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Frailty Trajectories in an Elderly Population-Based Cohort

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Abstract

BACKGROUND/OBJECTIVES—Little is known about longitudinal changes in frailty and how these changes impact adverse outcomes in elderly patients. Thus, we identified distinct frailty trajectories (clusters of individuals following a similar progression of frailty over time) in an aging population and estimated associations between frailty trajectories and emergency department visits, hospitalizations, and all-cause mortality.

DESIGN—Population-based cohort study

SETTING—Olmsted County, Minnesota

PARTICIPANTS—Olmsted County, Minnesota residents aged 60–89 in 2005

MEASUREMENTS—Longitudinal changes in frailty between 2005 and 2012 were measured by constructing a yearly Rockwood frailty index incorporating body mass index, 17 comorbidities, and 14 activities of daily living. The frailty index measures variation in health status as the proportion of deficits present among the 32 considered (range: 0–1).

RESULTS—Among the 16,443 Olmsted County residents aged 60–89 in 2005, 12,270 (74.6%) had at least 3 years of frailty index measures and were retained for analysis. The median baseline

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frailty index increased with older age: 0.11 for 60–69 year olds, 0.14 for 70–79 year olds, and 0.19 for 80–89 year olds. Among those 60–69 years of age at baseline, 3 distinct frailty trajectories were identified, whereas 2 trajectories were identified for the 70–79 and 80–89 year olds. Within each decade of age, increasing frailty trajectories were associated with increased risks of emergency department visits, hospitalizations, and all-cause mortality, even after adjustment for baseline frailty index.

CONCLUSION—The number of frailty trajectories differed by age. Within each age group, those in the highest frailty trajectory experienced greater healthcare utilization and worse survival. Frailty trajectories may offer a way to target aging individuals at higher risk of hospitalization or death for therapeutic or preventive interventions.

Keywords

frailty; aging; longitudinal studies; population research

INTRODUCTION

As the population ages, it is expected that the number of elderly individuals in the US will double by the year 2050, representing 20% of the total population.[1] Along with improved survival and increased life expectancies, increased expenditures and utilization of healthcare resources are imminent effects of the aging population.[2] Thus, it is important to measure changes in health status as people age and to understand the impact of these changes on adverse outcomes in the population.

Although health generally declines with increasing age, there is variability across individuals in health status at any given age.[3] This variation in health status can be measured using different methods, including measures of frailty. Frailty is a clinically recognized syndrome characterized by age-associated declines in physiologic reserve and function across multiple organ systems,[4–7] and is a major concern for aging populations because it has been shown to predict adverse outcomes, including hospitalizations, admission to long-term care institutions, and death.[6, 8]

Despite multiple studies demonstrating the utility of frailty measures at a single point in time to predict death,[9–16] sparse data exist regarding the impact of longitudinal changes in frailty on adverse outcomes. In a study of elderly individuals in the Rush Memory and Aging Project, both baseline frailty and longitudinal change in frailty were independently associated with the risk of all-cause mortality.[9] This study, which constructed a continuous composite measure of frailty based on a modification of a commonly used frailty phenotype, observed a 25% increased risk of death for those in the 75th percentile of change in frailty compared to those in the 25th percentile. However, this study did not assess differences between patients in the rate of frailty progression over time or the impact of frailty on other important adverse outcomes, such as healthcare utilization. Therefore, we aimed to identify distinct frailty trajectories (clusters of individuals following a similar progression of frailty over time) in an elderly population and to estimate associations between frailty trajectories and emergency department (ED) visits, hospitalizations and all-cause mortality.

METHODS

Study Population

This study was conducted using the 2005 population of Olmsted County, Minnesota aged 60–89 (n=16,443). Data were obtained from the Rochester Epidemiology Project (REP), a records-linkage system allowing virtually complete capture of health care utilization and outcomes in county residents.[17–20] The retrieval of nearly all health care related events occurring in Olmsted County is possible because this area is relatively isolated from other urban centers, and only a few providers deliver most health care to local residents. Demographic and ethnic characteristics of Olmsted County, Minnesota are representative of the state of Minnesota and the Midwest region of the US.[18] Furthermore, broad disease trends and age- and sex-specific mortality rates in Olmsted County are similar to national data.[18] This study was approved by the Mayo Clinic and Olmsted Medical Center Institutional Review Boards.

