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Impairments in Individual Autonomous Living Tasks and Time to Self-Care Disability in Middle-Aged and Older Adults

Ryan P. McGrath, PhD^{a,*}, Brian C. Clark, PhD^{b,c,d}, Kristine M. Erlandson, MD^e, Stephen D. Herrmann, PhD^f, Brenda M. Vincent, MS^g, Orman T. Hall, DO^h, and Kyle J. Hackney, PhD^a

^aDepartment of Health, Nutrition, and Exercise Sciences, North Dakota State University, Fargo, ND

^bOhio Musculoskeletal and Neurological Institute, Ohio University, Athens, OH

^cDepartment of Biomedical Sciences, Ohio University, Athens, OH

^dDepartment of Geriatric Medicine, Ohio University, Athens, OH

^eDepartment of Medicine, Divisions of Infectious Diseases and Geriatric Medicine, University of Colorado-Anschutz Medical Campus, Aurora, CO

^fSanford Research, Sioux Falls, SD

^gCenter for Clinical Management Research, VA Ann Arbor Healthcare System, Ann Arbor, MI

^hDepartment of Physical Medicine and Rehabilitation, University of Michigan, Ann Arbor, MI

Abstract

Objectives: Impairments in specific tasks that are necessary for independent living may identify future self-care limitations, and the use of time-varying covariates can better capture the fluidity in functional capacity trajectories over time. The purpose of this study was to determine the associations between individual instrumental activities of daily living (IADL) impairments and time to activities of daily living (ADL) disability for middle-aged and older adults in the United States.

Design: Longitudinal panel.

Setting: Detailed interviews that included physical, biological, and psychosocial measures were completed in person. The core interview was typically completed over the telephone.

Participants: A nationally representative sample of 15,336 adults aged at least 50 years from the 2006 wave of the Health and Retirement Study was followed for 8 years.

* Address correspondence to Ryan P. McGrath, PhD, Department of Health, Nutrition, and Exercise Sciences, North Dakota State University, NDSU Dept. 2620 PO Box 6050 Fargo, ND 58108-6050.

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Measures: Ability to perform IADL and ADL were self-reported at each wave. Separate covariate-adjusted Cox models were used to examine the time-varying associations between individual IADL impairments and time to ADL disability.

Results: The presence of each IADL impairment was associated with a higher hazard ratio for an ADL disability for the following functions: 2.52 [95% confidence interval (CI) 2.35, 2.70] for grocery shopping, 1.91 (CI 1.77, 2.06) for preparing hot meals, 1.55 (CI 1.37, 1.76) for taking medications, 1.48 (CI 1.36, 1.61) for managing money, 1.41 (CI 1.27, 1.57) for using a telephone, and 1.38 (CI 1.29, 1.48) for using a map.

Conclusions/Implications: Our findings provide insights into the disabling process by revealing how impairments in each IADL are differentially associated with time to ADL disability. Interventions aiming to retain function during aging should be informed by fluctuations in IADL performance and how specific IADL impairments may exacerbate functional capacity declines more so than others.

Keywords

Activities of daily living; aging; cognition; disability; frailty; function

Functional capacity is commonly measured by questionnaires concerning a person's ability to perform instrumental activities of daily living (IADL) and activities of daily living (ADL).

¹ Autonomous living tasks are assessed in IADL,² whereas ADL examine basic self-care abilities.³ Many working-age and older adults are living with IADL or ADL limitations,^{4,5} thereby making the preservation of functional capacity a major public health priority that would drastically reduce health care costs and improve quality of life for aging Americans and their families.⁶ However, more middle-aged and older adults are living with IADL impairments than ADL limitations.^{4,5} Functions included in IADL assessments represent higher-level cognitive tasks that typically decline before self-care tasks, which require greater physical functioning. Given that impairments in IADL often precede an ADL limitation, impairments in IADL may identify future declines in self-care abilities.⁷ Therefore, examining trends in functional loss from an early stage is important for detecting future functional deficits during aging.

The standard definitions of an IADL or ADL disability are the difficulty or inability to perform one or more IADL or ADL, respectively. While impairments in any number of IADL and ADL functions have been linked to poor health outcomes such as chronic morbidity and premature mortality,^{8,9} impairments in certain individual functions could be more robustly associated with clinically relevant health outcomes than others. For example, an impairment in preparing a hot meal has been shown to be associated with greater odds for multi-morbidity than impairments in other IADL for older adults.¹⁰ Thus, it is possible that traditional definitions for an IADL disability may not capture how impairments in specific IADL may predict future poor health outcomes such as an ADL disability, and fluctuations in IADL that occur over time.

When longitudinal study designs with repeated measures at close time intervals are implemented, shifts in functional capacity trajectories have been demonstrated.^{11,12}

Therefore, cross-sectional and certain longitudinal study designs may not adequately capture the dynamic associations between IADL and ADL that occur as adults age. Utilizing time-varying covariates in longitudinal study designs with repeated measures may provide a more detailed understanding for how factors that change during the life course are associated in middle-aged and older adults.

Uncovering aspects that potentiate the disabling process may help inform health care providers working with patients who are at risk for declines in functional capacity, and identify potential targets for interventions aiming to prevent functional deficits. Given that impairments in IADL may lead to future ADL limitations, evaluating how impairments in individual IADL are differentially associated with time to ADL disability may provide deeper insights into the disabling process. Accordingly, the purpose of this study was to determine the time-varying associations between individual IADL impairments and time to ADL disability for a nationally representative sample of middle-aged and older adults in the United States.

