index is able to accommodate a wide range of various health conditions including diseases, losses of function, disability and mental impairments. The total number of deficits is not defined as a rigid set of questions but may be accommodated to the number of questions in a particular survey.
3. *Validity*. The validity of this index is demonstrated in numerous studies, which cover different populations and countries (Andrew, Mitnitski, Kirkland and Rockwood 2012, Biritwum, et al. 2016, Backman, et al. 2017, Kojima, Iliffe and Walters 2018, Abelianskiy and Strulik 2020).
4. *Theoretical background*. This index has theoretical underpinnings, which consider aging as a process of accumulating damage and loss of reserves leading to a state of increased vulnerability for adverse health outcomes (Rockwood, Andrew and Mitnitski 2007, Rockwood, Jones, Wang, Carver and Mitnitski 2007, Rockwood, et al. 2017, Mousa, et al. 2018).
5. *Relative ease of use*. This index is based on a set of standard questions and does not require collection of biological specimens and biomarker measurement. This is important for actuarial practice where less expensive methods may be preferred. At the same time, biomarkers, if collected, can be incorporated in the index (Blodgett, Theou, Howlett and Rockwood 2017).

Questions available in the NHIS (the main source of data in this study) were adapted to the Frailty Index construction. The NHIS has over 60 questions related to health, which ensures accuracy of Frailty Index measurement (see Appendix B.3). The methodology of the Frailty Index construction is described in detail in the literature and used in many population surveys (such as NHANES, SHARE, HRS; (Mitnitski, MacKnight and Rockwood 2002, Searle, Mitnitski, Gill, Gahbauer and Rockwood 2008, Blodgett, et al. 2017, Abelianskiy, et al. 2020). This index supports our definition of healthy and unhealthy groups because it is based on accounting for adverse health outcomes and covers several domains of health: (1) disability, (2) mental health conditions, (3) chronic diseases and (4) loss of function (such as hearing or vision).

The FI is used to measure health of individuals and counts number of deficits related to health and well-being. It calculates a frailty score by dividing the number of deficits present by the total possible number of deficits. In the initial studies introducing the FI, the possible number of deficits based on a comprehensive Canadian survey had about 70. In later studies this number was reduced to 30 and fewer. Still the FI remains a robust predictor of mortality and is widely used in gerontological and demographic literature (Rockwood, et al. 2011, Rockwood, et al. 2012, Theou, et al. 2012, Rockwood, et al. 2017). It was demonstrated that an increased FI predicts higher risks of all-cause, CVD and respiratory-related mortality (Li, et al. 2019). A larger FI presents a greater risk factor at midlife than at older ages and has a significant population mortality impact that is greatest through midlife until the age of 80 (Li, et al. 2019).

The NHIS offers two sets of questions from the Person file and the Sample Adult file. A FI calculated on the basis of the Person file questions gives estimates that are too low compared to those published in the scientific literature.

Questions available in the Person file are related to disability deficits and do not cover all possible diseases and impairments. For this reason, we based our calculations of the Frailty Index on questions available in the Sample Adult file, which provides Frailty Index estimates comparable to the published estimates. A set of 64 questions from the Sample Adult file used for calculation of the Frailty Index is available in Appendix B.3.

For a small number of cases data are missing in the answers to the health questions. When information on specific deficits was missing for an individual, we calculated the deficit index based on the available information about potential deficits (i.e., if information was not available for x potential health deficits, the observed health deficits were divided by $64 - x$) (Abeliansky, et al. 2020).

Age trajectories for proportions of healthy and unhealthy individuals. Proportions of healthy and unhealthy individuals change with age. Figure B1 shows the proportion of healthy (not frail) individuals having $FI < 0.2$. Note that the proportion of healthy males is always higher compared to females, although this male advantage decreases with age.

Figure B1

PROPORTION OF MALES AND FEMALES WITH $FI < 0.2$ AS A FUNCTION OF AGE, BASED ON THE NHIS SAMPLE ADULT FILE FOR U.S. MALES AND FEMALES IN 2010–2014

