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Examining Heterogeneity of Functional Recovery Among Older Adults with Hip Fractures

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INTRODUCTION

With the increasing proportion of older adults in the population and increasing life expectancy, the number of hip fracture cases is expected to increase from what are already high levels. Despite the advanced medical and surgical treatments available, elderly hip fracture patients still have a high rate of mortality,^{1-2,1-2,5-6} functional disability,^{7-13,3,4} institutionalization,¹⁶⁻¹⁸ and require costly long-term care. As the success rate of surgical repair continues to improve, attention to postsurgical care has shifted to include functional restoration as an addition to standard procedures of acute care. Predictors of functional recovery among elderly hip fracture patients have been documented in many studies. Commonly used predictors include age, living arrangements, comorbidity, depression, prefracture function, delirium, cognitive function, unsteady gait, discharge to institution, and hospital length of stay.^{2,8-9, 11-13, 16} Predictive information can suggest valuable guides to physicians and medical professionals for providing treatments that can lead to improved

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functional recovery for hip fracture patients following surgery; however, few research studies have focused on individual differences. Monter-Odasso and associates examined individual differences in mobility in very frail older adults;⁴ Penrod and colleagues identified homogenous hip fracture subgroups that shared similar functional outcomes.^{15, 20} To our knowledge, none of the previous studies investigated individual differences in hip fracture functional recovery.

Aging is an individualized process that is distinctive for each individual with respect to covariates such as age, gender, living arrangements, comorbidity, and prefracture function; each individual can be expected to age differently. Using population or group means to predict individual functional recovery will often be misleading since this method ignores joint effects of the independent variables. To address the heterogeneity of the aging process and potentially different pathways to functional recovery, we examine determinants of longitudinal functional recovery following post-acute rehabilitation. We use a regression model appropriate for longitudinal data to demonstrate heterogeneity in functional recovery in elderly hip fracture patients. Our ultimate goals are to identify the nature and extent of variation or heterogeneity in functional recovery among older adults with hip fractures and provide insights regarding postacute rehabilitation planning.

METHODS

A one-year longitudinal study of “Rehabilitation and Functional Recovery after Hip Fracture” (Rehab&Hipfx) data was used for the study.^{5,6} The goal of the original Rehab&Hipfx study was to determine the effectiveness of postacute rehabilitation on functional recovery among older hip fracture patients and on the costs incurred during recovery. Data collection methods have been previously published.^{5,6} We briefly summarize the study as follows:

Study participants

The study sample consisted of 225 community residents age 65 years and over who sustained subcapital fractures of the hip between December 2000 and April 2002 and who were admitted to one of five rehabilitation facilities located in the Baltimore metropolitan area where they received hip surgery. Eligibility for participation in the study was based on the following criteria: (1) age 65 years or older, (2) community-dwelling, (3) admitted to one of five rehabilitation sites with a primary diagnosis of acute hip fracture (ICD-9-CM 820-820.9), (4) had a surgical procedure (ICD-9-CM 81.21, 81.40, 81.51, 81.52) for the first time, (5) non-pathological fracture, (6) Mini-Mental Status Examination score > 23, (7) no evidence of metastatic cancer, and (8) no evidence of Alzheimer’s disease or other dementia. A total of 225 patients satisfied these criteria, completed the interview, and served as the sample for the study. Information was obtained through interviews with each patient during postacute rehabilitation, and at two, six, and 12 months after postacute rehabilitation discharge. Interviews lasted approximately 45 minutes. Data collected included sociodemographics, health status, depression, physical functioning, perceived quality of life, and postacute physical therapy and occupational therapy sessions. Participant confidentiality and informed consent processes were in compliance with research protocols of the Johns Hopkins University and all five participating rehabilitation facilities.

