Journal of Applied Gerontology
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Journal of Applied Gerontology 2007; 26; 258
DOI: 10.1177/0733464807300566

The online version of this article can be found at:
http://jag.sagepub.com/cgi/content/abstract/26/3/258

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Age Distribution and Risk Factors for the Onset of Severe Disability Among Community-Dwelling Older Adults With Functional Limitations

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*This study examines age distribution and risk factors for the onset of severe disability among community-dwelling older adults with functional limitations. Data were obtained from the initial community-dwelling sample (*n *= 6,088) of the National Long-Term Care Survey in 1982 and the follow-up interviews in 1984, 1989, 1994, and 1999. Multiple proportional hazard regression was conducted using age at onset of severe disability as the dependent variable. Explanatory variables included chronic diseases and sociodemographic and personal characteristics. Of the 3,485 elders who were not severely disabled initially, 1,364 were identified as developing severe disability over time. The onset age ranged from 66 to 109 years with the peak occurring at 82 to 83 years. The predictors for earlier onset of severe disability were paralysis, arthritis, obesity, hypertension, and middle education level (Grades 9-12). These findings provide practical implications for identifying at-risk individuals and developing health behavior interventions to delay onset of severe disability.*

Keywords: *physical disability; activities of daily living; aging; longitudinal data*

Physical disability is a common health problem among older adults (Fried & Guralnik, 1997). However, time of onset of disability may vary among individuals. Older adults with functional limitations are at particularly high risk for developing severe disability (Ferrucci et al., 2004).

Journal of Applied Gerontology, Vol. 26 No. 3, June 2007 258-273
DOI: 10.1177/0733464807300566

People with functional decline have special needs for long-term health care services and the severely disabled account for most long-term care costs (Stallard, 2000; Wu, Carter, Goins, & Cheng, 2005). Therefore, preventing onset of severe disability will not only increase the quality of life in adulthood, but also reduce the health care and long-term care expenditures (Brooks, 2002). Understanding the timing and related risk factors for severe disability are critical for planning social service programs and designing interventions to prevent or delay the onset of severe disability.

Stuck and colleagues (1999) recently reviewed major longitudinal studies on risk factors related to functional decline and physical disability. The review identified 78 longitudinal studies conducted between 1985 and 1997. Many of these studies are secondary analyses using large national databases including the Alameda County Studies, the Established Populations for Epidemiologic Studies of Elderly, the Framingham Study, the Longitudinal Study of Aging, the Massachusetts Health Care Panel Study, and the National Health and Nutrition Examination Survey. All studies indicated that aging was the most important factor related to functional decline and physical disability. The risk of new onset of disability is similar between men and women after controlling for chronic conditions. Arthritis was identified in 18 studies as being significantly correlated with disability, followed by hypertension (13 studies confirmed), stroke, and diabetes (both confirmed by 12 studies). Other conditions were confirmed by 8 or fewer studies. The influence of marital status on disability depended on gender and social environment. These longitudinal analyses provided evidence of risk factors related to incidence of disability in the domains including biological, psychological, and social. No study has been conducted to examine the timing and risk factors related to the onset of severe disability. In addition, Stuck et al.'s review indicated that most of the studies used traditional designs with two-point assessments (baseline and one-time follow-up).

In this study, we aimed to fill this gap by analyzing data from the National Long-Term Care Survey (NLTCS; Clark, 1998). The NLTCS was conducted by the Duke University Center for Demographic Studies and sponsored by the National Institute of Aging. It surveys people in the United States aged 65 and older with a particular emphasis on the aged who

AUTHORS' NOTE: This study was supported by a research seed grant from West Virginia University College of Arts & Science. The authors thank Eric Stallard and Richard Pickett from the Center for Demographic Studies at Duke University and Peiyun She from the Institute for Policy Research at Cornell University for their helpful communications on the National Long-Term Care Survey data. This work was originally presented at the Gerontological Society of America's 58th Annual Scientific Meeting on November 18-22, 2005, in Orlando, Florida.

