Purpose
To assess the effects of an interdisciplinary intervention on the trajectories of functional recovery among older patients with hip fracture during 2 years after hospitalization.

Design and Methods
In a randomized controlled trial with 24-month follow-up, 162 patients >60 years were enrolled after hip-fracture surgery at a 3,000-bed medical center in northern Taiwan. Patients received an interdisciplinary program of geriatric consultation, in-hospital and at-home rehabilitation, and discharge planning (n = 80) or usual care (n = 82). Patients' functional status was assessed by the Chinese Barthel Index before discharge and at 1, 3, 6, 12, 18, and 24 months after discharge. Covariates included demographic attributes, depressive symptoms, and cognitive functioning. Latent class growth modeling was used to examine distinctive groups of individual trajectories within the sample.

Results
Functional recovery followed 3 distinct paths, approximated by either a quadratic or cubic function over time. These paths were (a) poor recovery (6.8%), (b) moderate recovery (47.5%), and (c) excellent recovery (45.7%). The interdisciplinary intervention significantly reduced the likelihood of poor recovery (relative risk ratio [RRR] = 0.05, p < .01) and moderate recovery (RRR = 0.17, p < .01), relative to excellent recovery. In addition, the major risk factors for poor or moderate recovery were older age, lower prefracture physical functioning, as well as higher depression scores and lower cognitive functioning before discharge. Implications Distinct trajectories of functional recovery can serve as useful outcome measures in clinical research and practice.

Key Words: Elders, Physical function, Intervention program, Group-based mixture models

Functional Recovery of Older Hip-Fracture Patients After Interdisciplinary Intervention Follows Three Distinct Trajectories

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Hip fracture is a leading cause of disability and death among older adults. Within 1 year after hip-fracture surgery, mortality ranged from 8.4% to as high as 36% in a systematic review of 63 studies (Abrahamsen, van Staa, Ariely, Olson, & Cooper, 2009). Furthermore, less than half of elderly patients completely regain ambulatory abilities and functional independence (Abrahamsen et al., 2009; Magaziner et al., 2003; Zidén, Kreuter, & Frändin, 2010). In addition, a hip fracture incurs substantial economic costs due to the required hospital and follow-up care (Cummings & Melton, 2002).

Most recovery after hip-replacement surgery has been shown to occur during the first 6 months after surgery, but many patients (44–60%) never regained prefracture level of physical functioning (Magaziner et al., 2000; Magaziner, Simonsick, Kashner, Hebel, & Kenzora, 1990; Shyu, Chen, Liang, Wu, & Su, 2004; Young, Brant, German,
Kenzora, & Magaziner, 1997). Although some patients (13%) continued to improve in functional status 6 months after discharge from a hospital, a similar proportion (14%) experienced a gradual decline (Magaziner et al., 1990). Even with rehabilitation, no more than 40% of patients completely regained their ability to perform activities of daily living (ADL) during the 1-year follow-up (Stenvall, Olofsson, Nyberg, Lundstrom, & Gustafson, 2007; Zidén et al., 2010).

Although multidisciplinary rehabilitation can help older patients regain ambulatory abilities and attain full functional recovery, the results are mixed, according to a recent meta-analysis (Handoll, Cameron, Mak, & Finnegan, 2009). This may be because prior studies have focused on the average course of recovery from hip fracture, without exploring the existence of multiple distinct trajectories. Hence, some important research questions remain unanswered. In particular, does functional recovery after hip fracture follow distinct courses? If so, how are these trajectories described in terms of their levels and rates of change over time? What factors affect the probabilities of following various paths of recovery?

Although multiple trajectories of functional disability have been reported among older adults (Deeg, 2005; Fauth, Zarit, Malmberg, & Johannson, 2007; Gill, Gahbauer, Han, & Allore, 2010; Liang, Xu, Bennett, Ye, & Quiñones, 2010), there has been no parallel observations among elderly patients with hip fracture. In the present research, we aimed to depict the multiple trajectories of functional recovery over a 2-year period among older Taiwanese who suffered a hip fracture. In addition, we analyzed the effects of an interdisciplinary intervention on the distinct courses of functional recovery. Therefore, instead of a variable-centered approach, we employed a person-centered approach that may identify high-risk patients and those who can benefit from the intervention.

