The Effect of Prior Disability History on Subsequent Functional Transitions

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Background. Many older persons experience multiple transitions between states of disability and independence, but little is known about the effect of prior disability history on subsequent functional transitions. Our objective was to determine the effect of prior disability on subsequent transitions between no disability, mild disability, severe disability, and death.

Methods. For 60 months, 754 persons aged 70 or older underwent monthly assessments of disability in basic activities of daily living. We used a multistate extension of the proportional hazards model to determine the effects of amount, defined as cumulative duration, and distribution, defined as number of episodes, of prior disability on subsequent functional transitions, adjusted for age, gender, cognitive status, timed gait, and habitual physical activity.

Results. For each additional month of prior disability, participants were more likely to make transitions representing new or worsening disability and were less likely to make transitions from disability to independence or from severe disability to death. Adjusting for the cumulative duration of prior disability, more episodes of prior disability were associated with a higher likelihood of most transitions, representing both increasing and decreasing disability, but had no effect on transitions to death.

Conclusions. Both the amount and distribution of prior disability are important determinants of the likelihood of subsequent functional transitions. Analytic methods that account for prior disability history should be used in studies of functional transitions, and new measures of disability burden are needed that incorporate distribution as well as amount of disability.

Recent evidence demonstrates that disability among older persons is a dynamic process, with many older persons making multiple transitions between states of disability and independence (1). Although previous studies of disability have evaluated multiple transitions over time (2–7), they have not explicitly evaluated the effect of prior disability history on subsequent functional transitions. In fact, most of these studies have used statistical models that assume no effect of prior disability history on subsequent functional transitions (3–5).

Several recent studies suggest that this assumption is false. In the Longitudinal Study of Aging, a functional transition since the previous interview, whether representing improved or worse function, increased the risk for functional change at the subsequent interview (8). Among older persons who have recently recovered from disability, the duration of that disability episode is a strong predictor of the time to subsequent disability or death (9). Even disability lasting less than 3 months is associated with an increased risk of subsequent disability and death (10). The objective of the current study was to determine the effect of the amount and distribution of prior disability on subsequent functional transitions among older persons.

Methods

Study Population

The study population was drawn from members of an ongoing longitudinal study of 754 community-dwelling persons, aged 70 years or older, who were initially nondisabled (i.e., required no personal assistance) in four basic activities of daily living (ADLs)—bathing, dressing, walking inside the house, and transferring from a chair. The assembly of the cohort, which took place between March 1998 and October 1999, has been described in detail elsewhere (11). Persons who required more than 10 seconds to walk back and forth over a 10-foot course as quickly as possible were oversampled to ensure a sufficient number of participants at increased risk for ADL disability (12,13). The participation rate was 75.2%. The study protocol was approved by the Yale Human Investigation Committee, and all participants gave informed consent.

Data Collection

Participants underwent comprehensive in-home assessments at baseline and every 18 months and had monthly telephone interviews for 5 years. The comprehensive assessments were completed by trained research nurses using standard instruments. In addition to timed gait, data were collected on demographic characteristics, cognitive status (14), habitual physical activity (15), and chronic conditions.

During monthly telephone interviews, participants were assessed for disability in the four basic ADL tasks. Interviewers used standard questions (13,16) which have been described in detail elsewhere (17). Participants who needed help from another person or were unable to complete an ADL task were considered disabled in that ADL. Complete details regarding the follow-up assessments, including formal tests of reliability and accuracy, have been provided elsewhere (18).

Follow-up interviews for the first 60 months were included. One hundred seventy-two participants (23%) died after a median follow-up of 33 months, and 32 (4.2%) dropped out of the study after a median follow-up of 21 months. Eight
percent of the monthly telephone interviews were completed by a proxy respondent.

**Multistate Model of Disability**

Our multistate model of disability includes four states as defined in Figure 1. Disability in one or two ADLs was considered mild, and disability in three to four ADLs was considered severe (19). An episode of disability was defined as a period of one or more consecutive months of reported disability that was preceded by independence and was followed by recovery of independence, death, or completion of follow-up. For example, a nondisabled participant who subsequently experienced 2 months of severe disability, followed by a month of mild disability, after which she recovered independence, would have had three transitions and one episode of disability. We characterized prior disability with two variables: cumulative duration in months to represent the amount of disability, and number of episodes to represent the distribution of disability over time.

