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Foundations of ADL Trajectories of Older Americans

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ABSTRACT

The disablement process may be viewed as a progression from disease to impairment to functional limitation and finally to activity limitation (frequently called "disability"). We use data from seven waves of the Health and Retirement Study, 1998 to 2010, to investigate for individuals ages 65 to 84 how baseline sociodemographic characteristics, self-reported diseases and pain, and functional limitation (physical, cognitive, sensory) are related to the dynamics of limitations in activities of daily living (ADLs). Our modeling approach jointly estimates multi-period trajectories of ADL limitation and mortality and yields estimates of the number of, shapes of, and factors associated with the most common trajectories.

In the conceptualization of the disablement process as proposed by, among others, Verbrugge and Jette (1994) and as depicted in Figure 1, a disease, such as arthritis, may lead to an impairment, such as joint stiffness and pain. The impairment may in turn result in a functional limitation (cognitive, sensory, or physical), such as difficulty bending, which may ultimately result in limitation of activities of daily living, such as bathing, also known as disability. This framework, of course, is simply a stylized representation of an inherently dynamic developmental course. Risk factors such as sociodemographic attributes as well as interventions may affect onset and progression of each phase. Especially in the transition from functional to activity limitation, the dynamics may be altered by changes in environment and behavior, use of assistive technology, and receipt of help. Understanding how the different phases of the disablement process relate to each other is valuable for both research and clinical purposes, and understanding how activity limitation develops is important for delaying or even preventing it (Guralnik & Ferrucci 2003; Jette et al. 1998).

Most analyses of the multi-period dynamics of the disablement process focus on changes over time at the individual level in the last two phases, namely, functional and activity limitations. For example, several studies have estimated trajectories of physical, cognitive, or activity limitations separately (e.g., Liang et al. 2008; Taylor 2011; Zimmer et al. 2012; Zimmer et al. 2014) or have combined indicators from the different phases into summary measures whose paths are traced (e.g., Liang, Wang et al. 2010; Yang & Lee, 2010).

Analyses typically assess how such sociodemographic risk factors as sex (e.g., Liang et al. 2008) and education (e.g., Taylor 2011), among others, are related to trajectories of functional and activity limitations. Many studies also look at the association of disease, the first phase of the disablement process, to limitation trajectories (e.g., Liang 2008, Taylor & Lynch 2011). Data on impairment, the

second phase, are typically not collected through population-level surveys, and analyses of the relation of impairment to subsequent trajectories of functional and activity limitation are rare if not nonexistent. Also fairly uncommon are analyses that attempt to model how the third phase, sensory, cognitive, and physical functional limitations are associated with multi-period trajectories of activity limitations, thus explicitly probing the last transition posited in the disablement process. One example is a study of older non-demented Pennsylvanians by Dodge and colleagues (2006) that found that relatively poor baseline cognitive function was predictive of poorer trajectories of instrumental activities of daily living (IADLs) up to ten years later. Another is Taylor and Lynch's (2011) analysis of National Long Term Care Survey data for three cohorts of people ages 65-69, which found that seeing and hearing problems played minor roles in trajectories of an indicator of instrumental and basic activity limitations combined.

This paper uses seven waves of longitudinal data from the Health and Retirement Study (HRS) for 1998 to 2010 to examine how sociodemographic risk factors, self-reported disease, a global pain index, and all three types of functional limitation at baseline are associated with trajectories of limitations in activities of daily living. We make use of a modeling approach that allows for the joint estimation of activity limitation and mortality trajectories (Haviland, Jones, & Nagin, 2011), which is important given that attrition from panel surveys of older adults is typically from mortality, which is not random but is associated with activity limitation. We use this approach to identify the number and shapes of the most common trajectories of activity limitation and estimate the association of the indicators of the earlier phases of the disablement process, as well as various sociodemographic risk factors, with the probability of membership in a particular trajectory group.

METHODS

Data

The HRS, a nationally representative biennial survey of Americans ages 50 and older, was launched in 1992. For purposes of our analysis, we limit our sample to those ages 65 to 84 in 1998, the year when many aspects of the survey as currently conducted were established. We begin with age 65, since data on some of the cognitive function measures of interest were not collected for the younger population. We use data from the seven biennial waves from 1998 to 2010, when surviving members of our sample would typically be ages 77 to 96 years old. Given the smaller numbers of respondents at even older ages in 2010, we chose to cap baseline age of the sample at 84. Our initial 1998 sample size of 9,471 includes 5,327 females and 4,144 males with responses regarding activity limitation for at least one survey wave (only 6 cases excluded from the original 9,477). We use the 1998 cross-sectional weights in all of our models.

Outcome Measures

At each survey wave respondents were asked if, because of a health, physical, or emotional problem, they have difficulty expected to last at least three months with six ADLs. The individual activities are dressing, walking across a room, bathing, eating, getting in or out of bed, and using the toilet. Respondents who reported no difficulty dressing and only one difficulty with physical functions (described below) were not asked the rest of the ADL questions and are assumed to have no difficulty with any ADL. For each wave and individual, we constructed a summary indicator of any ADL difficulty, which is equal to 1 if the respondent reports one or more difficulties, 0 if all six questions are answered and no difficulties are reported, and missing otherwise. Table 1 shows that in 1998, 18.3 percent of the sample reported some ADL difficulty.

Information about death was ascertained at follow-up, typically through interviews with a knowledgeable family member or friend. By the 2010 wave, 4,832 or 51% of the original 9,471 had died. An additional 757 or 8% were otherwise missing.