Calculation of the Frailty Index

The Rockwood frailty index measures variation in health status based on an accumulation of deficits (impairments, disabilities, diseases) by quantifying the amount of frailty in a given individual as the proportion of deficits present in that individual.[21, 22] This index has been shown to correlate and predict death equally well[23, 24] or more precisely[21, 25] than the biological phenotype of frailty, which is comprised of five physical indicators: low physical activity, weak grip strength, slow walking speed, exhaustion, and unintentional weight loss.[10] As the Rockwood frailty index performs well at predicting death and can be constructed using deficits available in the electronic medical record,[22] the frailty index is particularly useful for studying frailty in large populations.

We constructed a frailty index in 2005 using 32 deficits found in the electronic medical record: body mass index (BMI), 17 comorbidities, and 14 activities of daily living (ADLs; Table 1). The 17 comorbidities were chosen from a list of 20 chronic conditions identified by the US Department of Health and Human Services (US-DHHS).[26, 27] Less than 1% of the population had autism, hepatitis, or human immunodeficiency virus; thus, these conditions were excluded. Two occurrences of a code (either the same code or two different codes within the code set for a given disease) separated by more than 30 days and occurring between 2000 and 2005 were required for diagnosis. More extensive details about the definition of these conditions were reported elsewhere.[28] The 14 ADLs were self-reported and obtained from a questionnaire administered on at least a yearly basis to patients seen at one of the institutions. BMI was available electronically from one of the institutions.

All variables in the index were given 1 point when present and 0 points when not present, with the exception of BMI (18.5 to <25, 0 points; 25 to <30, 0.5 points; <18.5 or ≥30, 1 point) and the ADL, climbing 2 flights of stairs without rest (yes, with no difficulty, 0 points; yes, with difficulty, 0.5 points; no, 1 point). The frailty index was calculated as the cumulative points divided by 32 (range of 0–1). If 3 or fewer items were missing, the frailty index was calculated adjusting the denominator accordingly. However, a frailty index was not calculated when more than 3 items were missing. Repeated measures of frailty index

were calculated for each year through 2012 (one index per year), using the following rules: 1) once a given comorbidity was present, it was carried forward for subsequent years, 2) if multiple questionnaires were obtained in a calendar year, the questionnaire with the least number of missing questions was used, 3) if multiple, complete questionnaires were obtained in a year, the scores were averaged across the complete questionnaires, and 4) missing BMI values between the first and last available BMI were linearly interpolated. For each patient, the year of first available frailty index was considered the baseline frailty index measure.

Outcomes Ascertainment

Hospitalizations, ED visits, and deaths from any cause were obtained from January 1, 2005 through December 31, 2012. ED visits that resulted in a hospitalization were counted as both an ED visit and a hospitalization. In addition, in-hospital transfers or transfers between hospitals were counted as a single hospitalization.

Statistical Analysis

Analyses were performed using SAS statistical software, version 9.3 (SAS Institute Inc., Cary, NC) and R, version 3.0.2 (R Foundation for Statistical Computing, Vienna, Austria). Patients with at least 3 years of frailty measures were retained for analysis (n=12,270). Cohort characteristics at baseline were calculated as frequencies. K means cluster modeling for longitudinal data, a non-parametric hill-climbing algorithm, was used to identify distinct, homogenous clusters of frailty index trajectories within each decade of age group (60–69 years, 70–79 years, and 80–89 years).[29] Data were partitioned into homogenous subgroups and a mean trajectory was plotted to summarize the overall longitudinal change for each cluster. The optimum number of clusters in each age group was determined using the Calinksi and Harabatz criterion.[29] Results were similar for both sexes; therefore, men and women were pooled for the analyses.