**Statistical Analysis**

Data were available for 99.3% of the 39,106 monthly telephone interviews. Interval missing data on ADL disability were imputed using a method for multiple imputation that accounts for the correlation between repeated measures of disability, as suggested by Allison (20). Results of the analyses did not differ substantively when the simple “last and next” imputation method for longitudinal data described by Engels and Diehr (21) was used.

We calculated the rates of each transition, defined as exits from a state per 1000 person-months in that state. Confidence intervals for the transition rates were calculated by bootstrapping, using sampling with replacement on the complete cohort. One thousand samples were drawn, and the 2.5th and 97.5th percentiles were used to form the confidence intervals.

We used an extension of the Cox proportional hazards model for repeated events to evaluate the effects of the cumulative duration and the number of episodes of disability on the likelihood of subsequent functional transitions (22,23). We used a counting process which used the observed months of state entry and exit as the initiation and termination of the state (24,25) and estimated the effect of the variables denoting prior disability history on the individual transitions by including an interaction term of a dummy variable indicating the transition by each prior history variable (23). For each of the transitions, we exponentiated the coefficient for the interaction term to get the hazard ratio for each prior history variable (23). Prior disability history was determined at the time of entry into a new state. The Cox model is fairly robust to the distribution of time to event and can be used for nonproportional hazards which may occur with time-dependent variables (26). Because our models contained time-dependent variables and multiple transition events, standard methods are not available to check the proportional hazards assumption for this specific model.

We present the effects of cumulative duration and number of episodes of disability separately but, because the number of episodes contains information about the total amount and the distribution of disability over time, we then include both variables (which were correlated at $r = 0.59$) simultaneously in the final model. These results were adjusted for age, gender, cognitive status, timed gait, and habitual physical activity. The last three covariates were updated as indicated, using data from the comprehensive assessment immediately preceding entry into the state. We included age, gender, cognitive status, and gait speed because they are well-established predictors of disability (27). Habitual physical activity was included because it is a strong independent predictor of both transitions into and out of disability (9). All analyses were performed using SAS version 9.125, and all $p$ values are two-tailed.

**RESULTS**

The baseline characteristics of the study participants are shown in Table 1. Two hundred seventy-eight participants (37%) remained alive and nondisabled throughout the 5 years of follow-up and, therefore, experienced no transitions. The remaining 476 participants experienced a median (range) of 4 (1–32) transitions. The overall rate of transitions was 79 per 1000 person-months of follow-up. Rates were highest for transitions from mild to no disability and from severe to mild disability, and lowest for transitions from no disability to death, no disability to severe disability, and mild disability to death (Table 2).

Among participants who experienced at least one transition, 27 (5.7%) experienced only the transition from no disability to death and thus had no disability during follow-up. The

![Figure 1. A multistate model of disability. Boxes represent the four states, and arrows represent the possible transitions between states. No disability is defined as the ability to perform all four basic activities of daily living (ADLs) without personal assistance. Mild disability is defined as disability in one or two ADLs. Severe disability is defined as disability in three or four ADLs.](image)

**Table 1. Baseline Characteristics of Participants (N = 754)**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>Age, y</td>
<td>78.4 ± 5.3</td>
</tr>
<tr>
<td>Female</td>
<td>487 (65)</td>
</tr>
<tr>
<td>White</td>
<td>682 (90)</td>
</tr>
<tr>
<td>Married</td>
<td>361 (48)</td>
</tr>
<tr>
<td>Chronic conditions</td>
<td>1.7 ± 1.2</td>
</tr>
<tr>
<td>Cognitive status</td>
<td>26.8 ± 2.5</td>
</tr>
<tr>
<td>Timed gait, s</td>
<td>10.7 ± 6.3</td>
</tr>
<tr>
<td>Habitual physical activity</td>
<td>90 ± 58</td>
</tr>
</tbody>
</table>

*Note: *Values represent the mean ± standard deviation for continuous variables and number (percent) for binary variables.

