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Geriatric Impairments and Disability: The Cardiovascular Health Study

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Abstract

Objectives—Our objective was to determine the relative importance of geriatric impairments (including those in muscle strength, physical capacity, cognition, vision, hearing and psychological status) and chronic diseases in predicting subsequent functional disability in longitudinal analyses.

Design—We analyzed longitudinal data from the Cardiovascular Health Study. Multivariable Cox hazards regression modeling was used to analyze associations between time-dependent predictors and onset of disability in Activities of Daily Living (ADL) and mobility.

Setting/Participants—5888 community-dwelling elderly persons were followed for up to seven years.

Intervention—N/A

Measurements—Data were collected annually through in-person examinations.

Results—ADL disability developed in 15% of participants and mobility disability in 30%. A single multivariable model was developed that included demographics, marital status, body mass index, and number of impairments and diseases. The hazard ratios of having 1, 2, and ≥ 3 geriatric impairments (compared with none) for the outcome of ADL disability were 2.12 (95% CI 1.63–2.75), 4.25 (3.30–5.48), and 7.87 (6.10–10.17), respectively, and for having 1, 2, and ≥ 3 chronic diseases were 1.75 (1.41–2.19), 2.45 (1.95–3.07), and 3.26 (2.53–4.19), respectively. Similarly, the hazard ratios of having 1, 2, and ≥ 3 impairments for the outcome of mobility disability were 1.48 (1.27–1.73), 2.08 (1.77–2.45), and 3.70 (3.09–4.42), and for having 1, 2, and ≥ 3 diseases were 2.06 (1.76–2.40), 2.80 (2.36–3.31), and 4.20 (3.44–5.14).

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Conclusion—As compared with number of chronic diseases, the number of geriatric impairments was more strongly associated with subsequent ADL disability, and nearly as strongly associated with the subsequent mobility disability.

Keywords

geriatric impairments; disability; epidemiology

INTRODUCTION

The high prevalence of functional disability in older persons, with its attendant increased use of healthcare services and need for formal and informal care,^{1, 2} is one of the most pressing public health problems facing our healthcare system. Currently, there are over 7 million chronically disabled older Americans.³ The additional cost of medical and long-term care for newly disabled older Americans is estimated to be \$26 billion per year.⁴ Furthermore, older persons repeatedly identify maintenance of functional independence as a critical determinant of quality of life.^{5, 6}

Although many studies⁷ have examined risk factors for functional disability among community-living older persons, the relative importance of a broad range of geriatric impairments (including those in muscle strength, physical capacity, cognition, vision, hearing and psychological status) and chronic diseases has not been well-defined. While recognized by geriatricians for their prognostic importance,⁷ geriatric impairments fall outside the traditional disease-oriented model⁸ of clinical medicine and thus may be overlooked in the care of older persons in non-geriatric settings, particularly when they are subtle.^{9–11} With the aging of the population, the diminishing pool of geriatricians, and the prevailing disease-oriented model in most clinical settings, the relevance of geriatric impairments needs to be clearly defined in order to improve the care of older persons.

The overall objective of this study was to determine the relative prognostic importance of geriatric impairments and chronic diseases in determining functional disability in a large cohort of community-living older persons who were followed for seven years.

METHODS

Study Participants

The Cardiovascular Health Study (CHS) is an ongoing community-based, observational cohort study. The original objective of CHS was to identify factors associated with the onset of coronary heart disease and stroke in older persons. Beginning in 1989, 5201 men and women aged 65 years or older were recruited from four communities across the United States (Sacramento County, California; Washington County, Maryland; Forsyth County, North Carolina; and Allegheny County, Pennsylvania), with an additional 687 African Americans recruited beginning in 1992 to enhance minority representation. Potential participants were sampled from Medicare eligibility lists in each area. Those eligible included persons who were non-institutionalized, expected to remain in the area for the next three years, and able to provide informed consent. Potentially eligible persons who were wheelchair-bound or were receiving hospice treatment, radiation therapy or chemotherapy for cancer were excluded. Complete details on the inclusion/exclusion criteria have been previously reported.¹²

Data Collection

Data were collected every 12 months through in-person interviews and examinations. By the end of the analysis period, over 95% of the nondecedents participated in follow-up. We used the initial 1989 assessment as our baseline, incorporating the African-American cohort beginning in 1992. Seven years of follow-up were included for all participants.

Study Variables

Demographics—Age was considered in 5-year categories. Sex, race (non-white versus white), marital status (married versus not married, the latter category includes widowed), and highest level of education (less than high school versus at least completion of high school) were also included in the analyses.

Body Mass Index—Based on previous work demonstrating associations of low and high body mass index (BMI) with functional disability,¹³ we included similar categories for low (<21) and high (>30) BMI.