are functionally impaired, including community and institutional residents. The sample was randomly drawn from Medicare beneficiary enrollment files. An initial screening interview was used to identify functional status of the participants and to determine who would receive a subsequent detailed community or institutional interview. The NLTCS was conducted in 1982, 1984, 1989, 1994, 1999, and 2004. These surveys were designed to facilitate both longitudinal analyses, by following up with individuals in subsequent waves, and cross-sectional analysis, by adding a sample of eligible adults at each wave. The NLTCS has been used to estimate the prevalence rates of disability in the U.S. elderly population (Manton, Corder, & Stallard, 1993; Manton & Gu, 2001). Recently, Manton and colleagues (Manton, Gu, Huang, & Kovtun, 2004) have analyzed genetic determinants of disability using the 1999 NLTCS data. Cohort analysis for disability by following the individuals over all waves has not been conducted. Longitudinal analysis with repeated measurements is important because sufficient time is needed to adequately capture the individual's patterns of change in physical function. Accordingly, we analyzed the initial NLTCS community cohort and tracked their disability status in the five assessment points over the 17-year observation interval. The purposes were (a) to examine age distribution of the onset of severe disability and (b) to examine risk factors leading to earlier onset of severe disability.

Verbrugge and Jette (1994) proposed a conceptual model of the disablement process based on qualitative research. This model hypothesized that diseases and chronic conditions are the main causes of disability via specific impairments and functional limitations. In addition to the main disablement pathway, risk factors such as sociodemographic, lifestyle, psychological, and social factors can also regulate the disability progression.

Method

Data Source

The initial sampling frame of the NLTCS was adults aged 65 years or older drawn from the Medicare enrollment files in 1982. Screening interviews were conducted with approximately 36,000 people (a probability sample stratified by age, sex, and race) to identify functionally impaired individuals. Physical function was assessed using the Activities of Daily Living (ADL) scale, which contains six activity items including eating, dressing, bathing, toileting, mobility around the home, and transferring in/out of bed (Katz, Ford, Moskowitz, Jackson, & Jaffee, 1963; World Health

Table 1. Baseline Functional Status of the Initial Community Detailed Interview Cohort ($N = 6,088$)

	n	%
Number of ADL limitations[a]		
6	589	10
5	405	7
4	365	6
3	486	8
2	758	12
1	1220	20
IADL limitations[b] only	1729	28
Functional limitations[c] only	315	5
Chronic conditions[d] only	184	3
None of the above	37	0.6

a. Activity of Daily Living (ADL) limitations (6 items): eating, dressing, bathing, toileting, mobility around the home, and transferring in/out of bed.
b. Instrumental Activity of Daily Living (IADL) limitations (8 items): light housework, laundry, meal preparation, grocery shopping, getting around outside, walking to distant places outside, money management, and using telephone.
c. Functional limitations (7 items): climbing one flight of stairs, lifting a 10-pound package, bending, reaching above head, combing/brushing hair, washing hair, using fingers to grasp and handle small objects.
d. Chronic conditions (17 items): arthritis, Parkinson's, diabetes, cancer, obesity, heart attack, hypertension, stroke, asthma, epilepsy, emphysema, broken hip or bone, bronchitis, cerebral palsy, pneumonia, paralysis, and multiple sclerosis.

Organization, 1980). The participants were asked whether they were able to perform each of the six items without assistance from another individual for at least 3 months. A total of 6,088 older adults living in the community was identified and received the first detailed community interviews (Clark, 1998). As shown in Table 1, the majority (91.2%) of this sample had a chronic impairment of ADLs or IADLs (Instrumental Activity of Daily Living), whereas 5% had a functional limitation only (no ADL/IADL limitation). Among the 221 adults (3.6%) with good functional status (no ADL, IADL, or functional limitations), 184 of them had at least one chronic condition.

Analytic Sample

We first classified the sample into two groups by ADL status (severe disability or not). Adopting the criteria in other studies using the NLTCS data (Stallard, 2000; Stallard & Yee, 2000), inability in two or more ADLs was classified as severe disability. A total of 2,603 participants was already

severely disabled at entry. The final sample for analyzing the age of onset of severe disability was restricted to the 3,485 adults who were not severely disabled at entry. We then tracked their ADL status over the 17-year study period until they reached an endpoint (i.e., ADL limitations ≥ 2, death, loss to follow-up, or the end of data collection in 1999). Of the 3,485 participants, 80% had received at least one of the four follow-up interviews. In this community-based cohort, 606 became institutionalized either temporarily or permanently at the time of follow-up interviews and so their follow-up data were obtained by institutional interviews. The ADL scale was included in both community and institutional surveys, with consistent question wording in both surveys and across waves.