1 Number of nine self-reported, physician-diagnosed chronic conditions, namely hypertension, myocardial infarction, congestive heart failure, stroke, diabetes, arthritis, hip fracture, lung disease, and cancer (other than minor skin cancers).

2 Folstein Mini-Mental State Examination; scores range from 0 to 30, with higher scores representing better function.

3 Time to walk back and forth over a 10-foot course as quickly as possible.

4 Physical Activity Scale for the Elderly (PASE); scores range from 0 to 370, with higher scores representing greater activity.
remaining 449 participants experienced a median (range) of 5 (1–59) months of cumulative disability, distributed over a median (range) of 2 (1–15) episodes.

In unadjusted analyses, the cumulative months of prior disability had a significant effect on the risk of all subsequent functional transitions except the transition from mild disability to death (Table 3). For each month of prior disability, participants were more likely to make transitions representing new or worsening disability, were less likely to make transitions representing decreasing disability or recovery of independence, were more likely to transition from no disability to death, and were less likely to transition from severe disability to death. After adjustment for the number of episodes of prior disability, cumulative months of prior disability no longer had a significant effect on the transition from no disability to death (Table 3). Further adjustment for relevant covariates had no substantive effect on the association between months of prior disability and subsequent functional transitions (Table 3 and Figure 2).

In unadjusted analyses, the number of prior disability episodes was associated with a higher likelihood of transitions from no disability to all other states and from severe disability to mild disability. After adjusting for the cumulative duration of prior disability, however, the number of disability episodes was associated with an increased likelihood of all transitions between the three disability states, with only one exception, i.e., the transition from mild to severe disability; and the number of prior disability episodes had no effect on transitions to death. Further adjusting for the additional covariates had minimal effects on these associations (Table 3 and Figure 2).

**DISCUSSION**

Our results demonstrate that prior history of disability among older persons has a significant effect on the likelihood of subsequent functional transitions, independent of age, gender, cognitive status, timed gait, and habitual physical activity. Both the cumulative duration of prior disability and the number of prior episodes of disability were independently associated with subsequent functional transitions. We found that more months of prior disability were associated with a higher likelihood of new or increased disability, a lower likelihood of regaining independence, and a lower likelihood of transitioning from severe disability to death. More episodes of prior disability were associated with a higher likelihood of most transitions, representing both increasing and decreasing disability, but had no effect on transitions to death.

The effect of prior disability history on subsequent functional transitions is substantial. Our results suggest that a nondisabled person with one prior 2-month episode of disability would have a 59% greater risk of becoming mildly disabled than would a person with no prior disability, and a nondisabled person with two prior 1-month episodes would have twice the risk of developing mild disability (see Appendix for calculations). Conversely, a mildly disabled person with one prior 2-month episode of disability would have a 7% lower likelihood of returning to independence than would a person with no prior disability, and a person with two prior 1-month episodes would have an 8% greater likelihood of returning to independence. Although these latter effects are of a smaller magnitude than those noted above, they are in opposite directions, highlighting the impact of different distributions of disability on subsequent recovery.

The effect of cumulative duration of disability on transitions between states of disability and independence is relatively easy to understand; the greater the amount of prior disability, the more likely a person is to become newly or more disabled and the less likely she is to recover. The effects on transitions to death may differ between those with greater and lesser prior disability because of differences in the cause of death, and therefore in the functional trajectory preceding death (28,29). For example, persons with little or no prior disability might have fewer chronic diseases and subsequently develop disability from a new condition, such as metastatic cancer, that quickly leads to severe disability followed by death, resulting in high transition rates between these states. Conversely, persons with extensive prior disability might be more likely to suffer from disabling but nonfatal diseases such as arthritis, resulting in longer periods of severe disability preceding death and, therefore, lower rates for this transition. Consistent with this possible explanation, we have previously found that physically frail older persons are less likely to transition from severe disability to death than are those persons who are not physically frail (1).

