The Combined Effects of Baseline Vulnerability and Acute Hospital Events on the Development of Functional Dependence Among Community-Living Older Persons

Thomas M. Gill,¹ Christianna S. Williams,² and Mary E. Tinetti¹,²

¹Department of Internal Medicine and ²Department of Epidemiology, Yale University School of Medicine.

Background. Many older persons who are highly vulnerable do not develop functional dependence, whereas some older persons with low vulnerability do develop functional dependence. We conducted this study to determine the combined effects of baseline vulnerability and precipitating events on the development of functional dependence.

Methods. We analyzed data from two prospective, population-based cohort studies. The development cohort included 799 community-living persons, 72 years of age and older, who were independent in their activities of daily living (ADLs). The validation cohort included 1,051 comparable persons. Participants were classified by baseline vulnerability, defined on the basis of physical performance, cognitive status, and age, and by exposure to potential precipitating events, determined from information gathered from acute care hospital admissions. The primary outcome was the onset of functional dependence, defined as a new disability in one or more of the seven ADLs at the 1-year follow-up interview or admission to a skilled nursing facility prior to the 1-year interview.

Results. Functional dependence developed in 109 (13.6%) participants in the development cohort and in 100 (9.3%) participants in the validation cohort. The rates of functional dependence for the low, intermediate, and high vulnerability groups were 7.1%, 17.2%, and 40.1% (p<.001) in the development cohort and 4.8%, 15.0%, and 28.0% (p<.001) in the validation cohort. For the four categories (none, mild, moderate, severe) of precipitating events, the rates of functional dependence were 9.0%, 19.4%, 27.3%, and 53.2% (p<.001) in the development cohort and 5.1%, 12.0%, 28.2%, and 53.3% (p<.001) in the validation cohort. For both cohorts, when baseline vulnerability and precipitating events were analyzed in cross-stratified format, the rate of functional dependence increased progressively from low-risk to high-risk groups in all directions (double-gradient phenomenon). The contributions of baseline vulnerability and precipitating events to the development of functional dependence were independent and statistically significant.

Conclusions. Among community-living older persons, baseline vulnerability and precipitating hospital events contribute independently to the development of functional dependence and should each be targeted for intervention when developing strategies aimed at forestalling the onset of functional dependence.

Maintaining independent function is a primary goal of health care for older persons (1). To achieve this goal, clinicians caring for older persons need to know not only who is at risk for becoming dependent, but also why dependence develops among those who are at risk. To date, most published reports of functional dependence have focused on evaluating baseline risk (or vulnerability). Large epidemiologic studies, for example, have identified several demographic and health-related risk factors for functional dependence (2–5). More recently, investigators have focused on the effects of impairments in domains relevant to functioning. Guralnik and associates (6) have shown that objective measures of lower-extremity function are highly predictive of both decline in mobility and new disability in activities of daily living (ADLs) among community-living older persons. Gill and coworkers have demonstrated, furthermore, that poor performance on tests of physical capability is strongly associated with the onset of ADL disability in older persons with (7) and without (8) cognitive impairment, and that impairments in physical performance and cognitive status contribute independently to the risk of ADL disability (9).

Attention to baseline vulnerability alone, however, does not fully explain why older persons develop functional dependence. A sizable number of vulnerable elders, for example, do not develop functional dependence, and many elders who develop functional dependence have low vulnerability (6–9). These findings should not be surprising. While physical and cognitive impairments may make one vulnerable to events that precipitate functional dependence (10,11), they do not cause or precipitate functional dependence themselves.

In contrast to the accumulating body of knowledge concerning risk factors for functional dependence, relatively little is known about the events, other than catastrophic events such as a stroke or hip fracture, that actually precipitate functional dependence; and nothing is known about the interplay of baseline vulnerability and precipitating events on the development of functional dependence. These gaps in our knowledge base must be filled if we are to better understand the disabling process and to develop effective and efficient strategies to prevent or slow functional decline.

The objective of this study was to determine the combined effects of baseline vulnerability and precipitating events on the development of functional dependence. We postulated that functional dependence, like delirium (12) and injurious falls (13), involves a complex interrelationship between baseline vulnerability and precipitating events, such that older persons who are highly vulnerable may develop functional dependence...
with any precipitating event, even of mild severity. Conversely, older persons with low vulnerability will require a noxious insult or major event before they develop functional dependence. As potential precipitating events, we focused on acute care hospital admissions because their occurrence is readily identifiable and they often lead to new or worsening functional dependence in older persons (14). We developed and tested our model of functional dependence in two independent cohorts of community-living older persons.