The Dependent Variable

The dependent variable, age at the onset of severe disability, was calculated for each individual: age at onset = age at 1982 + years from 1982 to the onset of severe disability. We assumed that the event of disability onset might not just happen at the time of the interviews. The NLTCS included the question asking duration of disability for each ADL item (how long ago did it occur?), with response options such as, "less than 1 year," "1 to 5 years," and "5 years or more." Given the fact that the largest proportion of the answers was 1 to 5 years across the six ADLs, the midpoint of the interval between relevant assessments was used as the time of onset of severe disability.

Explanatory Variables

Sociodemographic. Race was classified as White or Other. Education levels were classified into three categories: low (Grade 8 or lower), middle (Grades 9-12), and high (some college or higher). Living locations were dichotomized into city (cities with populations ≥ 250,000, and suburbs of large cities) and others (countries, farms, small cities, and towns). Regions were classified into three categories: eastern (Boston, New York, Philadelphia, Charlotte, and Atlanta), central (Detroit, Chicago, Kansas City, Dallas, and Denver), and western (Seattle and Los Angeles). Marital status was classified into three categories: married, ever married (widowed, divorced, and separated), and never married. Income level was based on the report of 1982. Of the 6,088 participants, 1,130 (19%) did not report their income by responding, "do not know/refuse." Some of these participants did provide income levels 2 years later in 1984. Therefore, of the analytic sample (the 3,458 who were not severely disabled at entry), the final number with missing

income was 379 (11%). These missing data were coded separately so that the 379 adults would be retained in the multivariate analysis.

Personal characteristics. An overall level of life satisfaction was assessed by a global question, "How satisfied are you with your life as a whole?" at each assessment. In this study, the three response options were coded as 3 = *very satisfied*, 2 = *satisfied*, and 1 = *not satisfied*. Social Network was assessed by the question, "Do you keep in touch with any friends including neighbors, either by visit or telephone?" (yes/no). Hobby was assessed by the question, "Do you work on a hobby like painting, sewing, arts, and craft?" (yes/no). Religious Activity was assessed by the question, "Did you go to a religious service during the past month?" (yes/no).

Chronic conditions. Baseline and follow-up data of the 17 chronic conditions were included in this study: rheumatoid arthritis, Parkinson's, diabetes, cancer, obesity or overweight, heart attack, hypertension, stroke, asthma, bronchitis, emphysema, paralysis, broken hip or bone, cerebral palsy, pneumonia, epilepsy, and multiple sclerosis. The participants were asked whether they had each of these medical conditions at the time of the interview (yes/no). All chronic conditions had less than 0.4% missing data (4–26 among the 6,088 participants). These missing data were coded as not having the condition in the multivariate analysis.

Analytic Approaches

Age distribution for onset of severe disability. A percentage bar chart was used to present the distribution outcomes. The denominator used to calculate the percentages was the total number of severely disabled adults identified in follow-up interviews from 1984 to 1999.

Modeling age at onset of severe disability. Risk factors predicting earlier onset of severe disability were examined by a multiple proportional hazards regression (Cox, 1972; Woodward, 1999). Cox proportional hazards model is widely used in the analysis of survival data to explain the effect of explanatory variables on hazard rates. The dependent variable for this analysis was age at onset of severe disability. Explanatory variables included sociodemographics (gender, race, living location, regions, education, income, and marital status), personal characteristics (social network, religious services, hobby, and life satisfaction), and the 14 medical conditions with a baseline prevalence rate greater than 1%. Life satisfaction and medical conditions entered in the model were data prior to the onset of severe disability, or before participants were lost to follow-up, or before death. Other explanatory variables

were baseline data. Because of the larger sample size, the α value was set at 0.005 as the significance criterion of a predictor and for calculating the 99.5% confidence interval (CI) of a hazard ratio (*r*). All analyses were performed using SAS version 9.1.2 (SAS Institute, 2004).

Results

Sample Characteristics

The ages of the analytic sample ranged from 65 to 108 years, with an average of 76.3 years (*SD* = 7.1). The majority were White (88%) and two thirds were female (63%). About half of the sample were living in large cities or in suburbs of large cities (43%), were married (44%), had an income level below $10,000 (50%), and had no education or education below high school (52%).

