Diabetes, heart disease, and dementia: National estimates of functional disability trajectories

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Abstract

Background—This brief methodology report estimates the associations among diabetes, heart disease, and dementia, which may increase the difficulty of self-care, with functional disability trajectories jointly modeled with attrition over five years. National estimates are generated using sampling weights.

Design—Population-based complex survey design.

Setting—National Health and Aging Trends Study

Participants—Community-dwelling adults ≥ 65 years old (N=7,609).

Measurements—Annual in-person interviews included sociodemographic information, self-reported physician-diagnosed chronic conditions, six activities of daily living (ADL), and cognitive status. A joint model using group-based trajectory modeling estimated the number of ADL disabilities and attrition probability. Multinomial logistic regression with survey weights estimated the association among diabetes, heart disease, and dementia to resultant trajectories with the least disabled trajectory as reference.

Results—Three functional disability trajectories were identified: 26.9 million (76.3%) community-dwelling Medicare beneficiaries had no disability and a constant study attrition of 14.3%, 4.9 million (13.9%) had mild and increasing disability with 12% attrition in 2012 to 27.2%

in 2015, and 3.4 million (9.7%) had severe and increasing disability with 25.4% attrition in 2012 to 35% in 2015. Persons with possible dementia, or possible dementia and diabetes, or possible dementia with both diabetes and heart disease, had significantly increased odds of being on the "mild disability" trajectory relative to "no disability." Persons with probable dementia, representing over 1.5 million persons, regardless of concurrent conditions had significantly increased the odds of being on the "severe disability" trajectory relative to persons on the "no disability" trajectory.

Conclusions—Methods that generate national estimates, account for attrition and for multiple chronic conditions and cognitive status, may be useful for health policy-makers to provide care, support and services.

Keywords

Dementia; Diabetes; Heart disease; Functional Disability; Attrition; National Health and Aging Trends Study

Introduction

Functional independence is important for the majority of older patients who tend to prioritize remaining independent over living longer.[1] However, functional disability, whether transient or persistent, is common in older adults.[2] Estimating the national burden of disability among community-dwelling older adults may help policy makers plan and prepare for the needs of this population.

Although 75% of older adults have 2 chronic conditions, trajectory studies of function have typically focused on adults with individual health conditions[3]. Moreover, prior studies rarely accounted for attrition or provided nationally representative estimates. Although diabetes, heart disease, and dementia have been individually associated with functional decline[4], their joint impact on functional disability is less clear. Furthermore, diabetes and heart disease are highly prevalent and require complicated self-care management, including diet control, blood glucose and/or blood pressure monitoring, and use of multiple medications. Optimal management of diabetes and heart disease requires competent executive function. As a result, persons with dementia may face greater challenges in self-managing diabetes and heart disease and other complicated self-care conditions. Previous research found that persons with dementia were difficult to recruit and retain in studies; therefore, accounting for missing data is imperative to avoid bias[5,6].

In this brief methodology report, our aim was to quantify the associations between diabetes, heart disease, dementia, and their combinations with trajectories of functional disability accounting for attrition in a nationally-representative sample of American community-dwelling older adults.

Methods

Study sample

The National Health and Aging Trends Study (NHATS) is a nationally-representative sample of Medicare beneficiaries ≥ 65 years of age initiated in 2011 "designed to enhance understanding of trends and trajectories of late-life disability"[7]. The survey sampling weights allow for generation of national estimates (details were previously published[7]). The study protocol was approved by the Johns Hopkins University Institutional Review Board (IRB) and the Yale IRB (HIC# 1510016585). Written informed consent was obtained from all study participants or their proxy respondents.

In-person interviews, including cognitive and activities of daily living (ADL) assessments, were conducted by trained research staff in the homes of study participants living in the community[7]. Nursing home residents (n= 468, 5.7%) and residential care participants (n= 168, 2.0%) were excluded from the analysis because interviews were not done or incomplete[7]. The analytical sample was 7,609 community-dwelling participants, of whom 1,393 died (18.3%) and 2,511 (33.0%) dropped out over five years of annual follow-up.