The effect of number of episodes of prior disability is more complex, as the effect changes substantially with adjustment for cumulative months of prior disability. After adjustment, number of episodes is associated with an increased likelihood of transitions representing both improved and worsening function. The number of prior episodes combines two aspects of disability history: (i) the total amount of disability, and (ii) the way that disability is distributed over time. We believe that these two aspects may have different effects, which could cancel each other out, producing the lack of association we found in our unadjusted analyses of the effect of number of episodes of prior disability on transitions from disability to independence. For example, for a newly disabled person, having had several prior episodes of disability would decrease the chance of recovery because of the large total amount of prior disability, but increase the chance of recovery because the...
prior disability was more distributed over time. After adjusting for cumulative months of disability, the hazard ratios for prior disability episodes represent primarily the effect of the distribution of disability over time.

There are several possible clinical explanations for our findings. First, persons with many prior disability episodes have regained independence multiple times in the past, perhaps indicating high resilience and a higher likelihood of recovery. Second, persons with many prior disability episodes may be exhibiting the “unstable disability” that Campbell and Buchner (30) have described as a key feature of frailty. These persons may be on the cusp of disability, and thus transition between disability and independence with relatively minor perturbations in their underlying status. Third, the prior history of disability and rate of subsequent transitions likely differ according to the underlying causes of disability. For example, a chronic condition with frequent exacerbations, such as heart failure, might be associated with a history of many recurrent disability episodes and a high likelihood of recovery from subsequent episodes, whereas a progressive condition such as Parkinson’s disease might be associated with fewer prior disability episodes and a lower likelihood of recovery.

Table 3. Effect of Prior Disability History on Subsequent Functional Transitions

<table>
<thead>
<tr>
<th>Transition</th>
<th>Month of Prior Disability</th>
<th>Episode of Prior Disability</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Unadjusted</td>
<td>Adjusted for No. of Prior Episodes</td>
</tr>
<tr>
<td></td>
<td>Hazard Ratio (95% CI)</td>
<td>p Value</td>
</tr>
<tr>
<td>No disability to mild disability</td>
<td>1.21 (.94–1.57)</td>
<td>.01</td>
</tr>
<tr>
<td>No disability to severe disability</td>
<td>1.13 (.91–1.42)</td>
<td>.003</td>
</tr>
<tr>
<td>No disability to death</td>
<td>1.07 (.96–1.18)</td>
<td>.001</td>
</tr>
</tbody>
</table>

Note: *Covariates include age, gender, cognitive status, timed gait, and habitual physical activity. CI = confidence interval.

Our findings are relevant not only for disability research, but also for evaluating transitions in disability history on subsequent functional transitions. Such models are not appropriate when evaluating transitions in disability over time and may not be appropriate for evaluating transitions in other recurrent geriatric syndromes, such as falls and delirium. These findings also highlight the importance not only of the amount of prior disability, but also of the distribution of disability into discrete episodes. Additional measures of disability burden that account for the distribution of disability over time are needed to complement measures such as active and disabled life expectancy, which incorporate only the amount of disability. For example, just as prior epidemiologic studies have asked about number of episodes and cumulative days of disability, it may be useful to consider the distribution of disability over time and may not be appropriate for evaluating transitions in other recurrent geriatric syndromes, such as falls and delirium. These findings also highlight the importance not only of the amount of prior disability, but also of the distribution of disability into discrete episodes. Additional measures of disability burden that account for the distribution of disability over time are needed to complement measures such as active and disabled life expectancy, which incorporate only the amount of disability. For example, just as prior epidemiologic studies have asked about number of episodes and cumulative days of hospitalization or nursing home care in the prior year, future studies could ask similar questions about disability.