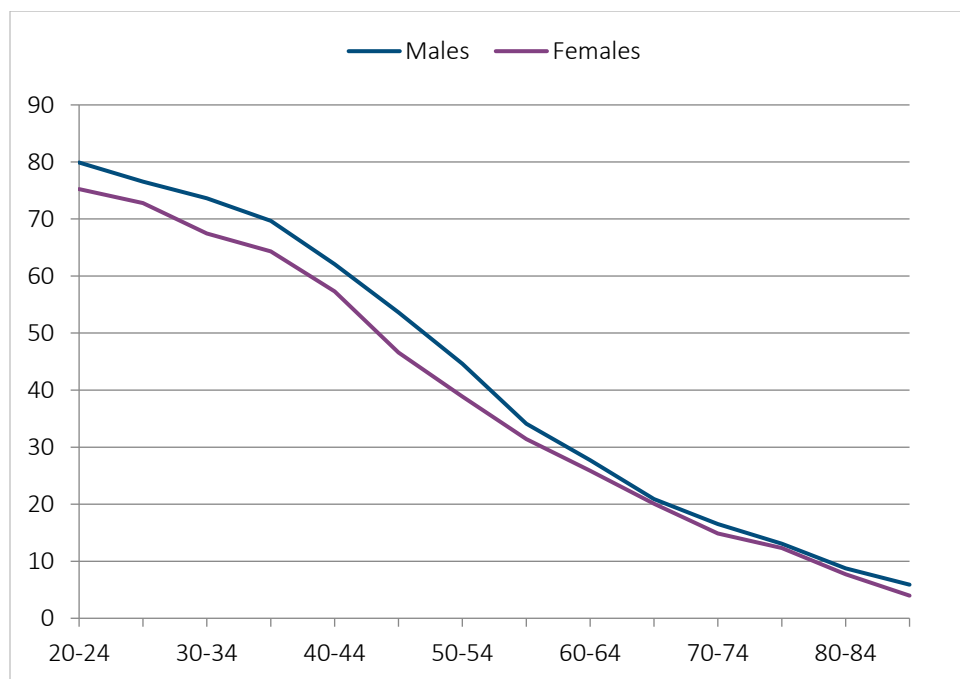


Figure B1 shows that the proportion of respondents without frailty rapidly declines with age and becomes almost equal to zero by age 85.

B.3 LIST OF DEFICITS TO CALCULATE FRAILTY INDEX FOR NHIS SURVEYS CONDUCTED BEFORE 2019

The Frailty Index was calculated using the following questions available in the Sample Adult files:

1. "Ever been told you have hypertension"
2. "Ever been told you had coronary heart disease"
3. "Ever been told you had angina pectoris"
4. "Ever been told you had a heart attack"
5. "Ever been told you had a heart condition/disease"
6. "Ever been told you had a stroke"
7. "Ever been told you had emphysema"
8. "Ever been told you had asthma"
9. "Ever been told you have an ulcer"
10. "Ever told by a doctor you had cancer"
11. "Ever been told that you have diabetes"
12. "Ever been told you had arthritis"
13. "Trouble hearing w/o hearing aid"
14. "Trouble seeing even w/glasses/lenses"
15. "Health worse compared w/ 12 months ago"
16. "Have health problem that requires special equipment"
17. "Difficult to walk 1/4 mile without special equipment"
18. "Difficult to climb 10 steps without special equipment"
19. "Difficult to stand 2 hours without special equipment"
20. "Difficult to sit 2 hours without special equipment"
21. "Difficult to stoop, bend or kneel without special equipment"
22. "Difficult to reach over head without special equipment"
23. "Difficult to grasp small objects without special equipment"
24. "Difficult to lift/carry 10 lbs without special equipment"
25. "Difficult to push large objects without special equipment"
26. "Difficult to go out to events without special equipment"
27. "Difficult to participate in social activities without special equipment"
28. "Difficult to relax at home without special equipment"
29. "Any functional limitation, all conditions"
30. "Vision/problem seeing causes difficulty with activity"
31. "Hearing problem causes difficulty with activity"
32. "Arthritis/rheumatism causes difficulty with activity"
33. "Back or neck problem causes difficulty with activity"
34. "Fracture, bone/joint injury causes difficulty with activity"
35. "Other injury causes difficulty with activity"
36. "Heart problem causes difficulty with activity"
37. "Stroke problem causes difficulty with activity"
38. "Hypertension/high blood pressure causes difficulty with activity"
39. "Diabetes causes difficulty with activity"
40. "Lung/breathing problem (e.g., asthma) causes difficulty with activity"
41. "Cancer causes difficulty with activity"
42. "Birth defect causes difficulty with activity"
43. "Intellectual disability, aka mental retardation causes difficulty with activity"
44. "Other developmental problem (eg, cerebral palsy) causes difficulty with activity"
45. "Senility causes difficulty with activity"