Tables 2 and 3 present frequency distributions of all study variables for the entire cohort (*n* = 6,088), as well as for the analytic sample (*n* = 3,485). Comparisons of frequency distributions by disability groups demonstrated cross-sectional bivariate associations between the variables and severe disability. The severe disability group contained significantly more elders aged older than 84 years, had lower levels of life satisfaction, had less contact with friends, and were less engaged in religious activities or hobbies with *p* values < 0.0001.

Age Distribution for Onset of Severe Disability

A total of 1,364 older adults was identified as having an onset of severe disability prior to death or before lost to follow-up. Among them, 716 (52%) were identified in 1984, 430 (32%) in 1989, 170 (12%) in 1994, and 48 (4%) in 1999. Age distribution for the onset of severe disability is displayed in Figure 1. Nearly half (48.6%) of the events took place from ages 76 to 83, with the peak being at ages 82 to 83. The earliest onset age was 66 years and the latest was 109 years.

Predictors and Hazard Ratios for Earlier Onset of Severe Disability

A total of 2,628 cases without any missing covariate values was used in the multiple regression analysis. Five significant factors emerged: paralysis (*r* = 2.55; CI = 1.7-3.8; *p* < .0001), obesity/overweight (*r* = 1.65; CI = 1.4-2.0; *p* < .0001), rheumatoid arthritis (*r* = 1.34; CI = 1.1-1.7; *p* = .0001), hypertension

Table 2. Sociodemographic and Personal Characteristics, and Comparisons of Those by Disability Status in 1982

	Overall (N = 6,088)		Disability Status: ADL < 2 (N = 3,485)		Disability Status: ADL ≥ 2 (N = 2,603)		
	n	%	n	%	n	%	p
Gender							.006
Male	2166	36	1290	37	876	34	
Female	3922	64	2195	63	1727	66	
Age							< .001
65-74	2481	41	1522	45	929	36	
75-84	2466	41	1414	41	1052	40	
85-94	1064	18	500	14	564	22	
95 or older	77	1	19	1	58	2	
Race							.03
White	5315	87	3070	88	2245	86	
Other	773	13	415	12	358	14	
Living location							.95
Large city or suburb of large city	2580	43	1479	43	1101	42	
Country, farm, small city, town	3485	57	1995	57	1490	58	
Region							.07
Eastern	2808	46	1627	47	1181	45	
Central	2556	42	1472	42	084	42	
Western	724	12	386	11	338	13	
Education							.01
Some college or higher	750	13	425	12	325	13	
Grades 9-12	2059	35	1240	36	819	33	
Grade 8 or below	3105	53	1746	52	1359	54	
Marital status							.32
Married	2636	44	1537	44	1099	42	
Widowed, divorced, separated	3124	52	1766	51	1358	52	
Never married	298	5	165	5	133	5	
Income							.11
$10,000 or more	1929	32	1067	31	862	33	
$5,000-$9,999	1901	31	1092	31	809	31	
$5,000 or less	1128	19	674	19	454	17	
Refused/don't know	1130	19	652	19	478	18	
Keeping in touch with friends	4867	80	2886	83	1981	76	< .0001
Working on a hobby (painting, sewing, arts, crafts)	1310	22	888	26	422	16	< .0001
Participating in religious services	2172	36	1527	44	645	25	< .0001
Very satisfied with life	1156	26	781	27	375	23	< .0001

NOTE: ADL = Activity of Daily Living.

Table 3. Chronic Conditions, and Comparisons of Those by Disability Status in 1982