Geriatric Impairments—The status of all geriatric impairments was updated annually, to reflect development of new impairments, or resolution of existing ones. Based on previous studies demonstrating an association with functional disability,¹⁴ 6 geriatric impairments were defined, including impairments in: muscle strength, physical capacity, cognitive function, vision, hearing, and psychological status. All impairments were classified as present or absent, as follows. Grip strength, a valid indicator of overall muscle strength¹⁵, was measured in the dominant hand using a hand-held JAMAR dynamometer set at level 2 (Patterson Medical Products, Inc., Bolingbrook, Illinois).¹⁶ A total of 3 attempts in maximal effort were performed, and the average value in kilograms was recorded. Low muscle strength was defined as the lowest quintile for sex and body mass index.¹⁷ Physical capacity was assessed using a measure of gait speed. The time to walk 15 feet (4.57 meters) at usual pace was recorded, and slow gait speed was defined as the lowest quintile for sex and height in meters/second.¹⁸ Cognitive function was measured using the Modified Mini-Mental State Exam (3MS)¹⁹ and the Digital Symbol Substitution Test.²⁰ The 3MS is an expanded version of the Folstein Mini-Mental State Exam, a widely used screening test for dementia.²¹ The 3MS incorporates four additional test items (date and place of birth, word fluency, similarities, and delayed recall of words), and expands the range of scores from 0–30 to 0–100. The Digit Symbol Substitution Test explores attention and psychomotor speed. Given a code table displaying the correspondence between pairs of digits (from 1 to 9) and symbols, participants fill in blank squares with the symbol that is paired to the digit, completing as many as possible in 90 seconds. This brief, but complex, task assesses several cognitive processes, including visual search, visuo-motor coordination, and cognitive flexibility. As in previous CHS work,²² cognitive impairment was defined as a score less than 80 on the Modified Mini-Mental State Exam or a score less than 19 (which represents 1.5 SD below the mean score for this group) on the Digital Symbol Substitution Test. Visual impairment was defined as being unable to see sufficiently well to drive, watch TV, or recognize someone across a room with or without glasses. Hearing impairment was defined as being unable to hear well enough to use the phone, listen to the radio, or carry on a conversation in a crowded room, with or without a hearing aid. (Both visual and hearing impairments were assessed through participant self-report.) Depressive symptoms, denoting impairments in psychological status, were classified as present based on a score of at least 8 on the (short form) CES-D.^{23, 24} Higher scores on the CES-D indicate a higher burden of depressive symptoms. The CES-D is a self-reported measure of depressive symptoms experienced during the previous week. Previous research has shown that the 10-item version of the CES-D retains good predictive accuracy relative to the original 20-item version.²⁴

Chronic Diseases—As with geriatric impairments, we selected chronic diseases for inclusion in these analyses based on previous studies demonstrating an association with functional disability.¹⁴ The specific diseases, which were all assessed according to the standardized CHS protocol,²⁵ included: peripheral vascular disease, diabetes mellitus, coronary artery disease (CAD), stroke, heart failure, osteoarthritis, and chronic obstructive pulmonary disease (COPD). The CHS criteria for peripheral vascular disease was based on participant report of exertional leg pain relieved by rest and or physician diagnosis of peripheral vascular disease. Participants were considered diabetic if they: reported a diagnosis of diabetes mellitus; had fasting serum glucose greater than 126 mg/dL; had a serum glucose of at least 200 mg/dL 2 hours following the oral glucose tolerance test (OGTT); or reported use of diabetic medications. CAD and stroke were ascertained at annual clinic visits and interim telephone interviews based on self reports of hospitalizations and other acute events. Discharge summaries, cardiac enzyme levels, and electrocardiograms were reviewed by the CHS Cardiovascular Events Committee to classify all potential cases of CAD and stroke. Potential cases of heart failure were ascertained on the basis of hospitalization for heart failure or self-report of a physician diagnosis of heart failure, as determined during clinic visits and telephone interviews. Osteoarthritis and COPD were assigned based on self-report of a physician diagnosis. The status of all diseases was updated annually, with the exceptions of arthritis (which was not assessed at the third year) and COPD (which was assessed only at baseline).

Functional Disability—We evaluated two distinct, albeit complementary functional outcomes: onset of activities of daily living (ADL) disability and onset of mobility disability. Both outcomes were assessed annually during in-person interviews. When questioned about ADLs, participants were asked to rate the degree of difficulty they had with each item as “none”, “some”, “a lot”, or “unable to do.” To enhance clinical relevance, ADL disability was defined as “a lot of difficulty” or being “unable to do” at least one of the basic ADLs (bathing, dressing, walking around the home, getting out of bed or a chair, eating, and using the toilet). This designation is based on previous work examining disability outcomes.²⁶ Mobility disability was similarly defined as “a lot of difficulty” or “unable to do” either climbing 10 stairs or walking ½ mile. For this analysis of incident disability, we considered only participants free of disability at baseline in ADL or mobility, respectively.

Statistical Analysis

For descriptive purposes, we compared demographic and clinical characteristics between participants with 0, 1, 2, and at least 3 geriatric impairments using the Mantel-Haenszel Chi-Square test. We used multivariable Cox hazards regression modeling to analyze the association between individual time-dependent predictor variables and time to onset of ADL/mobility disability. To assess model discrimination, c-statistics (and corresponding confidence intervals [CI]) were calculated, using methods developed for Cox models with time dependent covariates.²⁷ With the exception of demographic variables (sex, race, marital status, and highest level of education), all other variables were updated throughout the study period to reflect changes in status. Participants were censored at the time of onset of disability, loss to follow-up, or death.