Outcome measures

We examined two major outcome variables: physical (ADL) and instrumental (IADL) activities of daily living. The functional status of hip fracture patients was assessed using 12 items from the Multidimensional Functional Assessment Questionnaire (MFAQ) of the Older American Resources and Services (OARS) instrument.⁷ The first six questions which

pertain to ADL included eating, dressing, walking, transferring, bathing, and using the toilet. The remaining six questions related to IADLs and included using the telephone, grocery shopping, meals preparation, handling money, doing light housework, and doing heavy house work. The response options of the ADL and IADL questions were: for health or physical reasons did you have any difficulty in...? The response options were *yes* or *no*. Two summary scales were constructed by summing scores on each item of ADLs and IADLs. The score ranges for each scale were 0 to 12, with 0 indicating completely independent, and 12 completely unable to perform all six activities independently. That is, lower scores represented better recovery. The OARS instrument has been found to be reliable and valid for use with community elderly and has been used in more than 150 research and practice settings.⁸

Predictor Variables

Four broad categories of independent variables were included in this study: sociodemographics, social support, health status, and physical function. Sociodemographics included age, gender, race, and education, and living arrangement. Age in years was used as continuous variable. Social support included living arrangements (living alone vs. living with others) and whether he/she can count on children, siblings', relatives', and friends' help with daily tasks such as shopping, giving a ride, or household tasks (0 = *no*, 1 = *yes*). Health status was assessed through self-reports of chronic conditions and self-rated health. For chronic conditions, we asked the patient, "Has your doctor ever told you that you have any of the following diseases?" and the chronic conditions include vision impairment (0 = *no*, 1 = *yes*), stroke (0 = *no*, 1 = *yes*) and self-rated (1 = *excellent*, 5 = *poor*). Functional status included level of prefracture experience of ADL and IADL function.

Data Analysis

Frequency distributions, univariate, and bivariate analyses were performed to organize, and summarize the data; in addition several modern graphics were constructed. Independent variables associated with ADL and IADL outcomes that were significant at the $P < .10$ level, or clinically relevant, were retained for subsequent analyses. All others were ignored for present purposes. A linear mixed-effects regression model was used to examine factors associated with time-dependent change in functional recovery during the one-year period following postacute rehabilitation. This model provides a measure of the rate of change in ADL and IADL functional recovery over the entire follow-up period.⁹⁻¹⁰ The distinguishing features of this model, compared with standard multiple linear regression, include its ability to model the serial correlation across longitudinal measurements as well as the individual differences in time-related patterns of changes in function using random effects. The simple mixed-effects model with only one covariate and two fixed and random effects can be written as

$$Y_{ij} = (\beta_0 + \mathbf{b}_{i0}) + (\beta_1 + \mathbf{b}_{i1}) \mathbf{X}_{ij} + e_{ij}$$

where Y_{ij} represents the outcome variable of physical function for the i^{th} individual at the j^{th} time of observation, effects β_0 and β_1 represent the mean or average value for the intercept and average slope for the observed covariate $\mathbf{X}$, respectively, and e_{ij} represents lack of fit. The random effects parameters $\mathbf{b}_{i0}$ and $\mathbf{b}_{i1}$ represent the individual change or deviation of the i^{th} individual from the average intercept β_0 and the average slope β_1 , respectively. These two random effects allow for different estimates of the intercept and slope for each individual, where $\mathbf{b}_{i0}$ accounts for differing individual starting values and $\mathbf{b}_{i1}$ describes individual change across time. Thus, random effects are well suited to modeling of

heterogeneity of the elderly hip fracture patients. Random-effects estimates can also be used to generate predicted regression lines for selected individuals in order to take account of the heterogeneity of individuals on the selected covariates X_{ij} that were used to characterize individuals. Parameter estimates and standard errors of the estimates were obtained using a restricted maximum likelihood estimation procedure (Lindstrom MJ, 1988); each t-statistic for each fixed-effect covariate was calculated as the parameter estimate divided by its standard error estimate. A likelihood ratio test was used to assess significance of random effects for each covariance parameter in the model. The fixed-effect parameter estimates and their corresponding tests of significance depend on the estimates of the random effects and their covariance structure in the model, in order to account for serial correlations for time-dependent measurements.