Measures

NHATS Classifications of Possible and Probable Dementia—NHATS assessed cognition in three ways: 1) confirmation from the study participant or proxy of physician-diagnosed dementia or Alzheimer's disease, 2) probable dementia classification score (score ≥ 2/8 items) from the validated proxy-report, the Alzheimer's Disease (AD)-8 Screening interview and 3) cognitive test battery[8,9]. Domains of the cognitive tests included orientation (scale: 0-8, cut-off ≤ 3), memory (scale: 0-20, cut-off ≤ 3) and executive function (scale: 0-5, cut-off ≤ 1)[8]. Cut-off scores were defined as 1.5 standard deviations (SD) below the mean to indicate cognitive impairment[8]. Probable dementia was defined as cut-off scores in two of the three domains and as possible dementia was defined as a cut-off score in one domain[8]. The NHATS definition of probable and possible dementia was previously validated against dementia cases (sensitivity: 85.7%, 95% CI: 69.7; 95.2)[8].

Complicated self-care conditions—Participants or proxy respondents were asked if they ever had physician-diagnosed diabetes or heart disease, referred to as complicated self-care conditions.

Composite variable of diabetes, heart disease and cognitive status—We created a 12-level categorical variable based on all combinations of diabetes, heart disease and dementia (possible, probable or no dementia). This coding creates a parsimonious model. By using a composite variable, the model has more direct interpretation than two and three-way interactions.

Disability—The functional disability score was a sum of six ADLs (eating, dressing, bathing, toileting, transferring from bed, and getting around inside one's home) that the participants was unable to perform[10].

Covariates—Baseline demographic characteristics were collected via interview and included: age (65-74, 75-84 and ≥85), sex, race (white versus other), living status (alone versus with someone), education (≥ high school versus below high school), and having had a hospital stay in last 12 months (yes versus no). Baseline body mass index (BMI) was categorized as <25, 25-30, and ≥30 based on self-reported height and weight. A sum of physician-diagnosed, self-reported chronic conditions included: high blood pressure, arthritis, osteoporosis, lung disease, stroke, and cancer. A self-reported scale of overall health was used as an indicator for severity of illness. A total score of instrumental ADLs that participants were unable to do included: help with meals, laundry, light housework, groceries, taking medication, managing money and making telephone calls[10].

Statistical analyses

Baseline characteristics of the cohort were compared across functional trajectories using survey adjusted chi-square tests and one-way analysis of variance[11]. A joint model using group-based trajectory modeling estimated the number of ADL disabilities and attrition probability (death or dropout) over five years using Stata version 12 (see supplementary section)[12–14]. Therefore, nonrandom participant attrition was accounted for across trajectories and within trajectories over time[12]. As a sensitivity analysis, we re-ran the trajectory modeling without accounting for attrition.

Subsequently, a multinomial logistic regression that incorporates complex survey designs (Proc Surveylogistic, SAS version 9.4), estimated the association of complicated self-care conditions and dementia to each functional disability trajectory with the least disabled trajectory as reference. Potential confounding was adjusted for by including baseline covariates: age, sex, race, BMI, living situation, overall health, education, the number of instrumental ADLs disabled and the number of other chronic conditions. Wave one analytic weights along with the appropriate cluster and strata variables were applied to all analyses to generate national estimates of older Medicare beneficiaries that account for differential probabilities of selection and adjust for potential bias related to unit non-response[11].

Results

Study population characteristics

Baseline national estimates indicated that the majority (52.9%) of the people were 65-75 years old, had ~2 chronic conditions and 14.2% needed assistance with at least one ADL, 35.1% had either diabetes or heart disease and 10.9% and 10.0% had possible and probable dementia, respectively (Table 1).

Joint trajectory of disability and attrition over five years

Among the models evaluated, a zero-inflated Poisson model with three trajectories was the best solution, with an average posterior probability of assignment (PPA) ≥ 0.88. After applying analytic weights to the trajectory analysis, national estimates were: 76.3% of US community-dwelling adults ≥65 with no disability, 13.9% with mild increasing disability, and 9.7% with severe increasing disability (Figure 1A). Table 1 presents baseline characteristics per trajectory, which shows significant monotonic worsening of cognitive,

health and functional measures from no disability to mild increasing disability and to severe increasing disability. For example, at baseline persons on the "severe disability" trajectory had the greatest prevalence of complicated-self-care condition (50.8%, p-value <0.0001), worst perceived overall health (25.9% poor, p-value <0.0001), greatest number of other chronic conditions (mean 2.5, p-value <0.0001), required assistance with groceries (77.9%, p-value<0.0001), making meals (61.3%, p-value<0.0001), taking medications (52.2%, p-value<0.0001); diet control and medications are part of self-care of chronic conditions (Table 1). Frequencies, percentages at the sample and national estimates for diabetes, heart disease, dementia and their combinations across trajectories are provided in Supplementary table 1.