			Disability Status				
	Overall		ADL < 2		ADL ≥ 2		
	(N = 6,088)		(N = 3,485)		(N = 2,603)		
	n	%	n	%	n	%	p
Rheumatoid arthritis	4456	73	2478	71	1978	76	<.001
Hypertension	2866	47	1629	47	1237	48	.6
Obesity/overweight	1456	24	875	25	581	22	.01
Diabetes	999	16	484	14	515	20	<.0001
Bronchitis	810	13	430	12	380	15	.01
Emphysema	621	10	366	11	255	10	.36
Paralysis	545	9	121	3	424	16	<.0001
Asthma	456	8	236	8	193	7	.83
Stroke	433	7	129	4	304	12	<.0001
Broken hip or bone	427	7	160	5	267	10	<.0001
Heart attack	402	7	191	6	211	8	<.0001
Cancer	368	6	174	5	194	8	<.0001
Pneumonia	350	6	169	5	181	7	.0005
Parkinson's	175	3	51	2	124	5	<.0001
Epilepsy	50	0.8	19	0.6	31	1	.006
Multiple sclerosis	32	0.5	6	0.2	26	1	<.0001
Cerebral palsy	28	0.5	8	0	20	1	.002
Records of death between 1982 and 1999	1582	26	749	21.0	833	32	<.0001

NOTE: ADL = Activity of Daily Living. The 17 chronic conditions were listed in descending order of prevalence rates.

($r = 1.24$; CI = 1.0-1.5; $p = .0006$), and education. The middle education group had higher risk of developing severe disability than the low education group ($r = 1.25$; CI = 1.0-1.5; $p = .001$), whereas no significant difference was found between the high and the low education groups. Table 4 presents the estimated hazard ratio and the confidence interval for each variable, adjusted for the effects of other covariates in the model.

Discussion

This study analyzed age at onset of severe disability using the longitudinal data of the NLTCS collected from 1982 to 1999. This data set with repeated measurements over 17 years provides an opportunity to observe

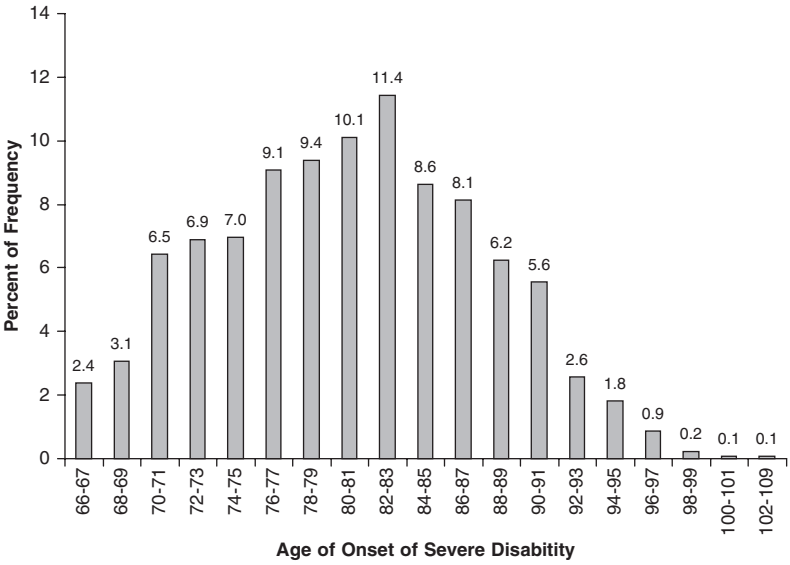

Figure 1. Age Distribution for the Onset of Severe Disability

NOTE: *N* = the 1,364 older adults who were identified as severely disabled in the follow-up interviews. The onset age ranged from 66 to 109 years, and 11.4% were onset at ages 82 to 83 years.

the distribution of onset of severe disability over a wide later age span from 65 to 108 years. The distribution demonstrates a large difference in the onset age among older adults with functional limitations living in a community. The onset age ranged from 66 to 109 years with the peak at 82 to 83 years. Given this large variability, it is necessary to investigate potential risk factors contributing to earlier onset of severe disability.

Recently, several studies used survival analysis to model time-to-onset of disability controlling for age. The explanatory variables included positive emotions (Penninx et al., 2000), gender, race, and chronic conditions (Dunlop, Manheim, Sohn, Liu, & Chang, 2002). In this study, we directly modeled age-at-onset of severe disability. This approach makes it possible to observe the timing of the onset. Such information has not been available in previous literature. In addition, a multiple regression was conducted using an extended set of explanatory variables including sociodemographic and personal characteristics, controlling for a long list of important chronic conditions. The large sample size and the long follow-up of the NLTCS increased the power of estimation for the hazard ratios.