Based on the influence estimates for fixed effects, twenty five outliers, each with the highest Cook's Distances (Cook's D) and complete ADL/IADL records at months 2, 6 and 12, were identified; they are shown in Figures 1A, 1B. The ADL and IADL functional recovery statistics are also given in Figure 2A and 2B. For each outlier profile, the observed values, the predicted values with 95% confidence intervals (given as vertical dashed lines), and the group averages at months 2, 6 and 12 are plotted in the same panel; Figures 2A and 2B correspond to ADL and IADL respectively.

To demonstrate heterogeneity of individual functional recovery, within the 25 ADL and 25 IADL outliers, three outliers each for ADL (204, 280, 305) and IADL (321, 343, 419) were selected to further characterize the varying individual functional recovery patterns. These six outliers are also individually shown in Figure 1A/1B, and Figure 2A/2B. Due to the interdependence of fixed effects and random effects in the mixed model, each outlier might have varying influence on fixed effects, random effects, and overall effects.¹¹

RESULTS

Table 1 summarizes the characteristics of the sample data. The average age was 80 and age ranged from 65 to 99 years. The majority of these patients were White (91%) and female (75%). Forty percent were currently married and 42% lived alone. Eighty-three percent reported having good social support from children, relatives, or friends whenever needing help with daily tasks such as shopping, giving a ride, or household tasks. In terms of health status, 44% reported visual impairments, 16% had had a stroke; and the self-rated health status was excellent/very good/good by 78%. In general, the group as a whole was relatively independent in ADL and IADL function. Most patients had no prefracture ADL (65%), with a mean score of 0.8; about two-fifths (39%) of patients had no prefracture IADL, with a mean IADL score of 1.5.

Determinants of group ADL functional recovery

The results of the longitudinal data analysis, using mixed-effects regression models on ADL functional recovery, identified significant predictors of the average of ADL functional recovery over the course of one year: time, vision impairments, stroke, self-rated health, and two interactions (1) time and vision impairments and (2) time and baseline ADL function. The parameter estimates for both time and time² had a significant effect on ADL function recovery. The presence of significant linear and quadratic time terms in the model indicates that the relationship of time with ADL function varied notably over time. Vision and stroke were significantly associated with ADL function; the positive beta estimate indicated that having impaired vision and a stroke were significantly associated with poor ADL functional recovery. Better self-rated health was associated with better ADL function recovery. The significant interaction between time and impaired vision indicates that impaired vision was significantly associated with poorer recovery in ADL function, when those with

impairments were compared to patients without impaired vision. The significant interaction between time and baseline ADL function indicates that patients with more impaired ADL function at baseline were statistically more likely to manifest poorer recovery in ADL function.

Determinants of group IADL functional recovery

Seven predictors had a significant association with IADL functional recovery. Both time and time² had a significant effect on IADL functional recovery, indicating that the effect of time on IADL function varied statistically over time. Age was significantly associated with ADL function, indicating that increasing age is associated with poor functional recovery. Having social support was associated with better functional recovery. The effects of having vision impairment or stroke were associated with poor functional recovery. Better self-rated health was associated with better functional recovery. The interaction effect of time and vision impairment indicates that patients with impaired vision were less likely to manifest IADL functional recovery than their counterparts with better vision. The interaction of time and baseline IADL function and time² with baseline IADL function indicates that the association of baseline IADL function with recovery in IADL function varied notably over time.

Group vs. Individual ADL functional recovery

Figure 1A provides the Influence Diagnostics plots¹¹ using the estimates of mixed-effects model (intercept and time) for ADL functional recovery for each individual in the study. The graphics identified 25 outliers whose Cook's Distance of fixed-effects were highest among all patients. These patients had relatively high magnitude (positive or negative) estimates of the random effects terms for intercept and time, suggesting that their ADL functional recovery patterns stood out from most of the other hip fracture patients in this study and their functional recovery patterns deviated from the whole group.