METHODS

Development Study

Subjects.—Potential participants in the development study were members of Project Safety, a probability sample of community-living persons, age 72 years and older, living in New Haven, Connecticut, in 1989. The sampling technique has been described in detail elsewhere (15). Fourteen hundred thirty-six persons were originally contacted. Only 44 (3%) failed to meet the three eligibility criteria, which included the ability to speak English, Spanish, or Italian; to follow simple commands; and to walk across a room without the assistance of another person. The 1,103 (79%) persons who agreed to participate underwent a comprehensive assessment in their homes by a trained research nurse using standard instruments.

Participants for the current study included the 933 members who (a) were independent at baseline (requiring no personal assistance) in seven ADLs: bathing, dressing, transferring from bed to chair, walking, eating, toileting, and grooming; and (b) had complete data on baseline vulnerability. Among those eligible, 38 had died and 96 had missing outcome data, leaving 799 participants in the development cohort. Compared with those in the development cohort, persons who died or who had missing outcome data were similar in age, gender, education, marital status, and number of chronic conditions.

Baseline vulnerability.—To assess baseline vulnerability, we focused on three factors—physical performance, cognitive status, and age—that have been shown in previous studies to be most strongly associated with the development of functional dependence (7–9,16) and that were also available for analysis in the validation cohort. Physical performance was assessed with the rapid gait test. Participants were asked to walk back and forth over a 10-foot course “as quickly as possible,” thus testing maximum speed of performance. Scores were dichotomized at 10 seconds, based on our previous work demonstrating a threshold response (at the worst quartile) between rapid gait scores and the development of functional dependence (7,8).

Table 1. Vulnerability Model for Functional Dependence

<table>
<thead>
<tr>
<th>Risk Group</th>
<th>Rapid Gait* (seconds)</th>
<th>MMSE Score†</th>
<th>Age (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>≤10</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Intermediate</td>
<td>&gt;10</td>
<td>≥24 AND &lt;85</td>
<td>—</td>
</tr>
<tr>
<td>High</td>
<td>&gt;10</td>
<td>&lt;24 OR ≥85</td>
<td>—</td>
</tr>
</tbody>
</table>

*For the development cohort, participants were asked to walk back and forth over a 10-foot course “as quickly as possible.” For the validation cohort, participants were asked to walk to the end of an 8-foot course at their usual speed, and scores were dichotomized at 13 seconds.

†Scores <24 on the Mini-Mental State Examination denote persons who are cognitively impaired (17).

‡The low-risk group includes participants who scored 10 seconds or less on rapid gait regardless of their MMSE score or their age.

Table 2. Criteria Used to Classify the Magnitude of Precipitating Events* and the Frequency of Specific Events in the Development and Validation Cohorts

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Development Cohort (n=799)</th>
<th>Validation Cohort (n=1051)</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>635</td>
<td>868</td>
</tr>
<tr>
<td>Mild</td>
<td>62</td>
<td>83</td>
</tr>
<tr>
<td>Moderate (any of the following)</td>
<td>55</td>
<td>78</td>
</tr>
<tr>
<td>1. LOS &gt; 7 days and not severe</td>
<td>49</td>
<td>74</td>
</tr>
<tr>
<td>Acute trauma and LOS ≤ 5 days</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Stroke and LOS ≤ 7 days and not hemiplegia</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Coma or intubated and LOS ≤ 14 days</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Severe (any of the following)</td>
<td>47</td>
<td>45</td>
</tr>
<tr>
<td>Acute trauma and LOS &gt; 5 days</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>Stroke with hemiplegia or stroke and LOS &gt; 7 days</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>Intubated and LOS &gt; 14 days</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Major thoracic/abdominal surgery and LOS &gt; 10 days</td>
<td>19</td>
<td>10</td>
</tr>
<tr>
<td>Acute renal failure/liver failure/pancreatitis and LOS &gt; 14 days</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>LOS &gt; 21 days and not psychiatric admission</td>
<td>8</td>
<td>13</td>
</tr>
</tbody>
</table>