46. "Depression/anxiety/emotional problem causes difficulty with activity"
47. "Weight problem causes difficulty with activity"
48. "Missing or amputated limb/finger/digit causes difficulty with activity"
49. "Musculoskeletal/connective tissue problem causes difficulty with activity"
50. "Circulation problems (including blood clots) cause difficulty with activity"
51. "Endocrine/nutritional/metabolic problem causes difficulty with activity"
52. "Nervous system/sensory organ condition causes difficulty with activity"
53. "Digestive system problem causes difficulty with activity"
54. "Genitourinary system problem causes difficulty with activity"
55. "Skin/subcutaneous system problem causes difficulty with activity"
56. "Blood or blood-forming organ problem causes difficulty with activity"
57. "Benign tumor/cyst causes difficulty with activity"
58. "Alcohol/drug/substance abuse problem causes difficulty with activity"
59. "Other mental problem/add/bipolar/schizophrenia causes difficulty with activity"
60. "Surgical after-effects/medical treatment causes difficulty with activity"
61. "Old age/elderly/aging-related problem causes difficulty with activity"
62. "Fatigue/tiredness/weakness causes difficulty with activity"
63. "Other impairment/problem causes difficulty with activity"
64. Current smoker

B.4 SPECIFIC MEASURES OF HEALTH IMPAIRMENT

Specific measures of health impairment included measures of mental conditions, disability and chronic diseases. This selection of health measures was based on consensus among the Project Oversight Group experts who discussed this issue.

NHIS Surveys Conducted before 2019

(1) Mental conditions or limitations of activity caused by mental impairments.

These include positive response to at least one of the following questions: (a) “Is limited by difficulty remembering”; (b) “Intellectual disability, also known as mental retardation, causes difficulty with activity”; (c) “Senility causes difficulty with activity”; (d) “Depression/anxiety/emotional problem causes difficulty with activity”; (e) “Other mental problem/ADD/bipolar/schizophrenia causes difficulty with activity.” In this study we used mostly information on memory impairments, items a and c.

(2) Disability defined as any limitation of activity. These include problems with ADLs or IADLs and limitations caused by difficulty remembering. Thus, mental conditions causing limitation of activity are a part of the disability definition.

(3) Chronic diseases.

These include positive response to at least one of the following questions:

1. “Ever been told you have hypertension”
2. “Ever been told you had coronary heart disease”
3. “Ever been told you had angina pectoris”
4. “Ever been told you had a heart attack”
5. “Ever been told you had a heart condition/disease”
6. “Ever been told you had a stroke”
7. “Ever been told you had emphysema”
8. “Ever told by a doctor you had cancer”
9. “Ever been told that you have diabetes”

Surveys conducted in 2019–2021. The NHIS made significant changes in its questionnaire after 2019 questionnaire redesign so that definitions of mental conditions and disability in 2019 became incompatible with earlier NHIS questionnaires. The NHIS explains this step in the following way: “The content and structure of the NHIS were updated in 2019 to better meet the needs of data users. Aims of the questionnaire redesign were to improve the measurement of covered health topics, reduce respondent burden by shortening the length of the questionnaire, harmonize overlapping content with other federal health surveys, establish a long-term structure of ongoing and periodic topics, and incorporate advances in survey methodology and measurement.”

(1) Mental conditions.

These include positive response to at least one of the following questions:

(a) “Difficulty remembering/concentrating”; (b) “Ever had dementia”; (c) “Ever had anxiety disorder”; (d) “Ever had depression”; (e) “Currently receiving counseling/therapy from mental health professional.”

Memory impairments are defined as at least one positive response to the following two questions: (a) “Difficulty remembering/concentrating” and (b) “Ever had dementia.”

(2) Disability or any limitation of activity.

Disability is defined using the Washington Group Short Set Composite Disability Indicator. The Washington Group (WG) Short Set is a set of questions designed to identify people with functional limitations. The Washington Group Short Set on Functioning (WG-SS) was developed, tested and adopted by the Washington Group on Disability Statistics (WG). The questions reflect advances in the conceptualization of disability and use the World Health Organization’s International Classification of Functioning, Disability, and Health (ICF) as a conceptual framework. Information about WG-SS is available at <https://www.washingtongroup-disability.com/question-sets/wg-short-set-on-functioning-wg-ss/>.

(3) Chronic diseases.

These include positive response to at least one of the following eight questions:

1. “Ever been told you have hypertension”
2. “Ever been told you had coronary heart disease”
3. “Ever been told you had angina pectoris”
4. “Ever been told you had a heart attack”
5. “Ever been told you had COPD, emphysema, or chronic bronchitis”
6. “Ever been told you had a stroke”
7. “Ever told by a doctor you had cancer”
8. “Ever been told that you have diabetes”

B.5 LIST OF DEFICITS TO CALCULATE FRAILTY INDEX FOR THE NHIS CONDUCTED IN 2019–2021

The Frailty Index was calculated using the following questions and other information available in the Sample Adult files:

1. “Ever been told you had hypertension”
2. “Ever been told you had coronary heart disease”
3. “Ever been told you had angina”
4. “Ever been told you had a heart attack”
5. “Ever been told you had a stroke”
6. “Ever been told you had COPD, emphysema or chronic bronchitis”
7. “Ever had asthma”
8. “Ever been told you had cancer”
9. “Ever had diabetes”
10. “Ever had arthritis”
11. “Ever had dementia”
12. “Ever had anxiety disorder”
13. “Ever had depression”
14. Obesity
15. Poor or fair self-rated health
16. “Had pain most days or every day”
17. “Difficulty seeing”
18. “Difficulty hearing”
19. “Difficulty walking/steps”
20. “Use equipment to get around”
21. “Difficulty walking 100 yards”
22. “Difficulty walking 1/3 mile”
23. “Difficulty walking steps”
24. “Difficulty walking 100 yards without aid”
25. “Difficulty walking 1/3 mile without aid”
26. “Difficulty walking steps without equipment”
27. “Difficulty walking 100 yards with aid”
28. “Difficulty walking 1/3 mile with aid”
29. “Difficulty walking steps with equipment”
30. “Difficulty communicating”
31. “Difficulty remembering/concentrating”
32. “Difficulty with self-care”
33. “Difficulty raising soda bottle”
34. “Difficulty using hands and fingers”
35. The Washington Group Short Set Composite Disability Indicator
36. “Difficulty doing errands alone”
37. “Difficulty participating in social activities”
38. Current smoker

Appendix C: Period Life Tables

Study of unhealthy longevity in this project relies on information available in the period or cross-sectional life tables.

Life expectancy is one of the key measures of the health status of a population and can be defined as follows: “The average number of years a baby born in a particular status or population can be expected to live if it experiences the current age-specific mortality rates of that particular status or population throughout its life.” A life table can start not only at birth but at later ages as well. In this project period life tables were constructed starting at age 45 years.

The calculation of life expectancy requires the construction of a period or current life table, a table of information that breaks down the mortality experience of a population by age. These age-specific rates are typically applied to a hypothetical cohort of newborns to calculate their average expected life span or life expectancy. Life expectancy at other ages can be calculated in a similar way; for example, life expectancy at age 45 can be calculated by applying the current age-specific mortality rates over the age of 45 to a hypothetical cohort of 45-year-olds. The period life table is the most effective way of summarizing the current mortality experience of a population and can also be used to make statistical inferences and comparisons between the mortality experience of different populations.

The life table may be complete (or unabridged) or abridged. In complete life tables the mortality experience is broken down by individual years of life and occasionally even further, particularly for mortality under one year of age. In abridged life tables the mortality experience is broken down by larger age intervals, usually of five years, though with the general exception of the first few years of life, that is, ages under one and one to four years.

In this project abridged life tables were constructed for hypothetical population cohorts aged 45 years and older, because the number of deaths at ages below 45 was too small for making accurate and reasonable conclusions for younger ages.

Thus, the period life table is a model of mortality applied to a hypothetical population cohort having the current age-specific mortality rates of that particular status or population throughout its life. It gives a good “snapshot” of mortality at a particular moment (or period) of time.

For limitations of period life tables see Appendix E.

C.1 METHODOLOGY OF LIFE TABLE CONSTRUCTION

The size of a survey of any given population is generally relatively small (particularly when several subgroups are analyzed), so we constructed abridged life tables for our analyses of the NHIS. For life table construction we used the standard method described by Chiang (Chiang 1978, 1984).

Life table construction starts with calculating the age-specific death rates M_i :

$$M_i = \frac{D_i}{P_i}$$

where D_i is the number of deaths in age interval i and P_i is the corresponding midyear population for age interval i ; P_i is often called the *person-years of exposure* or *exposed population* for age interval i .

In the case of the NHIS, we made several modifications to the procedure of death rate estimation. The NHIS is conducted continuously at different months and quarters within each calendar year, so it is not feasible to define a midyear exposed population for death rate calculation. Instead, we used the following approach. First, we identified the number of respondents (N_i) whose ages at their last birthday at the time of their participation in the survey were

within age interval i . Then, for each deceased respondent within each such group of respondents, we calculated the elapsed time in quarters between the survey date and the date of death. Deaths that occurred during the first four quarters after the survey date were used in estimating death counts associated with age interval i , allowing for the expectation that about half of these deaths would occur in the calendar year following the assigned survey year. We calculated the age-specific death rates using the number of respondents (N_i) and death counts (D_i) during the survey year for each five-year age group as follows. Instead of defining the exposure, P_i , as a midyear population we estimated P_i using the well-known formula $P_i = N_i - D_i/2$ (Chiang 1978). With this procedure we then calculated the age-specific death rates, M_i , using the formula shown above.