Within each decade of age, logistic regression was used to determine the associations of frailty trajectories with all-cause mortality (obtained over the same time frame as the frailty trajectories) after adjustment for individual age, sex, and baseline frailty index. Negative binomial regression was used to determine the associations of frailty trajectories with number of ED visits and hospitalizations occurring in the same time period. Multivariable models were used to adjust for individual age, sex, and baseline frailty index. Finally, all age and trajectory groups were combined and additional models with the 60–69 lowest trajectory as the referent group were used to compare age and frailty trajectory associations with mortality, hospitalizations and ED visits.

RESULTS

Among the 16,443 residents of Olmsted County, MN aged 60–89 in 2005, 12,270 (74.6%) had at least 3 years of frailty measures over the 8 years of the study. The demographics for those with at least 3 years of frailty measures were similar to the entire population (median age: 70.2 vs. 70.5; male: 44.5% vs. 45.0%; non-White race: 3.7% vs 5.0% for those with 3 or more years of frailty compared to the entire population, respectively). Of the 12,270

patients with at least 3 years of frailty, 49.3% were aged 60–69 and 15.6% were aged 80–89 (Table 1). The most common comorbidity present at baseline was hypertension (76%), whereas the least common were schizophrenia and substance abuse disorders (3% each). In addition, nearly 15% needed help climbing stairs, but less than 1% needed help feeding themselves.

The median baseline frailty index increased with older age: 0.11 for 60–69 year olds, 0.14 for 70–79 year olds, and 0.19 for 80–89 year olds. This equates to 1 extra deficit (comorbidity, ADL, or change in BMI) for the 70–79 year olds and 2.5 extra deficits for the 80–89 year olds compared to the 60–69 year olds at baseline. Three distinct frailty trajectories were identified in the 60–69 year olds, whereas 2 trajectories were identified for the 70–79 and 80–89 year olds (Figure 1). Over 8 years, the mean frailty index increased in all trajectories for all age groups. In addition, results were nearly identical between men and women in the same age group. For example, in the 70–79 year olds, the mean frailty index increased from 0.11 to 0.20 for both men and women in the lowest trajectory; this equates to an accumulation of 3 deficits over the 8 years of follow-up. In the highest trajectory, the mean frailty increased from 0.23 to 0.40 in men and 0.25 to 0.41 in women, or approximately 5 additional deficits accumulated over follow-up. Among the 80–89 year olds, the mean frailty increased from 0.14 to 0.25 in men and 0.13 to 0.26 in women in the lowest trajectory (4 additional deficits) and 0.28 to 0.51 in men and 0.28 to 0.48 in women in the highest trajectory (7 additional deficits).

The prevalence of each deficit at baseline and last follow-up among those in the highest trajectory in each age group is presented in Supplemental Table 1. At baseline, the prevalence of obesity was high in the 60–69 and 70–79 year olds and the prevalence of dementia, stroke, and most of the ADLs were much higher in the 80–89 year olds compared to the younger age groups. The cardiovascular comorbidities, with the exception of heart failure and stroke, as well as diabetes and arthritis, were the most common comorbidities and needing help climbing stairs, walking, and depending on assistive devices or other people to perform ADLs were the most common ADLs at baseline. For all age groups, the prevalence of nearly every deficit increased between baseline and last follow-up, with many comorbidities doubling in prevalence over time. In general, the 80–89 year olds experienced the largest increase in prevalence of the ADLs over follow-up.

A total of 36,293 ED visits, 22,709 hospitalizations, and 1,770 deaths were observed over 8 years. Within each decade of age (at baseline), the rates of ED visits and hospitalizations, as well as the proportion of patients who died over follow-up, increased with increasing frailty trajectory (Table 2). Among 60–69 year olds at baseline (2005), 2%, 6%, and 25% in the lowest, middle, and highest trajectory had died by the end of 2012. In the lowest and highest trajectories, respectively, 7% and 31% died among the 70–79 year olds, while 24% and 57% died among the 80–89 year olds.