On the basis of prior research, we hypothesized that patients with hip fracture may follow several courses of recovery including excellent, moderate, and poor recovery. First, even with rehabilitation, no more than 40% of patients completely regained their ability to perform ADL during the 1-year follow-up (Stenvall et al., 2007; Zidén et al., 2010). This result suggests that whereas some patients may recover fully in a timely fashion (i.e., excellent recovery), some would recover only partially (i.e., moderate recovery). Second, the maximum recovery of lower extremity function in one study was at 11.2 months, but some patients experienced new dependency during the second year (Magaziner et al., 2000). This result suggests a divergence in the course of recovery after hospitalization, that is, some patients may experience a course of poor recovery. We examined the recovery process over a period of 2 years because a significant proportion of patients did not fully recover to the level of functioning before their fracture during that period (Magaziner et al., 2000).

Furthermore, the risk of poor recovery physical functioning after hospitalization for hip fracture are correlated with older age (Alegre-López, Cordero-Guevara, Alonso-Valdivielso, & Fernández-Melón, 2005; Di Monaco, 2004; Magaziner et al., 1990; Penrod et al., 2008) and poor health conditions before discharge in terms of more depressive symptoms (Di Monaco, 2004; Hershkovitz, Kalandariov, Hermush, Weiss, & Brill, 2007), poor prefracture functional status (Alegre-López et al., 2005; Di Monaco, 2004; Hershkovitz et al., 2007; Magaziner et al., 1990), and poor cognitive functioning (Alegre-López et al., 2005; Di Monaco, 2004; Hershkovitz et al., 2007; Magaziner et al., 1990; Penrod et al., 2008). Hence, we evaluated the following three hypotheses.

Hypothesis 1 ($H_1$) Functional recovery during the 2 years after hospitalization for hip fracture has multiple distinct courses that can be characterized as excellent, moderate, and poor recovery.

Hypothesis 2 ($H_2$) The probabilities of better recovery during the 2 years after hospitalization for hip fracture are higher after an interdisciplinary intervention than usual care.

Hypothesis 3 ($H_3$) The risk of poor recovery during the 2 years after hospitalization for hip fracture are correlated with older age and poor health conditions before discharge in terms of more depressive symptoms, poor functional status, and poor cognitive functioning.

Design and Methods

Design and Data

Data came from a clinical trial on the effectiveness of an interdisciplinary intervention program for older people with hip fracture (Shyu et al., 2010). Patients meeting the research criteria from September 2001 to November 2004 were approached; of these 345 patients, 162 agreed to participate and were randomized to an experimental group ($n = 80$) and control group ($n = 82$). The randomization resulted in two equivalent groups. They were similar in
follow-up (Stenvall et al., 2007; Zidén et al., 2010). And poor recovery. First, even with rehabilitation, courses of recovery including excellent, moderate, identify high-risk patients and those who can benefit from an interdisciplinary intervention program for older patients (Shyu et al., 2010). Although some patients (13%) continued to improve in functional status 6 months after discharge from a hospital, a similar proportion (14%) experienced a gradual recovery over a 2-year period among older Taiwanese who suffered a hip fracture. In addition, we analyzed the effects of an interdisciplinary intervention program for the elderly with hip fracture. In the present research, we aimed to explore the existence of multiple distinct trajectories of functional recovery during the 2 years after hospitalization for hip fracture; (c) receiving hip arthroplasty or internal fixation; (d) able to perform a full range of motions against gravity, and some or full resistance, with a prefraction Chinese Barthel Index (CBI) score >70, representing moderate dependency or better in ADL; and (e) living in northern Taiwan. Criterion (d) was intended to identify participants with a reasonable potential for recovery after receiving rehabilitation. Patients were excluded if they were (a) severely cognitively impaired and completely unable to follow orders (determined by a score <10 on the Chinese Mini-Mental State Examination [MMSE], Yip et al., 1992) or (b) terminally ill.

Usual Care

The control group received usual care only. Patients were cared for by orthopedists and consultations for internal medicine care were occasionally made depending on the patient’s condition. Before surgery, routine examinations included X-ray, electrocardiogram, testing for blood chemistry, and blood cell counts. After surgery, patients were transferred to the trauma or orthopedic wards when their vital signs had stabilized. Rehabilitation did not start until 2 to 3 days after surgery and primarily focused on how to exercise and change position while still in bed. Patients in the control group received on average 1.1 (SD = 1.6) sessions of physical therapy. They were usually discharged around 1 week after surgery without at-home rehabilitation, nursing care, or telephone follow-ups. Usual care did not include geriatric assessment, in-home rehabilitation, and predischARGE home assessment.