National estimates of the probabilities of attrition per wave by trajectory are shown in Figure 1B. The "no disability" trajectory had the lowest attrition probabilities over time (14.3%), followed by the "mild disability" trajectory (12.0%-27.2%) and the "severe disability" trajectory had the highest probability of attrition (25.4%-35.0%).

Sensitivity analysis of the trajectory model without attrition over-represented the proportion of older adults on the mild increasing disability trajectory and under-represented the proportion of older adults on the no disability trajectory when compared to the joint model that included attrition. The posterior probability of assignment showed a better fit for the joint model with attrition (Supplemental Table 2).

Figure 2 presents multinomial logistic regression results. All covariates were significant except for race (p-value=0.44) and education (p-value=0.65).

Associations of diabetes, heart disease and dementia status with the "mild disability" trajectory—For cognitively intact persons, having diabetes in the absence of heart disease (hereafter referred to as diabetes alone) significantly increased the odds of being on the "mild disability" trajectory compared with the "no disability" trajectory (Figure 2). Persons with possible dementia alone, or possible dementia and diabetes, or possible dementia with both diabetes and heart disease, had significantly greater odds of being on the "mild disability" trajectory relative to "no disability." Persons with probable dementia alone had significantly greater odds of being on the "mild disability" trajectory relative to persons on the "no disability" trajectory.

Of the estimated 4.9 million persons on the "mild disability" trajectory, given the prevalences of diabetes and possible dementia, persons with these were most frequent. Although people with diabetes and no dementia were significantly at risk for both "mild" and "severe" disability, in absolute terms national estimates for "mild disability" were double the "severe disability" trajectory (710,407 and 336,852 respectively, Supplementary table 1).

Associations of diabetes, heart disease and dementia status with "severe disability" trajectory—For cognitively intact persons, having diabetes alone or having both diabetes and heart disease significantly increased the odds of being on the "severe disability" trajectory relative to persons on the "no disability" trajectory (Figure 2). For

persons with possible dementia, having heart disease, or both diabetes and heart disease significantly increased the odds of being on the "severe disability" trajectory relative to persons the "no disability". Persons with probable dementia, regardless of concurrent complicated self-care conditions had significantly increased the odds of being on the "severe disability" trajectory relative to persons on the "no disability" trajectory.

Of an estimated 3.4 million persons on the "severe disability" trajectory, over 1.5 million had probable dementia (Supplemental table 1). Persons with possible dementia and heart disease (with or without diabetes) had national estimates that were higher on the "severe disability" trajectory than the "mild disability" trajectory (Supplementary table 1).

Discussion

In this longitudinal nationally-representative cohort of community-dwelling adults 65 years old, we found three distinct functional disability trajectories. Our results found attrition rates closely followed the shape of each trajectory with greater disability leading to increased attrition rates. For the trajectory without disability over time, there was a low, stable level of attrition. Following the "mild disability" trajectory, at baseline there was negligible disability, which increased concurrently with attrition. At the end of five years, the "mild disability" trajectory had similar attrition and disability estimates compared to the baseline estimates of "severe disability" trajectory. There were combinations of complicated self-care conditions and cognitive status that were only significantly associated with "mild disability" (possible dementia with or without diabetes) or only significantly associated with "severe disability" (diabetes and heart disease, heart disease and possible dementia, probable dementia with any combinations of diabetes or heart disease).