After adjustment for baseline age, sex, and baseline frailty index, increasing frailty trajectories were associated with an increased odds of death and increased rates of ED visits and hospitalizations for each age group (Table 3). Compared to those in the lowest trajectory, a 2.1-fold (rate ratio (RR) 2.11, 95% confidence interval (CI) 1.92–2.32) and 6.1-

fold (RR 6.09, 95% CI 5.14–7.21) increased rate of hospitalizations were observed in the middle and highest trajectory in the 60–69 year olds. 70–79 year olds in the highest trajectory had a 2.6-fold (RR 2.55, 95% CI 2.31–2.80) increased risk, and 80–89 year olds in the highest trajectory had a 2.1-fold (RR 2.10, 95% CI 1.87–2.35) increased risk compared to those in the lowest trajectory for each age group. The associations for ED visits were similar to the hospitalization results for all comparisons. In contrast, the associations for all-cause mortality were generally higher, with a 3.0-fold (odds ratio (OR) 2.96, 95% CI 2.19–4.01) and 15.3-fold (OR 15.26, 95% CI 10.06–23.14) increase in odds of death among the middle and highest trajectory compared to the lowest trajectory in the 60–69 year olds. An approximately 4-fold increased odds of all-cause mortality was observed for those in the highest trajectory for both the 70–79 (OR 3.77, 95% CI 3.04–4.69) and 80–89 year olds (OR 4.00, 95% CI 3.07–5.21).

In an attempt to better discern the roles of age and frailty trajectories on the risk of adverse outcomes, we repeated the analyses using the 60–69 year olds in the lowest trajectory as the reference group for all comparisons (Table 4). Older age is strongly associated with all-cause mortality, but is less influential on the risk of hospitalizations and ED visits. In unadjusted models, the risks of all-cause mortality increased dramatically with age and were only slightly attenuated after adjustment for sex and baseline frailty index. After adjustment for age, sex, and baseline frailty index, the 60–69 year olds in the middle trajectory (OR 2.49, 95% CI 1.80–3.44) exhibited a similar risk of death as the 80–89 year olds in the lowest trajectory (OR 2.74, 95% CI 1.67–4.49). Finally, those in the highest trajectories exhibited similar risks of all-cause mortality (ORs 10.06 (7.04–14.38), 6.33 (4.27–9.36), and 8.44 (5.02–14.21) in the 60–69, 70–79, and 80–89 year olds, respectively). In contrast, in unadjusted models, the risks of hospitalizations and ED visits were similar for the middle trajectory of the 60–69 year olds and the lowest trajectories of the 70–79 and 80–89 year olds; a similar risk was also observed for the highest trajectories of all age groups. The same patterns were observed after adjustment for age, sex, and baseline frailty index, and the rate ratios were only slightly attenuated after adjustment.

DISCUSSION

Our population-based study provides important data on the number and pattern of distinct frailty trajectories by age using a measure of frailty that takes advantage of longitudinal data accessible through the electronic medical record. The novel methodology allowed us to study changes of frailty in the population over 8 years of follow-up and to identify differences in the number of distinct frailty trajectories (clusters of individuals following a similar progression of frailty over time) by age. We found that the youngest age group (60–69 year olds) had 3 distinct frailty trajectories, whereas 2 trajectories were apparent in the oldest groups. Among individuals in the highest frailty trajectories, cardiovascular comorbidities and arthritis were most commonly present. Additionally, the prevalence of the comorbidities and ADLs increased over follow-up in all age groups; however, the 80–89 year olds experienced the largest increase in prevalence of the ADLs over follow-up. Finally, we assessed the association of the frailty trajectories with adverse outcomes including ED visits, hospitalizations, and all-cause mortality and found that for all age

groups, higher frailty trajectories were associated with increased rates of ED visits, hospitalizations, and deaths.

Associations of Frailty with Age and Sex

Our population-based study found differences in frailty by age but no differences were observed between men and women of the same decade of age. The observation that frailty increases with age is well established;[30] however, our study has provided information that greater variability in frailty exists at younger ages, with 3 different frailty trajectories identified in the 60–69 year olds and 2 trajectories identified in the 70–79 and 80–89 year olds.