To assess associations with disability according to the number of impairments and diseases, respectively, we again used multivariable Cox hazards regression modeling, with 0, 1, 2, and at least 3 impairments or diseases as the time-dependent predictor variables of interest. All (time-varying) covariates shown in Table 2 were included in a single model of ADL disability and in a single model of mobility disability, respectively. These include age, sex, race, marital status, education, BMI, (number of) chronic diseases and (number of) geriatric impairments.

Rates of missing baseline data were generally low. The highest missing rate for any single variable was 6.9% for muscle strength, with all other variables missing <5%. However, rates of missing data increased after baseline. By the final year of follow-up, the highest rates of missing data were seen for: grip strength (missing in 15.0%), cognition (missing in 14.6%), and physical capacity (missing in 13.8%). To explore the issue of bias due to missing data, we determined (using the entire data set without stratification) the ignorability of missing data using both Little's²⁸ and Troxel's^{29, 30} tests. The data failed to reject the missing at random criteria.³¹ Therefore we applied sequential longitudinal imputation methods for missing data over the follow-up period. Missing data were not imputed after death or terminal loss to follow-up. Every statistical analysis in this study was repeated using 10 imputed data sets. The final analytic result from 10 repeated runs was summarized using the SAS 9.2 procedure PROC MIANALYZE.³²

All analyses were conducted using SAS software version 9.2 (SAS Institute, Cary, North Carolina). The authors had full access to and take full responsibility for the integrity of the data. All authors have read and agree to the manuscript as written.

Role of the Funding Sources

The study was conducted at the Yale Claude D. Pepper Older Americans Independence Center (P30AG21342). Dr. Gill is the recipient of a Midcareer Investigator Award in Patient-Oriented Research (K24AG021507) from the National Institute on Aging. Dr. Chaudhry is the recipient of a Paul Beeson/K23 Career Development Award (K23AG030986) from the National Institute on Aging. The research reported in this article was supported by contract numbers N01-HC-85079 through N01-HC-85086, N01-HC-35129, N01 HC-15103, N01 HC-55222, N01-HC-75150, N01-HC-45133, grant number U01 HL080295 from the National Heart, Lung, and Blood Institute, with additional contribution from the National Institute of Neurological Disorders and Stroke. A full list of principal CHS investigators and institutions can be found at <http://www.chs-nhlbi.org/pi.htm>. The manuscript was reviewed and approved by the Publications and Presentations committee of the Cardiovascular Health Study. The funding sources had no role in the design, conduct, or analysis of the study or in the decision to submit the manuscript for publication.

RESULTS

The baseline characteristics of the study population are shown in Table 1. Of the 5,888 participants, 44.8% had no geriatric impairments, 31.2% had 1, 15.2% had 2, and 8.8% had at least three. The prevalence of the geriatric impairments increased with advancing age: while 55.7% of participants aged 65–69 years had no impairments at baseline, only 20% of those aged 80 years or older had none; and while only 3.3% of those in the youngest age group had 3 or more impairments, a quarter of the oldest age group had at least 3. African-American race, “unmarried” marital status, and less than high school education were all associated with a larger number of impairments. Among the chronic diseases, participants with a history of stroke and heart failure were most likely to have at least 3 impairments.

At baseline, impairments in physical capacity (22.1%), muscle strength (20.0%), and psychological status (21.5%) were most common, followed by impairments in cognition (13.2%), hearing (7.9%) and vision (7.1%). As shown in Figure 1, the baseline prevalence of each impairment increased with advancing age, although the sharpest increases were observed for impairments in cognition, muscle strength, and physical capacity.

The prevalence of impairments and diseases increased over the follow-up period, as incident conditions developed. By the final year, 31.8% of participants had impaired psychological

status, 22.4% had cognitive impairment, and 10.7% had hearing impairment. Considering the chronic diseases, 26.0% of participants had coronary artery disease by the final year, 8.2% had cerebrovascular disease, and 10.7% had heart failure.

Of the 5646 participants who were free of disability in all of the ADLs at baseline, 869 (15%) developed ADL disability over a median follow-up of 6 years. Of the 5174 participants who were free of disability in mobility at baseline, 1577 (30%) developed mobility disability over a median follow-up of 5 years.

Shown in Table 2 are the multivariable associations of the time-dependent predictor variables with disability in ADLs and mobility, respectively. The strongest, multivariable associations with onset of ADL disability were seen with impairment in physical capacity (hazard ratio [HR] 3.03, $P < 0.001$), arthritis (HR 1.75, $P < 0.001$), psychological status (HR 1.71, $P < 0.001$), stroke (HR 1.69, $P < 0.001$), and cognitive impairment (HR 1.62, $P < 0.001$). The strongest associations with onset of mobility disability were seen with impairment in physical capacity (HR 2.24, $P < 0.001$), peripheral vascular disease (HR 1.77, $P < 0.001$), arthritis (HR 1.71, $P < 0.001$), stroke (HR 1.70, $P < 0.001$), and BMI > 30 (HR 1.59, $P < 0.001$).