Table 4. Longitudinal Analysis for the Onset of Severe Disability Using Multiple Proportional Hazard Regression ($n = 2,628$)

Independent Variable in the Model	*Hazard Ratio*	*(99.5% CI)*
Sex		
Female	1.17	(0.94–1.46)
Male	1.00	
Living location		
Large city or suburb of large city	0.94	(0.78–1.12)
Country, farm, small city, town	1.00	
Race		
White	1.06	(0.80–1.41)
Other	1.00	
Region		
Eastern	1.01	(0.75–1.36)
Central	0.99	(0.74–1.34)
Western	1.00	
Marital status		
Married	1.13	(0.72–1.77)
Widowed, divorced, separated	0.88	(0.57–1.37)
Never married	1.00	
Income		
< $5,000	1.05	(0.82–1.35)
$5,000-$9,999	1.06	(0.86–1.31)
≥ $10,000	1.00	
Education		
Some college or higher	1.06	(0.79–1.41)
Grades 9-12	1.25	(1.03–1.50)*
Grade 8 or lower	1.00	
Keeping in touch with friends	0.93	(0.72–1.20)
Working on a hobby (painting, sewing, arts, crafts)	0.97	(0.80–1.18)
Participating in religious services	1.02	(0.86–1.22)
Life satisfaction	0.91	(0.79–1.06)
Rheumatoid arthritis	1.34	(1.08–1.66)**
Hypertension	1.24	(1.04–1.49)**
Obesity/overweight	1.65	(1.35–2.02)***
Diabetes	1.20	(0.94–1.53)
Bronchitis	1.15	(0.88–1.50)
Emphysema	1.07	(0.78–1.48)
Paralysis	2.55	(1.70–3.83)***
Asthma	1.37	(0.99–1.90)
Stroke	0.78	(0.48–1.27)
Broken hip or bone	1.11	(0.75–1.65)
Heart attack	0.89	(0.58–1.36)
Cancer	0.79	(0.50–1.25)
Pneumonia	0.86	(0.57–1.29)
Parkinson's	1.33	(0.77–2.31)

NOTE: The dependent variable is age of onset of severe disability.
*$p < .005$. **$p < .001$. ***$p < .0001$.

This analysis identified five underlined factors leading to earlier onset of severe disability: paralysis, arthritis, hypertension, obesity, and education. This result supports the hypothesis that diseases and chronic conditions are the main causes of disability. In addition, our findings add support to the suggestion from Stuck et al.'s (1999) summary review that arthritis and hypertension are top risk conditions related to disability. Rheumatoid arthritis, a chronic autoimmune disease, is a systemic inflammatory condition that causes joint destruction, pain, swelling, and stiffness. Therefore, it is a common cause of disability among older adults. Acute events such as a stroke or an organ impairment illness often cause dramatic changes in functional status rapidly with high mortality rates and would be expected to have an immediate effect on physical function. This may be a reason that they did not contribute to the prediction and were only associated with severe disability cross-sectionally.

Although the effect of obesity on both morbidity and mortality has been examined extensively, the relationship between obesity and disability has been neglected in past research (Stuck et al., 1999). Recently, growing studies reveal that obese older adults have higher risk of ADL disability (Ferraro, Su, Gretebeck, Black, & Badylak, 2002; Jenkins, 2004; Reynolds, Saito, & Crimmins, 2005). Our finding adds support to the accumulated body of knowledge on the long-term effect of obesity on functional decline. As obesity and hypertension are strongly related to lifestyle, the predictability of these conditions for onset of severe disability suggests that behavioral factors are important in the disability process. They may exert their effect on disability through the diseases they cause. Interventions targeting health behavioral change to control the development of these chronic diseases may make a significant contribution to the prevention or delay of onset of severe disability. Some recent intervention studies to promote physical activities and healthy diet have shown promising effects among old men (McCrone, Brendle, & Barton, 2001) and among elders with functional limitations using either one-to-one counseling in general practice or community-wide promotion of walking (Cyarto, Moorhead, & Brown, 2004).