Sociodemographic Risk Factors

In selecting sociodemographic risk factors for our models, we focused on variables that have been found to be associated with ADLs in the cross-section and that were unlikely to change in anticipation of the onset of a reported limitation. So, for example, we included whether or not someone was married, but we did not include living arrangement. Nor did we include a measure of income since activity limitation may affect one's financial well-being. The baseline distributions of the measures we use are also shown in Table 1. The proportion of respondents with missing values for these items is generally small. For cases of missing dichotomous variable responses, we recoded them as 0 and generated a missing flag. For cases of missing continuous variable responses, we assigned the mean by sex and generated a missing flag.

The mean age of our sample at baseline was 73.06 years. Fifty-seven percent is female, over 8.30% black, and 4.99% Hispanic. Being older, female, black, or Hispanic are all expected to be associated with greater ADL limitation (Liang et al. 2008).

There is a growing literature suggesting the influence of early-life factors on late-life health and functioning (e.g., Freedman et al. 2008). We explored two indicators of childhood well-being, namely, childhood health and a childhood socioeconomic (SES) score (Montez and Hayward 2013) that is based on seven potential adversities: low education of father, low education of mother, family poverty, family move for financial reasons, family received financial help, father had a blue collar occupation, and never

lived with father. Only 1.72% reported poor childhood health, and the mean childhood SES score at baseline was 2.03 adversities.

For education, we considered several specifications—continuous, four categories, and five categories. The first provided the best fit. The average number of years of education for our sample is 11.78 years. Over half of the sample was married at baseline. We expect both education and marriage to be protective (Schoeni et al. 2008).

Forty-three percent of the respondents resided in urban areas at baseline, and 35% were in the South. We also considered a four-region categorization of region and a variable focusing solely on the East South Central region, but ultimately Southern residence provided the best fit, so we report on it here. Urban residence is expected to be protective, but living in the South disadvantageous (Murray et al. 2008).

Disease and Impairment Measures

The Health and Retirement Study asked about diseases with a question in the form of "Has a doctor ever told you that you have . . . ." The one exception among the diseases that we use in our models is arthritis, the question for which was in the form of "Have you ever had or has a doctor ever told you that you have arthritis or rheumatism." Heart problem includes heart attack, coronary heart disease, angina, congestive heart failure, or other heart problems. Lung problem was defined as chronic lung disease such as chronic bronchitis or emphysema, and psychological problem as an emotional, nervous, or psychiatric problem. Missing responses were recoded as 0 and a flag generated.

BMI was calculated using self-reported weight and height. We tested using BMI as a continuous variable, but found that a five-category representation worked best. Those missing responses were calculated using the mean weight and height by gender, and a flag generated.

Pain, our only indicator of the second phase of the disablement process, was ascertained via two questions: (1) Are you often troubled by pain? and (2) How bad is the pain most of the time (mild, moderate, severe)? We generated a pain level indicator that ranged from 0 for none to 3 for severe. We also investigated using just the first question and using a group of categorical variables based on the two questions, but found that the simple continuous variable explained the most variance. Missing responses were recoded as 0.

Functional Limitation Measures

For physical functioning, questions similar in format to the ADL questions asked about sitting 2 hours, getting up from a chair, climbing several flights of stairs, lifting and carrying 10 pounds, stooping, picking up a dime, reaching arms above the shoulders, moving a large object, and walking several blocks. For each individual, we constructed a summary indicator of any physical function difficulty, which is equal to 1 if the respondent reports one or more difficulties, 0 if all questions are answered and no difficulties are reported, and missing otherwise. As shown in Table 1, over two-thirds of respondents reported difficulty with at least one physical function at baseline. Almost 6% of respondents were missing information on at least one of the nine components and did not indicate difficulty with any of the others. We recoded them as 0 and generated a missing flag.

Cognitive function was ascertained using a modified Telephone Interview Cognitive Screen (maximum score of 35). Twenty of the points related to immediate and delayed recall, 4 to date orientation, 4 to

word recognition and naming the president and vice president, 2 to backwards counting, and 5 to serial-7 subtraction. Almost 8% of respondents did not complete the test, and we assigned them the mean score for their gender in our sample (while also generating a missing flag). The resulting mean score for the sample is 22.17 out of a possible perfect score of 35. We also experimented with using a cutpoint for cognition, a score of 8 or lower, but found that the continuous score had a stronger association with our outcome.

Respondents were asked in 1998 to rate on a 5-point scale their eyesight, using glasses or corrective lenses. We created a variable indicating poor eyesight, including the lowest category on the scale and reports of being legally blind, altogether over 6% of the sample. The 0.03% percent missing answers were coded as 0, and a missing flag generated.

Responses to a similar question regarding hearing (with a hearing aid if used) were handled in the same way, and just over 6% of the sample reported having poor hearing.

Statistical Analysis

There were two stages in the modeling process, although they are ultimately done simultaneously. The first stage identified the common trajectories of ADL difficulty and mortality, and the second stage estimated the associations of risk factors with these trajectories. We used a group-based trajectory (GBT) model developed by Nagin and colleagues (Jones et al. 2001; Jones & Nagin 2007; Nagin 1999; Nagin 2005). The approach is based on finite mixture modeling and uses maximum likelihood estimation to identify groups of individuals following a discrete number of common trajectories. The technique was initially developed for research in psychology and criminology, but recently has been applied to the study of limitation in older life (Dodge et al. 2006; Gill et al. 2010; Liang, Xu et al. 2010).