Probabilities of dying during the age interval i were calculated using a standard formula (Chiang 1978):

$$q_i = \frac{n_i \cdot M_i}{1 + (1 - a_i) \cdot n_i \cdot M_i}$$

where n_i is the length of the interval (five years for abridged life table) and a_i is the fraction of life lived by those who died in the age interval (0.5 for adult ages). Then all functions of life table were calculated using standard formulas (Chiang 1978, 1984) described below. Chiang's method assumes a linear change in the number of survivors during the age interval.

The *probability of dying* was calculated from the observed annual age-specific mortality rate using the linear method; that is, it was assumed that deaths are distributed evenly over the age interval. At the last age interval ω :

$$q_\omega = 1.$$

Below we give the main functions of period life table for a hypothetical (or synthetic) cohort.

Probability of surviving interval i , p_i :

$$p_i = 1 - q_i.$$

$p_\omega = 0$: All those surviving to the start of the final age interval die during the final age interval.

Number alive (number of survivors) at start of interval i , l_i :

$$l_i = l_{i-1} p_{i-1}.$$

It is common practice to start with a hypothetical cohort of size 100,000. So $l_0 = 100,000$.

Number dying in interval i , d_i :

$$d_i = l_i - l_{i+1}$$

$$d_\omega = l_\omega.$$

All those surviving to the start of the final age interval die during the final age interval.

Person-years lived in interval i , L_i :

$$L_i = n_i l_{i+1} + n_i a_i d_i.$$

Person-years lived in the last age interval, L_ω , are estimated as

$$L_{\omega} = l_{\omega}/M_{\omega}.$$

Survival in the final age interval is assumed to be exponential. The number of years lived is given by the number of survivors at the start of the age interval divided by the observed annual age-specific mortality rate.

Person-years lived beyond start of interval i , T_i :

$$T_i = \sum L_j, \text{ where } j = i \text{ to } \omega.$$

Summation is made from the last age group (85 and above in our case) to the initial age (45 in our case).

Observed expectation of life at start of interval i (life expectancy), e_i :

$$e_i = T_i/l_i.$$

The life expectancy at the start of an age interval is the total number of years lived beyond the start of the interval divided by the number alive at the start of the interval.

Variance of Life Expectancy

First, sample variance of probability of surviving in interval (probability of dying) is calculated.

Assuming that observed deaths are binomially distributed, the variance of probability of surviving in an interval is given by the formula

$$S^2_{p(i)} = q^2 p_j / D_j.$$

The variance of the observed annual age-specific mortality rate for the final age interval is

$$S^2_{M(\omega)} = M_{\omega} (1 - M_{\omega}) / P_{\omega}.$$

The variance of the total number of years lived by the cohort is the sum of weighted variances:

$$S^2_{T(i)} = \sum l_j^2 [e_{j+1} + (1 - a_j) n_j]^2 S^2_{p(j)}, \text{ for } j = i \text{ to } \omega - 1.$$

The variance of the total number of years lived by the cohort is the sum of the weighted variances of the proportions surviving each age interval.

In the final age interval the variance of the number of years lived depends not on the variance of the proportion surviving the age interval but on the variance of the observed annual age-specific mortality rate. For the last age interval the variance of the number of years lived is calculated according to Silcock's method (Silcocks, Jenner and Reza 2001) as

$$S^2_{T(\omega)} = (l_{\omega}^2 / M_{\omega}^4) S^2_{M(\omega)}.$$

Variance of e_i is calculated using the formula

$$S^2_{e(i)} = S^2_{T(i)} / l_i^2.$$

In the final age interval, the variance of the number of years lived depends not on the variance of the proportion surviving the age interval but on the variance of the observed annual age-specific mortality rate.

Assuming that the estimates of life expectancy are normally distributed, the 95% confidence limits are given by the formula

$$e_i \pm 1.96 S_{e(i)}$$

where $S_{e(i)}$ is the standard error of e_i (square root of the variance for e_i).

The methodology used in this project, along with the findings into the available options for life expectancy calculation for small areas, has been described in full in Eayres and Williams (2004). It is also available in the SEPHO life expectancy calculator (Eayres 2017).

C.2 NOTES ON LIFE TABLE CONSTRUCTION FOR SMALL POPULATIONS

Although the NHIS has a large sample size, life table construction for sex-health subgroups may encounter difficulties caused by a small population size. The problem of life table construction has received sufficient attention from researchers over the last 20 years (Silcocks, et al. 2001, Silcocks 2004, Williams, Dinsdale, Eayres and Tahzib 2005, Arias, et al. 2018). In most cases life tables have been constructed for small geographic areas, and life expectancy at birth was the main indicator of interest.