To assess the effect of adding geriatric impairments to the full multivariable models (containing all covariates shown in Table 2, i.e., age, sex, race, marital status, education, BMI, and chronic diseases), we calculated c-statistics before and after adding all six geriatric impairments to the models. For the model of ADL disability, the c-statistic before adding the geriatric impairments was 0.726 (95% CI 0.709 – 0.742). The c-statistic after all six geriatric impairments were added increased to 0.771 (95% CI 0.755–0.787). This improvement in c-statistic was statistically significant, $P < 0.001$. For the model of mobility disability, the c-statistic before adding the geriatric impairments was 0.691 (95% CI 0.678 – 0.703). The c-statistic after all six geriatric impairments were added increased to 0.716 (95% CI 0.703–0.729). This improvement in c-statistic was statistically significant, $P < 0.05$.

Table 3 shows the adjusted associations of the number of impairments and diseases with the onset of disability in ADLs and mobility, respectively. The geriatric impairments were generally more strongly associated with ADL disability than the chronic diseases, with differences in strength of association increasing as the number of impairments/diseases increased. For mobility, the number of impairments was nearly as strongly associated with disability as the number of chronic diseases. Among those without mobility disability at baseline, 8.5% died without ever having documented mobility disability.

Among those without ADL disability at baseline, 12.1% died without ever having documented ADL disability. Because death and disability are competing outcomes, we re-ran our analyses using a combined outcome of disability or death, and the results were similar to those seen with disability alone (available upon request).

DISCUSSION

Our results demonstrate that when compared with chronic diseases, geriatric impairments are more strongly associated with the onset of disability in ADLs, and nearly as strongly associated with the onset of disability in mobility. Among the impairments, those in physical capacity, psychological status, and cognition had the strongest associations with onset of disability in ADLs and mobility. These impairments are amenable to interventions, including exercise training, psycho-behavioral programs, and caregiver services, suggesting that they can serve as therapeutic targets to reduce the burden of disability in older persons. Strategies to prevent the onset of disability should be a priority. For all too many older persons, the onset of functional disability is the harbinger of a downward spiral: one marked

by increasing frailty, dependence on caregivers, hospitalization, and possibly nursing home placement. The economic toll on our health care system is staggering, and patients and their families are left with greatly diminished quality of life.

While several previous studies⁷ have examined the prognostic importance of geriatric impairments and chronic diseases on an array of functional outcomes, few^{33–35} have directly compared their respective magnitude of associations. Our study has several unique strengths. We included seven years of annual follow-up on over 5000 older persons, allowing us to account for the development of new impairments and diseases. Prior work has had more limited follow-up,^{33, 34} smaller cohorts,³⁵ and did not account for diseases and impairments that develop after the initial assessment.³⁴ Detailed medical record review supplemented self-reported information for several chronic diseases, enhancing the validity of our data. Previous studies have relied on self-report only.^{33, 34} Attrition for reasons other than death was small, further strengthening the validity and generalizability of our results. Geriatric impairments were assessed using well-recognized, contemporary measures. The functional outcomes selected (i.e. ADLs and mobility) represent every day tasks that are important for independent community living, and are among the most widely used measures of functional abilities. We used sophisticated multiple imputation methods to address missing data, an important issue in longitudinal studies of older persons. Missing data can bias results, reduce power, and affect generalizability. Notably, intercurrent health events, cognitive impairment, and functional decline can all result in incomplete longitudinal data.^{36, 37} The generalizability of our results is enhanced by the fact that the CHS data were collected from a representative sample of community-living older persons from across the U.S., with a large proportion of African-Americans. Our findings are also distinct from those derived from other large aging cohorts, including Health ABC,^{26, 38, 39} the Baltimore Longitudinal Study of Aging,^{40, 41} InCHIANTI,^{42–44} Rotterdam,⁴⁵ as well as work by other prominent aging investigators,^{46–51} which have examined the prognostic importance of individual geriatric impairments as risk factors for functional disability, but have not compared the relative importance of a broad range of geriatric impairments and chronic diseases.

Our inclusion of gait speed as one of the geriatric impairments may raise concern about “auto- correlation”, i.e., that measures of physical capacity should predict disability better than chronic diseases because they are measuring the same thing. However, it is important to note physical capacity (gait speed) was more strongly associated with onset of disability in activities of daily living (ADLs) than with mobility disability, as shown in Table 2. When examining the prognostic importance all geriatric impairments together (as shown in Table 3), we also see that the impairments were more strongly associated with onset of disability in ADL than mobility. If the observed associations were driven by autocorrelation, we would expect stronger associations between geriatric impairments and mobility than with ADLs, which include eating, bathing, dressing, walking around the home, getting out of bed or a chair, and using the toilet. Furthermore, we included several geriatric impairments distinct from physical capacity, including impairments in cognition, vision, hearing, and psychological status which (as shown in Table 2) were independently associated with onset of disability in mobility and ADLs.