Early applications of this technique and others used to investigate multi-period trajectories of late-life limitation (e.g., hierarchical linear models) have assumed that all attrition is random or at best have included a "control" variable for mortality, which is conceptually awkward since disability precedes mortality. The recent enhancement of the GBT approach to allow for the joint modeling of the outcome of interest and non-random missingness (Haviland et al. 2011) is a welcome development, given that mortality is associated with late-life limitation and clearly is not random. This joint modeling has been successfully applied by Zimmer and colleagues in analysis of ADL and mortality trajectories in China (Zimmer et al. 2010) and physical functional limitation and mortality trajectories in Taiwan (Zimmer et al. 2014). Here we use this enhanced technique, which has been described in detail elsewhere (Haviland et al. 2011; Zimmer et al. 2010).

Important outputs of the GBT model are (1) the number of groups that most efficiently characterize the course of limitation, (2) coefficients that describe the shape of the trajectory by age for each group, and (3) the estimated proportion of the population at baseline most likely to follow each of the trajectories. Given the dichotomous nature of our primary outcome, any ADL difficulty, it is modeled as a logit function of age. Age is specified either linearly or quadratically, depending on the best fit for each group. Mortality is modeled as a logit of linear age at the last survey wave. To facilitate model convergence (Jones 2013), age is scaled by subtracting 77, the average age of our sample's respondents across all seven survey waves, and dividing by ten.

Different numbers of groups and possible specifications of age (linear, quadratic) for each group are explored. The best base model is chosen on the basis of the largest Bayesian Information Criterion (BIC) and two diagnostic tests suggested by Nagin (2005). The BIC (= log-likelihood – 0.5 * (number of parameters) * ln (sample size)) takes into consideration both explanation of variance (log-likelihood) and

a penalty for adding variables to a model and the possibility of overfitting. The BIC is negative, so the largest BIC is the least negative one. The two diagnostic tests are based on posterior probabilities, which are calculated post-estimation and indicate the probability that an individual belongs to each of the groups in the model. For each individual, the posterior probabilities sum to one, and the largest posterior probability for each individual is an indication for the most likely group to which the individual belongs. This indication of most likely group may differ from the assignment made as a result of the maximum likelihood estimation. One test of model fit is that the average posterior probability across individuals who are most likely to belong to a particular group is 0.70 or higher. A second test compares the proportions of the sample associated with the groups on the basis of highest posterior probabilities and the proportions generated by the maximum likelihood assignments. These two proportions should be similar.

After ascertaining the best base model and the associated number of groups and specification of age for each group, we re-fit the model and in the same maximum likelihood procedure simultaneously estimated via a multinomial logistic regression the association of sociodemographic characteristics, disease and pain, and functional limitation to membership in particular ADL trajectory groups. All of the variables that we used in this stage of the modeling are assessed solely at baseline (with the exception of proxy response and interview mode, which are discussed below). Some of the factors may vary with time (e.g., marital status, urban residence, residence in the South, diseases, pain, and functional limitations). Our interest is to understand how baseline values of these variables are associated with ADL trajectories. Moreover, given the two-year survey interval and the ambiguity surrounding timing of changes in ADL difficulty and these variables, we do not use this longitudinal information. In any case, had we opted for including time-varying covariates, it would have been necessary to do so at the stage

of estimating the base model, but our goal in the first stage was to determine common pathways of ADL difficulty, not identify factors associated with group membership.

In all of our multinomial models, for each individual, we controlled for the proportion of interviews that were based on information from a proxy as opposed to self-responses and for the proportion of interviews that are face to face as opposed to by phone. Several studies have found that proxy respondents are more likely to report limitation than are respondents themselves (Rodgers and Miller 1997; Santos-Eggimann et al. 1999; Todorov & Kirchner 2000), and Rodgers and Miller (1997) have documented an association between face-to-face interview and greater reports of ADL limitation. As shown in Table 1, on average, individuals in our sample had proxy interviews 11.72% of the time. From 1998 to 2002, the proportion face to face was relatively low (41.8, 22.5, 32.91%, respectively, for our sample in the three waves; not shown) and was reserved primarily for those ages 80 and over. In 2004, there was a substantial increase to 72.8% in an effort to obtain consent for use of linked administrative data, and beginning in 2006, at least half the sample for each wave was interviewed face to face for purposes of collecting biomarkers and conducting performance tests (71.5, 71.4, 63.3%). On average, as shown in Table 1, individuals in our sample had face-to-face interviews 48.33% of the time.

We assessed the sensitivity of our results to our recoding of missing item response, as described above, by re-estimating models including a flag indicating a missing value for each variable. In only one instance, as will be mentioned below, were results materially different, but the difference was not of importance for our overall results. Because of the very small number of missing responses for most variables, including the missing flags in our models occasionally resulted in singular or asymmetric variance matrices, which prevented the calculation of standard errors. Accordingly, we opted not to include the missing flags in the models whose results are presented in this paper.