*A complete set of operational details is available upon request.
†Length of stay.
‡Includes fractures, other injurious falls, motor vehicle accidents.
§Includes lobectomy, hemicolecotomy, coronary artery bypass surgery.
who were cognitively impaired from those who were cognitively intact (17). Age was dichotomized at 85 years to distinguish the old-old from the young-old (16). Different combinations of these three dichotomous factors were subsequently evaluated. The selection of the final vulnerability model, shown in Table 1, was guided by two basic principles. First, the strategy should identify participants at low, intermediate, and high risk for functional dependence; and second, the strategy should identify a sizable number of participants in each of the three risk groups to ensure that the combined effects of baseline vulnerability and precipitating events could be adequately evaluated. The risk of functional dependence among participants who scored 10 seconds or less on rapid gait was low regardless of the participants’ MMSE score or age. Alternative cutpoints for the MMSE and age were evaluated but did not improve upon the final vulnerability model.

Precipitating events.—Information on precipitating events was gathered from acute care hospital admissions. These admissions were identified during the 1-year follow-up period from three complementary sources: extracted hospital discharge records, data tapes from the Health Care Financing Administration (HCFA), and a computerized database at the Veterans Affairs (VA) Medical Center in West Haven, Connecticut. Hospital discharge records were surveyed on a continuous basis at the two acute care hospitals in New Haven. These two hospitals account for over 90% of acute care admissions for persons living in New Haven. For each admission, a short extraction form was completed, which included information on hospital, date of admission and discharge, major procedures, and principal diagnoses at discharge, coded according to the International Classification of Diseases, 9th Revision, Clinical Modification. Comparable information on admissions to hospitals within and outside of New Haven was obtained from the HCFA data tapes. These admissions had been identified previously using a set of matching algorithms described in an earlier report (18).

Finally, for participants who indicated that they had been hospitalized at the VA Medical Center, we searched the Decentralized Hospital Computer Program (DHCP) database for admissions during the follow-up period and extracted information on length of stay, major procedures, and principal diagnoses at discharge.

To classify precipitating events, we used information on principal diagnoses at discharge, major procedures, and length of stay, an important marker of illness severity (16). Precipitating events were classified as none when there were no hospital admissions or, otherwise, as mild, moderate, or severe based on the criteria shown in Table 2. These criteria were developed a priori using clinical judgment, but were later validated empirically as part of the study. None of the criteria denoted a functional outcome. All classifications were made without knowledge of the participants’ outcome state. The intrarater reliability of the classification scheme was excellent (Kappa=1.0).

Outcome.—Self-reported ADLs were reassessed during a follow-up interview in the home at one year. When available, proxy responses were used for participants who were unable to complete this assessment (0.8%). Admissions to skilled nursing facilities were ascertained from two sources: (a) the Connecticut Long Term Care Registry, using a previously described matching procedure (19); and (b) the HCFA data tapes, which provide information on Medicare-reimbursed admissions to facilities within and outside of Connecticut. The outcome was the onset of functional dependence, defined as a new disability (unable to perform or require personal assistance) in one or more of the seven ADLs at the 1-year interview or admission to a skilled nursing facility prior to the 1-year interview.

Validation Study

Subjects.—Potential participants in the validation study were members of the New Haven site of the Established Populations for Epidemiologic Studies of the Elderly (EPESE) program. This program was established in 1982 as a longitudinal, community-based cohort study of noninstitutionalized persons aged 65 years or older living in New Haven. The study design has been published elsewhere (20). Fewer than 1% of the group have been lost to follow-up. Members have been interviewed yearly about their health status, medical history, medications, functional status, and income. Members had an assessment of physical performance for the first time in 1988. Of the 1,671 members who participated in the 1988 EPESE interview, 1,121 were independent in their ADL function (using the same definition as in the development study) and had complete data on baseline vulnerability. Of these, 40 had died and 30 had missing outcome data, leaving 1,051 participants in the validation cohort. Compared with those in the validation cohort, persons who died or who had missing outcome data were older (mean age, 79.3±5.1 years) and had fewer chronic conditions (mean ± SD, 1.3±1.1) than those in the development cohort (mean ± SD, 1.2±1.0) (Table 3).
test of linear trend for baseline vulnerability within each category of precipitating events and for precipitating events within each category of baseline vulnerability. 