Intervention Program

The treatment group received the intervention, a 3-month interdisciplinary program. It included geriatric consultation services, a continuous rehabilitation program, and discharge-planning services. Geriatric assessment/consultation was administered by a geriatrician and geriatric nurses during hospitalization, both before and after surgery in order to detect potential medical or functional problems, as well as to decrease delays before surgery. A geriatric nurse conducted a 60-min comprehensive preoperative assessment and a 30-min postoperative assessment, whereas the geriatrician provided consultation before surgery. Based on geriatric assessments, consultations were provided to the surgeon in charge regarding the timing of surgery, use of infection and thromboembolic prophylaxis, urinary tract management, postoperative nutrition management, and delirium management.

In-hospital and at-home rehabilitation programs were delivered by geriatric nurses and physical therapists. These programs comprised a hip fracture-oriented intervention and fitness enhancing intervention, with individualized exercise protocols according to each patient’s condition. Exercise protocols progressed from ankle dorsiflexion with knee extension, isometric full knee extension, gently bouncing vertical jump with semiflexed knee and foot on the floor, and ball-rolling activities to enhance proprioception. Starting on the first day after surgery, participants in the experimental group received one physical therapy session per day from a geriatric nurse (mean = 5.4, SD = 2.4). During the hospital stay, participants also received two or three visits from a physical therapist (mean = 3.1, SD = 1.6) and one visit from a rehabilitation physician. In the first month after discharge, participants received four nursing visits, and in the second and third months, they received one visit every 2 weeks. Additional visits were made if necessary. On average, participants received 9.9 (SD = 2.3) nursing visits for education/consultation during in-home rehabilitation. The physical therapist also made home visits during the first week, third week, and third month after discharge to provide consultation for in-home rehabilitation. On average, each participant in the experimental group
received 3.0 (SD = 1.1) home visits from a physical therapist.

Geriatric nurses administered discharge planning to maintain continuity of care and ensure appropriate referrals. Predischarge assessment included family caregivers’ competence, resources, patients’ self-care ability, and requirements for community or long-term care services. The geriatric nurses also made an in-home visit for 30 min before discharge to assess the home environment and suggested needed modifications. These nurses also monitored patients’ adherence to clinical follow-up. A nurse also made a 5- to 10-min phone call first, third, and sixth months after discharge.

Measures and Instruments

Dependent Variable: Functional Status.—Participants’ functional status (performance of ADLs) was assessed using the 10-item CBI (Chen, Dai, Yang, Wang, & Teng, 1995), which includes eating, transferring, going to the toilet, personal hygiene, bathing, getting dressed, walking, going upstairs and downstairs, bowel control, and bladder control. Responses to each CBI item are scored with two or three categories. For example, for eating, going to the toilet, personal hygiene, bathing, getting dressed, walking, going upstairs and downstairs, bowel control, and bladder control, participants receive a score of 0, 5, or 10 if they cannot perform the task, assistance is required, or if they can perform without any help, respectively. For personal hygiene and bathing, participants receive 0 if they cannot perform or need assistance, and 5 if they are independent, respectively. For transferring and walking, participants receive 0, 10, or 15 if they cannot perform, need assistance, or are independent, respectively. The total CBI score ranges from 0 (total dependence) to 100 (total independence). CBI validity, reliability, and suitability for elderly Taiwanese patients have been substantiated (Shyu et al., 2004). Cronbach’s alphas for the CBI in this study were .83 to .93.

Predictors.—Data were collected on participants’ age, gender, education, time of surgery, and type of surgery using a researcher-designed form. Data on comorbidities (heart disease, hypertension, stroke, dementia, Parkinson’s disease, diabetes, asthma or lung disease, renal disease, liver disease, and cancer) were collected through both self-report and medical records. Prefracture functional status was assessed by the CBI, as recalled by the patient at admission.

Depressive symptoms were measured by the 15-item Chinese version of the Geriatric Depression Scale—short form (GDS-s). GDS scores range from 0 to 15, with higher GDS scores indicating more depressive symptoms (Burke, Roccaforte, & Wengel, 1991). The internal consistency reliability and construct validity of the GDS-s have been established for older Taiwanese (Liu, Lu, Yu, & Yang, 1998). For this study, Cronbach’s alpha was .78.

Cognitive functioning was assessed using the Chinese version of the MMSE (Yip et al., 1992), which was translated from the English version MMSE (Folstein, Folstein, & McHugh, 1975). The 11-item MMSE assesses participants’ orientation, memory, common sense, ability to use language, ability of construction, as well as thinking content, form, and processes (Folstein et al., 1975). The total score ranges from 0 to 30, with a higher score indicating better cognitive functioning. Satisfactory interrater agreement and construct validity have been reported (Lou, Dai, Huang, & Yu, 2003).