RESULTS

Table 2 presents the results from the best base model, which has three groups. Age is best modeled with a linear specification for the ADL limitation trajectories of Groups 1 and 3, but as a quadratic for Group 2. The maximum likelihood estimation assigned about 40% of the sample each to Groups 1 and 2 and less than 20% to Group 3. Among those most likely to belong to each group on the basis of posterior probabilities, the average posterior probabilities for each group are 0.83, 0.79, and 0.83, respectively, well above the 0.70 criterion mentioned above. The group assignments based on posterior probabilities are also similar to the maximum likelihood group assignments, 40.8 versus 39.5% for Group 1, 41.9 versus 42.8% for Group 2, and 17.4 versus 17.7% for Group 3. Some four-group models had bigger BICs, but the diagnostics based on posterior probabilities were not acceptable.

Figure 2 presents for each group the predicted probabilities by age of ADL limitation. Group 3's predicted probability of ADL limitation starts high at 0.48 at age 65 and then increases to 0.99 by age 94. Group 2's probability starts much lower, but by age 80 is 0.34, by age 85 is 0.64, and ultimately reaches the same level as Group 3's. Group 1 experiences a low probability of ADL difficulty until the mid-80s, followed by a fairly steep increase to a maximum predicted probability of ADL limitation of over 0.70 by age 96. So for the over 80% of the sample who are members of Groups 1 and 2, the probability of any ADL limitation remains relatively low until age 80, but for all three groups, the probabilities are high by the mid-90s.

The predicted probabilities of mortality by age in Figure 3 follow a hierarchy by group similar to that of ADL limitation, with Group 1 the lowest and Group 3 the highest. Again, the risks are quite low for Group 1 until the mid-80s, but then increase rapidly and approach those of the two higher groups by the

mid-90s. The mortality probabilities for Groups 2 and 3 are similar to each other, suggesting that members of Group 3 are spending a longer period with ADL limitation at the end of life than are members of Group 2.

Table 3 shows the association of sociodemographic factors, disease, pain, and functional limitations with trajectory group membership. The bivariate results are for models with the base trajectory specification as reported in Table 2 plus a multinomial logit regression with the specific variable, controls for proportion of responses by proxy and proportion of responses face to face, and a constant. For each variable, the table presents the logit coefficients for the risk of membership in Groups 2 and 3 versus Group 1, the reference category. Also shown for each variable is the BIC from its bivariate model. Sensitivity analyses that included the missing flag for the variable in the bivariate models, as well as the missing flag for proportion of face-to-face interviews resulted in smaller (worse) BICs than for the comparable bivariate models without the flags in all cases except for that of childhood SES score. However, in either specification of childhood SES scores, the coefficients were very small, and subsequent sensitivity analysis in multivariate models indicated that inclusion of the missing flag did not alter the results substantively.

For sake of comparison, we ranked the bivariate models by size of the BIC. The bivariate model with physical functional limitation has the largest BIC of -32,473.95, followed by pain level (-32,626.00), arthritis (-33,185.81), psychological problem (-33,031.61), and cognition (-33,036.10). The BICs for the sociodemographic/early-life risk factors tend to be the smallest, suggesting that those factors explain the least variance in the probability of group membership. All of the coefficients on these variables are statistically significant except for female and child health poor for the Group 2 versus Group 1 comparison and urban for both comparisons.

The impression of the relative unimportance of the sociodemographic/early-life risk factors in trajectory group membership is confirmed when we compare the next three models in Table 3: one that includes all of the sociodemographic/early-life risk factors, a second that includes all the diseases and pain level, and a third that includes the four functions. The BICs for these models are respectively -33,100.29, -32,107.05, and -32419.81. Thus, as a group, the diseases and pain variables explain the most variance after accounting for the number of variables in the models. The BIC for the sociodemographic/early-life model is bigger than the BICs of the bivariate models for the sociodemographic/early-life factors individually, although the education bivariate model comes close (-33,107.67). However, the bivariate model BICs for the top 11 of all 22 variables (ranked by BIC) are larger than the BIC for the sociodemographic/early-life model.

In the disease/pain model, having a BMI of 40 or over results in the greatest risk of Group 2 versus Group 1 membership and of Group 3 versus Group 1 membership. However, having a BMI of under 35 is much less associated with differential group membership. Other relatively important disease factors are lung problems, diabetes, psychological problems, and stroke. In moving from the bivariate models to the disease/pain model, the size of the coefficients on arthritis and heart problem appear to be substantially reduced. The pain level coefficient is not comparable to the disease coefficients given the continuous nature of the pain level variable, but its size is relatively stable in moving from the bivariate to the disease/pain model.

In the functional limitation model, the coefficients on physical functional limitation remain large, although smaller than in the bivariate model. The coefficients on poor eyesight and poor hearing are also substantially reduced, and in particular, poor hearing is no longer significantly associated with

Group 2 versus Group 1 membership. The coefficients for cognition are relatively stable, but because of the continuous nature of the variable are not comparable to the coefficients on the other three functional limitation variables.

Next in Table 3 is the full model in which all variables are included. The BIC is -31,818.35, the biggest thus far. In this model, among the sociodemographic/early-life risk factors, significant coefficients remain only for female (marginally for G2 vs. G1), black (both comparisons), Hispanic (G3 vs. G2), and being married (both comparisons). All the disease/pain variables remain significant except for the first comparison (G2 vs. G1) for heart problem and some of the lower BMI categories, as well as BMI greater than or equal to 40 for the first comparison. In the latter case, the result may be a function of the very small proportion of the sample in this category (1.16%). To the extent that coefficients can be compared within the model, lung problem, the top two categories of BMI, and diabetes stand out.