Procedure. — The assessment of baseline vulnerability, ascertainment and classification of precipitating events, and ascertainment and definition of outcome were identical to those in the development study with only two exceptions. First, physical performance was assessed with the usual gait test because rapid gait was not measured in EPESE. Participants were asked to walk to the end of an 8-foot course at their usual speed (21). As was done previously for rapid gait (7,8), scores for usual gait were dichotomized (at 13 seconds) to distinguish participants in the worst quarter from those in the best three quarters of timed performance. Among community-living older persons, scores for rapid gait and usual gait are highly correlated ($r=0.84$; unpublished data from Project Safety). Second, self-reported ADLs were reassessed during a follow-up telephone (rather than home) interview at one year. Proxy responses were used for only a small proportion of participants (3.9%).

Statistical Analysis

In bivariate analysis, rates of functional dependence were calculated for categories of baseline vulnerability and precipitating events. Because some participants had more than one hospital admission during the follow-up period, rates of functional dependence for precipitating events were calculated separately for the first hospital admission, the most severe hospital admission, and the last hospital admission. Results for these three approaches were comparable. In this report, results are presented only for the most severe hospital admission. Next, the combined effects of baseline vulnerability and precipitating events on the development of functional dependence were assessed using a cross-stratification technique (9,13) that categorizes participants by levels of both baseline vulnerability and precipitating events.

The Mantel-Haenszel chi-square statistic was used to test for linear associations, first for baseline vulnerability and precipitating events alone, and then for precipitating events within categories of baseline vulnerability and for baseline vulnerability within categories of precipitating events. To assess the independent effects of baseline vulnerability and precipitating events, two binomial regression models were developed (22). Model 1 included only baseline vulnerability and precipitating events; Model 2 included baseline vulnerability, precipitating events, and several other baseline characteristics listed in Table 3. For each model, a logarithmic link function was specified, and adjusted relative risks and Wald 95% confidence intervals were calculated. Baseline vulnerability and precipitating events were treated as categorical variables, with low vulnerability and no event serving as the reference groups, respectively. To account for participants with missing data, an indicator variable was included for body mass index, the only baseline characteristic with more than 1% missing data.

A comparable set of analyses was performed for the validation cohort. All analyses were carried out using SAS Version 6.12 (SAS Institute, Cary, NC) software.

RESULTS

Development Study

The baseline characteristics of the development cohort are shown in Table 3. Of the 799 study participants, 13 were admitted to a skilled nursing facility and 96 were found to have ADL disability at the 1-year interview, giving an outcome rate of 13.6%. There were 240 acute care hospital admissions during the follow-up period. One hundred thirty-six (56.7%) admissions were ascertained by both local surveillance and HCFA data tapes, 29 (12.1%) admissions were ascertained by local surveillance alone, and 38 (24.1%) admissions were ascertained by HCFA data tapes alone. An additional 17 (7.1%) admissions were ascertained through the West Haven VA's DHCP database. Of the 164 participants hospitalized during the follow-up period, 118 were hospitalized once, 27 were hospitalized twice, and 19 were hospitalized three or more times.

Figure 1. Rates of functional dependence cross-classified by categories of baseline vulnerability and precipitating events. A: the results for the validation cohort; B: the results of the validation cohort. Baseline vulnerability and precipitating events are defined, respectively, in Tables 1 and 2. Shown within each box are the number of participants with functional dependence divided by the number of participants in the specified category. Rates of functional dependence are shown within the parentheses. The overall rates of functional dependence in the development and validation cohorts were 13.6% and 9.3%, respectively. For both cohorts, $p<.001$ by $\chi^2$ test of linear trend for baseline vulnerability within each category of precipitating events and for precipitating events within each category of baseline vulnerability.

Table 3. Rates of acute care hospital admissions by level of baseline vulnerability and precipitating events.