Our study finding that no differences were observed by sex contradicts previous reports of increased levels of frailty in women compared to men. Among 11 studies reporting sex-specific prevalence estimates of frailty identified in a systematic review, the weighted average prevalence of frailty was higher in women (9.6%) compared to men (5.2%).[30] However, none of these 11 studies used the Rockwood index to define frailty, which may partly explain the inconsistency with the results of our study. The majority of the aforementioned studies used the frailty phenotype developed by Fried and colleagues, which defines frailty based on the following 5 variables: low physical activity, weak grip strength, slow walking speed, exhaustion, and unintentional weight loss.[10] However, a study assessing longitudinal changes of the Rockwood frailty index in 4 birth cohorts from the Health and Retirement Survey found that women, on average, have higher levels of frailty than men, but that the rates of change over time did not differ between men and women except for the youngest birth cohort (aged 49–64 years) where women had faster rates of change compared to men.[31] This is consistent with results from our population-based study of individuals 60 years of age or older at baseline which found the number and pattern of frailty trajectories is similar across sex indicating that men and women accumulate deficits (increase frailty) at a similar rate.

Associations of Frailty with Adverse Outcomes

Frailty is associated with increased risks of falls, hospitalizations, admission to skilled nursing facilities, and death.[6, 8] However, few studies have assessed changes in frailty over time and the associations of these changes with adverse outcomes. Results over a 12-year period from the Canadian National Population Health Survey indicated that those who were fittest at baseline tended to remain healthy, and those who were most frail at baseline were the most likely to die and used more health care services.[3] This report did not assess the progression of frailty within individuals over time and how this change over time impacted outcomes. In a study of 832 elderly individuals, a continuous composite measure of frailty was developed using a modified Fried frailty phenotype and measured annually for up to 8 years.[9] Baseline frailty and annual change in frailty were independently associated with the risk of death and those in the 75th percentile of change in frailty exhibited a 25% increased risk of death compared to those in the 25th percentile of change in frailty.

Our study expands the work of these previous studies by grouping individuals according to similar progression of frailty over time (frailty trajectories) and assessing the association of

these frailty trajectories with adverse outcomes. We found that those in the highest frailty trajectory in each age group experienced higher rates of ED visits, hospitalizations, and all-cause mortality compared to similar aged individuals in lower frailty trajectories. Furthermore, we observed that older age is highly influential on the risk of all-cause mortality, but not for hospitalizations and ED visits. Importantly, after age and baseline frailty index is taken into account, the trajectories of frailty are significantly associated with these adverse outcomes, with the highest trajectories in all age groups similarly associated with the greatest risks of all-cause mortality, hospitalizations, and ED visits.

Limitations, Strengths, and Implications

There are many different ways to measure frailty, with more than 20 different definitions in the literature,[4, 32] and our results may have differed if a different method of measuring frailty was employed. There is a growing consensus that, although there is some overlap between comorbidity, disability, and frailty, that frailty is a distinct clinical entity.[33] Nevertheless, although measures of frailty that incorporate physical assessments, such as the Fried biological phenotype,[10] may be considered the gold standard, a distinct advantage of the Rockwood frailty index is that it can be tailored to the information available in the medical record and does not require physical assessments or administration of standardized questionnaires. In addition, the frailty index has been shown to predict death more precisely than the frailty phenotype in some studies.[21, 25] Furthermore, frailty is a dynamic process and represents a continuum rather than a distinctly defined cutpoint,[4, 34, 35] which adds to the utility of using the frailty index to capture changes in frailty over time. Second, some potentially useful data for the frailty index, such as self-reported measures of general health, or additional geriatric conditions that may contribute to frailty were not available in the electronic medical record and were not included in the calculation of the frailty index. However, the frailty index is optimized when 30–40 different variables are used;[22] thus, adding extra variables beyond the 32 included in our index may not have added any benefit. Third, we required at least 3 years of frailty index in order to calculate the trajectories, which resulted in deleting approximately one-quarter of the population aged 60–89 from our analyses, 17% of whom had died within 3 years. Those included were similar with respect to demographics compared to the entire elderly population of Olmsted County. However, the baseline frailty index was higher for those excluded in the 70–79 and 80–89 year olds compared to those with at least 3 years of frailty index. This suggests that differences observed between frailty trajectories may have been larger if these individuals could have been included in the analysis.