Several studies have investigated the effects of income and education on disability in adulthood. Some of these studies showed that lower socioeconomic status was associated with higher risk of disability (Berkman et al., 1993; Guralnik, LaCroix, & Abbott, 1993; Rogers, Rogerts, & Belanger, 1992). Other studies (House, Lantz, & Herd, 2005) found that these associations are neither constant nor continually increasing over the adult life course; rather, they are small in early adulthood, increase through middle and early old age (ages 55-84 years), and then diminish in later old age. Such a pattern may be due to some combination of physiological and biomedical factors, as suggested by Robert and House (1994). A recent study using a sample of

Italian elders aged 65 or older demonstrated that after adjusting for all physiological impairments, the association between education and mobility was no longer significant (Coppin et al., 2006). This result appears to confirm the interaction of physiological factors and education in the disability process. Our study reveals that the risks for the middle (Grades 9-12) and the low education groups were different, whereas income disparity in functional decline was not significant cross-sectionally nor longitudinally. This finding supports the emerging hypothesis that education status plays a larger role in functional decline than income status (House et al., 2005). On the other hand, the finding suggests that the link between education and disability may not be linear in some populations. Therefore, categorical education measures should be used in further analysis of the disability process to avoid the potential bias of using a continuous measure for education years. Further research is needed to clarify why the middle education group has a higher risk of developing severe disability in this population. As suggested in previous literature, physiological factors may account for an intermediate variable between education and severe disability, because education disparities may differentiate physiological buffers among older adults, in particular among those who are experiencing some degree of functional limitation and earlier disability. Better understanding of this issue would help in designing effective interventions targeted at different educational groups to foster physiological well-being in this population.

There are some limitations in this analysis. Because there is no specific measure for age of onset of severe disability as mentioned in the Method section, the onset age is an estimation based on the duration report. In addition, the survey questions were answered by either self-report or proxy for those who were incapable or cognitively unequipped to answer the surveys. Because participants were allowed to provide responses by self-reports to some questions and by proxy to other questions in the survey, we were not able to control for proxy responses in the multivariate analysis, which may increase the unexplained variance in the dependent variable. This study analyzed the timing and the predictors of onset for severe disability regardless of their subsequent disability status. We hope to analyze the possibility of functional status recovery in a future study.

Conclusion

The 17-year longitudinal NLTCS data demonstrated the timing of onset of severe disability among old adults with functional limitations living in the community. The prospective analysis using this large sample identifies five predictors of earlier onset of severe disability with sufficient power. These

results provide practical implications for identifying at-risk individuals in the community and suggest directions for developing health behavior interventions to delay the onset of severe disability in this high-risk population.

References

Berkman, L., Seeman, T., Albert, M., Blazer, D., Kahn, R., Mohs, R., et al. (1993). High, usual and impaired functioning in community-dwelling older men and women: Findings from the MacArthur Foundation Research Network on Successful Aging. *Journal of Clinical Epidemiology*, *46*, 1129-1140.

Brooks, P. (2002). Impact of osteoarthritis on individuals and society: How much disability? Social consequences and health economic implications. *Current Opinion in Rheumato*, *114*, 573-577.

Clark, R. (1998). *An introduction to the National Long-Term Care Survey*. Available from www.cds.duke.edu

Coppin, A., Ferrucci, L., Lauretani, F., Phillips, C., Chang, M., Bandinelli, B., et al. (2006). Low socioeconomic status and disability in old age: Evidence from the InChianti Study for the mediating role of physiological impairments. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, *61*, 86-91.

Cox, D. (1972). Regression models and life tables. *Journal of the Royal Statistical Society, 34*, 187-220.

Cyarto, E., Moorhead, G., & Brown, W. (2004). Updating the evidence relating to physical activity intervention studies in older people. *Journal of Science and Medicine in Sport*, *7*, 30-38.

Dunlop, D., Manheim, L., Sohn, M., Liu, X., & Chang, R. (2002). Incidence of functional limitation in older adults: The impact of gender, race, and chronic conditions. *Archives of Physical Medicine and Rehabilitation*, *83*, 964-971.

Ferraro, K., Su, Y., Gretebeck, R., Black, D., & Badylak, C. (2002). Body mass index and disability in adulthood: A 20-year panel study. *American Journal of Public Health*, *92*, 834-840.

Ferrucci, L., Guralnik, J., Studenski, S., Fried, L., Cutler, G., & Walston, J. (2004). Designing randomized, controlled trials aimed at preventing or delaying functional decline and disability in frail, older persons: A consensus report. *Journal of the American Geriatrics Society*, *52*, 625.