This study also has several limitations, which should be considered when interpreting our results. The CHS data included in this study were collected beginning in 1989 through 1996. Clinical practice has certainly changed since this time and it is possible that the relationship between geriatric impairments and functional disability has changed. However, given the dominance of the disease-oriented model and relative invisibility of geriatric impairments within this model, it is unlikely that the relationship between impairments and outcomes has changed substantially. In addition, because CHS excluded institutionalized persons, this

cohort is not representative of all elderly patients.¹² However, exclusion of institutionalized elderly persons is consistent with our focus on examining the onset of functional disability among those with intact function at baseline. Although we have contrasted geriatric impairments and chronic diseases, some impairments may in fact be due to diseases (e.g., vision impairments due to diabetes mellitus). The relationships between impairments and diseases are often complex, but given the prevailing disease-oriented model, it is still useful to consider impairments and diseases separately for our purposes. The observational nature of this study limits the ability to draw a causal connection between the presence of geriatric impairments and functional disability. While treatment rates of impairments and diseases, secondary complications, application of tertiary prevention, and effects of hospitalizations are all important issues to consider, they are outside the scope of the available data.

Medicine has been slow to develop strategies to provide optimal care for older patients, despite the aging of the population. Although chronic diseases have been the focus of attention in the traditional disease-oriented model of care, our work demonstrates that geriatric impairments are stronger determinants of disability in ADLs, and nearly as strong for mobility disability. Previous work has called for the abandonment of disease as the primary focus of medical care, with greater attention to geriatric impairments and functional abilities.⁸ Defenders of the status quo argue that “this is nothing new, we already do this.”⁵² While some clinicians may practice in this fashion, the organization, quality assessment, and reimbursement of medical care remain firmly rooted in the disease-specific model of care, making systematic, widespread diffusion of geriatric assessments into everyday clinical practice outside of geriatric settings nearly impossible. Our results, which are consistent with prominent models of functional disability⁵³, should be used to help guide the development of more patient-centered care for older patients, based on the routine assessment and management of geriatric impairments to prevent functional disability.

Most older persons live in the community and are not under the primary care of geriatricians. There is a need for increased focus on geriatric impairments in diverse health care settings. With the rapid aging of our population, health care must evolve to better meet the needs of older persons.

Acknowledgments

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References

1. Greene VL. Substitution between formally and informally provided care for the impaired elderly in the community. *Med Care*. 1983; 21:609–619. [PubMed: 6865520]
2. Jette AM, Tennstedt S, Crawford S. How does formal and informal community care affect nursing home use? *J Gerontol B Psychol Sci Soc Sci*. 1995; 50:S4–S12. [PubMed: 7757829]
3. Manton KG, Gu X. Changes in the prevalence of chronic disability in the United States black and nonblack population above age 65 from 1982 to 1999. *Proc Natl Acad Sci U S A*. 2001; 98:6354–6359. [PubMed: 11344275]