Figure 1B demonstrate the heterogeneity of functional recovery among elderly with hip fracture using the parameter estimates for the final model presented in Table 2A, covariate information and their estimates of the random effects. To help characterize the nature of the heterogeneity in functional recovery, three outliers (#204, #280, and #305) were selected. Using the covariate information for these three individuals given in Table 3, their estimates of the random effects given in Table 4, and the parameter estimates from the final model presented in Table 2, the predicted curves for an average person and each of the three individuals are shown in Figure 1B. For example, this Figure shows that patient #204 experienced good functional recovery at two months and her ADL function at that point was notably better than the average; however, her ADL function deteriorated thereafter through the one-year follow-up. She experienced worse ADL function (mean=5) compared to the group (mean=2.10). In contrast, patient #305 experienced worse ADL recovery (mean = 6) than the average person (mean = 3.56) at two months; however, his ADL function continued to improve at six months and through the course of one year. Patient #280 had ADL worse (higher) scores, considerably above the average ADL at two months. We infer that #280 did not experience any ADL functional improvement at two months and thereafter throughout the one-year follow-up period.

Group vs. Individual IADL functional recovery

Similar to ADL functional recovery, Figure 2A gives the Influence Diagnostics plots of for IADL functional recovery for all persons in the study. Examination of the figure shows that there were 25 outliers. These patients had IADL scores that differed from what could be predicted from these covariates. Similar to ADL function, we choose three outliers (#419, #343, #231) for discussion purposes. Using the covariate information for these three individuals (Table 3), their random-effects estimates (Table 4), and the parameter estimates

from the final IADL model in Table 2, the predicted IADL functions for an average person and the three outlier patients are shown in Figure 2B. This Figure shows that patient #419 had IADL scores above the average (worse functioning). Despite his functioning being worse than the average patient, he did experience IADL functional recovery after two months postacute rehabilitation and continued to improve until six months, like average patients in the study; thereafter, his function deteriorated as judged by his observed score at 12 months. Patient #343 had an IADL score below the average (better functioning). This patient experienced IADL functional recovery after two months postacute rehabilitation and continued to improve throughout the year. His functional recovery was notably better than that of the average.

DISCUSSION

The overall trend of recovery in ADL function is seen at two months post-acute rehabilitation, and continues to improve at six months, after which the ADL functional recovery appears to slow down and remain constant through the end of the one-year follow-up. This similar trend of ADL functional recovery has been evidenced in other studies.¹³⁻¹⁵ However, this model cannot be expected to describe results for all elderly hip fracture patients. This figure demonstrates that the predicted IADL functional recovery of some patients, for example patients #204, #280, #305, using average estimates, would be misleading.

For example, patient #204 experienced ADL functional recovery that deviated from the full group. She was 74 years old, White, with high school education, had no prefracture ADL disability, no self-reported vision impairment, no reported stroke, and her self-rated health was very good (Table 3). Her ADL functional recovery, if not better than the group average, at least should be similar to it, using the overall predicted values. This patient experienced functional recovery much better than the average patients at two months; however, her ADL function deteriorated after two-months postacute rehabilitation and continued to deteriorate throughout the year, compared to the group trend (Figure 1B). This different trend prompted examination of some of her other characteristics (data not included in the model) for clues to her functional deterioration. Based on results of the overall model, this patient was not at higher risk of having poorer ADL functional recovery, and yet her ADL functional recovery did not indicate any recovery to her prefracture ADL level at six months postacute rehabilitation, and it deteriorated throughout the year. Detailed examination of her medical record showed numerous pre-existing chronic conditions (osteoporoses, fear of falling, depression), and these seem likely to have affected her recovery. As Fried and Guralnik¹² suggest, a major underlying cause of physical disability is chronic disease, including both acute events and slowly progressive diseases; chronic conditions and complications such as those noted may have triggered the progression of her functional disability.