Previous trajectory research in the oldest of the old that jointly modelled ADLs and survival in China, similarly found three distinct trajectories, with survival probabilities decreasing with ADL difficulty[15]. A study estimating trajectories of physical functioning in adults 26-70 years old over 11 years found five trajectories using the Short-form 36 where 54% of the individuals had a "stable slightly limited course" of physical functioning indicating some disability[16]. Our results may differ from these studies because of different outcome scales, covariates, country differences, jointly modelling attrition, age of the sample population and the length of the study. Neither of the prior studies focused on cognitive impairment or comorbid conditions that may require complicated-self-care.

Previous trajectory research found persons who died from advanced dementia, had the highest levels of disability in the last year of life[17]. Moreover, Han et al[18] found increasing burden of disability, hospitalization and institutionalization as community-dwelling older people aged, particularly for those with a declining cognitive trajectory. This agrees with our findings that persons with probable dementia alone or in combination with either or both complicated-self-care conditions had significantly increased odds of being on the "severe disability" trajectory and had the highest (45%) hospitalizations in the year before baseline.

Our study reinforces the need for health policies addressing functional disability among persons with multiple chronic conditions. It is important to examine the unique combination

of dementia with other chronic conditions because dementia may make self-care more difficult. Improving diabetes and/or heart disease self-care may decrease preventable hospitalizations, and in turn disability, as hospitalization has been associated with ADL disability[2,19]. A meta-analysis found preventative home visits that included a multicomponent geriatric assessment and multiple follow-up home visits reduced functional decline and mortality in community-dwelling older adults[20]. Another review presented evidence that home visits using exercise therapy reduced disability in community-dwelling dementia participants; however, they did not report multimorbidity[21].

The strengths of this study include 7600 representative community-dwelling adults 65 years old with analytic weights to provide national estimates. Only one article previously jointly modeled disability and attrition to prevent a healthy survivor bias further increasing the novelty of these methods[15]. Previous simulation studies showed that jointly modelling attrition and functional disability reduces bias and misrepresentation of group allocation compared to the group based trajectory model that does not take attrition into account[12]. Even the least disabled trajectory had 46.1% attrition after five years. Cognitive impairment, heart disease and diabetes are associated with an increased risk of disability, death and lost to follow-up[5,22,23]. Missing data is known to bias results; therefore, research must use methods to address missingness[6]. This study used a range of participant characteristics, annual visits over five years and a validated dementia method. No studies have examined the influence of complicated-self-care with dementia.

This study also has limitations. NHATS recorded physician-diagnosed self-reported chronic conditions and 5.8% used a proxy to complete the baseline interview, a potential source of imprecision on confidence intervals. Proxy responses may introduce bias as previous research found that although older adults remember common chronic conditions well, they have more difficulty reporting ADLs[24]. Moreover diabetes, the 6th leading cause of disability is commonly under-diagnosed because many individuals are asymptomatic and type 1 and 2 diabetes may differ on associations with disability[25,26]. Cognitive status and complicated-self-care conditions were set at baseline and not updated over the course of follow-up. Finally, as disease-specific severity measures were not available, we used a self-reported score of overall health as a surrogate measure for overall disease severity.

Future research should focus not just on the presence of chronic conditions and their associations with healthcare utilization, but should also investigate interventions to reduce the burden of functional disability. For example, informal caregivers, who may provide medical assistance, may attenuate the impact of dementia on functional disability in the presence of chronic conditions that require self-management, such as diabetes and heart disease.

Conclusion

This paper provides a robust method to estimate the national burden of disability at a population-level in community-dwelling older adults to help plan for the needs of the US population. The majority of US community-dwelling older adults live without disability; however, approximately a quarter are likely to have increasing functional disability over

five-years. Of health policy concern is that 4.9 million and 3.4 million older Americans are estimated to follow the "mild" and "severe" disability trajectories. This paper shows that combinations of diabetes, heart disease and cognitive status have differing odds of functional disability and attrition. Adoption of methods that provide national estimates, account for attrition and quantify the effects of chronic conditions, will reduce bias in estimates health policy-makers utilize.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Impact Statement for Brief Report