Procedure

Before data were collected from participants, the study was approved by the hospital’s institutional review board. Participants were recruited from the emergency room by research assistants. Patients who agreed to participate were randomly assigned to either an experimental or control group. Participants in the experimental group received routine hospital care as well as the intervention program. Participants in the control group received only routine hospital care and regular social contact, provided by a research nurse. The participants gave consent to receive either the usual care or the interdisciplinary intervention. The intervention was described in the consent form, but participants were not told to which group they were assigned. All participants were assessed during hospitalization and at 1, 3, 6, 12, 18, and 24 months after discharge.

Statistical Analysis

To identify distinctive groups of individual trajectories within the sample, we used latent class growth modeling, a semi-parametric statistical technique, to analyze longitudinal data. This approach classifies individuals into groups based on similarities of individual trajectories over time (Jones, Nagin, & Roeder, 2001; Nagin, 2005). Trajectory
parameters are derived by latent class analysis through maximum likelihood estimation with the following specifications:

\[ Y_{iT}^{**} = \beta_0^g + \beta_1^g \text{Time}_{iT} + \epsilon_{iT}^g \quad i = 1, \ldots n. \] (1)

The latent variable \( Y_{iT}^{**} \) represents the underlying functional status of individual \( i \) at time \( T \) (e.g., 1 month) given membership in group \( g \). “Time” refers to the time of assessment relative to baseline. The coefficients \( \beta_0^g \) and \( \beta_1^g \) are associated with the intercept and rate of change in functional status. \( \epsilon_{iT}^g \) is an disturbance term assumed to be normally distributed, with a zero mean and constant variance.

Within each group, functional status was analyzed as an intercept only, linear or nonlinear, model of time. We present Equation 1 as a linear function of time as an illustration. Parameters were estimated to define the shape of the trajectories and the probability of group membership. The number of groups was chosen on the basis of the Bayesian information criterion where its value is the lowest (Jones et al., 2001; Jung & Wickrama, 2008).

Trajectory group membership was subsequently treated as a dependent variable and was predicted by demographic covariates, applied in a fashion similar to that of multinomial logistic regression analysis. To examine the linkages between covariates and the functional status trajectories, we evaluated the following specifications:

\[ \pi_g(z_i) = e^{z_i \beta^g} / \sum_g e^{z_i \beta^g}, \] (2)

where \( \pi_g \) represents the parameters of a multinomial logit model that captures the effects of time-constant covariates \( z_i \) (e.g., age, gender, group, and education) on \( \pi_g \) and the probability of membership in group \( g \) (Nagin, 2005). An SAS software package, with accompanying PROC TRAJ, was used to simultaneously estimate Equations 1 and 2 (Jones et al., 2001).

A multilevel specification such as the group-based mixture models has more than one outcome variable. First, regarding intrapersonal changes, functional status is specified as a function of time since hospital discharge, that is, the trajectory of functional recovery, which may be characterized in several distinct groups (Equation 1). Second, in the structural part of specifications describing interpersonal variations (Equation 2), the trajectory groups identified in Equation 1 (i.e., poor, moderate, and excellent recovery) are treated as the dependent variables and assumed to depend on various covariates such as the interdisciplinary intervention and baseline health status.

This approach differs from a traditional method of longitudinal analysis such as analysis of variance, for which the data must be balanced and time-structured. That is, all participants are assessed an identical number of occasions, and each set of occasions is identical across individuals. We used multilevel models of change that are flexible because they can analyze more complex data sets in which the number of waves and spacing can vary across participants (Raudenbush & Bryk, 2002; Singer & Willet, 2003). Multilevel models are based on the assumption of missing at random (MAR), that is, the probability of missing data due to mortality and attrition depends only on observed data for either covariates or outcome variables, hence permitting valid inference (Nagin & Odgers, 2010; Raudenbush & Bryk, 2002). Besides using MAR to adjust for selection bias due to mortality and attrition, we included dummy variables in Equation 2 to differentiate participants with complete data during the study period from those who died or dropped out. Participants who refused to accept home visits (\( n = 37, 22.8\% \)) for detailed assessment gave permission to use telephone follow-up data on service utilization, falls, and mortality.

Results

Participants’ Characteristics

Participants had an average age of 78.16 years (SD = 7.76), with over two-thirds being female and approximately half illiterate (Table 1). The majority of patients had undergone surgery within 48 hr of hip fracture (61.7%) and had received internal fixation of the fracture (63%). The average number of chronic diseases before admission was 1.49, with an average CBI score of 96.08, GDS score of 5.51, and MMSE score of 23.70. No characteristics differed significantly between patients in the experimental and control groups.