Methods

Participants

Data from the Health and Retirement Study (HRS) were analyzed for this study. Cleaned and standardized RAND HRS data were joined with other necessary HRS sections. The HRS is designed to observe the health and financial status of aging Americans.¹³ Data are provided for a nationally representative sample of community-dwelling adults older than 50 years in the United States.¹³ Participants in the HRS are reinterviewed biannually and followed longitudinally until death. To maintain national representation of the survey over time, new cohorts of participants are intermittently added to the original sample. A multistage probability design is employed, including geographical stratification and oversampling of certain demographic groups. Sample weights are supplied to account for the multistage area probability design and were used in the analyses. More information for the HRS is published elsewhere.¹⁴

Those who participated in the 2006 wave of the HRS were included ($n = 18,469$) and followed for 8 years (2008, 2010, 2012, and 2014 waves). Starting with the 2006 wave, half of the sample completed detailed face-to-face interviews that included physical, biological, and psychosocial measures. The other half sample completed the core interview, usually by telephone. To reduce participant burden and study-related expenses, the half-samples alternated the enhanced interviews at each subsequent wave. Interview response rates have been $>80\%$ for each wave of the HRS.¹³

Written informed consent was provided by each participant before entering the HRS and the University's Behavioral Sciences Committee Institutional Review Board approved the protocols. Data used in this analysis contained no direct identifiers, thereby ensuring participant anonymity.

Measures

Outcome variable—At each wave, participants reported their ability to walk across a room, shower or bathe, eat, get in or out of bed, use the toilet, and dress themselves. Those indicating difficulty or an inability to perform any of the 6 ADL were considered having an ADL disability.

Exposure variables—Participants told survey interviewers about their ability to perform 6 IADL at each wave: using a map, preparing hot meals, taking medications, managing money, using a telephone, and shopping for groceries. Those reporting difficulty or an inability to perform an IADL were considered impaired for that particular IADL function.

Covariates—Age, sex, race and ethnicity (Black, Hispanic, White), height, and body mass were self-reported by participants at each wave. Body mass index (BMI) was calculated as body mass divided by height in meters-squared.

A Smedley spring-type hand-held dynamometer (Scandidact, Denmark) was used to measure handgrip strength. Before performing the test, interviewers explained the protocol and fit the dynamometer to each participant's hand size. A practice trial was then performed with the arm at the side and elbow flexed 90 degrees while standing. Those unable to stand or position their arm while gripping the dynamometer could be seated and rest their upper arm on an object for support. Starting with the nondominant hand, participants performed 2 measures on each hand, alternating between hands. If only one hand could be used for testing, a 30-second break was allowed between assessments.¹⁵ For each measure, participants squeezed the dynamometer with maximal effort, and then released the muscle contractions. The highest handgrip strength measurement from a single trial on either hand was included in the analyses. Those that had a surgical procedure, swelling, inflammation, intense pain, or an injury in both hands did not participate in handgrip strength assessments. Handgrip strength measurements were a part of the enhanced face-to-face interviews, so data for either the 2006 or 2008 waves, and the 2010 or 2012 waves, were concatenated.

Cognition was assessed with a series of tests from the modified Telephone Interview of Cognitive Status (TICS), a validated cognitive screening tool from the Mini-Mental State Examination that was designed for population-based studies.¹⁶ A 27-point composite scale was used for respondents under age 65 years that included immediate and delayed word recall from a list of 10 words (0–20 points), serial sevens subtraction test beginning with the number 100 (0–5 points), and counting backward at maximal speed for 10 continuous numbers starting from 20 (0–2 points). Those with scores less than 7 were considered as having a severe cognitive impairment.¹⁷

For respondents aged at least 65 years, cognitive function was assessed with a 35-point composite scale. The added assessments that were included on the 35-point scale were mental status questions such as object naming (0–2 points), date naming (0–4 points), and correctly identifying the current president and vice president of the United States (0–2 points). Those with scores less than 8 were considered severely cognitively impaired.¹⁸ Proxy respondents were excluded (n = 2735) because the assessment of cognition for proxies includes the ability to perform 5 IADL.¹⁷

Morbidity was collected by self-report of health care provider–diagnosed hypertension, diabetes, cancer (excluding minor skin cancer), lung disease such as bronchitis or emphysema, a heart condition (eg, coronary heart disease, angina, congestive heart failure), stroke, emotional or psychiatric problems, and arthritis or rheumatism. A morbidity count was summed at each wave and included in the analyses.

At each wave, participants reported if they had ever smoked more than 100 cigarettes in their lifetime, and if they were currently smoking cigarettes.

Mental health was assessed at each wave with the 8-item Center for the Epidemiologic Studies Depression (CES-D) scale.¹⁹ Participants reported if they experienced any negative (felt depressed, everything was an effort, restless sleep, was lonely, felt sad, and could not get going) or positive indicators (felt happy, enjoyed life; reverse scored) for depressive symptoms during the week before the interview date. Scores ranged from 0 to 8, with higher values indicating more depressive symptoms. The continuous score was used in analyses.

A single-item measure of self-perceived health was assessed at each wave, whereby participants evaluated their health as either excellent, very good, good, fair, or poor.

Statistical Analysis

Separate Cox proportional hazard regression models examined the time-varying associations between individual IADL impairments and time to ADL disability after adjusting for handgrip strength, age, sex, race and ethnicity, BMI, severe cognitive impairments, morbidity, CESD score, smoking history, current smoking status, and self-perceived health. The number of days since entering the study until ADL disability or date of last interview was the time variable, and date of birth was the entry variable to account for left truncation. Censoring occurred if participants did not have an ADL disability by the 2014 wave or if they dropped out of the study.

A sensitivity analysis was performed to determine the potential confounding effect of sex. We stratified the models by sex to determine if estimates changed by >10%. If the estimates for each IADL impairment in the sex-stratified models changed by >10%, there was evidence of confounding for sex in the models.²⁰ An alpha of 0.05 was used and analyses were conducted with SAS 9.4 software (SAS Institute, Cary, NC).