We certify that this work is novel. The potential impact of this research to health policy includes the following. Using nationally-representative data of older adults, we demonstrate a method to calculate national estimates on the trajectories of functional disability that accounts for attrition. We also quantify the association between cognitive impairment, diabetes and heart disease with differing functional disability trajectories.
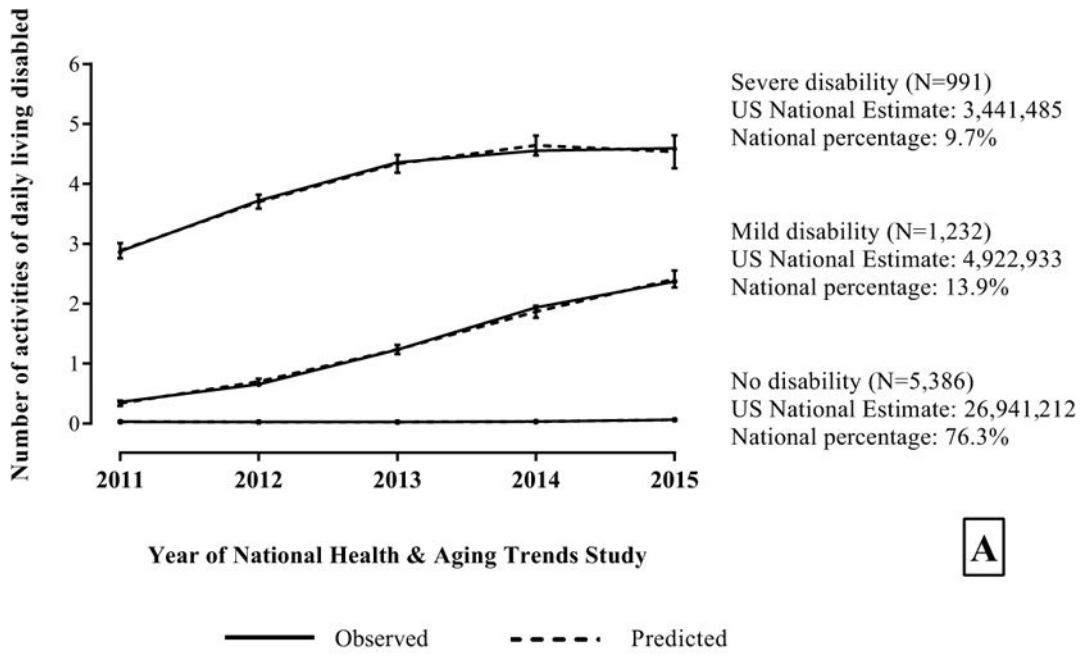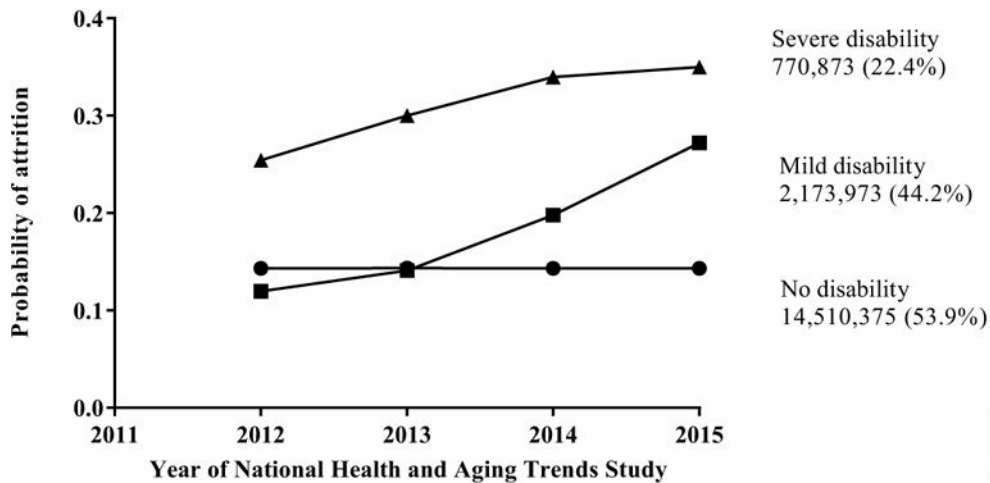
Figure 1.
Panel A: Trajectories of functional disability over five years jointly modelled with attrition (panel B) using the National Health and Aging Trends Study with 2011 analytic weights to derive national estimates. Higher scores indicate increased functional disability. Panel B: Annual attrition probabilities and national estimates based on the joint modeling of functional disability (panel A) and attrition trajectories. Attrition was jointly modelled with the functional disability trajectories and 2011 analytic weights were applied to determine the number of participants remaining in each trajectory per year. The four-group model had the