Life expectancy at birth is an appropriate indicator of mortality, which is widely used in assessing regional differences in population health. Calculating life expectancy at birth and at subsequent ages requires the construction of a life table. The main problem in constructing a life table for small groups is the small size of the population. The small population size also means a small number of deaths and, in some cases, zero events in the age interval under study when estimating age-specific death rates. Methodological studies based on Monte Carlo simulations have shown that (a) life expectancy is overestimated as population size decreases; (b) standard errors for life expectancy are inversely proportional to population size; (c) life expectancy and its standard error are normally distributed for relatively large populations but show marked asymmetry as population size decreases; and (d) robust mortality tables and reliable estimates of life expectancy can be obtained with reasonable certainty for populations of at least 5,000, in which case a correction for zero values of age-specific mortality rates is not necessary except in the last open interval, where zero or very low mortality is replaced by the national mean (Silcocks, et al. 2001, Eayres, et al. 2004, Silcocks 2004, Williams, et al. 2005).

The recommendations developed by British statisticians (Office of National Statistics) can be summarized as follows (Williams, Scott and Scott 1995, Williams, et al. 2005):

- It is not recommended to calculate life expectancy for populations with fewer than 5,000 person-years at risk.
- Life expectancy and its standard error should be calculated from a summary life table with five-year age intervals (0, 1–4, 5–9,...) and the last interval of 85 and more years, using the Chiang-adjusted methodology.
- If in the last age interval 85 and above a zero number of deaths is found, then use the corresponding national average of the mortality rate.
- If null deaths occur in age intervals other than 85 and above, these nulls should not be adjusted or replaced by other figures.

In this project we adopted the methodology of life table construction developed by the South East Public Health Observatory (SEPHO), which takes into account recommendations of British statisticians (Eayres 2017).

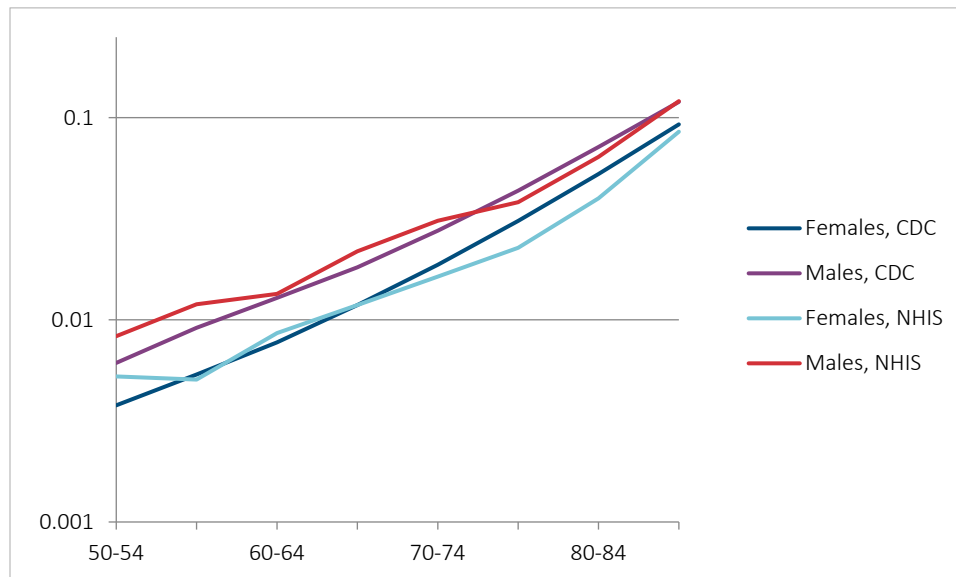
C.3 VALIDATION OF LIFE TABLE CONSTRUCTION METHOD

To provide an external validation of our approach to the period life table construction, we have conducted a comparison of age-specific death rates obtained with survey data with official death rates for the same years. Our working sample of the NHIS combined five calendar survey years to increase the sample size, so we used survey data for 2010–2014.

Figure C.1 shows mortality on a log scale for males and females based on official Centers for Disease Control (CDC) data (taken from the Human Mortality Database) and on NHIS data for ages over 50 years where most deaths occur. Note that the NHIS underestimates mortality after age 75 compared to the official data. This problem may be related to the fact that the NHIS surveys only noninstitutionalized respondents. It is known that the percentage of people in nursing homes rapidly increases after age 80 (Decker 2005).

Figure C.1

MORTALITY (LOG SCALE) AFTER AGE 50 FOR MALES AND FEMALES IN 2010–2014
ACCORDING TO THE OFFICIAL CDC DATA AND ESTIMATES BASED ON THE NHIS DATA, CDC
DATA TAKEN FROM THE HUMAN MORTALITY DATABASE



Thus, the official mortality age trajectories are steeper compared to mortality based on the survey data. Still, we believe that the agreement in mortality between the official data and the survey data is satisfactory and allows us to provide representative estimates of mortality for U.S. healthy and unhealthy individuals aged 45–49 years and older. With the exception of very old ages, NHIS data show good agreement with the official CDC data.