Fried, L., & Guralnik, J. (1997). Disability in older adults: Evidence regarding significance, etiology, and risk. *Journal of the American Geriatrics Society*, *45*, 92-100.

Guralnik, J., LaCroix, A., & Abbott, R. (1993). Maintaining mobility in late life. Demographic characteristics and chronic conditions. *American Journal of Epidemiology*, *137*, 845-857.

House, J., Lantz, P., & Herd, P. (2005). Continuity and change in the social stratification of aging and health over the life course: Evidence from a nationally representative longitudinal study from 1986 to 2001/2002 (Americans' Changing Lives Study). *The Journals of Gerontology: Series B*, *60*, S15-S26.

Jenkins, K. (2004). Obesity's effects on the onset of functional impairment among older adults. *The Gerontologist*, *44*, 206-216.

Katz, S., Ford, A., Moskowitz, R., Jackson, B., & Jaffee, M. (1963). Studies of illness in the aged: The index of ADL, a standardized measure of biological and psychosocial function. *Journal of the American Medical Association*, *185*, 914-919.

Manton, K., Corder, L., & Stallard, E. (1993). Estimates of change in chronic disability and institutional incidence and prevalence rates in the U.S. elderly population from the 1982, 1984, and 1989 National Long-Term Care Survey. *The Journals of Gerontology: Social Science*, *48*, S153-S166.

Manton, K., & Gu, X. (2001). Changes in the prevalence of chronic disability in the United States Black and nonBlack population above age 65 from 1982 to 1999. *Proceedings of the National Academy of Sciences of the United States of America*, *98*, 6354-6359.

Manton, K., Gu, X., Huang, H., & Kovtun, M. (2004). Fuzzy set analyses of genetic determinants of health and disability status. *Statistical Methods in Medical Research*, *13*, 395-408.

McCrone, S., Brendle, D., & Barton, K. (2001). A multibehavioral intervention to decrease cardiovascular disease risk factors in older men. *AACN Clinical Issues*, *12*, 5-16.

Penninx, B., Guralnik, J., Bandeen-Roche, K., Kasper, J., Simonsick, E., & Fried, L. (2000). The protective effect of emotional vitality on adverse health outcomes in disabled older women. *Journal of the American Geriatrics Society*, *48*, 1359-1366.

Reynolds, S., Saito, Y., & Crimmins, E. (2005). The impact of obesity on active life expectancy in older American men and women. *The Gerontologist*, *45*, 438-444.

Robert, S., & House, J. (1994). Sociodemographic status and health across the life course. In R. Abeles, H. Gift, & M. Ory (Eds.), *Aging and quality of life* (pp. 253-274). New York: Springer.

Rogers, R., Rogerts, A., & Belanger, A. (1992). A disability-free life among the elderly in the United States: Sociodemographic correlates of functional health. *Journal of Aging and Health*, *4*, 19-42.

SAS Institute, Inc. (2004). *SAS/STAT user's guide* (Version 9.1.2). Cary, NC: Author.

Stallard, E. (2000). Retirement and health: Estimates and projections of acute and long-term care needs and expenditures of the U.S. elderly population. In *Retirement needs framework* (SOA Monograph M-RS00-1, p. 175). Schaumburg, IL: Society of Actuaries.

Stallard, E., & Yee, R. (2000). *Non-insured home and community-based long-term care incidence and continuance tables. Actuarial report issued by the long-term care experience committee*. Schaumburg, IL: Society of Actuaries.

Stuck, A., Walthert, J., Nikolaus, T., Bula, C., Hohmann, C., & Beck, J. (1999). Risk factors for functional status decline in community-living elderly people: A systematic literature review. *Social Science & Medicine*, *48*, 445-469.

Verbrugge, L., & Jette, A. (1994). The disablement process. *Social Science & Medicine*, *38*, 1-14.

Woodward, M. (1999). *Epidemiology study design and data analysis: Texts in statistical science*. New York: Chapman and Hall.

World Health Organization. (1980). *International classification of impairments, disabilities, and handicaps*. Geneva: Author.

Wu, B., Carter, M., Goins, T., & Cheng C. (2005). Emerging services for community-based long-term care (CBLTC) in urban China: A systematic analysis of Shanghai's community-based agencies. *Journal of Aging and Social Policy*, *17*, 37-60.

Article accepted January 24, 2007

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