highest BIC (-20,771), and the incremental change from the three-group model was smaller than that from the two-group to the three-group models (2* (BICij): 468 versus 3,478). We choose the two models with the highest BIC, i.e., the four- and three-group models, as contenders for further evaluation. The final three-group model was chosen over the four-group alternative after evaluating the model outputs and trajectory plots, comparing the average and minimal Posterior Probability of assignment (PPA) for each group, examining the distinctiveness and interpretability of the trajectories and group sizes.
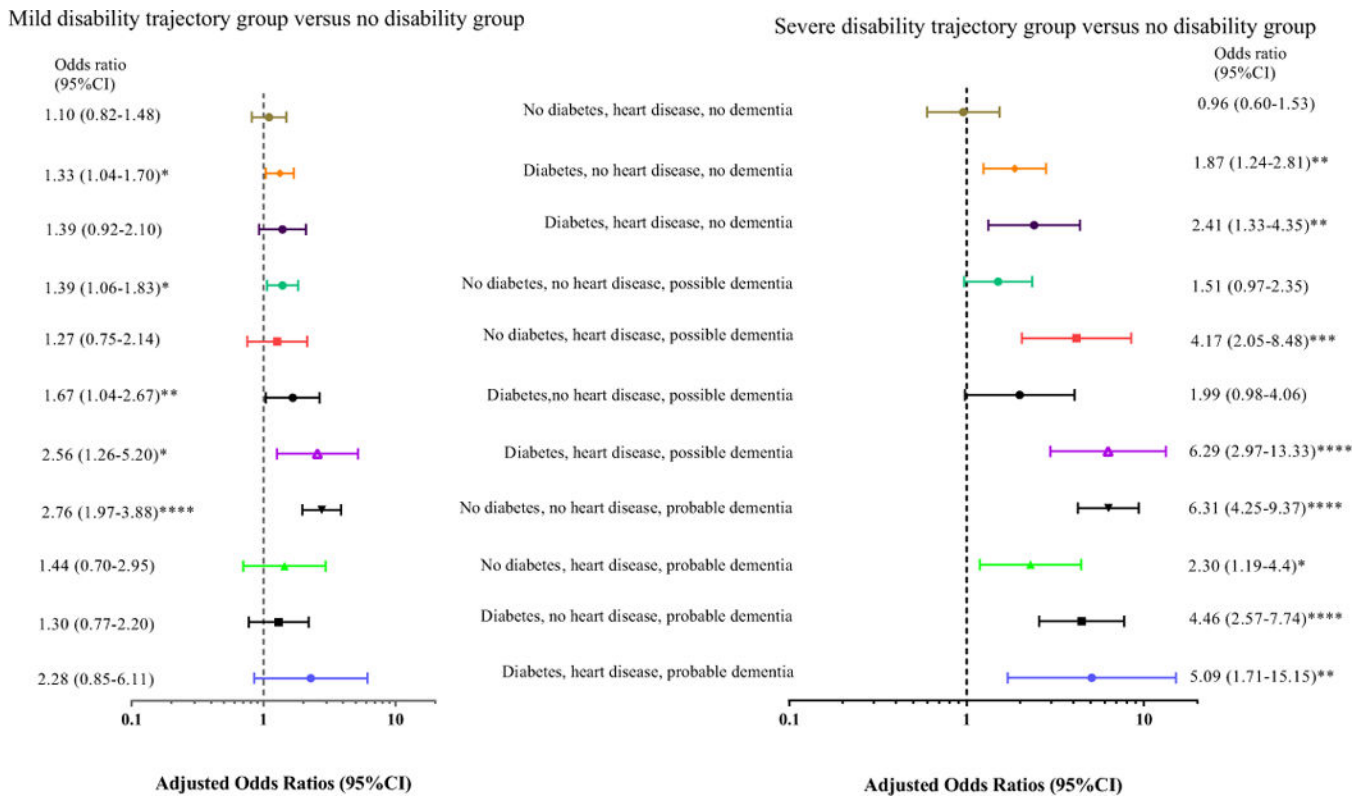
Figure 2.
Log-scale forest plot of the adjusted odds ratios and their 95% confidence intervals of being on the "mild" or "severe" disability trajectories for combinations of diabetes, heart disease and dementia status. The reference group, which has the value of one on the x-axis, were persons on the no functional disability trajectory. *=0.05, **=0.01, ***<0.001, ****<0.0001. Multinomial logistic regression models adjusted for age (five year intervals from 65 years old), sex, race, living situation, education, the number of IADLS disabled, BMI, self-reported overall health and the number of chronic conditions. See Supplementary table 1 for a breakdown of original sample sizes and national estimates per combination.