Estimates of life expectancy at age 45 years for males and females for all NHIS respondents in 2010–2014 (34.07 and 40.99) are close to the official estimates by the CDC, 34.14 and 37.88. The lower official estimate of life expectancy for females may be related to the absence of institutionalized respondents in the NHIS taking into account that the prevalence of females in nursing home facilities is significantly higher than that of males (Gurwitz 2005).

C.4 DECOMPOSITION METHOD OF LIFE EXPECTANCY

According to the method proposed by Arriaga (1984), the cumulative effect of differences in mortality in the age group $(x, x+n)$ on life expectancy at birth is (Preston, Heuveline and Guillot 2001)

$$\Delta_x = \frac{l_x^1}{l_0^1} \cdot \left[\frac{L_x^2}{l_x^2} - \frac{L_x^1}{l_x^1} \right] + \frac{T_{x+n}^2}{l_0^1} \cdot \left[\frac{l_x^1}{l_x^2} - \frac{l_{x+n}^1}{l_{x+n}^2} \right]$$

Where l_x, L_x, T_x are standard values from the life table, and indices 1 and 2 correspond to population 1 and population 2, respectively (that is, the two populations being compared) rather than to an exponent. The first term in the above equation corresponds to the direct effect of changes in mortality in the age group $(x, x+n)$, that is, the effect on life expectancy that arises from changes in the number of person-years lived in the interval $(x, x+n)$. The second term of the equation corresponds to the sum of indirect and interaction effects, that is, the fact that the additional numbers of people living to age $x+n$ are exposed to the risk of new mortality conditions.

For the last open age interval, only one direct effect is calculated by the formula

$$\Delta_\omega = \frac{l_\omega^1}{l_0^1} \cdot \left[\frac{T_\omega^2}{l_\omega^2} - \frac{T_\omega^1}{l_\omega^1} \right]$$

It can be shown that

$$e_0^1 - e_0^2 = \sum_0^\infty \Delta_x$$

The above equations correspond to the contribution of different age groups to the differences between values of life expectancy at birth. In principle, the same equations can be used to estimate the contribution of age groups to the differences between life expectancy at any age a if we replace l_0 with l_a in the above formulas. In our case the initial age is equal to 45 years.

The method of age decomposition of differences in life expectancy can be extended to decompose the contribution of individual causes of death to observed differences in life expectancy. The basic assumption in using this decomposition method is the assumption that the distribution of causes of death is constant over a given age interval. Given this assumption, the contribution of differences in total all-cause mortality in a given age group can be proportionally distributed among the differences in mortality by cause in a given age group. Thus, the specific contribution to the differences in mortality from cause i in age group $(x, x+n)$ can be determined using the following equation:

$$\begin{aligned} \Delta_x^i &= \Delta_x \cdot \frac{m_x^{i(2)} - m_x^{i(1)}}{m_x^{(2)} - m_x^{(1)}} \\ &= \Delta_x \cdot \frac{R_x^{i(2)} \cdot m_x^{(2)} - R_x^{i(1)} \cdot m_x^{(1)}}{m_x^{(2)} - m_x^{(1)}} \end{aligned}$$

Where R_x^i denotes the proportion of deaths from cause i in the age interval $(x, x+n)$, that is, D_x^i/D_x . In this case, D_x^i corresponds to the observed number of deaths from cause i in the age interval $(x, x+n)$, and D_x is the corresponding number of deaths from all causes. Indices (1) and (2) correspond to the compared populations. The values of m_x correspond to the tabulated all-cause mortality rates, which can be obtained from the usual life table, because $m_x = d_x/L_x$. In this formula, the value of Δ_x corresponds to the contribution of differences in all-cause mortality in the age interval $(x, x+n)$ to the observed differences in life expectancy. It can be shown that

$$\Delta_x = \sum_i \Delta_x^i$$

Appendix D: Life Tables Excel File

Users interested in exploring the results in more detail (or recreating the figures) can find the mortality and life expectancy estimates in an Excel file (Appendix D_Unhealthy_Longevity_LT.xlsx) available to download where this report is published. Period life tables were calculated using the methodology described in Appendix C.1. Life tables were constructed for all five measures of health as well as for multimorbidity cases (total of 72 life tables). Life tables start at age 45 years, and the last age interval is 85 and older years.

Table D1 gives the calculated life tables.