The final phase of modeling involved sequentially dropping variables from the full model and comparing BICs. First to be dropped were variables for which the p-values on both their coefficients were 0.10 or greater, namely, child health poor, childhood SES, education, urban residence, and Southern residence. The resulting BIC (not shown) was -31,777.98, bigger than the BIC on the full model, indicating a good tradeoff between explanatory power and number of variables included. Subsequent models (not shown) dropped female and categories of BMI less than 35, then hearing, then Hispanic, and finally heart problem. In the final model, the so-called parsimonious model, in Table 3, at least one of the coefficients for each variable has a p-value of less than 0.05, and the BIC is -31,757.96, the largest of all we found. Of the sociodemographic/early-life variables, only being black and being married remain. All but heart problems of the diseases and pain variables are included, and three of the four functional limitation variables –physical, cognitive, vision—remain.

SUMMARY AND DISCUSSION

The trajectories of ADL limitation for older Americans from 1998 to 2010 can best be described by three common pathways. Members of the group with the lowest overall probabilities of ADL limitation at all ages (39.5% of the baseline sample) experienced little chance of ADL difficulty until their mid-80s. In contrast, members of the group with the highest probabilities (17.7% of the baseline sample) already had an almost 50-50 chance of limitation by age 65, and the probability increased to almost 1.0 by age 90. The mortality probability trajectories of the three groups followed the same hierarchy as the ADL limitation trajectories with those in the highest ADL difficulty probability group experiencing the highest probabilities of dying.

In comparison to disease, pain, and functional limitation, sociodemographic and early-life characteristics had weak associations with trajectory group membership. This result confirms the importance of the early phases of the disablement process and their relationships with subsequent activity limitation. Neither sex nor education was influential in multivariate models including the other types of factors. Previous analysis of HRS data for the 50-and-over population from 1995 to 2006 (Liang et al. 2008) found using a growth-curve model that socioeconomic status and prior health status could at least partially explain gender differences in changes in ADL and IADL limitations. Here, we analyze HRS data for an older population and a later period and use a different statistical approach. We find in our sociodemographic/early-life model in comparison to the female bivariate model, the coefficient on female for the first comparison remains insignificant, and the positive coefficient for the second comparison (G3 vs. G1) is substantially reduced in size. In the full model, neither coefficient on female is significantly different from zero. In additional analysis (results not shown), we found that adding female to the functional limitation model led to an increase in the BIC but adding it to the disease/pain model

resulted in little change in the BIC. These results suggest that the association of being female with higher limitation trajectory group membership is operating indirectly primarily through diseases and pain. Thus, our analysis provides a potential explanation for the sex differences in late-life activity limitation that are commonly found.

For education, as shown in Table 3, its coefficient on the second comparison in the sociodemographic/early-life model is substantially smaller than in the bivariate model (-0.144 vs. -0.107). When we added education to the disease/pain model, it is -0.104, and when we add it to the functional limitation model, it is -0.047 (results not shown). Thus, the beneficial influence of education may operate indirectly on group membership via functional limitations. It could be that those with less education are more likely to have a functional limitation, given that they have a disease. Other studies focusing on the role of education have found that education may be important for onset of functional and activity limitations but not for their progression (e.g., Taylor 2011; Zimmer & House, 2003; Zimmer et al. 1998).

The deleterious influence of childhood SES score is essentially eliminated in the sociodemographic/early-life multivariate model, as is the influence of Southern residence and being Hispanic. Urban residence is not significant even in the bivariate model. The Hispanic coefficient on the second comparison in the full model does become significant again, but the variable is eliminated in the parsimonious model. The association of poor child health with higher limitation trajectory group membership is eliminated in models including baseline diseases and pain (results not shown).

Being black is persistently associated with worse ADL trajectories across the models, whereas being married is associated with better trajectories. The former may reflect the cumulative disadvantage that

blacks experience throughout their lives, differential severity and management of disease, differential accommodation of limitations, and differential self-reporting of activity limitation. The latter may reflect the benefits of social support through marriage, differential management of disease, and differential accommodation of limitations. The marriage result also may partially be a measurement artifact, since the HRS question does not specify whether or not difficulty with activities is to be assessed with or without assistance. It is only after difficulty is acknowledged that a question about receipt of help is asked. Thus, some married people who receive help from spouses may indicate no difficulty, whereas unmarried people may answer the question in terms of difficulty without assistance.

As a group, diseases and pain level, which represent the first and second phases of the disablement process, are the factors most strongly associated with ADL trajectory group membership. Only the variable indicating heart problem at baseline does not remain in our parsimonious model. In recent decades, heart disease has become less associated with activity limitation (Freedman et al. 2007; Martin & Schoeni 2014). Improved management of heart disease has been shown to have played an important role in disability reduction (Cutler, Landrum, & Stewart 2008), even as prevalence of heart disease has increased as a result of stable incidence and improved survival (Pearson 2007).

Lung problem, diabetes, and obesity are especially associated with membership in Group 2 versus Group 1. These three conditions plus psychological problem and stroke are also strongly associated with membership in Group 3 versus Group 1. The relatively weak association of cancer with trajectory group membership is consistent with other research (e.g., Martin & Schoeni 2014) that has found that cancer is not strongly associated with activity limitation at the population level. The vicissitudes of cancer treatments, while often severe, may be of such duration that their chances of being ascertained in a biennial survey are reduced. The association of arthritis with trajectory group membership decreases

considerably, especially for the second comparison (G3 vs. G1), in moving from the bivariate model to the disease/pain model and on to the full model. Adding arthritis to the functional limitation model results in a significantly *negative* coefficient on arthritis for the first comparison (G2 vs. G1) and cuts the size of the coefficient on the second comparison by two-thirds (results not shown). Thus, the association of arthritis with ADL trajectory is captured in part by the association of functional limitations with activity limitation.