Table 1

National estimates based on characteristics of NHATS participants at baseline by functional disability trajectories

	All	No disability	Mild increasing disability	Severe increasing disability	p-value[d]
Population-weighted estimates of trajectories	35,305,630	26,941,212	4,922,933	3,441,485	
Demographics					
Age (%)					<0.0001
65-74	52.9	59.7	36.7	22.5	
75-84	33.7	32.2	39.3	38.0	
85+	13.4	8.1	24.0	39.5	
Female (%)	56.6	54.4	61.9	66.1	<0.0001
White, non-Hispanic (%)	81.5	82.6	79.37	75.4	<0.0001
High school (%)	78.2	81.4	71.2	63.1	<0.0001
Living with someone (%)	70.2	70.8	69.0	67.6	<.0001
BMI					<0.0001
<25 normal	34.4	32.7	37.1	44.6	
25 – 29.9 overweight	37.7	39.6	32.0	31.1	
30 obese	27.8	27.7	30.9	24.4	
Cognition					
Dementia (%)					<0.0001
No cognitive impairment	79.0	86.1	68.9	38.1	
Possible dementia	10.9	9.4	15.8	15.5	
Probable dementia	10.0	4.4	15.3	46.4	
Used proxy for interview	5.8	2.2	6.8	32.8	<0.0001
Health					
Diabetes present (%)	23.9	21.4	29.7	34.7	<0.0001
Heart disease present (%)	17.5	15.0	22.7	29.4	<0.0001
Complicated-self-care present (diabetes and/or heart disease) (%)	35.1	31.6	43.5	50.8	<0.0001
Total chronic conditions [c] mean, (SD)	1.9 (0.02)	1.8 (0.02)	2.3 (0.04)	2.5 (0.05)	<0.0001
Self-rated health					<0.0001
Excellent	14.8	17.6	6.6	4.6	
Very good	29.5	33.5	19.1	13.0	

	All	No disability	Mild increasing disability	Severe increasing disability	p-value[d]
Good	30.7	30.7	35.2	24.1	
Fair	18.4	14.9	27.5	32.3	
Poor	6.7	3.3	11.7	25.9	
Hospital stays in last 12 months (%)	21.0	16.5	29.3	45.0	<0.0001
Function					
Total ADL[a] (mean, SD)	0.4 (0.01)	0.025 (0.003)	0.4 (0.02)	2.9 (0.08)	<0.0001
Help with at least one ADL (%)	14.2	2.2	31.2	85.4	<0.0001
Total IADL[b] (mean, SD)	0.8 (0.03)	0.3 (0.02)	1.2 (0.06)	4.0 (0.02)	<0.0001
Shopping assistance (%)	17.7	7.1	32.4	77.9	<0.0001
Meals assistance (%)	11.4	4.2	15.5	61.3	<0.0001
Medication assistance (%)	10.0	4.1	13.3	52.2	<0.0001

Note. There were 7,609 people included from the National Health and Aging Trends study, representing 35.3 million older adults.

[a]Total activities of daily living score (ADL) consisted of: Eating, bathing, dressing, toileting, transferring from bed and getting around inside one's home.

[b]Instrumental activities of daily living (IADL) score consisted of a sum score of help with: meals, laundry, housework, groceries, money, medications and the telephone. With both scales higher scores mean increased dependency.

[c]Sum of chronic conditions included: Blood pressure, Arthritis, Osteoporosis, Lung disease, Stroke and Cancer.

[d]P-values represent second-order chi-square values for categorical variables against group membership and analysis of variance for continuous variables compared to group membership.