Results

After excluding proxy respondents, another 398 were excluded for missing covariates at each wave. There were 15,336 participants included (97.4%), and a data flow diagram for those included is presented in Figure 1. The descriptive characteristics of the participants are shown in Table 1. An IADL impairment in reading a map was most frequent among participants, and between 16% and 19% had an ADL disability. To make comparisons for descriptive variables between waves, the means and 95% confidence intervals (CIs) are in Appendix 1. The weighted descriptive characteristics of the participants are in Appendix 2.

A Sankey Bar Chart²¹ is shown in Figure 2 to illustrate the fluidity in the number of IADL limitations participants had at each wave. This type of chart allows for changes within

categorical groups to be viewed over time, specifically, how proportions within a given category contribute to other categories at subsequent time points. For our investigation, although participants may have experienced improvements, consistency, or declines in their IADL abilities over time, IADL impairments tended to increase with age. For those with at least 1 IADL impairment, 60% had a single impairment and <1% had all 6 for the 2006 wave, whereas 47% had a single IADL impairment and 3% had all 6 for the 2014 wave.

The results for the time-varying associations between individual IADL impairments and time to ADL disability are depicted in Figure 3. An impairment in each of the following IADL were associated with a higher hazard for an ADL disability: 2.52 (CI 2.35, 2.70) for grocery shopping, 1.91 (CI 1.77, 2.06) for preparing a hot meal, 1.55 (CI 1.37, 1.76) for taking medications, 1.48 (CI 1.36, 1.61) for managing money, 1.41 (CI 1.27, 1.57) for using a telephone, and 1.38 (CI 1.29, 1.48) for using a map. Full results from the models examining the associations between each IADL impairment and time to ADL disability are listed in Table 2.

The results for the associations between individual IADL impairments and time to ADL disability for males and females are presented in Appendices 3 and 4, respectively. A >10% change did not occur when comparing the estimates for either of the sex-stratified models to the overall model, thereby suggesting sex was not confounding in our analyses.

Discussion

The principal results of this investigation demonstrate that impairments in all IADL were differentially associated with a higher hazard for ADL disability in middle-aged and older adults in the United States. Specifically, the highest hazard ratios were seen in participants with IADL impairments in grocery shopping and hot meal preparation. These results provide insights into the disabling process by identifying how the presence of impairments in individual IADL may accelerate time to ADL disability. Health care providers working with patients that are at risk for reduced functional capacity and targeted interventions aiming to retain function as adults age should consider how impairments in specific IADL may exacerbate the disabling process.

Although IADL impairments may predict future ADL disability,⁷ few studies have previously assessed the connection between individual IADL impairments and subsequent ADL disability. For our population of community-dwelling middle-aged and older adults, the magnitude of the hazard ratios for the associations between impairments in grocery shopping or preparing hot meals and subsequent ADL disability was strong. The ability to grocery shop is primarily driven by physical attributes such as carrying items and being mobile.²² Physical functioning is a key component of ADL performance, so this finding is not surprising. Similarly, motor and process skills are necessary to prepare a hot meal.²³ These skills may connect with the same skills that are necessary for performing most ADL. Middle-aged and older adults who have difficulty or are unable to prepare a hot meal or shop for groceries likely have a poor nutritional status. Losing the ability to perform these tasks may serve as a mechanism for developing an ADL limitation.

Impairments in “first impact” IADL such as taking medications and managing money have been connected with subsequent ADL disability and are possibly driven by deficits in the attention skills necessary for completing these tasks.^{24,25} Spatial awareness skills are important to use a map.²⁶ An impairment in using a map may make it challenging for individuals to find landmarks and items in the free-living environment. Deficiencies in these factors may influence several self-care tasks necessary to perform ADL, which explains why our results suggest that an impairment in using a map was associated with an ADL disability. Likewise, planning and process skills are needed to independently use a telephone.²⁴ Deficits in these skills may translate to reduced self-care abilities that are necessary for completing ADL.

Our results also demonstrated that participants experienced changes in their IADL functional trajectories over time. Hardy et al²⁷ revealed that frail older adults had higher rates of transitions from less to more disability compared to those who were not frail. Another similar investigation found that community-dwelling older adults with newly acquired functional limitations were able to recover from their disability within a year.²⁸ While improvements from functional limitations are often short lasting, the mutability in the number of IADL impairments raises key questions about how independent living tasks can be retained during aging. Preventing acute health events that cause IADL impairments and promoting rehabilitation is important for IADL recovery.²⁸ Targeted interventions aiming to preserve IADL function should continually evaluate IADL over time to determine which individuals are experiencing changes in the functional capacity trajectories and what IADL are most likely to be recovered. However, more research is needed to determine how to best prevent and decelerate functional loss.

Based on our findings, we suggest that consideration be given to modifying the standard binary definition for an IADL disability. Our results clearly indicate that IADL impairments are dynamic over time, and an impairment in each IADL is differentially associated with an ADL disability. Therefore, it is likely that individual IADL impairments are differentially associated with other clinically relevant health outcomes. Changes in societal norms may also lead to an overestimation of impairments for certain IADL functions. For example, the use of global positioning systems and mobile phones may make evaluations of map reading ability outdated, especially as the aging population grows.²⁹ More research is needed to enhance assessments of IADL functions, including examining what tasks are assessed, avoiding overlaps in the skills needed to perform functions, acknowledging changes in functional status over time, and advancing outcome measures for better capturing functional capacity in middle-aged and older adults.

Some study limitations should be noted. Self-reported physical activity was not included in our models because the questionnaire used in the HRS has not been well-validated. Other functional measures such as the physical function index were not included because walking and transferring ability is assessed in ADL. Similarly, gait speed was only performed in those aged at least 65 years and could therefore not be included. We were unable to concatenate handgrip strength data for the 2014 wave with the 2016 wave because those data have not yet been released. It is possible that our results are underestimated because those who dropped out or died likely had poor functional capacity. Moreover, we did not have

complete data for participants at each wave. Participants were followed starting at the 2006 wave and if there were missing covariates for a given wave, those data were excluded from the models for that wave. This was accounted for when determining the time variable for our Cox models. Nevertheless, multilevel models can overcome intermittent missingness between waves, and participant drop-out was <5% between waves.^{30–32} Detailed missing covariate information is presented in Appendix 5.