Trajectories of Functional Status

Our analyses identified three trajectories of postoperative functional recovery among patients in the experimental and control groups (Table 2, Figure 1), supporting \( H_i \). The first trajectory, as a quadratic function with a positive linear slope (slope = 5.33, \( p < .05 \)) and a negative quadratic slope (\( b = -0.70, p < .001 \)) over time, could be characterized as poor recovery (\( n = 11, 6.8\% \)).
Patients in this group experienced a slight improvement in ADL performance, from mean CBI scores in the high 40s to high 50s, during the first 6 months after surgery. During the remaining 18 months, functional status declined substantially (Figure 1).

The second trajectory, approximated by a cubic function, has a positive linear slope ($b = 10.47$, $p < .001$), a negative quadratic slope ($b = -0.84$, $p < .001$) and a positive cubic slope ($b = 0.02$, $p < .001$) over time (Table 2). As shown in Figure 1, functional status (ADL performance) improved substantially from mean CBI scores in the 50s to mid-80s during the first 6 months after hospitalization and remained steady during the following 6 months. From months 12–18, functional status declined before stabilizing in month 18 at a mean CBI score in the mid-70s. As the patients in this group never fully regained their functional independence during the 2-year study period, this trajectory can be described as moderate recovery ($n = 77$, 47.5%).

The third trajectory, which mimics a cubic function, entails a positive linear slope ($b = 18.51$, $p < .001$), a negative quadratic slope ($b = -1.41$, $p < .001$), and a positive cubic slope ($b = 0.03$, $p < .001$) over time (Table 2). Patients in this group had significantly higher baseline CBI scores (by 13–16 points) than patients in the other two groups. In addition, full recovery was largely accomplished

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Table 1. Sample Demographics and Baseline Measures Across Functional Classes and for the Total Sample ($N = 162$)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Poor recovery ($n = 11$)</th>
<th>Moderate recovery ($n = 77$)</th>
<th>Excellent recovery ($n = 74$)</th>
<th>Total ($N = 162$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female, $n$ (%)</td>
<td>8 (72.7)</td>
<td>60 (77.9)</td>
<td>43 (58.1)</td>
<td>111 (68.5)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>82.45 (6.52)</td>
<td>80.14 (8.15)</td>
<td>75.45 (6.59)</td>
<td>78.16 (7.76)</td>
</tr>
<tr>
<td>Experimental group, $n$ (%)</td>
<td>2 (18.2)</td>
<td>33 (42.9)</td>
<td>45 (60.8)</td>
<td>80 (49.4)</td>
</tr>
<tr>
<td>Education, $n$ (%)</td>
<td>2 (18.2)</td>
<td>33 (42.9)</td>
<td>45 (60.8)</td>
<td>80 (49.4)</td>
</tr>
<tr>
<td>Illiterate</td>
<td>6 (54.5)</td>
<td>45 (58.4)</td>
<td>28 (37.8)</td>
<td>79 (48.8)</td>
</tr>
<tr>
<td>Time of surgery, $n$ (%)</td>
<td>7 (63.6)</td>
<td>45 (58.4)</td>
<td>48 (64.9)</td>
<td>100 (61.7)</td>
</tr>
<tr>
<td>Type of surgery, $n$ (%)</td>
<td>5 (45.5)</td>
<td>6 (54.5)</td>
<td>6 (54.5)</td>
<td>17 (10.5)</td>
</tr>
</tbody>
</table>

Note. Functional status was measured by the Chinese Barthel Index; cognition, Mini-Mental State Examination; depression, Geriatric Depression Scale—short form. Values are mean (SD) unless otherwise indicated. $p$ Values were determined by chi-square or univariate analysis of variance tests.

Table 2. Estimated Trajectory Classes and Group-Specific Growth Parameters of Functional Status ($N = 162$)

<table>
<thead>
<tr>
<th>Growth parameter</th>
<th>Poor recovery</th>
<th>Moderate recovery</th>
<th>Excellent recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>47.59**</td>
<td>50.47**</td>
<td>63.59**</td>
</tr>
<tr>
<td>Linear slope</td>
<td>5.33*</td>
<td>10.47**</td>
<td>18.51**</td>
</tr>
<tr>
<td>Quadratic slope</td>
<td>-0.70**</td>
<td>-0.84**</td>
<td>-1.41**</td>
</tr>
<tr>
<td>Cubic slope</td>
<td>0.02**</td>
<td>0.03**</td>
<td></td>
</tr>
<tr>
<td>Group proportion</td>
<td>6.8%</td>
<td>47.5%</td>
<td>45.7%</td>
</tr>
<tr>
<td>Sigma</td>
<td>17.80**</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Model fit statistics
- BIC ($N = 901$): -2848.65
- BIC ($N = 154$): -2836.29
- AIC fit index: -2815.03
- Log likelihood: -2801.03

Notes. BIC = Bayesian information criterion and AIC = Akaike’s information criterion. Level 1, $N = 901$, and Level 2, $N = 154$.