Table D1

LIST OF PERIOD LIFE TABLES IN THE EXCEL FILE

Life Table Name	Worksheet Name
Total population (all respondents) in 2010–2014, by sex	Lifetable_t1
Total population (all respondents) in 2015–2018, by sex	Lifetable_t2
Self-rated health, by health status (healthy/unhealthy) and sex, 2010–2014	Lifetable_1
Frailty Index, by health status (FI<0.2/FI≥0.2) and sex, 2010–2014	Lifetable_2
Mental conditions, by health status (no mental conditions/mental conditions) and sex, 2010–2014	Lifetable_3
Memory impairments, by health status (no memory impairments/memory impairments) and sex, 2010–2014	Lifetable_4
Other mental conditions, by health status (no other mental conditions/other mental conditions) and sex, 2010–2014	Lifetable_5
Disability, by health status (no disability/disability) and sex, 2010–2014	Lifetable_6
Chronic diseases, by health status (no chronic diseases/chronic diseases) and sex, 2010–2014	Lifetable_7
Multimorbidity for one disease, two diseases, three or more diseases, by sex, 2010–2014	Lifetable_8
Self-rated health, by health status (healthy/unhealthy) and sex, 2015–2018	Lifetable_9
Frailty Index, by health status (FI<0.2/FI ≥ 0.2) and sex, 2015–2018	Lifetable_10
Mental conditions, by health status (no mental conditions/mental conditions) and sex, 2015–2018	Lifetable_11
Memory impairments, by health status (no memory problems/memory problems) and sex, 2015–2018	Lifetable_12
Other mental conditions, by health status (no other mental conditions/other mental conditions) and sex, 2015–2018	Lifetable_13
Disability, by health status (no disability/disability) and sex, 2015–2018	Lifetable_14
Chronic diseases, by health status (no chronic diseases/chronic diseases) and sex, 2015–2018	Lifetable_15
Multimorbidity for one disease, two diseases, three or more diseases, by sex, 2015–2018	Lifetable_16

Appendix E: Limitations

The study of unhealthy longevity in this project relies on information available in the period or cross-sectional life tables with data taken from the National Health Interview Survey (NHIS).

Limitations of data source. The NHIS is a cross-sectional health interview survey rather than a longitudinal study when individual characteristics are followed over time. It gives only limited opportunities for cohort analysis providing linked mortality information for survey respondents.

Another limitation of the NHIS is the collection of health information based on self-reports rather than objective evaluation by physician. This is a common limitation for many surveys, although in some studies such as NHANES data are collected in a laboratory. This is a trade-off between obtaining objective health information and obtaining a nationally representative very large population sample.

Finally, the NHIS does not survey institutionalized persons. This may result in underestimation of mortality after age 80, particularly for females, because females are much more prevalent in nursing homes (Gurwitz 2005).

Limitations of used health measures. No gold standard exists for measuring unhealthiness, so the selection of measures was based on the existing scientific literature on the topic and judgment of experts in the field. Some measures have obvious limitations. For example, in the case of self-rated health it is difficult to interpret the meaning of this measure, and it may be very subjective. On the other hand, the mortality of unhealthy persons according to self-reported health is close to the mortality of unhealthy persons based on a much more sophisticated health measure (Frailty Index). Measures of three more specific health conditions (mental conditions, disability and chronic diseases) heavily depend on the specific questions offered by the NHIS.

Limitations of period life tables. In this project we constructed period life tables of healthy and unhealthy subpopulations to obtain age-specific mortality risks by health status and calculated life expectancy with corresponding 95% confidence intervals at different ages. A period life table is a snapshot of a population's mortality experience at a point in time. A major limitation of period life tables is that estimated mortality risk at different ages basically comes from different cohorts with different mortality experiences. Thus, period life tables represent a model of survival for a hypothetical rather than a real cohort.

Some researchers are particularly critical of period life tables constructed for health-related characteristics compared to invariable traits such as sex. For example, Perron et al. (Perron, Simard, Brisson, Hamel and Lo 2017) outline two primary limitations of the period life table approach: it does not take into account transitions between healthy and unhealthy statuses, and it cannot control for changes in mortality risk that occur over the life course for most chronic conditions. Guillot (Guillot 2011) called these limitations, respectively, heterogeneity bias and cohort influence bias, which complicates the interpretation of life expectancy levels and trends compared with life expectancy based on cohort observation.

At the same time, other researchers consider period life tables useful because they can summarize the mortality experience of different subpopulations over time using more timely mortality information (Steensma, et al. 2018). For this reason, period life tables are widely used by the scientific community and the general public. These authors suggest some approaches to minimize potential biases arising from the use of this method. To minimize heterogeneity bias, they suggest constructing multistate life tables, but the NHIS does not have sufficient information for constructing multistate life tables. Steensma and colleagues have substantial experience constructing period life tables for certain health conditions of the Canadian population. They believe, based on their experience, that any theoretical biases in period life expectancy measures are minimal (Steensma, et al. 2018).

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