Pain level, the one indicator of the second phase of the disablement process in our analysis, has a persistently strong association with membership in worse ADL trajectory groups across the models. Our analysis was limited by having only the one global indicator of pain, which may reflect the severity of diseases in the first phase of the disablement process. The new National Health and Aging Trends Study (NHATS), first fielded in 2011, annually asks a large sample of older people questions about pain and weakness of different areas of the body (NHATS 2013). Going forward, as multiple waves of data become available, NHATS should become a valuable resource for understanding the relation of impairment to trajectories of late-life activity limitation.

Physical and cognitive limitation are significantly associated with membership in the groups with higher probability of ADL limitation, as indicated by their bivariate models having the first and fifth largest BICs, respectively. Poor eyesight is also in the top ten. Poor hearing, although associated with trajectory group membership bivariately, is not included in our parsimonious model. That hearing is the least associated of the functions with trajectory group membership makes sense given the nature of the ADLs—dressing, walking across a room, bathing, eating, transferring, and using the toilet. Such may not have been the case had this study focused on trajectories of IADLs, such as shopping and using the telephone.

Looking to the future, the more complex marital histories of the Baby Boom generation may not augur well for future ADL trajectories of the older population, although other forms of social support may be substituted. It is difficult to predict changes in prevalence of specific diseases, since as noted earlier in the case of heart disease, prevalence is a function of incidence and survival, which in turn are based on prevention and management. More generally, using self-reports of diseases was not ideal for our modeling purposes since reporting may be influenced by access to health care, diagnosis criteria, and health literacy, among other factors.

Temporal improvements among older Americans in vision (Martin & Schoeni 2014) and cognitive function (Sheffield & Peek 2011) augur well for future ADL trajectories. At the same time, the recent increase in physical functional limitations in the 65 and over population (Martin & Schoeni 2014) suggests that, all things equal, more Americans would be members of worse ADL trajectory groups in the future.

An important limitation in this effort to understand better the disablement process and in particular the influence of functional limitations on activity limitation trajectories is the failure to include information on the environment in which activities are carried out, the use of assistive technology, and modification of how activities are performed. Disability or activity limitation is not simply a function of underlying capacity of the individual, but rather reflects a gap between that capacity and the demands of the particular activity in the circumstances in which it is being conducted. Although the HRS did have an experimental module focused on the environment and home modification in 2006, the accommodations that may influence the course of the disablement process have not been a focus of regular HRS data

collection. The new NHATS will be an important resource for investigating the influence of these domains in the future.

Other study weaknesses include the limited nature of the HRS cognitive measures, which through 2010 focused solely on memory and mental status. Starting in 2012, HRS includes a measure of fluid intelligence that involves working with a series of numbers (Lee & Gutsche 2013). Also, ideally, we would have used performance tests as well as self-reports of physical function, but only in 2006 did HRS begin to conduct these tests on alternate halves of the sample by wave. Thus, multiple waves of ADL data subsequent to these tests are not yet available for the entire sample.

Future analysis might profitably explore the association of individual physical functional limitations with ADL trajectories and even with trajectories of individual activities, such as bathing. Given the different nature of IADLs and ADLs, modeling of trajectories of difficulty with IADLs might provide further insight into how the ability of older people to care for themselves evolves as they age.

Figure 1. Disablement Process

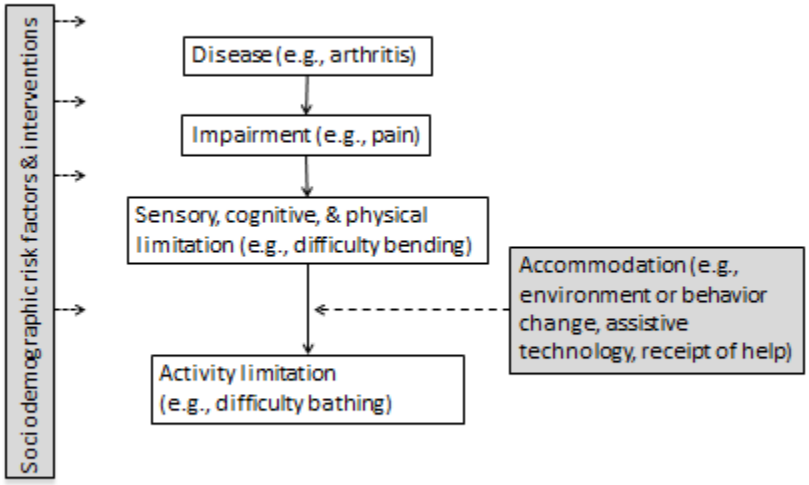

Table 1. Weighted Frequencies of Variables at Baseline in 1998 for Analysis Sample (n=9,471)