*p < .05. **p < .001.
during the first 3 months after hospitalization and certainly by the end of the first 6 months (Figure 1). During the following 18 months, these patients maintained total independence (CBI = 100). Hence, this trajectory can be characterized as excellent recovery (n = 74, 45.7%).

These three trajectories remained distinct and robust, even when adjusted for several covariates, including age, gender, education, prefracture CBI score, and health conditions (i.e., number of chronic diseases, GDS score, and MMSE score).

**Effects of Interdisciplinary Intervention**

The interdisciplinary intervention significantly benefited the functional recovery of older Taiwanese hip-fracture patients, even after adjusting for all covariates (i.e., age, cognitive function, prefracture functional status, and depressive symptoms). Compared with the control group (Table 3), the experimental group was less likely to experience poor recovery (b = −2.91, relative risk ratio [RRR] = 0.05, p < .01) or moderate recovery (b = −1.80, RRR = 0.17, p < .01). Relative to excellent recovery, the risk of poor recovery for participants in the experimental group was only 5% of that for those in the control group. The probability of moderate recovery for those who received the interdisciplinary intervention was 17% of the risk for patients in the control group. Hence, our findings provide evidence to support the hypothesized beneficial effect of the interdisciplinary intervention on functional recovery (H2).

**Effects of Other Covariates**

In addition, the trajectories of functional recovery were significantly associated with baseline cognitive function and prefracture functional status. For every 1-point increase in MMSE score, the risk of experiencing poor recovery (b = −0.22, RRR = 0.80, p < .05) or moderate recovery (b = −0.20, RRR = 0.82, p < .01) decreased by 20% or 18%, respectively (Table 3). On the other hand, for every 1-point increase in prefracture CBI score, the risk of poor recovery (b = −0.31, RRR = 0.73, p < .01) or moderate recovery (b = −0.22, RRR = 0.80, p < .05) decreased by 27% or 20%, respectively (Table 3).

Furthermore, age and depressive symptoms were associated with greater risk of moderate recovery but not poor recovery (Table 3). For every 1-year increase in age, the risk of moderate

<table>
<thead>
<tr>
<th>Trajectory</th>
<th>Parameter</th>
<th>Estimate</th>
<th>Relative risk ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent recovery</td>
<td>Reference group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor recovery</td>
<td>Constant</td>
<td>23.84</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Experimental group</td>
<td>−2.91</td>
<td>0.05**</td>
</tr>
<tr>
<td></td>
<td>Age (years)</td>
<td>0.13</td>
<td>1.14</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>−0.80</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td>Elementary education and above</td>
<td>0.83</td>
<td>2.29</td>
</tr>
<tr>
<td></td>
<td>No. of comorbidities at admission</td>
<td>−0.18</td>
<td>0.83</td>
</tr>
<tr>
<td></td>
<td>Prefracture functional status</td>
<td>−0.31</td>
<td>0.73**</td>
</tr>
<tr>
<td></td>
<td>Depression before discharge</td>
<td>0.18</td>
<td>1.20</td>
</tr>
<tr>
<td></td>
<td>Cognition before discharge</td>
<td>−0.22</td>
<td>0.80*</td>
</tr>
<tr>
<td>Moderate recovery</td>
<td>Constant</td>
<td>19.73</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Experimental group</td>
<td>−1.80</td>
<td>0.17**</td>
</tr>
<tr>
<td></td>
<td>Age (years)</td>
<td>0.10</td>
<td>1.11*</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>−0.83</td>
<td>0.44</td>
</tr>
<tr>
<td></td>
<td>Elementary education and above</td>
<td>0.05</td>
<td>1.05</td>
</tr>
<tr>
<td></td>
<td>No. of comorbidities at admission</td>
<td>0.09</td>
<td>1.10</td>
</tr>
<tr>
<td></td>
<td>Prefracture functional status</td>
<td>−0.22</td>
<td>0.80*</td>
</tr>
<tr>
<td></td>
<td>Depression before discharge</td>
<td>0.16</td>
<td>1.18*</td>
</tr>
<tr>
<td></td>
<td>Cognition before discharge</td>
<td>−0.20</td>
<td>0.82**</td>
</tr>
</tbody>
</table>

Model fit statistics

- BIC (N = 867) = −2774.05
- BIC (N = 146) = −2747.33
- AIC fit index = −2702.57
- Log likelihood = −2672.57

**Notes.** BIC = Bayesian information criterion and AIC = Akaike’s information criterion. Level 1, N = 867, and Level 2, N = 146. *p < .05. **p < .01.
recovery increased by 11% \((b = 0.10, \text{RRR} = 1.11, p < .05)\) relative to excellent recovery. More depressive symptoms were associated with a greater risk of moderate recovery \((b = 0.16, \text{RRR} = 1.18, p < .05)\) relative to excellent recovery. Nonetheless, depressive symptoms were not correlated with the risk of poor recovery.