Conclusions/Relevance

Impairments in individual IADL were each associated with a higher hazard for ADL disability in middle-aged and older adults; however, the presence of certain IADL impairments may accelerate time to ADL more than others. Our findings should be used to inform health care providers and interventions aiming to preserve IADL functions as adults age. More research is needed to identify which individuals experience improvement, persistence, or regression in their functional capacity trajectories over time, and how losses in certain IADL can be recovered. Such information may help aging adults retain function and slow the disabling process.

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Appendix

Appendix 1

Means and 95% Confidence Intervals for the Descriptive Characteristics of the Participants

	2006 Wave	2008 Wave	2010 Wave	2012 Wave	2014 Wave
Handgrip strength, kg	31.6 (31.4, 31.8)	31.7 (31.5, 31.9)	31.4 (31.1, 31.7)	31.6 (31.3, 31.8)	28.7 (28.4, 29.0)
Age, y	66.9 (66.7, 67.1)	68.3 (68.2, 68.5)	69.8 (69.7, 70.0)	71.2 (71.0, 71.3)	72.5 (72.3, 72.6)
Female, %	60.0 (59.2, 60.8)	60.5 (59.6, 61.3)	60.9 (60.0, 61.7)	61.3 (60.5, 62.2)	62.1 (61.2, 63.1)
White, %	81.4 (80.3, 82.0)	81.5 (80.9, 82.2)	81.2 (80.6, 81.9)	81.4 (80.7, 82.1)	81.0 (80.2, 81.7)
Black, %	13.7 (13.1, 14.2)	13.5 (12.9, 14.1)	13.7 (13.1, 14.3)	13.4 (12.8, 14.0)	13.7 (13.0, 14.3)
Hispanic, %	8.7 (8.2, 9.1)	8.8 (8.3, 9.2)	8.7 (8.2, 9.2)	9.0 (8.5, 9.5)	9.0 (8.5, 9.6)
Body mass index	28.0 (27.9, 28.1)	28.2 (28.1, 28.3)	28.2 (28.1, 28.3)	28.2 (28.1, 28.3)	28.2 (28.1, 28.3)
Severe cognitive impairment, %	2.4 (2.1, 2.6)	2.0 (1.8, 2.2)	1.4 (1.2, 1.6)	1.6 (1.4, 1.8)	3.1 (2.8, 3.5)
Number of morbid conditions	1.9 (1.9, 1.9)	2.1 (2.0, 2.1)	2.2 (2.2, 2.3)	2.4 (2.3, 2.4)	2.5 (2.5, 2.5)
Depression score	1.5 (1.4, 1.5)	1.4 (1.3, 1.4)	1.3 (1.3, 1.4)	1.3 (1.3, 1.4)	1.3 (1.3, 1.4)
Current smoker, %	14.2 (14.0, 14.5)	13.0 (12.8, 13.3)	11.8 (11.5, 12.0)	10.9 (10.7, 11.2)	9.5 (9.3, 9.8)
Previous smoker, %	57.2 (56.6, 58.1)	56.7 (56.0, 57.6)	56.2 (55.5, 57.2)	55.6 (54.7, 56.6)	54.8 (53.8, 55.7)
Self-rated health, %					
Excellent	11.6 (11.1, 12.2)	9.3 (9.1, 9.5)	9.3 (9.1, 9.5)	8.6 (8.4, 8.8)	7.2 (7.0, 7.4)
Very good	30.0 (29.4, 30.8)	30.0 (29.8, 30.4)	32.3 (31.9, 32.6)	31.5 (31.2, 31.9)	30.2 (29.8, 30.5)
Good	30.9 (30.7, 31.3)	32.6 (32.3, 32.9)	32.6 (32.3, 33.0)	32.8 (32.5, 33.2)	34.6 (34.2, 35.0)

	2006 Wave	2008 Wave	2010 Wave	2012 Wave	2014 Wave
Fair	19.8 (19.6, 20.1)	19.9 (19.7, 20.2)	19.2 (18.9, 19.5)	19.6 (19.3, 19.9)	20.9 (20.6, 21.3)
Poor	7.3 (7.1, 7.4)	7.9 (7.7, 8.1)	6.4 (6.2, 6.6)	7.2 (7.0, 7.4)	6.8 (6.6, 7.0)
Reading a map, IADL impairment, %	20.2 (19.6, 20.8)	20.2 (19.5, 20.9)	18.5 (17.9, 19.2)	18.9 (18.3, 19.7)	19.9 (19.2, 20.7)
Taking medications, IADL impairment, %	2.4 (2.2, 2.7)	2.4 (2.2, 2.7)	2.5 (2.3, 2.9)	2.8 (2.5, 3.1)	3.0 (2.7, 3.3)
Using a phone, IADL impairment, %	2.6 (2.4, 2.9)	2.8 (2.5, 3.1)	3.5 (3.2, 3.8)	3.4 (3.1, 3.8)	4.3 (3.9, 4.7)
Grocery shopping, IADL impairment, %	10.4 (9.9, 10.9)	9.6 (9.1, 10.1)	9.9 (9.3, 10.4)	10.4 (9.9, 11.0)	11.2 (10.6, 11.8)
Managing money, IADL impairment, %	7.3 (6.9, 7.7)	7.0 (6.5, 7.4)	8.0 (7.5, 8.4)	8.0 (7.5, 8.5)	9.3 (8.8, 9.9)
Preparing hot meals, IADL impairment, %	8.2 (7.8, 8.7)	8.1 (7.7, 8.6)	8.0 (7.5, 8.5)	8.7 (8.2, 9.3)	8.9 (8.3, 9.4)
ADL disability, %	16.6 (16.4, 16.8)	16.1 (15.9, 16.4)	17.6 (17.4, 17.9)	17.5 (17.2, 17.8)	19.2 (18.9, 19.5)