Our study has many strengths, including the population-based setting, the large number of elderly individuals included, and the capture of longitudinal changes of frailty within this population over an 8 year period. In addition, we have provided evidence of the utility of electronic data sources to define frailty in elderly populations.

These findings have important implications in light of the observation that frailty is a dynamic condition and can be improved. Indeed, evidence from randomized controlled trials indicate that exercise and dietary interventions improve fitness in pre-frail and frail individuals.[36] Furthermore, our observation that the prevalence of comorbidities increases

dramatically over time for individuals in the highest frailty trajectory in all age groups, underscores the importance of managing existing conditions and increasing prevention efforts to reduce the accumulation of additional comorbidities at all ages. In particular, the cardiovascular comorbidities were the most prevalent among individuals in the highest frailty trajectories, which identifies an area for intervention that may have a large impact on preventing frailty in the elderly.

Conclusions

In this longitudinal, population-based study, we found that the number of frailty trajectories differed by age, with a larger number of distinct frailty trajectories in the youngest age group. Those in the highest frailty trajectory within each age group experienced higher rates of ED visits, hospitalizations, and all-cause mortality compared to those in lower frailty trajectories. Identification of predictors of the highest frailty trajectories, along with the assessment of changes in frailty in patients over time, may offer ways to target aging individuals at high risk of hospitalization or death for therapeutic or preventive interventions.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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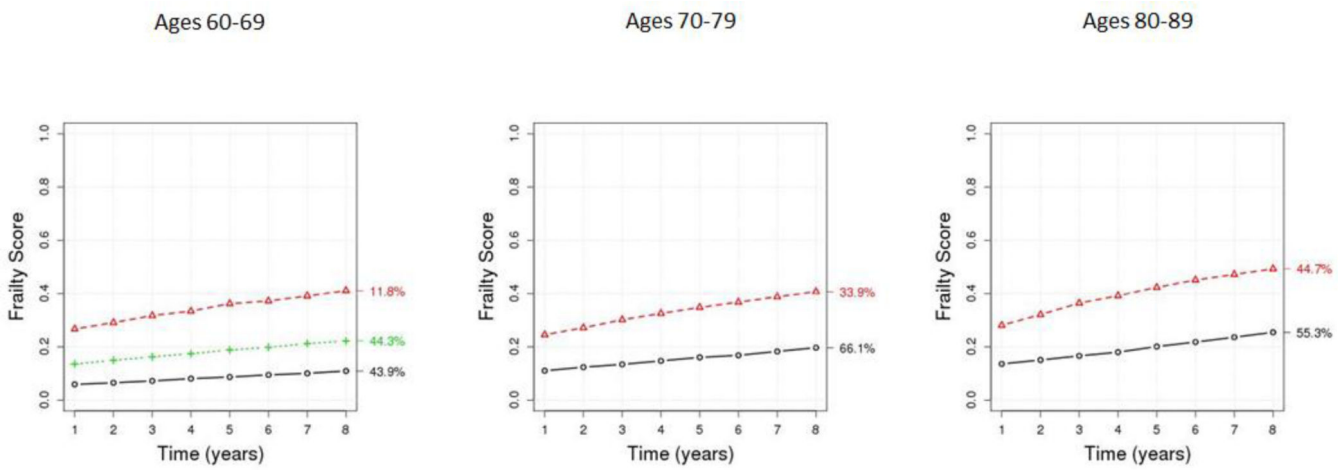

Figure 1. Frailty trajectory plots in the 60–69, 70–79, and 80–89 year old age groups

The black line indicates the lowest trajectory, the green line indicates the middle trajectory, and the red line indicates the highest trajectory. The percentage next to each trajectory indicates the proportion of individuals in that trajectory.