4. Guralnik JM, Alexih L, Branch LG, et al. Medical and long-term care costs when older persons become more dependent. *Am J Public Health*. 2002; 92:1244–1245. [PubMed: 12144976]
5. Sullivan MD, Kempen GI, Van Sonderen E, et al. Models of health-related quality of life in a population of community-dwelling Dutch elderly. *Qual Life Res*. 2000; 9:801–810. [PubMed: 11297022]
6. Waite LJ, Hughes ME. At risk on the cusp of old age: Living arrangements and functional status among black, white and Hispanic adults. *J Gerontol B Psychol Sci Soc Sci*. 1999; 54:S136–144. [PubMed: 10363044]
7. Stuck AE, Walthert JM, Nikolaus T, et al. Risk factors for functional status decline in community-living elderly people: A systematic literature review. *Soc Sci Med*. 1999; 48:445–469. [PubMed: 10075171]
8. Tinetti ME, Fried T. The end of the disease era. *Am J Med*. 2004; 116:179–185. [PubMed: 14749162]
9. Boustani M, Baker MS, Campbell N, et al. Impact and recognition of cognitive impairment among hospitalized elders. *J Hosp Med*. 2010; 5:69–75. [PubMed: 20104623]
10. Pinholt EM, Kroenke K, Hanley JF, et al. Functional assessment of the elderly. A comparison of standard instruments with clinical judgment. *Arch Intern Med*. 1987; 147:484–488. [PubMed: 3827424]
11. Piccoliori G, Gerolimon E, Abholz HH. Geriatric assessment in general practice using a screening instrument: Is it worth the effort? Results of a South Tyrol Study. *Age Ageing*. 2008; 37:647–652. [PubMed: 18703519]
12. Fried LP, Borhani NO, Enright P, et al. The Cardiovascular Health Study: Design and rationale. *Ann Epidemiol*. 1991; 1:263–276. [PubMed: 1669507]
13. Galanos AN, Pieper CF, Cornoni-Huntley JC, et al. Nutrition and function: Is there a relationship between body mass index and the functional capabilities of community-dwelling elderly? *J Am Geriatr Soc*. 1994; 42:368–373. [PubMed: 8144820]
14. Stuck AE, Siu AL, Wieland GD, et al. Comprehensive geriatric assessment: A meta-analysis of controlled trials. *Lancet*. 1993; 342:1032–1036. [PubMed: 8105269]
15. Rantanen T, Guralnik JM, Foley D, et al. Midlife hand grip strength as a predictor of old age disability. *JAMA*. 1999; 281:558–560. [PubMed: 10022113]
16. Hirsch CH, Fried LP, Harris T, et al. Correlates of performance-based measures of muscle function in the elderly: The Cardiovascular Health Study. *J Gerontol A Biol Sci Med Sci*. 1997; 52:M192–200. [PubMed: 9224430]
17. Fried LP, Tangen CM, Walston J, et al. Frailty in older adults: Evidence for a phenotype. *J Gerontol A Biol Sci Med Sci*. 2001; 56:M146–156. [PubMed: 11253156]
18. Barzilay JI, Blaum C, Moore T, et al. Insulin resistance and inflammation as precursors of frailty: The Cardiovascular Health Study. *Arch Intern Med*. 2007; 167:635–641. [PubMed: 17420420]
19. Teng EL, Chui HC. The Modified Mini-Mental State (3MS) examination. *J Clin Psychiatry*. 1987; 48:314–318. [PubMed: 3611032]
20. Swan GE, Carmelli D, LaRue A. Performance on the digit symbol substitution test and 5- year mortality in the Western Collaborative Group Study. *Am J Epidemiol*. 1995; 141:32–40. [PubMed: 7801963]
21. Folstein MF, Folstein SE, McHugh PR. “Mini-mental state”. A practical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res*. 1975; 12:189–198. [PubMed: 1202204]
22. Johnston SC, O’Meara ES, Manolio TA, et al. Cognitive impairment and decline are associated with carotid artery disease in patients without clinically evident cerebrovascular disease. *Ann Intern Med*. 2004; 140:237–247. [PubMed: 14970146]
23. Radloff L. The CES-D scale: A self-report depression scale for research in the general population. *Appl Psychol Measure*. 1977; 1:385–401.
24. Andresen EM, Malmgren JA, Carter WB, et al. Screening for depression in well older adults: Evaluation of a short form of the CES-D (Center for Epidemiologic Studies Depression Scale). *Am J Prev Med*. 1994; 10:77–84. [PubMed: 8037935]

25. Gottlieb DJ, Punjabi NM, Newman AB, et al. Association of sleep time with diabetes mellitus and impaired glucose tolerance. *Arch Intern Med.* 2005; 165:863–867. [PubMed: 15851636]
26. Newman AB, Simonsick EM, Naydeck BL, et al. Association of long-distance corridor walk performance with mortality, cardiovascular disease, mobility limitation, and disability. *JAMA.* 2006; 295:2018–2026. [PubMed: 16670410]
27. Kremers, W. Concordance for Survival Time Data: Fixed and Time-Dependent Covariates and Possible Ties in Predictor and Time. Rochester: Mayo Clinic; April. 2007
28. Little R. A test of missing completely at random for multivariate data with missing values. *J Am Statist Assoc.* 1988; 83:1198–1202.
29. Troxel A, Ma G, Heijttian D. An index of local sensitivity to nonignorability. *Statistica Sinica.* 2004; 14:1221–1237.
30. Ma G, Troxel A, Heijttian D. An index of local sensitivity to nonignorable drop-out in longitudinal modeling. *Stat Med.* 2005; 24:2129–2150. [PubMed: 15909292]
31. Pothoff R, Tudor G, Pieper K, et al. Can one assess whether missing data are missing at random in medical studies? *Stat Methods Med Res.* 2006; 15:213–234. [PubMed: 16768297]
32. SAS/STAT 9.2 User's Guide. Cary, NC: SAS Institute; 2008.
33. Spiers NA, Matthews RJ, Jagger C, et al. Diseases and impairments as risk factors for onset of disability in the older population in England and Wales: Findings from the Medical Research Council Cognitive Function and Ageing Study. *J Gerontol A Biol Sci Med Sci.* 2005; 60:248–254. [PubMed: 15814870]
34. Jagger C, Matthews R, Matthews F, et al. The burden of diseases on disability-free life expectancy in later life. *J Gerontol A Biol Sci Med Sci.* 2007; 62:408–414. [PubMed: 17452735]
35. Bootsma-van der Wiel A, Gussekloo J, De Craen AJ, et al. Common chronic diseases and general impairments as determinants of walking disability in the oldest-old population. *J Am Geriatr Soc.* 2002; 50:1405–1410. [PubMed: 12164998]
36. Hughes DC, Blazer DG, George LK. Age differences in life events: A multivariate controlled analysis. *Int J Aging Hum Dev.* 1988; 27:207–220. [PubMed: 3243654]
37. Masuda M, Holmes TH. Life events: Perceptions and frequencies. *Psychosom Med.* 1978; 40:236–261. [PubMed: 663053]
38. Atkinson HH, Rosano C, Simonsick EM, et al. Cognitive function, gait speed decline, and comorbidities: The health, aging and body composition study. *J Gerontol A Biol Sci Med Sci.* 2007; 62:844–850. [PubMed: 17702875]
39. Cesari M, Kritchevsky SB, Newman AB, et al. Added value of physical performance measures in predicting adverse health-related events: Results from the Health, Aging And Body Composition Study. *J Am Geriatr Soc.* 2009; 57:251–259. [PubMed: 19207142]
40. Davey A, Halverson CF Jr, Zonderman AB, et al. Change in depressive symptoms in the Baltimore longitudinal study of aging. *J Gerontol B Psychol Sci Soc Sci.* 2004; 59:270–277.
41. Talbot LA, Morrell CH, Fleg JL, et al. Changes in leisure time physical activity and risk of all-cause mortality in men and women: The Baltimore Longitudinal Study of Aging. *Prev Med.* 2007; 45:169–176. [PubMed: 17631385]
42. Ferrucci L, Bandinelli S, Benvenuti E, et al. Subsystems contributing to the decline in ability to walk: Bridging the gap between epidemiology and geriatric practice in the InCHIANTI study. *J Am Geriatr Soc.* 2000; 48:1618–1625. [PubMed: 11129752]
43. Bean JF, Leveille SG, Kiely DK, et al. A comparison of leg power and leg strength within the InCHIANTI study: which influences mobility more? *J Gerontol A Biol Sci Med Sci.* 2003; 58:728–733. [PubMed: 12902531]
44. Ble A, Volpato S, Zuliani G, et al. Executive function correlates with walking speed in older persons: The InCHIANTI study. *J Am Geriatr Soc.* 2005; 53:410–415. [PubMed: 15743282]
45. Tas U, Verhagen AP, Bierma-Zeinstra SM, et al. Incidence and risk factors of disability in the elderly: The Rotterdam Study. *Prev Med.* 2007; 44:272–278. [PubMed: 17184831]
46. Vestergaard S, Patel KV, Bandinelli S, et al. Characteristics of 400-meter walk test performance and subsequent mortality in older adults. *Rejuvenation Res.* 2009; 12:177–184. [PubMed: 19594326]