Similar to ADL functional recovery, the overall IADL functional recovery was seen at two months postsurgery, and it slows down at six months, then gradually levels off throughout the year. This trend also has been observed in previous work,¹³⁻¹⁵ also previous studies have suggested that most elderly hip fracture patients do not regain their IADL function back to prefracture level.^{13-14, 16-17} However, this overall trend may not be applicable for a number of individuals. For example, patient #343 had an IADL functional recovery which was much better than expected. Patient #343 had a noticeable IADL functional recovery at six months and continued to improve over the course of one year, despite the predictor variable that would lead to poorer IADL functional recovery, that is, his poorer prefracture IADL function status (IADL=3). This 76 year-old Black female patient improved remarkably on IADL functions after receiving postacute rehabilitation and continued to improve beyond prefracture IADL function at the one-year follow-up (IADL=0), despite prefracture IADL

disability and chronic conditions. She had hypertension, diabetes, osteoarthritis, fear of falling, and used an assistive device for mobility at baseline; she also received regular help for daily activities. Using the overall or average results to predict her IADL function would have been inaccurate and misleading.

Detailed study of outlier profiles can offer insights as to why some individuals recover differently in ADL or IADL function compared with others with similar characteristics. This study provides measures for individual heterogeneity and identifies individual hip fracture patients who in many cases did not follow the overall patterns of change that characterized results for many hip fracture patients. Information about the overall group and particular individuals can be useful in helping to understand the complex and dynamic processes that characterize hip fracture functional recovery. To foster functional autonomy, individualized ADL and IADL functional recovery models can supplement other clinical tools for planning rehabilitation services and flagging attention to the fact that individuality of patients be attended closely, such as signs of physical disability, depression and the like.

There are limitations of the study that should be mentioned. Participants in this study were recruited from the Baltimore metropolitan area; therefore, sociodemographic characteristics may limit the generalizability of the findings to other hip fracture patients residing in other cities and States. The Rehab&Hipfx study had stringent eligibility criteria as it was designed to evaluate the effectiveness of postacute rehabilitation. Due to these inherent data source limitations, the findings of this study may be applicable only to hip fracture patients with similar characteristics.

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Figure 1A. Plot of Outliers* in ADL function Based on Cook's Distance for Mixed-effect Model
 *Outlier diagnostics: The 25 observations with highest Cook's Distances (>0.009) and complete data were selected; their individual plots are given in Figure 1B.

Figure 1B. Observed ADL Functional Recovery Outlier Profiles*, Mixed-effect Model Based Predicted Profiles and the Group Average ADL Profile

*Three outliers (204, 280, 305) for ADL were selected to further characterize the varying individual functional recovery patterns in the text.

Figure 2A. Plot of Outliers* in IADL function Based on Cook's Distance for Mixed-effect Model

*Outlier diagnostics: The 25 observations with highest Cook's Distances (>0.009) and complete data were selected; their individual plots are given in Figure 2B.

Figure 2B. Observed IADL Functional Recovery Outlier Profiles*, Mixed-effect Model Based Predicted Profiles and the Group Average IADL Profile

*Three outliers (321, 343, 419) for IADL were selected to further characterize the varying individual functional recovery patterns in the text.

Table 1

Sociodemographic Characteristics of the Study Sample (n=225)

Characteristics	Percent
Age 65-74	24.4
75-84	50.2
85+	25.3
Range	65-99
Mean (sd)	79.7 (7.4)
Female	74.1
Race(white)	91.0
Education attainment (> 12 yrs)	67.9
Mean (sd)	12.4 (6.8)
Currently married	40
Social support at baseline*	51.8
Living alone	42
Assistive device use	40
Vision Impaired	44
Self-reported stroke	16.4
Self-rated health at baseline (Ex/VG/Good)	78
Mean(sd)	2.8 (1.0)
Baseline ADL disability	65.2
Mean (sd)	0.8 (1.3)
Baseline IADL disability	38.9
Mean (sd)	1.5 (1.8)