Table 1

Baseline Characteristics[a] of the Olmsted County, MN Population Aged 60–89

	N=12,270
Age group, years	
60–69	6,045 (49.3%)
70–79	4,314 (35.1%)
80–89	1,911 (15.6%)
Male	5,461 (44.5%)
Body mass index, kg/m^2	
<18.5	110 (0.9%)
18.5 to <25	2,889 (25.0%)
25 to <30	4,591 (39.7%)
≥30	3,974 (34.4%)
Comorbidities	
Hypertension	9,356 (76.3%)
Congestive heart failure	1,672 (13.6%)
Coronary artery disease	4,481 (36.5%)
Cardiac arrhythmia	6,145 (50.1%)
Hyperlipidemia	9,573 (78.0%)
Stroke	1,918 (15.6%)
Arthritis	7,292 (59.7%)
Asthma	1,127 (9.2%)
Cancer	5,929 (48.3%)
Chronic kidney disease	2,358 (19.2%)
Chronic obstructive pulmonary disease	2,091 (17.0%)
Dementia	1,208 (9.9%)
Depression	2,713 (22.1%)
Diabetes	6,049 (49.3%)
Osteoporosis	2,771 (22.6%)
Schizophrenia	392 (3.2%)
Substance abuse disorders (drug and alcohol)	345 (2.8%)
Activities of Daily Living	
Need help preparing meals	559 (4.6%)
Need help feeding yourself	98 (0.8%)
Need help dressing yourself	330 (2.7%)
Need help using the toilet	184 (1.5%)
Need help with housekeeping	932 (7.6%)
Need help climbing stairs	1,814 (14.8%)
Need help bathing	404 (3.3%)
Need help walking	1,271 (10.4%)
Need help using transportation	449 (3.7%)
Need help getting in and out of bed	1,586 (13.7%)

	N=12,270
Need help managing medications	440 (3.6%)
Depend on assistive devices (walker, cane, etc.) or other people to perform activities of daily life	1,516 (12.7%)
Dependent on a device for normal breathing	626 (5.4%)
Climb 2 flights of stairs without rest	
No	1,039 (9.0%)
Yes, with difficulty	2,896 (25.2%)
Yes, with no difficulty	7,565 (65.8%)

Values are N (%).

[a]Age is given in the year 2005 and the remaining variables are from the first year of frailty. Because we allowed up to 3 missing variables in the frailty index calculation, some numbers in the table may not add up to 12,270.

Table 2

Number of Deaths and Rates of Hospitalizations and Emergency Department Visits Occurring over the Trajectory Period by Frailty Trajectory

	Lowest Trajectory	Middle Trajectory	Highest Trajectory
60–69 Year Olds			
N	2656	2677	712
Deaths, N (%)	52 (2.0%)	157 (5.9%)	175 (24.6%)
Hospitalization rate[a]	8.9	20.5	67.3
ED Visit rate[a]	15.5	31.7	93.0
70–79 Year Olds			
N	2853	--	1461
Deaths, N (%)	197 (6.9%)	--	458 (31.4%)
Hospitalization rate[a]	16.9	--	62.9
ED Visit rate[a]	28.3	--	90.3
80–89 Year Olds			
N	1057	--	854
Deaths, N (%)	248 (23.5%)	--	483 (56.6%)
Hospitalization rate[a]	28.2	--	76.5
ED Visit rate[a]	50.6	--	118.4

[a] Rate per 100 person years

Table 3

Odds Ratios for All-cause Mortality and Rate Ratios for Hospitalizations and Emergency Department Visits Occurring over the Trajectory Period by Age Group

	Unadjusted			Adjusted[a]		
	Lowest Trajectory	**Middle Trajectory**	**Highest Trajectory**	**Lowest Trajectory**	**Middle Trajectory**	**Highest Trajectory**
60–69 Year Olds						
All-cause mortality	1.00 (ref)	3.06 (2.31–4.05)	15.39 (11.51–20.57)	1.00 (ref)	2.96 (2.19–4.01)	15.26 (10.06–23.14)
Hospitalizations	1.00 (ref)	2.31 (2.13–2.51)	7.72 (6.93–8.60)	1.00 (ref)	2.11 (1.92–2.32)	6.09 (5.14–7.21)
ED visits	1.00 (ref)	2.08 (1.94–2.23)	6.16 (5.59–6.78)	1.00 (ref)	1.93 (1.78–2.09)	5.05 (4.36–5.86)
70–79 Year Olds						
All-cause mortality	1.00 (ref)	--	5.92 (5.02–6.98)	1.00 (ref)	--	3.77 (3.04–4.69)
Hospitalizations	1.00 (ref)	--	3.71 (3.45–4.00)	1.00 (ref)	--	2.55 (2.31–2.80)
ED visits	1.00 (ref)	--	3.18 (2.97–3.40)	1.00 (ref)	--	2.16 (1.98–2.36)
80–89 Year Olds						
All-cause mortality	1.00 (ref)	--	4.85 (3.99–5.89)	1.00 (ref)	--	4.00 (3.07–5.21)
Hospitalizations	1.00 (ref)	--	2.78 (2.54–3.03)	1.00 (ref)	--	2.10 (1.87–2.35)
ED visits	1.00 (ref)	--	2.38 (2.19–2.57)	1.00 (ref)	--	1.89 (1.70–2.10)