Appendix 2

Weighted Descriptive Characteristics of the Participants

	2006 Wave (n = 66,063,974)	2008 Wave (n = 61,052,307)	2010 Wave (n = 57,131,325)	2012 Wave (n = 54,671,767)	2014 Wave (n = 51,234,395)
Handgrip strength, kg	33.26 ± 0.13	33.32 ± 0.13	32.68 ± 0.16	32.90 ± 0.17	30.21 ± 0.20
Age, y, mean ± SD	65.26 ± 0.09	66.68 ± 0.09	68.13 ± 0.10	69.45 ± 0.09	70.66 ± 0.10
Female	36,781,874 (55.6)	34,387,591 (56.3)	33,382,234 (58.4)	32,081,756 (58.6)	30,220,522 (58.9)
White	56,878,338 (86.0)	52,716,232 (86.3)	50,484,690 (88.3)	48,345,697 (88.4)	45,152,213 (88.1)
Black	6,105,992 (9.1)	5,517,123 (9.0)	4,299,111 (7.5)	4,009,107 (7.3)	3,770,485 (7.3)
Hispanic	4,640,021 (7.0)	4,282,656 (7.0)	3,207,027 (5.6)	3,137,753 (5.7)	3,008,565 (5.8)
Body mass index, mean ± SD	28.18 ± 0.05	28.35 ± 0.06	28.28 ± 0.06	28.24 ± 0.06	28.32 ± 0.07
Severe cognitive impairment	1,794,442 (2.7)	1,249,514 (2.0)	658,902 (1.1)	683,328 (1.3)	1,122,772 (2.1)
Number of morbid conditions, mean ± SD	1.85 ± 0.01	1.99 ± 0.01	2.12 ± 0.01	2.26 ± 0.01	2.38 ± 0.01
Depression score, mean ± SD	1.49 ± 0.02	1.38 ± 0.02	1.28 ± 0.02	1.30 ± 0.02	1.27 ± 0.02
Current smoker	9,775,345 (14.8)	8,259,112 (13.5)	6,731,788 (11.7)	6,069,769 (11.1)	4,974,438 (9.7)
Previous smoker	37,817,836 (57.3)	34,631,939 (56.8)	31,807,499 (55.7)	30,121,931 (55.1)	27,820,203 (54.3)
Self-rated health					
Excellent	8,650,996 (13.1)	6,190,449 (10.1)	6,238,143 (10.9)	5,414,403 (9.9)	4,535,210 (8.8)
Very good	20,724,026 (31.4)	19,546,642 (32.0)	19,882,310 (34.8)	18,669,129 (34.1)	16,869,719 (32.9)
Good	19,796,146 (30.0)	19,312,251 (31.6)	17,985,666 (31.4)	17,473,663 (31.9)	17,451,159 (34.0)
Fair	12,154,709 (18.4)	11,283,004 (18.4)	9,701,473 (16.9)	9,488,358 (17.3)	9,266,808 (18.0)
Poor	4,659,251 (7.0)	4,682,281 (7.6)	3,297,095 (5.7)	3,583,042 (6.5)	3,081,675 (6.0)
Reading a map, IADL impairment	11,631,151 (17.6)	10,461,171 (17.1)	8,863,921 (15.5)	8,474,065 (15.5)	8,119,995 (15.8)
Taking medications, IADL impairment	1,554,410 (2.3)	1,423,263 (2.3)	1,270,892 (2.2)	1,279,988 (2.3)	1,160,608 (2.2)

	2006 Wave (n = 66,063,974)	2008 Wave (n = 61,052,307)	2010 Wave (n = 57,131,325)	2012 Wave (n = 54,671,767)	2014 Wave (n = 51,234,395)
Using a phone, IADL impairment	1,555,092 (2.3)	1,496,430 (2.4)	1,711,818 (2.9)	1,540,044 (2.8)	1,624,860 (3.1)
Grocery shopping, IADL impairment	6,431,024 (9.7)	5,147,817 (8.4)	5,051,836 (8.8)	4,847,266 (8.8)	4,566,935 (8.9)
Managing money, IADL impairment	4,543,779 (6.8)	3,965,775 (6.4)	3,889,670 (6.8)	3,746,273 (6.8)	3,745,628 (7.3)
Preparing hot meals, IADL impairment	4,948,382 (7.4)	4,319,842 (7.0)	3,938,677 (6.8)	4,051,098 (7.4)	3,617,914 (7.0)
ADL disability	10,318,279 (15.6)	9,000,099 (14.7)	8,974,930 (15.7)	8,274,199 (15.1)	8,237,425 (16.0)

SD, standard deviation.

Results are presented as n (%) unless otherwise noted.

Appendix 3

The Time-Varying Associations Between Individual IADL Impairments and Time to ADL Disability for Males