Our finding that prior disability is associated with subsequent functional transitions raises additional questions for future research. In the current analysis, we did not evaluate whether the effect of prior disability history was sustained over time; additional studies are needed to determine if the time since a prior disability episode alters its effect on subsequent functional transitions. As monthly assessment of function will not be feasible for many studies, we are planning to evaluate the intervals over which older persons can accurately report their disability in a subsequent study. We also did not investigate the mechanisms that underlie the effect of prior disability. Potential mediators of the effect, such as depressive symptoms, self-efficacy, and physical capabilities, should be investigated. Finally, whether the effect of prior disability differs on the basis of its underlying causes should be examined.
but also for clinical practice, in that they support a view of disability as a chronic condition, which might be best managed in the context of the chronic disease model (31). In addition to treating acute episodes of disability, with rehabilitative services for example, ongoing monitoring and maintenance therapies may be needed to minimize the frequency and severity of subsequent disability episodes. Just as the occurrence and severity of exacerbations of chronic conditions (such as obstructive lung disease and heart failure) are included in the medical record as important predictors of disease prognosis, episodes of disability could be noted and serve as markers of high risk of future adverse outcomes.

Several aspects of our analyses warrant comment. First, we have no information about disability prior to the start of the study, so the disability history is richer for later transitions than for earlier ones. The counting method used for our analyses, however, accounted for the duration of time participants had been followed when a transition took place. Second, we chose to use a categorical measure of disability rather than a continuous measure of functional status. Thus, participants with function near the threshold of requiring help from another person likely required smaller absolute changes in function to make transitions than did those participants far above or below the threshold of disability. However, we feel that the threshold of requiring help from another person has critical implications for an older person’s ability to live alone, the burden upon caregivers, and the need for long-term care. Third, because our participants were members of a single health plan in a small urban area, our results may not be generalizable to older persons in other settings. However, our population did reflect the demographic characteristics of persons aged 70 years or older in New Haven County; these characteristics are comparable to those in the United States as a whole (32).

Fourth, 8% of our monthly interviews were completed by proxies. Although we have demonstrated high reliability for our proxy assessments (18), previous research suggests that proxies tend to overestimate functional deficits, although this is less true for basic ADLs than for other, potentially more subjective measures such as instrumental ADLs, cognition function, or affective function (33–35). Finally, although our disability assessment was highly reliable, some of the transitions could have been due to measurement error rather than true changes in function. This could be problematic, because participants who are unreliable in their self-reports of ADL function would be more likely than those who are reliable to report both multiple prior episodes of disability and subsequent transitions. Nonetheless, because even brief disability episodes are associated with subsequent disability and mortality (10), measurement error is unlikely to account for our finding that greater numbers of prior episodes are associated with subsequent recovery from disability.

**Conclusion**

Prior disability history has a significant effect on the likelihood of subsequent disability and recovery among older persons. Independent of the amount of prior disability, the distribution of disability over time affects the likelihood of subsequent transitions between states of disability and independence. Studies of functional transitions could be improved by the use of analytic methods that account for prior disability history. New measures of disability burden that incorporate the distribution of disability over time as well as the amount of disability are needed. Finally, prior disability history may be a useful clinical indicator for risk of subsequent functional transitions.

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REFERENCES


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APPENDIX

\[ \text{HR}_{\text{transition}} = e^{[\text{lnHR per month} \times \text{months of prior disability}] + \text{ (lnHR per episode)} \times \text{episodes of prior disability}]} \]

where \( \text{HR}_{\text{transition}} \) = hazard ratio for transition relative to no prior disability history

For one prior 2-month episode of disability:

\[ \text{HR}_{\text{no to mild disability}} = e^{[\text{ln1.11} \times 2] + \text{ (ln0.89) \times 1}} = 1.59 \]

\[ \text{HR}_{\text{mild to no disability}} = e^{[\text{ln0.89} \times 2] + \text{ (ln1.17) \times 1}} = 0.93 \]

For two prior 1-month episodes of disability:

\[ \text{HR}_{\text{no to mild disability}} = e^{[\text{ln1.11} \times 2] + \text{ (ln0.89) \times 2}} = 2.05 \]

\[ \text{HR}_{\text{mild to no disability}} = e^{[\text{ln0.89} \times 2] + \text{ (ln1.17) \times 2}} = 1.08 \]