Hence, these results support the hypothesized correlations between trajectories of functional recovery and risk factors such as age, cognitive functioning, prefracture functional status, and depressive symptoms \((H_3)\). Nevertheless, it is interesting to note that these factors in conjunction with the interdisciplinary intervention did not discriminate the trajectory of moderate recovery from that of poor recovery.

Finally, patients in the excellent recovery group differed significantly from those in the moderate or poor recovery groups. In particular, patients in the latter two groups were more likely to be older, female, less educated, more functionally impaired before hip fracture, and to have more depressive symptoms and lower cognitive functioning at baseline (Table 1). Even with these variables controlled, the interdisciplinary intervention led to a significant reduction in the probabilities for less than an excellent recovery (Table 3).

**Discussion**

To the best of our knowledge, this study is the first to depict distinctive prototypical trajectories of functional recovery among elderly patients with hip fracture. Furthermore, we analyzed how the covariates might be associated with these trajectories in distinct fashions. The present research built upon a prior study of ours that focused on the average trajectory of functional recovery after hip fracture (Shyu et al., 2010). Using the generalized linear equations, we showed that the functional recovery after hip fracture was largely linear. Moreover, participants who received the interdisciplinary intervention had a higher mean CBI score than those in the control group \((b = 9.22, p < .001)\), reflecting significantly better recovery during the 24 months after discharge. However, the existence of multiple distinct trajectories, and predictors of each trajectories were not explored. In the present study, we used the group-based mixture models approach (Nagin, 2005) to reveal that underlying this average trajectory were three distinct courses of recovery \((i.e., \text{poor, moderate, and excellent recovery})\).

These courses differed significantly in terms of the levels and rates of change in functional status throughout the 2-year study period following the fracture. One was approximated by a quadratic function \((i.e., \text{poor recovery})\), and the other two could be depicted as two different cubic functions \((i.e., \text{moderate and excellent recovery})\). Fewer than half the patients \((45\%)\) experienced excellent recovery, which was characterized by better functional status at baseline and a speedy recovery during the first 3 months before reaching full independence at 6 months after hospital discharge. In contrast, a similar proportion of patients \((47\%)\) experienced only moderate recovery and never regained total independence, although functional status improved substantially during the first 6 months after discharge. This study also found that a small minority of patients \((7\%)\) experienced poor recovery in that after a modest improvement during the first 6 months, functional status deteriorated rapidly and reached total dependence over the following 12 months. Although most recovery occurred during the first 6 months after hip-replacement surgery, many patients \((44–60\%)\) have never regained their prefracture level of physical functioning (Magaziner et al., 1990, 2000; Shyu et al., 2004; Young et al., 1997). Furthermore, a small proportion of patients \((14\%)\) actually experienced a gradual decline after 6-month postdischarge (Magaziner et al., 1990). These observations are consistent with the trajectory of moderate recovery in the present study.

Our findings are consistent with previous observations that after a hip fracture approximately 50% of patients did not regain their independence in ADL performance (Stenvall et al., 2007; Zidén et al., 2010). Nonetheless, our research provides significant new insights regarding the natural history of functional recovery after a hip fracture by quantitatively depicting the levels and rates of change in functional status over 2 years. Our results (Table 2, Figure 1) show that the three trajectories were all nonlinear. Whereas the trajectory of poor recovery could be described by a quadratic function, the moderate and excellent recovery trajectories were characterized by two distinct cubic functions with different intercepts. These trajectories are more informative than measures of functional status at one or two time points because a significant health difference at a given time may diminish or even reverse at a later time. Furthermore, distinct trajectories may reflect differences in etiology and thus call for targeted treatments. As argued
previously, traditional longitudinal data analysis focuses on the average trajectory of recovery and how individuals with various attributes deviate from this trajectory. In the present research, we hypothesized multiple distinct trajectories, with differential effects of the intervention on the probabilities of falling into these courses of recovery.