	% or mean	% missing
Any ADL difficulty	18.31	--
Age (years; mean)	73.06	--
Female	57.17	--
Black	8.30	0.05
Hispanic	4.99	0.06
Child health poor	1.72	0.24
Childhood SES score (0-7 adversities; mean)	2.03	28.38
Education (years; mean)	11.78	0.31
Married	57.97	0.08
Urban residence	42.65	--
Residence in the South	35.01	0.08
Arthritis ever	54.10	0.08
Cancer ever	13.59	0.11
Diabetes ever	14.45	0.07
Heart problem ever	26.91	0.06
Lung problem ever	8.77	0.06
Psychological problem ever	9.06	0.04
Stroke ever	9.40	0.06
BMI < 19.5	5.26	1.08
19.5≤BMI<25.0	37.66	1.08
25.0≤BMI<30.0	39.39	1.08
30.0≤BMI<35.0	13.39	1.08
35.0≤BMI<40.0	3.15	1.08
BMI≥40.0	1.16	1.08
Pain level (0-3; mean)	0.51	0.15
Any physical functional difficulty	69.92	5.80
Cognitive summary score (0-35; mean)	22.17	7.72
Poor eyesight	6.42	0.03
Poor hearing	6.14	0.06
Proportion of responses per individual by proxy (mean)	11.72	--
Proportion of interviews per individual face-to-face (mean)	48.33	0.00

Table 2. Maximum Likelihood Logit Results for ADL Limitation and Mortality Trajectories from Best Base Model (n=9,471)			
	Group 1	Group 2	Group 3
Parameters for any ADL limitation trajectory			
Intercept	-4.849 (0.255)***	-1.302 (0.139)***	1.685 (0.141) ***
Linear scaled age	3.045 (0.160)***	1.930 (0.066)***	1.464 (0.118) ***
Quadratic scaled age	---	0.521 (0.088)***	---
Parameters for mortality trajectory			
Intercept	-3.331 (0.211) ***	-1.851 (0.049) ***	-1.222 (0.049) ***
Linear scaled age at previous wave	1.800 (0.189) ***	1.135 (0.061) ***	0.804 (0.076) ***
Group size (%)	39.5	42.8	17.7
	BIC = -33481.99		
Standard errors are in parentheses.			
*** p < .001			

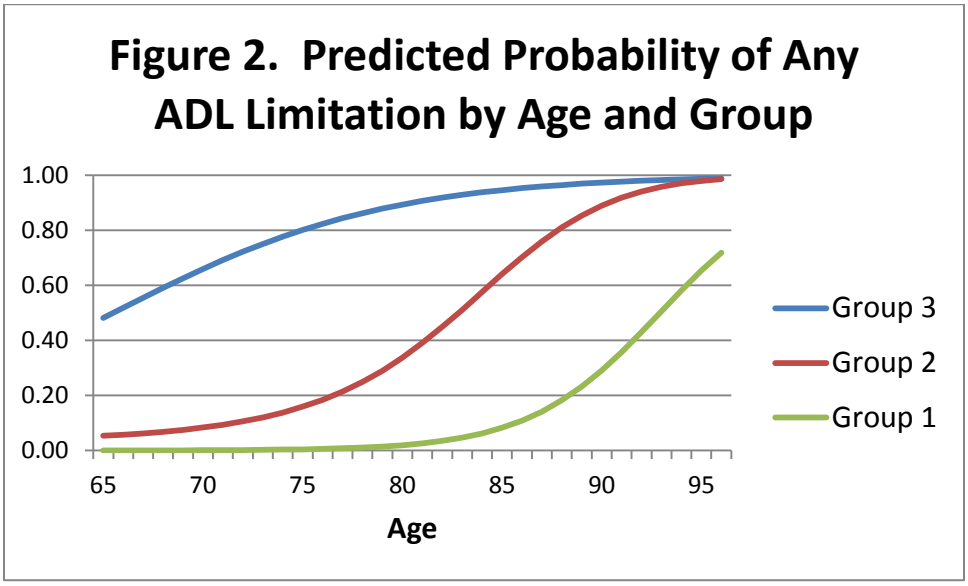
Figure 2. Predicted Probability of Any ADL Limitation by Age and Group
1.00
0.80
0.60
0.40
0.20
0.00
65
70
75
80
85
90
95
Age
Group 3
Group 2
Group 1

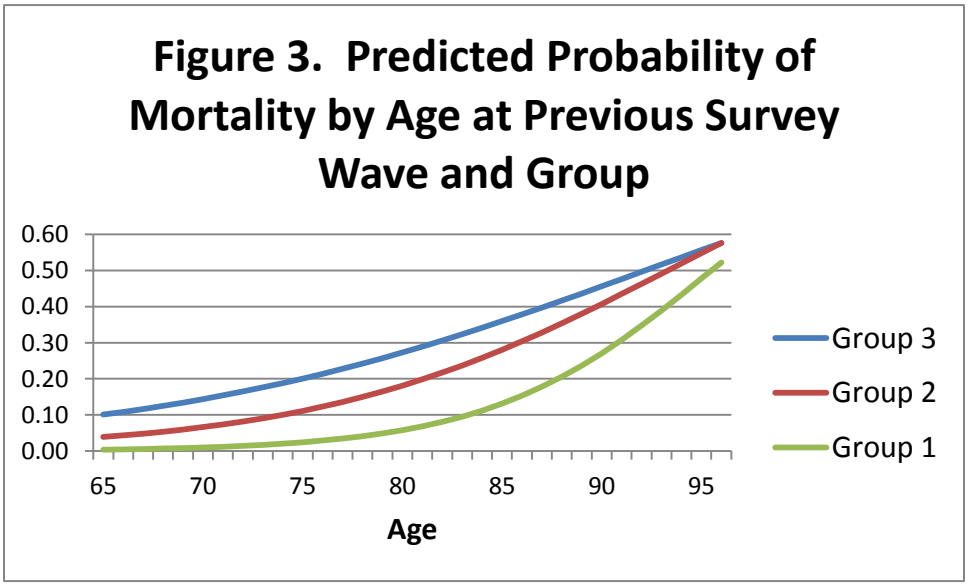
Figure 3. Predicted Probability of Mortality by Age at Previous Survey Wave and Group
0.60
0.50
0.40
0.30
0.20
0.10
0.00
65
70
75
80
85
90
95
Age
Group 3
Group 2
Group 1