<table>
<thead>
<tr>
<th>Baseline Vulnerability</th>
<th>Precipitating Event</th>
<th>Admission Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Mild</td>
<td>13%</td>
</tr>
<tr>
<td>Low</td>
<td>Moderate</td>
<td>28%</td>
</tr>
<tr>
<td>Low</td>
<td>Severe</td>
<td>35%</td>
</tr>
<tr>
<td>Moderate</td>
<td>Mild</td>
<td>35%</td>
</tr>
<tr>
<td>Moderate</td>
<td>Moderate</td>
<td>35%</td>
</tr>
<tr>
<td>Moderate</td>
<td>Severe</td>
<td>35%</td>
</tr>
<tr>
<td>Severe</td>
<td>Mild</td>
<td>35%</td>
</tr>
<tr>
<td>Severe</td>
<td>Moderate</td>
<td>35%</td>
</tr>
<tr>
<td>Severe</td>
<td>Severe</td>
<td>35%</td>
</tr>
</tbody>
</table>

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The rates of functional dependence for the low, intermediate, and high vulnerability groups were 41/574 (7.1%), 17/99 (17.2%), and 51/126 (40.1%), respectively ($\chi^2$ test of linear trend=95.3; $p<.001$), representing a 5.7-fold increased risk for functional dependence between the low and high vulnerability groups. For the four categories (none, mild, moderate, severe) of precipitating events, the rates of functional dependence were 57/635 (9.0%), 12/62 (19.4%), 15/55 (27.3%), and 25/47 (53.2%; $\chi^2$ test of linear trend=80.4; $p<.001$), representing a 5.9-fold increased risk for functional dependence between the none and severe groups.

The combined effects of baseline vulnerability and precipitating events on the development of functional dependence are shown in Figure 1A. With only two exceptions, the rate of functional dependence increased progressively from low-risk to high-risk groups in all directions (i.e., across rows, across columns, or diagonally). This “double-gradient” phenomenon suggests that both baseline vulnerability and precipitating events contribute independently to the development of functional dependence. As hypothesized, participants with low vulnerability were unlikely to develop functional dependence except in the setting of a severe precipitating event (33.3% [severe] vs 5.9% [none, mild and moderate groups combined]; $p<.001$). Moreover, among participants with high vulnerability, those without a precipitating event were considerably less likely to develop functional dependence than were those with a precipitating event (28.3% [absent] vs 73.5% [present]; $p<.001$). Despite this diminished risk, however, participants with high vulnerability but no precipitating event had a similar likelihood of developing functional dependence as participants with low vulnerability who had a severe precipitating event (28.3% vs 33.3%).

Shown in Table 4 (top panel) are the relative risks and 95% confidence intervals relating the categories of baseline vulnerability and precipitating events to functional dependence. The risk of functional dependence increased across categories of both baseline vulnerability and precipitating events, independent of the effect of the other (Model 1), confirming the results of the unadjusted analyses. Comparable results were found for Model 2, which adjusted for baseline vulnerability or precipitating events, where appropriate, as well as for age, gender, race (white, other), marital status, housing type (public age-restricted, private age-restricted, community), education (in years), number of chronic conditions (0–8), and body mass index (sex-specific tertiles and indicator variable for group with missing data).

**Validation Study**

Of the 1,051 participants in the validation cohort, 25 were admitted to a skilled nursing facility and 73 were found to have ADL disability at the follow-up interview, giving an outcome rate of 9.3%. There were 280 acute care hospital admissions during the follow-up period. Two hundred twelve (75.7%) admissions were ascertained by both local surveillance and HCFA data tapes alone, 19 (6.8%) admissions were ascertained by local surveillance alone, 37 (13.2%) admissions were ascertained by HCFA data tapes alone, and 15 (5.4%) admissions were ascertained through the West Haven VA’s DHCP database. Of the 205 participants hospitalized during the follow-up period, 154 were hospitalized once, 36 were hospitalized twice, and 15 were hospitalized three or more times. Compared with participants in the development cohort (Table 3), participants in the validation cohort were slightly younger, were more likely to be married, but were less likely to be female, white, and to live in private, age-restricted housing. Otherwise, years of education, number of chronic conditions, body mass index, MMSE scores, and baseline vulnerability were comparable in the two cohorts.

The rates of functional dependence for the low, intermediate, and high vulnerability groups were 37/768 (4.8%), 21/130 (15.0%), and 40/143 (28.0%), respectively ($\chi^2$ test of linear trend=82.3; $p<.001$), and for the four categories (none, mild, moderate, severe) of precipitating events were 44/868 (5.1%), 10/83 (12.0%), 22/78 (28.2%), and 24/45 (53.3%) ($\chi^2$ test of linear trend=141.9; $p<.001$). When the combined effects of baseline vulnerability and precipitating events were evaluated (Figure 1B), the “double-gradient” phenomenon was again observed (with only one exception), replicating the results from the development cohort. The independent contributions of baseline vulnerability and precipitating events were confirmed in both multivariable models (Table 4, bottom panel). There was a marginal interaction between baseline vulnerability and precipitating events in both multivariable models (Model 1, $p = .07$; Model 2, $p = .16$).