[a] Adjusted for age, sex, and baseline frailty index.

ED, emergency department

Table 4

Odds Ratios for All-cause Mortality and Rate Ratios for Hospitalizations and Emergency Department Visits Occurring over the Trajectory Period across Age and Trajectory Groups

	All-Cause Mortality	Hospitalizations	Emergency Department Visits
Unadjusted			
60–69, lowest trajectory	1.00 (ref)	1.00 (ref)	1.00 (ref)
60–69, middle trajectory	3.12 (2.27–4.29)	2.31 (2.14–2.50)	2.08 (1.94–2.22)
60–69, highest trajectory	16.32 (11.91–22.55)	7.70 (6.97–8.51)	6.16 (5.63–6.74)
70–79, lowest trajectory	3.71 (2.72–5.07)	1.91 (1.77–2.07)	1.86 (1.74–1.99)
70–79, highest trajectory	22.87 (17.01–30.74)	7.10 (6.54–7.71)	5.90 (5.49–6.35)
80–89, lowest trajectory	15.35 (11.27–20.91)	3.16 (2.88–3.48)	3.31 (3.04–3.59)
80–89, highest trajectory	65.19 (48.01–88.54)	8.77 (7.98–9.63)	7.83 (7.20–8.52)
Adjusted[a]			
60–69, lowest trajectory	1.00 (ref)	1.00 (ref)	1.00 (ref)
60–69, middle trajectory	2.63 (1.90–3.63)	1.97 (1.82–2.14)	1.82 (1.69–1.95)
60–69, highest trajectory	10.94 (7.66–15.62)	5.09 (4.53–5.73)	4.28 (3.84–4.76)
70–79, lowest trajectory	3.32 (2.43–4.54)	1.72 (1.59–1.86)	1.69 (1.58–1.81)
70–79, highest trajectory	16.08 (11.62–22.23)	4.84 (4.38–5.36)	4.19 (3.82–4.59)
80–89, lowest trajectory	13.66 (9.97–18.70)	2.73 (2.48–3.01)	2.91 (2.67–3.17)
80–89, highest trajectory	44.84 (31.85–63.14)	5.73 (5.11–6.43)	5.34 (4.81–5.92)
Adjusted[b]			
60–69, lowest trajectory	1.00 (ref)	1.00 (ref)	1.00 (ref)
60–69, middle trajectory	2.49 (1.80–3.44)	1.96 (1.81–2.12)	1.80 (1.68–1.93)
60–69, highest trajectory	10.06 (7.04–14.38)	5.03 (4.47–2.12)	4.19 (3.77–4.66)
70–79, lowest trajectory	1.42 (0.98–2.06)	1.52 (1.36–1.71)	1.41 (1.28–1.56)
70–79, highest trajectory	6.33 (4.27–9.36)	4.25 (3.72–4.86)	3.43 (3.05–3.87)
80–89, lowest trajectory	2.74 (1.67–4.49)	2.18 (1.82–2.61)	2.07 (1.76–2.42)
80–89, highest trajectory	8.44 (5.02–14.21)	4.54 (3.74–5.51)	3.74 (3.14–4.46)

[a] Adjusted for sex and baseline frailty index.

[b] Adjusted for age, sex, and baseline frailty index.