Table 2
Estimates of Fixed-Effects in ADL and IADL Functional Recovery using Mixed-Effects Model

Characteristic	(A) ADLS(N=211)			(B) IADL(N=212)		
	Parameter estimate	Standard error	P value	Parameter estimate	Standard error	P value
Intercept	0.15	1.14	0.90	-0.05	1.11	0.97
Month	-0.33	0.07	<0.0001	-0.39	0.07	<0.0001
Month * month	0.02	0.004	0.0002	0.02	0.004	<0.0001
Age (in year)	-0.02	0.01	0.08	0.04	0.01	0.004
Gender (0=female, 1=male)	-0.01	0.22	0.96	-0.12	0.22	0.58
Race (0=non white, 1=white)	0.10	0.31	0.75	0.26	0.30	0.39
Education(0=<12 yrs, 1= $\geq$ 12yrs)	0.09	0.20	0.63	-0.24	0.19	0.21
Living alone (0=no, 1=yes)	-0.05	0.19	0.79	-0.25	0.19	0.19
Social support at baseline (0=no, 1=yes)	-0.44	0.25	0.08	-0.61	0.24	0.01
Vision impaired (0=no, 1=yes)	1.78	0.26	<0.0001	1.48	0.22	<0.0001
Had stroke (0=no, 1=yes)	0.90	0.25	0.0004	0.55	0.24	0.02
Assistive device use (0=no, 1=yes)	0.28	0.21	0.17	0.40	0.20	0.04
Self-rated health (1=excellent, 5=poor)	0.34	0.08	<0.0001	0.25	0.07	0.0002
ADL or IADL at baseline	0.08	0.11	0.49	-0.61	0.24	0.01
Month * Vision impairment	-0.12	0.03	<0.0001	-0.09	0.02	0.0004
Month * baseline ADL/IADL	0.05	0.01	<0.0001	0.09	0.03	0.003
Month ² * baseline ADL/IADL	-	-	-	-0.005	0.002	0.02

Table 3

Proportions or Means on Selected Characteristics for the Group and Selected Individual patients regarding ADL and IADL Functional Recovery

Variable	Overall Mean (%)	Selected Individual Patients & their characteristics					
		ADL			IADL		
Individual ID *	–	204	280	305	419	343	321
Age	80	74	97	90	81	76	80
Gender	25% Male	F	F	M	F	F	M
Race	91% White	White	White	Black	White	Black	White
Education (≥12 yrs)	68%	≥12 (12yrs)	≥12 (14 yrs)	<12 (5 yrs)	≥12 (12 yrs)	≥12 (12 yrs)	<12 (9 yrs)
Living alone	(42%)	No	Yes	No	No	No	Yes
Currently Married	(40%)	Yes	No	No	No	Yes	No
Vision impaired	44%	No	No	Yes	Yes	No	Yes
Had a stroke	16%	No	No	Yes	No	No	Yes
Self-rated health	40% (Good)	VG	Ex	Fair	Good	VG	VG
Social support at baseline	83% Yes	Yes	Yes	Yes	Yes	Yes	Yes
ADL at Baseline	0.76	0	0	0	2	1	0
2month	3.21	0	5	4	5	1	5
6month	2.35	5	5	2	1	1	5
12month	2.10	5	5	0	6	1	4
IADL at Baseline	1.54	0	1	1	0	3	0
2month	3.56	3	5	6	4	3	6
6month	2.89	4	5	6	2	0	6
12month	2.71	0	5	6	6	0	6

* In compliance with IRB protocol and to protect patient's confidentiality, each patient was assigned a randomly-generated ID number.

Table 4

Random Effects Estimates of ADL and IADL Functional Recovery for the Identified Individual Outliers

ADL			IADL		
ID number	Intercept	Time	ID number	Intercept	Time
Average	0.15	-0.33	Average	-0.05	-0.39
204	0.83	0.05	419	0.30	0.12
280	2.22	0.77	343	-1.02	-0.11
305	-1.01	-0.006	321	1.64	0.08