Table 3. Results from Multinomial Logit Risk-Factor Estimation of Group Membership (n=9,471)

	Bivariate Models						Sociodemographic/Early Life Model				Disease/Pain Model				Functional Limitation Model				Full Model				Parsimonious Model			
	Coefficients						Coefficients				Coefficients				Coefficients				Coefficients				Coefficients			
	Group 2 vs. Group 1		Group 3 vs. Group 1		BIC	BIC Order	Group 2 vs. Group 1		Group 3 vs. Group 1		Group 2 vs. Group 1		Group 3 vs. Group 1		Group 2 vs. Group 1		Group 3 vs. Group 1		Group 2 vs. Group 1		Group 3 vs. Group 1		Group 2 vs. Group 1		Group 3 vs. Group 1	
Female	-0.016		0.471	***	-33171.81	16	-0.129		0.289	**									-0.186	ǂ	0.007					
Black	0.707	***	1.025	***	-33162.95	15	0.482	***	0.674	***									0.424	**	0.773	***	0.475	**	0.775	***
Hispanic	0.334	*	0.739	***	-33184.49	20	-0.028		0.230										0.215		0.671	**				
Child health poor	0.358		1.285	***	-33180.89	18	0.253		1.100	**									-0.245		0.004					
Childhood SES score	0.080	**	0.181	***	-33176.82	17	0.001		0.063	ǂ									-0.051		-0.059					
Years of education	-0.091	***	-0.144	***	-33107.67	12	-0.080	***	-0.107	***									-0.023		0.010					
Married in 1998	-0.336	***	-0.756	***	-33141.42	13	-0.295	***	-0.521	***									-0.278	**	-0.506	***	-0.231	**	-0.481	***
Urban residence in	-0.028		-0.100		-33194.66	22	0.029		0.002										0.051		0.049					
Residence in South in 1998	0.138	ǂ	0.329	***	-33185.81	21	0.073		0.153	ǂ									0.061		0.133					
Arthritis ever	0.906	***	1.797	***	-32912.58	3					0.699	***	1.099	***					0.483	***	0.695	***	0.487	***	0.761	***
Cancer ever	0.315	**	0.525	***	-33181.92	19					0.317	**	0.539	***					0.297	*	0.584	***	0.276	*	0.549	***
Diabetes ever	1.238	***	1.843	***	-33044.47	7					1.236	***	1.674	***					1.145	***	1.441	***	1.203	***	1.600	***
Heart problem ever	0.558	***	1.197	***	-33082.32	11					0.295	**	0.661	***					0.088		0.443	***				
Lung problem ever	1.451	***	2.227	***	-33064.20	10					1.644	***	2.239	***					1.397	***	1.922	***	1.430	***	1.947	***
Psychological problem ever	1.223	***	2.300	***	-33031.61	4					1.067	***	1.749	***					0.849	***	1.443	***	0.816	***	1.442	***
Stroke ever	0.576	***	1.884	***	-33049.07	8					0.703	***	1.956	***					0.490	*	1.576	***	0.477	*	1.579	***
19.5≤BMI<25.0	-0.071		-0.916	***	-33039.06	6					-0.063		-0.742	**					0.067		-0.445	ǂ				
25.0≤BMI<30.0	0.075		-0.476	**							0.038		-0.331						0.152		-0.053					
30.0≤BMI<35.0	0.603	*	0.421	*							0.467	ǂ	0.462	ǂ					0.426		0.597	*				
35.0≤BMI<40.0	1.417	***	1.805	***							1.189	**	1.665	***					1.240	*	1.785	***	1.080	**	1.806	***
BMI≥40.0	1.834	*	3.017	***							1.195	ǂ	2.634	***					1.106		2.586	***	0.884		2.568	***
Pain level (0-3; mean)	0.700	***	1.406	***	-32626.00	2					0.564	***	1.209	***					0.460	***	1.021	***	0.453	***	1.022	***
Physical functional limitation in 1998	1.591	***	4.599	***	-32473.95	1									1.324	**	2.706	***	1.120	***	3.455	***	1.130	***	3.532	***
Cognitive summary score in 1998	-0.086	***	-0.133	***	-33036.10	5									-0.114	**	-0.075	***	-0.062	***	-0.108	***	-0.070	***	-0.112	***
Poor eyesight in 1998	0.909	***	2.246	***	-33061.92	9									0.149		1.275	***	0.397	ǂ	1.321	***	0.433	ǂ	1.361	***
Poor hearing in 1998	0.729	***	1.283	***	-33158.79	14									0.917	ǂ	0.430	**	0.361		0.552	*				
BIC							-33100.29				-32107.05				-32419.81				-31818.35				-31757.96			

All models (bivariate and multivariate) have the same base trajectory specification as reported in Table 2 and include controls for proportion of reponses per individual by proxy, proportion of interviews per individual that are face to face, and a constant.

ǂ <.10, * p < .05, ** p < .01, *** p<.001

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