	Using a Map	Preparing Hot Meals	Taking Medications	Managing Money	Using a Telephone	Shopping for Groceries
	HR (CI)	HR (CI)	HR (CI)	HR (CI)	HR (CI)	HR (CI)
IADL limitation (Ref: no IADL limitation)	1.40 (1.21, 1.63)	1.88 (1.65, 2.14)	1.58 (1.30, 1.93)	1.40 (1.21, 1.62)	1.52 (1.27, 1.82)	2.41 (2.14, 2.71)
Handgrip strength (5-kg decrease)	1.07 (1.04, 1.10)	1.07 (1.04, 1.11)	1.07 (1.04, 1.10)	1.07 (1.04, 1.11)	1.08 (1.05, 1.11)	1.06 (1.03, 1.10)
Age	1.00 (0.99, 1.00)	0.99 (0.99, 1.00)	1.00 (0.99, 1.01)	1.00 (0.99, 1.00)	1.00 (0.99, 1.00)	0.99 (0.99, 1.00)
White (Ref: not white)	0.99 (0.79, 1.24)	0.98 (0.79, 1.22)	0.99 (0.79, 1.24)	0.97 (0.78, 1.20)	0.99 (0.79, 1.24)	1.02 (0.82, 1.27)
Black (Ref: not black)	1.16 (0.90, 1.51)	1.18 (0.91, 1.52)	1.20 (0.93, 1.56)	1.18 (0.92, 1.52)	1.22 (0.94, 1.58)	1.24 (0.96, 1.60)
Hispanic (Ref: not Hispanic)	1.01 (0.84, 1.21)	1.05 (0.88, 1.26)	1.07 (0.90, 1.27)	1.04 (0.87, 1.24)	1.03 (0.87, 1.23)	1.04 (0.87, 1.25)
Body mass index	1.03 (1.02, 1.04)	1.03 (1.02, 1.04)	1.03 (1.02, 1.04)	1.03 (1.02, 1.04)	1.03 (1.02, 1.04)	1.03 (1.02, 1.04)
Cognitive impairment (Ref: not impaired)	1.22 (0.94, 1.59)	1.17 (0.90, 1.52)	1.20 (0.92, 1.56)	1.25 (0.96, 1.63)	1.18 (0.89, 1.55)	1.13 (0.88, 1.45)
Morbidity*	1.04 (1.00, 1.08)	1.02 (0.99, 1.06)	1.03 (0.99, 1.07)	1.03 (0.99, 1.07)	1.04 (1.00, 1.07)	1.01 (0.97, 1.04)
Depression score	1.16 (1.13, 1.19)	1.16 (1.14, 1.19)	1.17 (1.14, 1.19)	1.16 (1.13, 1.19)	1.16 (1.14, 1.19)	1.15 (1.13, 1.18)
Current smoker (Ref: nonsmoker)	1.00 (0.86, 1.17)	1.02 (0.87, 1.18)	1.04 (0.89, 1.21)	1.02 (0.88, 1.19)	1.01 (0.86, 1.18)	0.98 (0.84, 1.14)
Previous Smoker (Ref: nonsmoker)	1.17 (1.04, 1.32)	1.18 (1.05, 1.33)	1.17 (1.04, 1.32)	1.17 (1.05, 1.32)	1.20 (1.07, 1.35)	1.19 (1.06, 1.33)
Self-rated health status (Ref: excellent)						
Very good	1.41 (1.02, 1.96)	1.44 (1.05, 1.99)	1.37 (0.99, 1.89)	1.44 (1.04, 1.99)	1.42 (1.03, 1.97)	1.47 (1.07, 2.03)
Good	3.35 (2.45, 4.57)	3.45 (2.53, 4.69)	3.28 (2.40, 4.48)	3.41 (2.51, 4.64)	3.37 (2.47, 4.61)	3.52 (2.59, 4.79)
Fair	3.35 (4.00, 7.60)	5.77 (4.20, 7.92)	5.44 (3.95, 7.50)	5.69 (4.14, 7.81)	5.55 (4.03, 7.65)	5.47 (3.98, 7.51)
Poor	7.48 (5.31, 10.53)	7.25 (5.17, 10.18)	7.23 (5.13, 10.20)	7.45 (5.31, 10.47)	7.50 (5.32, 10.57)	6.81 (4.85, 9.56)

HR, hazard ratio; Ref, referent.

* For Every 1 Condition.

Appendix 4

The Time-Varying Associations Between Individual IADL Impairments and Time to ADL Disability for Females

	Using a Map HR (CI)	Preparing Hot Meals HR (CI)	Taking Medications HR (CI)	Managing Money HR (CI)	Using a Telephone HR (CI)	Shopping for Groceries HR (CI)
IADL limitation (Ref: no IADL limitation)	1.36 (1.26, 1.46)	1.96 (1.79, 2.16)	1.53 (1.30, 1.80)	1.52 (1.37, 1.68)	1.34 (1.17, 1.53)	2.61 (2.40, 2.85)
Handgrip strength (5-kg decrease)	1.03 (1.02, 1.05)	1.03 (1.01, 1.05)	1.04 (1.02, 1.06)	1.04 (1.02, 1.06)	1.04 (1.01, 1.05)	1.03 (1.01, 1.04)
Age	1.01 (1.00, 1.01)	1.01 (1.00, 1.01)	1.01 (1.00, 1.01)	1.01 (1.00, 1.01)	1.01 (1.00, 1.01)	1.00 (1.00, 1.01)
White (Ref: not white)	1.15 (0.97, 1.36)	1.13 (0.95, 1.35)	1.16 (0.98, 1.38)	1.14 (0.97, 1.35)	1.16 (0.98, 1.38)	1.13 (0.94, 1.34)
Black (Ref: not black)	1.44 (1.20, 1.73)	1.52 (1.25, 1.83)	1.51 (1.25, 1.82)	1.48 (1.23, 1.78)	1.53 (1.27, 1.84)	1.41 (1.17, 1.71)
Hispanic (Ref: not Hispanic)	0.97 (0.86, 1.09)	1.02 (0.91, 1.16)	0.99 (0.87, 1.11)	0.98 (0.86, 1.10)	0.99 (0.88, 1.12)	1.03 (0.91, 1.16)
Body mass index	1.02 (1.02, 1.03)	1.02 (1.02, 1.03)	1.02 (1.02, 1.03)	1.02 (1.02, 1.03)	1.02 (1.02, 1.03)	1.02 (1.01, 1.02)
Cognitive impairment (Ref: not impaired)	1.08 (0.88, 1.32)	0.99 (0.80, 1.23)	1.03 (0.83, 1.28)	0.99 (0.80, 1.23)	1.04 (0.84, 1.29)	0.96 (0.78, 1.18)
Morbidity*	1.05 (1.02, 1.07)	1.03 (1.00, 1.06)	1.04 (1.01, 1.07)	1.05 (1.02, 1.07)	1.05 (1.02, 1.08)	1.02 (0.99, 1.05)
Depression score	1.12 (1.11, 1.14)	1.12 (1.10, 1.14)	1.13 (1.11, 1.14)	1.12 (1.11, 1.14)	1.13 (1.11, 1.15)	1.11 (1.09, 1.13)
Current smoker (Ref: nonsmoker)	1.02 (0.91, 1.15)	1.02 (0.90, 1.15)	1.03 (0.92, 1.16)	1.01 (0.90, 1.14)	1.02 (0.91, 1.15)	0.97 (0.85, 1.09)
Previous smoker (Ref: nonsmoker)	0.96 (0.89, 1.03)	0.97 (0.90, 1.04)	0.96 (0.89, 1.04)	0.96 (0.89, 1.03)	0.97 (0.90, 1.04)	0.99 (0.62, 1.06)
Self-rated health status (Ref: excellent)						
Very good	1.88 (1.38, 2.55)	1.94 (1.43, 2.63)	1.94 (1.42, 2.66)	1.91 (1.41, 2.60)	1.90 (1.40, 2.58)	1.99 (1.47, 2.71)
Good	3.98 (2.95, 5.37)	4.19 (3.11, 5.65)	4.20 (3.09, 5.71)	4.11 (3.05, 5.54)	4.11 (3.04, 5.54)	4.22 (3.13, 5.69)
Fair	7.78 (5.74, 10.56)	7.96 (5.87, 10.80)	8.41 (6.15, 11.49)	8.14 (6.00, 11.03)	8.23 (6.07, 11.16)	7.50 (5.52, 10.17)
Poor	11.64 (8.50, 15.94)	10.80 (7.89, 14.79)	12.57 (9.12, 17.34)	11.99 (8.76, 16.42)	12.14 (8.87, 16.62)	9.29 (6.78, 12.75)