47. Chang M, Phillips C, Coppin AK, et al. An association between incident disability and depressive symptoms over 3 years of follow-up among older women: The Women's Health and Aging Study. *Aging Clin Exp Res*. 2009; 21:191–197. [PubMed: 19448392]
48. Vasunilashorn S, Coppin AK, Patel KV, et al. Use of the Short Physical Performance Battery Score to predict loss of ability to walk 400 meters: Analysis from the InCHIANTI study. *J Gerontol A Biol Sci Med Sci*. 2009; 64:223–229. [PubMed: 19182232]
49. McDermott MM, Guralnik JM, Tian L, et al. Baseline functional performance predicts the rate of mobility loss in persons with peripheral arterial disease. *J Am Coll Cardiol*. 2007; 50:974–982. [PubMed: 17765125]
50. Marsh AP, Miller ME, Saikin AM, et al. Lower extremity strength and power are associated with 400-meter walk time in older adults: The InCHIANTI study. *J Gerontol A Biol Sci Med Sci*. 2006; 61:1186–1193. [PubMed: 17167161]
51. Melzer D, Lan TY, Guralnik JM. The predictive validity for mortality of the index of mobility-related limitation--results from the EPESE study. *Age Ageing*. 2003; 32:619–625. [PubMed: 14600003]
52. Foster DW. The demise of disease? I don't think so. *Am J Med*. 2004; 116:186–187. [PubMed: 14749163]
53. Nagi, S. Some Conceptual Issues in Disability and Rehabilitation. In: Susman, M., editor. *Sociology and Rehabilitation*. Washington D.C: American Sociological Association; 1965. p. 100-113.

Figure 1.
Baseline Prevalence of Geriatric Impairments by Age Group

Table 1

Baseline Participant Characteristics (N=5888)

Characteristic	All Participants	Geriatric Impairments, %			P Value
		0	1	2 ≥3	
Overall Prevalence		44.8	31.2	15.2	8.8
Age					<0.001
65–69 y	34.3	55.7	30.0	11.0	3.3
70–74 y	31.8	49.6	32.3	12.9	5.2
75–79 y	20.4	35.6	33.3	18.4	12.7
≥ 80 y	13.5	20.0	28.3	26.5	25.2
Sex					0.095
Female	57.6	45.2	30.7	15.6	8.5
Male	42.4	44.3	31.8	14.7	9.2
Race					<0.001
White	83.6	47.8	31.4	13.7	7.1
Non-white	16.4	29.3	30.1	23.1	17.5
Marital status					<0.001
Married	66.1	49.1	30.9	13.6	6.4
Unmarried	33.8	36.6	31.6	18.3	13.5
Education					<0.001
< high school	29.4	29.7	31.5	21.9	16.9
≥ high school	70.3	51.2	31.1	12.4	5.3
Body Mass Index					0.013
<21	8.6	41.0	29.2	17.6	12.2
21–30	71.6	46.6	30.8	14.2	8.4
>30	19.8	40.1	33.3	17.8	8.8
Chronic Diseases					
Peripheral Vascular Disease	2.6	25.5	30.7	29.2	14.6
Diabetes Mellitus	22.8	37.3	32.4	18.5	11.8
Coronary Artery Disease	19.4	35.5	33.3	18.2	13.0
Stroke	4.2	25.0	24.2	25.3	25.5