**DISCUSSION**

In this prospective cohort study of nondisabled, community-living older persons, we found that baseline vulnerability and precipitating hospital events contribute independently to the de-

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**Table 4. Relative Risks Relating Categories of Baseline Vulnerability and Precipitating Events to Functional Dependence**

<table>
<thead>
<tr>
<th>Baseline Vulnerability</th>
<th>Unadjusted</th>
<th>Model 1*</th>
<th>Model 2†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>1.0†</td>
<td>1.0†</td>
<td>1.0†</td>
</tr>
<tr>
<td>Intermediate</td>
<td>2.4 (1.4, 4.1)</td>
<td>2.5 (1.5, 4.1)</td>
<td>2.5 (1.5, 4.2)</td>
</tr>
<tr>
<td>High</td>
<td>5.7 (3.9, 8.2)</td>
<td>4.5 (3.1, 6.5)</td>
<td>4.0 (2.7, 6.0)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Precipitating Events</th>
<th>Unadjusted</th>
<th>Model 1*</th>
<th>Model 2†</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>1.0†</td>
<td>1.0†</td>
<td>1.0†</td>
</tr>
<tr>
<td>Mild</td>
<td>2.2 (1.2, 3.8)</td>
<td>2.2 (1.3, 3.7)</td>
<td>2.5 (1.6, 3.9)</td>
</tr>
<tr>
<td>Moderate</td>
<td>3.0 (1.9, 5.0)</td>
<td>2.9 (1.9, 4.4)</td>
<td>3.2 (2.2, 4.8)</td>
</tr>
<tr>
<td>Severe</td>
<td>5.9 (4.1, 8.5)</td>
<td>3.7 (2.7, 5.2)</td>
<td>3.3 (2.4, 4.7)</td>
</tr>
</tbody>
</table>

*Adjusted for either baseline vulnerability or precipitating events, where appropriate.
†Adjusted for baseline vulnerability or precipitating events, where appropriate, as well as for age (in years), gender, race (white, other), marital status, housing type (public age-restricted, private age-restricted, community), education (in years), number of chronic conditions (0–8), and body mass index (sex-specific tertiles and indicator variable for group with missing data).
‡Reference group.
development of functional dependence. We also found that older persons with low vulnerability are unlikely to develop functional dependence except in the setting of a severe precipitating event, whereas older persons who are highly vulnerable may develop functional dependence with any precipitating event, even of mild severity. These findings indicate that clinicians and investigators need to consider the combined effects of baseline vulnerability and precipitating events when characterizing the mechanisms or pathways by which older persons develop functional dependence. Our model of precipitating events superimposed upon predisposing impairments has now been shown to operate in delirium (12), injurious falls (13), and functional dependence and may offer investigators a valuable vehicle to study other geriatric syndromes, such as urinary incontinence, pressure sores, and adverse driving events.

Our results provide empirical evidence to support other related models of disability and frailty (23–25). In his textbook, Brocklehurst (23) postulated that many frail, older persons manage to remain in the community by balancing assets, which maintain independence, with deficits, which threaten independence; and that “breakdown” occurs either by the addition of an acute or subacute medical problem to the deficit side of the balance or by the loss of social support from the asset side of the balance. Rockwood and associates (24) extended this model to describe a more dynamic process in which perturbations in assets and deficits lead to changes in functional status. Finally, Campbell and Buchner (25) proposed that disability may arise from a single catastrophic event, such as a stroke or traumatic amputation, in an otherwise robust individual, or from small precipitants, such as a change in drug therapy, cold weather, or an attack of bronchitis, in a frail older person.

Our model of baseline vulnerability included physical performance, cognitive status, and age. Impairments in physical performance and cognitive status are two of the main determinants of preclinical disability (7–9), a postulated state of compromised function that may not be evident clinically (11). Other investigators have suggested that impairments in key domains, such as physical performance and cognitive status, act to deplete physiologic reserve, thereby leaving older persons vulnerable to previously innocuous insults or challenges (10). Although age is an important risk factor for functional dependence (16), it likely serves, in part, as a proxy for an array of deleterious factors that are unmeasured or difficult to measure. To dichotomize the three elements of our vulnerability model, we used commonly accepted (16,17) or empirically derived (7,8) cutpoints. Although the model stratified participants into three distinct risk groups in both the development and validation cohorts, some misclassification of risk may have occurred. Scores below 24 on the MMSE, for example, may reflect low educational attainment rather than cognitive impairment (26). Furthermore, despite advanced age, some elderly persons remain remarkably robust (27). If present, misclassification of risk would have weakened our results by placing less vulnerable participants with those who were more vulnerable.