HR, hazard ratio; Ref, referent.

* For every 1 condition.

Appendix 5

Number of Missing Observations for Each Wave

	2006 Wave	2008 Wave	2010 Wave	2012 Wave	2014 Wave
Handgrip strength*	2620	1670	2099	1545	5600
Age	0	0	0	0	0
Sex	0	0	0	0	0
Race and ethnicity	2	0	0	0	0
Body mass index	191	125	123	99	96
Severe cognitive impairment	0	0	0	0	0
Number of morbid conditions	0	2	1	0	0
Depression score	7	1	268	4	0
Current smoker	41	33	23	12	7
Previous smoker	39	32	22	11	4
Self-rated health	20	10	5	14	7
IADL—Reading a map	14	7	18	32	30
IADL—Taking medications	219	159	147	140	132
IADL—Using a phone	8	5	3	11	12
IADL—Grocery shopping	7	6	5	16	14
IADL—Managing money	9	5	8	14	15
IADL—Preparing hot meals	7	5	7	16	13
ADL disability	0	0	0	0	0

* Measures alternated for participants at each wave.

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Fig. 1.

Data flow schematic for those included. *Measures of handgrip strength have not yet been released for the other half sample in the 2016 wave.

Fig. 2.

Sankey bar chart for illustrating changes in the number of IADL impairments at each wave.

Fig. 3.

Forest plot for the associations between impairments in individual IADL and time to ADL disability. The models were adjusted for handgrip strength, age, sex, race and ethnicity, body mass index, severe cognitive impairment, morbidity, depression score, smoking history, current smoking status, and self-perceived health.

Table 1

Descriptive Characteristics of the Participants

	2006 Wave (n = 15,336)	2008 Wave (n = 13,863)	2010 Wave (n = 12,495)	2012 Wave (n = 11,601)	2014 Wave (n = 10,471)
Handgrip strength, kg	31.6 ± 11.1	31.7 ± 11.0	31.4 ± 13.9	31.6 ± 14.0	28.7 ± 10.9
Age, y, mean ± SD	66.9 ± 10.6	68.3 ± 10.3	69.8 ± 9.4	71.2 ± 9.6	72.5 ± 9.4
Female	9205 (60.0)	8387 (60.5)	7614 (60.9)	7122 (61.3)	6512 (62.1)
White	12,490 (81.4)	11,307 (81.5)	10,156 (81.2)	9446 (81.4)	8483 (81.0)
Black	2105 (13.7)	1879 (13.5)	1714 (13.7)	1561 (13.4)	1435 (13.7)
Hispanic	1336 (8.7)	1222 (8.8)	1091 (8.7)	1048 (9.0)	949 (9.0)
Body mass index, mean ± SD	28.0 ± 5.8	28.2 ± 5.9	28.2 ± 6.0	28.2 ± 5.9	28.2 ± 5.9
Severe cognitive impairment	374 (2.4)	282 (2.0)	182 (1.4)	189 (1.6)	333 (3.1)
Number of morbid conditions, mean ± SD	1.9 ± 1.4	2.1 ± 1.4	2.2 ± 1.4	2.4 ± 1.4	2.5 ± 1.4
Depression score, mean ± SD	1.5 ± 1.9	1.4 ± 1.9	1.3 ± 1.9	1.3 ± 1.9	1.3 ± 1.9
Current smoker	2188 (14.2)	1813 (13.0)	1474 (11.8)	1272 (10.9)	1002 (9.5)
Previous smoker	8782 (57.2)	7863 (56.7)	7033 (56.2)	6455 (55.6)	5737 (54.8)
Self-rated health					
Excellent	1791 (11.6)	1293 (9.3)	1169 (9.3)	999 (8.6)	762 (7.2)
Very good	4614 (30.0)	4172 (30.0)	4036 (32.3)	3661 (31.5)	3163 (30.2)
Good	4748 (30.9)	4524 (32.6)	4080 (32.6)	3808 (32.8)	3624 (34.6)
Fair	3042 (19.8)	2768 (19.9)	2402 (19.2)	2279 (19.6)	2195 (20.9)
Poor	1121 (7.3)	1096 (7.9)	803 (6.4)	840 (7.2)	720 (6.8)
Reading a map, IADL impairment	3100 (20.2)	2806 (20.2)	2319 (18.5)	2200 (18.9)	2088 (19.9)
Taking medications, IADL impairment	379 (2.4)	337 (2.4)	323 (2.5)	329 (2.8)	315 (3.0)
Using a phone, IADL impairment	413 (2.6)	495 (2.8)	442 (3.5)	405 (3.4)	452 (4.3)
Grocery shopping, IADL impairment	1600 (10.4)	1342 (9.6)	1237 (9.9)	1216 (10.4)	1174 (11.2)
Managing money, IADL impairment	1125 (7.3)	971 (7.0)	999 (8.0)	929 (8.0)	983 (9.3)
Preparing hot meals, IADL impairment	1268 (8.2)	1133 (8.1)	1005 (8.0)	1020 (8.7)	932 (8.9)
ADL disability	2552 (16.6)	2239 (16.1)	2210 (17.6)	2039 (17.5)	2014 (19.2)