Characteristic	All Participants	Geriatric Impairments, %			P Value
		0	1	2 ≥3	
Heart Failure	4.7	22.1	32.9	24.1	20.9 <0.001
Arthritis	51.5	38.3	31.9	18.3	11.5 <0.001
COPD	12.8	38.1	32.7	18.9	10.3 <0.001

Abbreviation: COPD, chronic obstructive pulmonary disease. Percentages shown for participants with 0,1,2, and ≥ 3 impairments total 100% across rows; percentages shown for all participants total 100% down column.

Table 2Multivariable Models for Onset of Disability in ADL and Mobility^a

	ADL		Mobility	
	HR (95% CI)	P Value	HR (95% CI)	P Value
Age ^b	1.20(1.11, 1.30)	<0.001	1.29(1.22, 1.37)	<0.001
Female Sex	1.34(1.13, 1.58)	<0.001	1.57(1.38, 1.78)	<0.001
Non-white Race	1.18(0.98, 1.42)	0.083	1.22(1.05, 1.42)	0.010
Unmarried	1.08(0.92, 1.27)	0.326	1.13(0.99, 1.28)	0.068
Education < high school	0.96(0.81, 1.14)	0.658	1.10(0.97, 1.25)	0.128
Body Mass Index < 21	1.14(0.87, 1.49)	0.339	0.97(0.79, 1.19)	0.781
Body Mass Index > 30	1.55(1.29, 1.85)	<.001	1.59(1.38, 1.82)	<.001
Geriatric Impairments				
Muscle strength	1.35(1.12, 1.63)	0.002	1.17(1.02, 1.34)	0.026
Physical capacity	3.03(2.56, 3.59)	<0.001	2.24(1.95, 2.57)	<0.001
Cognition	1.62(1.30, 2.02)	<0.001	1.26(1.06, 1.50)	0.008
Vision	1.52(1.25, 1.85)	<0.001	1.23(1.05, 1.46)	0.013
Hearing	1.15(0.91, 1.45)	0.236	1.26(1.00, 1.58)	0.047
Depressive symptoms	1.71(1.46, 2.01)	<0.001	1.54(1.36, 1.75)	<0.001
Chronic Diseases				
Peripheral Vascular Disease	1.29(0.91, 1.82)	0.146	1.77(1.32, 2.37)	<0.001
Diabetes Mellitus	1.26(1.05, 1.52)	0.013	1.39(1.20, 1.60)	<0.001
Coronary Artery Disease	1.07(0.90, 1.27)	0.442	1.36(1.18, 1.56)	<0.001
Stroke	1.69(1.34, 2.14)	<0.001	1.70(1.37, 2.11)	<0.001
Heart Failure	1.46(1.15, 1.87)	0.002	1.36(1.09, 1.70)	0.007
Arthritis	1.75(1.50, 2.04)	<0.001	1.71(1.53, 1.92)	<0.001
COPD	1.40(1.15, 1.70)	<0.001	1.58(1.35, 1.86)	<0.001

Abbreviations: ADL, activities of daily living; HR, hazard ratio; CI, confidence interval; COPD, chronic obstructive pulmonary disease

^a Models include all covariates shown in Table 1^b Age categorized as shown in Table 1: 65–69 years, 70–74 years, 75–79 years, and 80+ years.

The relationship between age categories and outcomes were linear (data not shown.)

Table 3Adjusted Association of Impairments and Diseases with Onset of Disability in ADL and Mobility ^a

	ADL	Mobility
	HR (95% CI) ^b	HR (95% CI) ^b
Geriatric Impairments		
0 (N = 2639)	Reference	Reference
1 (N = 1836)	2.12 (1.63, 2.75)	1.48 (1.27, 1.73)
2 (N = 896)	4.25 (3.30, 5.48)	2.08 (1.77, 2.45)
3+ (N = 517)	7.87 (6.10, 10.17)	3.70 (3.09, 4.42)
Chronic Diseases		
0 (N = 1631)	Reference	Reference
1 (N = 2378)	1.75 (1.41, 2.19)	2.06 (1.76, 2.40)
2 (N = 1276)	2.45 (1.95, 3.07)	2.80 (2.36, 3.31)
3+ (N = 603)	3.26 (2.53, 4.19)	4.20(3.44, 5.14)

Abbreviations: ADL, activities of daily living; HR, hazard ratio; CI, confidence interval

^a Hazard ratios derived from a single model for ADL disability and a single model for mobility disability. Models include all (time-varying) covariates shown in Table 2, i.e., age, sex, race, marital status, education, body mass index, chronic diseases and geriatric impairments.

^b All P values < 0.001