To classify precipitating events, we used information on a combination of hospital-related factors, including principal discharge diagnosis, major procedures, and length of stay. With few exceptions, the magnitude of an event cannot be adequately determined from a diagnosis alone. Moreover, because many older persons are susceptible to other complications not directly related to the illness or injury for which they were hospitalized, functional decline often cannot be attributed to the acute problem leading to hospitalization (28). Length of stay, a key component of our criteria, has been shown in previous studies to be an important marker of illness severity (16). Of note, our classification scheme was found to be reliable and created clinically meaningful and statistically significant risk gradients across the four categories of precipitating events for both the development and validation cohorts.

Previous studies of functional dependence have focused largely on baseline vulnerability (2–9). The role of specific events on the development of functional dependence has been less well characterized. One cross-sectional study reported that arthritis, injury, stroke, heart disease, and pain in joints were the most common diseases and symptoms attributed by older persons to difficulty with ADL function (29). A prospective cohort study found that a substantial proportion of older persons were hospitalized with one of a small number of common diagnoses, including stroke, hip fracture, congestive heart failure, and pneumonia, during the year they became severely disabled (30). By evaluating the combined effects of baseline vulnerability and precipitating events, our study builds upon this earlier work and, in turn, advances our understanding of how functional dependence develops among community-living older persons.

Strengths of the current study include the use of three complementary sources to ensure the complete ascertainment of hospital admissions, and the availability of high-quality data from two large, population-based cohorts of community-living older persons, which allowed us to develop and validate our model in independent samples. Despite some notable differences in baseline characteristics between the two cohorts, our model of baseline vulnerability and precipitating events created distinct and statistically significant risk gradients in the validation cohort, with a 26.7-fold increased risk for functional dependence between the low- and high-risk groups.

Several limitations, however, warrant discussion. First, although we had information on most major health events, we had no information on health events that did not lead to hospitalization (e.g., a prolonged upper respiratory tract infection) or on “nonhealth” events (e.g., the death of a family member). Of participants who developed functional dependence in the development and validation cohorts, 52% and 45%, respectively, did not have an acute hospital admission, suggesting that functional dependence in older persons is often insidious (11) or is precipitated by less potent health events or by nonhealth events. Second, in the validation cohort, information on self-reported ADLs was collected during a face-to-face assessment at baseline and a telephone interview at 1 year. A recent report has demonstrated that the prevalence of ADL disability may differ depending on the mode of data collection (31). Third, some participants may have developed ADL disability and then recovered their ADL function prior to the 1-year interview. Previous studies have reported that up to 30% of disabled, community-living older persons recover their ADL function within 2 years (1,32). Fourth, we had no information on whether participants received interventions aimed at maintaining or restoring functional ability after a precipitating event. Finally, we cannot determine from our data how often a single process, such as congestive heart failure or rheumatoid arthritis, underlies both vulnerability and the events that precipitate functional dependence. These limita-
tions can best be addressed with a prospective cohort study designed specifically to determine the mechanisms of disability and recovery among community-living older persons.

Despite these limitations, our results suggest potential strategies that may be aimed at forestalling the onset of functional dependence among older persons. One strategy, for example, might be to decrease vulnerability among the most vulnerable elders, perhaps by improving physical capabilities through an exercise-based intervention (33). A second, complementary strategy might be to prevent (34) or aggressively treat (35) the precipitating events themselves. Yet, a third strategy might focus on preventing functional decline among hospitalized elders, perhaps through the use of specially designed acute care units (36). Further research is needed to identify the specific events that precipitate functional dependence among older persons and to determine whether these events differ among persons with different levels of baseline vulnerability.

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Address correspondence to Dr. Thomas M. Gill, Yale University School of Medicine, Dorothy Adler Geriatric Assessment Center, 20 York Street, New Haven, CT 06504. E-mail: gill@gwpo.ynhh.com

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