This study offers strong evidence that an interdisciplinary intervention, consisting of geriatric consultation, rehabilitation, and discharge planning, yielded significant benefits in terms of functional recovery. Relative to excellent recovery, the probabilities of poor recovery or moderate recovery for participants who received the intervention were only 5% or 17% of that for those who received routine care. Additional predictors of moderate or poor recovery included older age, poor prefracture functional status, and greater depressive symptoms and cognitive impairment at baseline. These findings are consistent with prior observations that patients’ premorbid physical and cognitive functions were the overwhelming important predictors of functional outcomes after hip fracture (Alegre-López et al., 2005; Di Monaco, 2004; Hershkovitz et al., 2007; Magaziner et al., 1990). Although functional recovery from hip fracture has been positively associated with social support (Shyu, Tang, Tsai, Liang, & Chen, 2006), the effects of social support on different trajectories of recovery remain to be examined. However, baseline sociodemographic attributes, functional status, and cognitive functioning did not discriminate the moderate recovery group from the poor recovery group (Table 1). On the other hand, these three trajectory groups differed significantly in terms of medical care use and mortality during the 2-year period of observation (Table 4). In particular, those in the poor recovery group tended to have the greatest risks for hospital readmission, emergency room visits, and death.

Together, these findings reinforce the validity of the three distinct trajectories, particularly the differences between the group with excellent recovery and those who experienced moderate or poor recovery. Furthermore, trajectories of functional recovery may constitute a class of very useful outcome measures in clinical research and practice, as a more complete understanding requires examining health changes at multiple times over an extended period. Knowledge of these trajectories can be used to design primary, secondary, and tertiary interventions and to ascertain their relative effectiveness and efficiency. For example, an interdisciplinary intervention can be delivered to patients with hip fracture to decrease the risk of poor recovery.

Like all scientific endeavors, this research could have been improved in several respects. First, all participants came from one medical center. Thus, replications across different sites in Taiwan and other nations are required to extend the generalizability of our findings. Second, participants for this research were limited to those with CBI scores >70, without severe cognitive impairment, and living at home. Thus, the extent to which our findings can be applied to patients with poorer baseline physical and mental conditions and living in a nursing home remains to be determined. Third, this research centered on the trajectories of functional status, which is but one of multiple health outcomes after a hip fracture. Other key outcomes may include cognitive functioning, emotional status, and health-related quality of life. Trajectories of all these outcomes could conceivably be charted, and more importantly, their interconnections could be analyzed. Fourth, prefracture functional status was assessed by retrospective self-report, which may have increased measurement errors.

In conclusion, functional recovery among elderly patients who suffered a hip fracture followed three distinct courses: poor recovery (6.8%), moderate recovery (47.5%), and excellent recovery (45.7%). Substantial improvement in functional status during the first 3 months following hospitalization is

Table 4. Poor Outcome Comparisons Across Functional Classes During the 2-Year Postdischarge Period (N = 162)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Poor recovery (n = 11)</th>
<th>Moderate recovery (n = 77)</th>
<th>Excellent recovery (n = 74)</th>
<th>Total (n = 162)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital readmission, n (%)</td>
<td>8 (72.7)</td>
<td>29 (37.7)</td>
<td>14 (18.9)</td>
<td>51 (31.5)</td>
<td>.000</td>
</tr>
<tr>
<td>Emergency room visit, n (%)</td>
<td>8 (72.7)</td>
<td>19 (24.7)</td>
<td>8 (10.8)</td>
<td>35 (21.6)</td>
<td>.000</td>
</tr>
<tr>
<td>Institutionalization, n (%)</td>
<td>2 (18.2)</td>
<td>4 (5.2)</td>
<td>5 (6.8)</td>
<td>11 (6.8)</td>
<td>.277</td>
</tr>
<tr>
<td>Mortality, n (%)</td>
<td>8 (72.7)</td>
<td>9 (11.7)</td>
<td>5 (6.8)</td>
<td>22 (13.6)</td>
<td>.000</td>
</tr>
<tr>
<td>Occurrence of falls, n (%)</td>
<td>6 (54.5)</td>
<td>29 (37.7)</td>
<td>29 (39.2)</td>
<td>64 (39.5)</td>
<td>.562</td>
</tr>
</tbody>
</table>

Note. p Values were determined by chi-square tests.
critical for regaining long-term total functional independence. An interdisciplinary intervention consisting of geriatric consultation, rehabilitation, and discharge planning yielded significant beneficial effects. In addition, baseline physical and cognitive functions were important predictors of functional recovery. The distinct trajectories of functional recovery can serve as useful outcome measures in clinical research and practice.

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