SD, standard deviation.

Results are presented as n (%) unless otherwise noted.

Table 2
The Time-Varying Associations Between Individual IADL Impairments and Time to ADL Disability

	Using a Map HR (CI)	Preparing Hot Meals HR (CI)	Taking Medications HR (CI)	Managing Money HR (CI)	Using a Telephone HR (CI)	Shopping for Groceries HR (CI)
IADL limitation (Ref: no IADL limitation)	1.38 (1.29,1.48)	1.91 (1.77, 2.06)	1.55 (1.37,1.76)	1.48 (1.36, 1.61)	1.41 (1.27, 1.57)	2.52 (2.35, 2.70)
Handgrip strength (5-kg decrease)	1.04 (1.02,1.06)	1.04 (1.02, 1.06)	1.04 (1.03,1.06)	1.04 (1.02, 1.06)	1.05 (1.03, 1.06)	1.03 (1.02,1.05)
Age	1.00 (1.00, 1.01)	1.00 (1.00, 1.01)	1.01 (1.00, 1.01)	1.00 (1.00, 1.01)	1.00 (1.00, 1.01)	1.00 (1.00, 1.00)
White (Ref: not white)	1.09 (0.95, 1.25)	1.08 (0.94, 1.24)	1.10 (0.95, 1.26)	1.07 (0.93, 1.22)	1.10 (0.96, 1.26)	1.09 (0.94, 1.25)
Black (Ref: not black)	1.34 (1.16, 1.56)	1.41 (1.20, 1.64)	1.40 (1.20, 1.64)	1.38 (1.18, 1.60)	1.42 (1.22, 1.66)	1.36 (1.16,1.29)
Hispanic (Ref: not Hispanic)	0.98 (0.89, 1.09)	1.04 (0.94, 1.15)	1.02 (0.92, 1.13)	1.00 (0.91,1.11)	1.01 (0.91, 1.12)	1.03 (0.93, 1.14)
Male (Ref: not male)	1.13 (1.04, 1.22)	1.06 (0.99, 1.15)	1.07 (0.99, 1.15)	1.06 (0.98, 1.15)	1.06 (0.98, 1.15)	1.10 (1.02, 1.18)
Body mass index	1.03 (1.02, 1.03)	1.02 (1.02, 1.03)	1.03 (1.02,1.03)	1.03 (1.02, 1.03)	1.03 (1.02, 1.03)	1.02 (1.02, 1.03)
Cognitive impairment (Ref: not impaired)	1.13 (0.97, 1.33)	1.06 (0.90, 1.25)	1.09 (0.92, 1.29)	1.08 (0.92, 1.28)	1.09 (0.92, 1.29)	1.02 (0.87, 1.20)
Morbidity*	1.04 (1.02, 1.06)	1.03 (1.01, 1.05)	1.04 (1.01,1.06)	1.04 (1.02, 1.06)	1.04 (1.02, 1.07)	1.02 (1.00, 1.04)
Depression score	1.14 (1.12, 1.15)	1.14 (1.12, 1.15)	1.14 (1.12,1.16)	1.14 (1.12, 1.15)	1.14 (1.13, 1.16)	1.13 (1.11,1.14)
Current smoker (Ref: Nonsmoker)	1.02 (0.92, 1.11)	1.01 (0.92,1.11)	1.03 (0.94, 1.14)	1.02 (0.92, 1.12)	1.01 (0.92,1.11)	0.97 (0.88, 1.06)
Previous Smoker (Ref: Nonsmoker)	1.02 (0.96, 1.09)	1.03 (0.97, 1.10)	1.03 (0.96, 1.09)	1.02 (0.96, 1.09)	1.03 (0.97, 1.10)	1.04 (0.98, 1.11)
Self-rated health status (Ref: excellent)						
Very good	1.67 (1.34, 2.09)	1.71 (1.37, 2.14)	1.67 (1.33, 2.10)	1.70 (1.36, 2.12)	1.68 (1.35, 2.11)	1.76 (1.41, 2.19)
Good	3.71 (2.99, 4.60)	3.86 (3.11, 4.79)	3.78 (3.03, 4.70)	3.81 (3.07, 4.72)	3.79 (3.05, 4.71)	3.91 (3.16, 4.86)
Fair	6.79 (5.44, 8.47)	7.02 (5.63, 8.76)	7.04 (5.63, 8.82)	7.07 (5.67, 8.81)	7.06 (5.66, 8.81)	6.64 (5.33, 8.28)
Poor	9.83 (7.81, 12.38)	9.35 (7.43, 11.77)	10.11 (8.00, 12.77)	9.98 (7.93, 12.57)	10.09 (8.01, 12.70)	8.34 (6.62,10.50)

ADL, activities of daily living; IADL, instrumental activities of daily living; HR, hazard ratio; Ref, referent.

Significant results are bolded.

* For every 1 condition.